PRESIDENT 1914

OF

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

THE AMERICAN SOCIETY OF
MECHANICAL ENGINEERS

TRANSACTIONS

VOLUME 36

ST. PAUL-MINNEAPOLIS MEETING
NEW YORK MEETING
1914

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NOTE:—Numbers in parentheses indicate number of years the member has yet to serve.

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Alaska	3	Nevada	3
Arizona	11	New Hampshire	14
Arkansas	5	New Jersey	311
California	173	New Mexico	5
Canal Zone	11	New York	1598
Colorado	31	North Carolina	19
Connecticut	252	North Dakota	2
Delaware	26	Ohio	405
District of Columbia	46	Oklahoma	6
Florida	7	Oregon	9
Georgia	23	Pennsylvania	729
Hawaii	13	Philippine Islands	4
Idaho	2	Porto Rico	6
Illinois	421	Rhode Island	93
Indiana	90	South Carolina	6
Iowa	26	South Dakota	3
Kansas	21	Tennessee	31
Kentucky	14	Texas	36
Louisiana	30	Utah	15
Maine	20	Vermont	19
Maryland	53	Virginia	38
Massachusetts	561	Washington	36
Michigan	215	West Virginia	17
Minnesota	73	Wisconsin	132
Mississippi	4	Wyoming	1
Missouri	108		
Montana	12	Total	5820

FOREIGN COUNTRIES

Africa	12	India	3
Australia	7	Italy	3
Austria	3	Japan	7
Belgium	4	Mexico	9
British West Indies	1	Norway	3
Canada	103	Roumania	1
Central America	1	Russia	9
Channel Islands	1	Scotland	2
China	1	South America	20
Cuba	13	Spain	3
Dutch East India	2	Sweden	4
England	67	Switzerland	4
Finland	2	Turkey	1
France	12	West Indies	1
Germany	19		
Holland	1	Total	319

BY RESIDENCE

Membership in United States	5820
Membership in Foreign Countries	319
Present address unknown	3
Total Membership	**6142**

By Grades

Honorary Members	14
Members	4153
Associates	372
Associate-Members	317
Juniors	1286
Total Membership	6142

CONTENTS OF VOLUME XXXVI

ST. PAUL-MINNEAPOLIS, NEW YORK AND MONTHLY MEETINGS

TRANSACTIONS

OF

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

VOLUME 36—1914

THE proceedings of the meetings of The American Society of Mechanical Engineers for the year 1914 are contained in this volume, together with an account of the various activities of the Society for this year. The papers and discussion presented at the Spring and Annual Meetings are given nearly in full, and brief reference is made to the various local meetings, a more complete account of which will be found in The Journal for 1914. The reports of special committees received by the Council during this period and ordered published are also included and the important events in the work of the Society are recorded in the report of the Council on Page 5. The reports of the Standing Committees for the year were published in The Journal for December 1914.

JAMES HARTNESS

James Hartness, President of The American Society of Mechanical Engineers for the year 1914, was born in Schenectady, N. Y., in 1861. The first twenty years were spent at Cleveland, Ohio, where after graduating from the public schools he began practical work in machinery buildings plants. For the next three years he held a position as foreman of a manufacturing plant in Winsted, Conn., and for the four years following, was with a hardware manufacturing plant in Torrington, Conn., where he finally served as inventor.

In the fall of 1888, Mr. Hartness designed machinery for the Jones and Lamson Machine Company at Springfield, Vt., and shortly afterward took an active part in the management of this company. He served successively as superintendent, manager and, for the last dozen years, as president. During this period he has become one of the most prominent manufacturers in New England and one of the most widely known engineers in the country, particularly in the machinery building industry, through the invention and manufacture of the Flat Turret Lathe and of various other machines and tools for turning metal. The fundamental idea in these machines has been to produce certain kinds of work, generally classed as engine lathe work, with greater expedition and economy than could be accomplished with the engine lathe. He has taken out in all over eighty American patents on his various inventions.

The Jones and Lamson Machine Company with which Mr. Hartness' engineering success has been associated, was formerly the old Robbins and Lawrence Company, started at Windsor, Vt., over sixty-five years ago. They originally built a general line of machine tools, but gradually specialized on turret lathes, so that the history of this firm appears to be practically the history of the turret lathe itself from its very beginning. Various features now in common use were developed from time to time until about 1882 when the turret lathe had practically become standardized in the form of the present high turret machine of commerce with the various features of power-feed, lever-operated back gears, etc., and was being built in sizes that were very large for those times. It was then tending to find its work in the engine lathe field rather than in strictly screw machine work.

The turret lathe remained stationary in its development at this point for several years, until Mr. Hartness' connection with the concern which began in the fall of 1888. He at once saw the possible development of the turret lathe, and inaugurated a series of improvements which brought it into the field of bar and shaft work of a kind that had previously been considered engine lathe work pure and simple.

In studying the problem he considered the merits of three forms of turrets,—the disk turret, the barrel turret, and the flat turret. He found that the disk turret had been anticipated by the Gray turret lathe built on a small scale some years previously in Alabama. He patented the barrel turret, but did not consider it as the most practical form for use in the hands of workmen with no especial training for the machine. The flat turret appealed to him as meeting the requirements in a practical way for a broad extension of the turret lathe field, making possible the turning of long pieces, such as shafts and spindles, etc., from the bar with an accuracy and rapidity not previously possible. The form of the turret permitted a firm tool surface on which the specialized turning tools could be clamped; and what was especially important, permitted the locating of the locking pin directly under the cutting tool, instead of on a very much smaller diameter, as with the old-fashioned form of turret. The turret was also gibbed at the outside on a larger diameter than the location of the cutting tools.

The tools themselves were of original construction, embodying principles now universally used in all turret lathes for doing bar work. The principal feature of the improvements was the provision of adjustable blades and back rests in the same holder to which the severe strains of cutting were thus confined without permitting deflection and lack of truth, even in turning of the most slender variety.

One interesting feature of Mr. Hartness' first work on the flat turret lathe may be mentioned. He was working on a certain important detail of turret lathe construction, and after a long study had settled on a certain form of mechanism as being the logical construction. In looking through the archives of the firm, he found a sketch of the identical mechanism made many years previously by Mr. Fred Howe, who was the mechanical genius mainly responsible for the splendid line of original design brought out in the early history of the firm. After the first natural feeling of disappointment, Mr. Hartness took courage from the thought that he had come to the identical conclusions reached by this thoroughly skilled and original mechanic of an earlier generation, and so continued his work in the development of what is now the flat turret lathe.

For several years Mr. Hartness has had as one of his pleasures the study of astronomical subjects and in 1910 he invented the turret equatorial telescope, which had as its very practical object the protection of the astronomer engaged in making observations from the rigors of a cold winter climate. This end was attained without the serious optical loss that had been involved in previous designs, and is generally considered a marked step in advance which will have an important bearing on the results obtained by astronomers when working under severe climatic conditions. One of these instruments was built, and erected at his residence at Springfield, Vt., and formed the subject of a paper before the Society at the Annual Meeting of 1910.

As all of Mr. Hartness' friends and acquaintances know, he is a man of strong individuality, which shows in everything his hand touches. The machines he has designed could have been designed by no one else. They will be mistaken by no one for the work of another designer. The same applies to the business organization and methods of management of the firm of which he is the head. Many of these ideas have been set forth at some length in his book, the Human Factor in Works Management.

Previous to his election to the presidency of the Society, Mr. Hartness was a vice-president and in the absence of President W. F. M. Goss served in the capacity of president during last summer's trip through Germany. In every city visited he was called upon to address the German and American engineers.

Mr. Hartness became a member of The American Society of Mechanical Engineers in 1891. He is a fellow of the American Association for the Advancement of Science, and a member of the Institution of Mechanical Engineers, the Verein deutscher Ingenieure, the Astronomical and Astrophysical Society of America, the London Astronomical Society, the Royal Arts Society, Vermont State Board of Education, the Boston Chamber of Commerce, and is a vice-president of the Western New England Chamber of Commerce. He was granted the honorary degrees of M.E. by the University of Vermont in 1910 and M.A. by Yale University in 1914.

ANNUAL REPORT OF THE COUNCIL

The Council presents its annual report of the activities of the Society during the year 1914, although it is possible to mention in the space permitted only the more important and conspicuous phases of the work.

The Standing Committees have given in detail the features of their activities for the year in the reports published in the December issue of The Journal.

As a development of the Society's work, sub-committees of the Committee on Meetings are active in a great variety of branches of the engineering profession, such as the science of administration, cement, fire protection, air machinery, depreciation and obsolescence, hoisting and conveying, industrial building, iron and steel, machine shop practice, railroads, textiles, and a new committee on protection of industrial workers. Five of these committees have produced papers or reports for the Annual Meeting. It is the expectation that eventually all committees will not only make comprehensive reports on the progress of their branch of engineering, but furnish one or more specific papers of major importance and it is thus intended that the Transactions shall contain each year an authoritative review of the state of the art.

The Gas Power Section as such has been reconstituted as a committee, since it has been found that the committee form lends itself to more uniform and simple administration.

Finances. The appropriations at the beginning of the Society year are limited to 90 per cent of the estimated income. During the year just closed these appropriations were increased on account of extraordinary activities, so that the expenses of the year amounted to approximately 95 per cent of the income.

The growth of the Society during the past year has resulted in a large increase in receipts from initiation fees. By resolution of the Council instead of applying these funds to defray the considerable expense of bringing in the members, all of the fees are deposited in a special fund to retire certificates of indebtedness issued to pay for the land of the Society. We now have four years' payments in hand. It has been the policy of the Council to pay all requests on interest bearing dates, January and July, whether or not such requests exceeded the prescribed payment of $6000 per annum. For this reason the fund is allowed to accumulate to an amount sufficient to meet possible demands, insuring the confidence of all.

Certificates of indebtedness amounting to $20,500 have been retired leaving $60,300 outstanding; new investments have been made of $19,385.70. Though the estimated income of 1915 will be slightly larger than that of 1914, the appropriations for the coming year have been reduced below the expenditures of last year, as conservatism is considered the wisest financial policy for this year due to the unusual conditions. While theoretically all the funds paid into the Society are to be converted into benefits for the membership and the profession generally, with the increasing membership and financial transactions, a slightly larger working capital is necessary and a further reason for economy is thus obvious.

Meetings. The usual two general meetings of the Society have been held, one in New York in December and the Spring Convention which this year was held in St. Paul-Minneapolis, an approximate attendance of 1400 members and guests at the former and 500 at the latter were recorded. Thirty-eight papers were presented at these meetings, not including reports of professional committees.

Local meetings under the direction of the various section committees are now held in 13 cities, viz., Atlanta, Buffalo, Boston, Chicago, Cincinnati, Los Angeles, New Haven, New York, Milwaukee, Minnesota, Philadelphia, San Francisco, St. Louis. The Council has made it a distinct policy to encourage the local organizations to cooperate in every way and to develop the local engineering bodies. The programs of the Society meetings are more than ever comprehensive and an effort is being made to secure in the course of a year papers in each of the principal branches of mechanical engineering.

International Engineering Congress. The governing boards of the five national engineering societies under whose auspices the Congress is to be held have recently reconsidered all the conditions now obtaining throughout the world, and have decided to continue the Congress and to do everything possible to make it a success.

A committee has been organized to undertake the reception of visitors and arrange generally for the parties, routes, etc. Dr. Alex. C. Humphreys is Chairman, W. M. McFarland, Vice-Chairman, Charles Warren Hunt, Secretary and W. L. Saunders, Treasurer.

Local reception committees in various centers will shortly be appointed. It is expected that the Director, George M. Brill, who served so efficiently in 1904, 1910 and 1913, on committees in connection with international meetings, will from now on devote practically all his time to the organization of the work throughout the United States.

The following is the personnel of the committee of this Society: E. D. Meier, Ambrose Swasey, Calvin W. Rice, and George M. Brill, Director.

Pan-American Scientific Congress. The United States through the Department of State has arranged for a Pan-American Scientific Congress to be held in Washington in October 1915, following the International Engineering Congress. Since our Society assisted in the earlier congress in 1908, it is again invited. It was recommended that the same societies who are patrons of the International Congress be invited and this the Department of State has been pleased to do. We thus have in this matter the first occasion of which we know where the Government has officially recognized the engineering societies as representing the profession. It is expected that the leading men of science from all the countries of North and South America will officially attend this Congress and in turn our industrial concerns will arrange visits in connection with the professional duties, thus developing cultural relations and mutual confidence.

Relations with Other Organizations. During the year the Society has been represented by Honorary Vice-Presidents at the following meetings: Washington Academy of Sciences in commemoration of W J McGee, held in Washington, D. C., J. A. Holmes; National Rivers and Harbors Congress, Washington, General Wm. H. Bixby; Aeronautical Society Conference in December, Elmer A. Sperry; Dedication John Fitch Memorial, and Atlantic Deeper Waterways Association, Major Wm. H. Wiley.

Representatives of the American Society of Civil Engineers, American Institute of Consulting Engineers, the Western Society of Engineers and The American Society of Mechanical Engineers in joint committee are preparing a biography of the late Alfred Noble which is to be published uniformly in the proceedings of the various organizations of which Mr. Noble was a member.

The Society is gradually extending its relations with sister organizations and now exchanges courtesies in the matter of library and house privileges with the American Gas Institute, New York, the American Institute of Electrical Engineers, New York, the American Institute of Mining Engineers, New York, the American Society of Civil Engineers, New York, the Boston Society of Civil Engineers, Boston, Mass., the Chemists' Club Library, New York, the Cleveland Engineering Society, Cleveland, Ohio, the Columbia University Library, New York, the Dayton Engineers' Club, Dayton, Ohio, the Detroit Engineering Society, Detroit, Mich., the Engineers' Club of Baltimore, Baltimore, Md., the Engineers' Club of Philadelphia, Philadelphia, Pa., the Engineers' Society of Pennsylvania, Harrisburg, Pa., the Engineers' Society of Western Pennsylvania, Pittsburgh, Pa., the Iron and Steel Institute, London, England, the Louisiana Engineering Society, New Orleans, La., the New York Railroad Club, New York, the Pacific Northwest Society of Engineers, Seattle, Wash., the Rochester Engineering Society, Rochester, N. Y., the Scranton Engineers' Club, Scranton, Pa., the Technology Club of Syracuse, Syracuse, N. Y., and the Western Society of Engineers, Chicago, Ill.

At a meeting in December Geheimrat Fr. Romberg of the Verein deutscher Ingenieure addressed the Council on matters concerning technical and industrial education and asked the assistance and suggestions of the Society. Dr. Alex. C. Humphreys, chairman of the Society's Committee on Engineering Education, later reported that the Carnegie Foundation for the Advancement of Teaching has agreed to report on the status of engineering education in America.

Through our initiative a committee has been formed with representatives from many organizations to take up the consideration of a method of standardization for graphic presentation. The appointments on this committee are:

Actuarial Society of America	Wendell M. Strong
American Academy of Political and Social Science	F. A. Cleveland
American Association for the Advancement of Science	J. McK. Cattell
American Association of Public Accountants	Robert H. Montgomery
American Chemical Society	Alexander Smith
American Economic Association	Walter S. Gifford
American Genetic Association	Chas. B. Davenport
American Institute of Electrical Engineers	N. A. Carle
American Institute of Mining Engineers	Judd Stewart
American Mathematical Society	H. E. Hawkes
American Psychological Association	Edward L. Thorndike
American Society of Civil Engineers	Edgar Marburg
American Society of Mechanical Engineers	Willard C. Brinton

American Society of Naturalists	**J. Arthur Harris**
American Society of Testing Materials	**F. E. Schmitt**
American Statistical Association	**Leonard P. Ayres**
Bureau of the Census	**Joseph A. Hill**
Bureau of Standards	**H. D. Hubbard**

The National Board of Fire Underwriters have requested the coöperation of this Society in the standardization of piping for sprinkler apparatus. The Council appointed Charles A. Olson who has been chosen chairman of the committee.

The American Society for Testing Materials asked the appointment of representatives of the Society on a special committee considering the modification of the Briggs Standard for Pipe Threads, and Stanley G. Flagg, Jr., and John C. Bannister are the appointees.

Standardization work has been actively followed by the committees on flanges; pipe threads; boiler specifications; dimensions in screw threads; threads for fixtures and fittings; changes in the patent laws of the United States; power tests, a most voluminous report comprising standard methods for testing prime movers and all types of auxiliary apparatus; researches into the subject of standardization of safety valves; standardization of commercial filters.

The Boiler Code and associate committees have given an extraordinary amount of time and personal work to the preparation of the preliminary report, which is to be presented at the Annual Meeting in December. They have invited and are receiving helpful suggestions and the interested coöperation of 40 or more organizations including the railway, boiler and safety valve engineers all over the United States.

Public Relations. The outcome of a joint conference of members of the national engineering societies, including the American Institute of Consulting Engineers, was a resolution of the Council approving the appointment of engineers qualified by training and experience for positions on public service commissions and as heads of engineering departments in national, city and state governments.

The city of New York asked this Society to appoint a representative on a special board to pass upon the specifications and tests for fire hose. By mutual agreement of the Council and the Chamber of Commerce, H. deB. Parsons was appointed to represent the two organizations jointly.

Special Committees. The reports of the Committees on Catalogues and Code of Ethics have been completed this year.

Prof. A. M. Greene, Jr., member of the Council and professor of mechanical engineering of Rensselaer Polytechnic Institute, has been appointed to fill the vacancy caused by the death of Alfred Noble on the Conference Committee of the engineering societies in the matter of registration of engineers.

Gifts. Through the generosity of Henry Hess, member of the Council, there have been established two funds of $1000 each, the income from which is to be awarded for the best paper by a Junior member of the Society and to such two enrolled members of any student branch as contribute the best papers.

These are the only prizes of this character in the gift of the Society at this time and they should stimulate the efforts of these two classes of our membership.

J. S. Lane has loaned to the Society letters patent, which were issued in 1825 before the establishment of the Patent Office, and bearing the signatures of John Quincy Adams, President, and Henry Clay, Secretary of State.

J. W. Lieb has given the joint library of the engineering societies a series of most valuable volumes covering the work of Leonardo da Vinci. This generous and thoughtful act was a sequel to the presentation by Mr. Lieb at our last Annual Meeting, of a masterful address on Leonardo da Vinci, the Artist, Philosopher and Engineer.

Publications. During the year 12 numbers of The Journal have been issued, one volume of Transactions, the Year Book, and a volume of Condensed Catalogues.

The Foreign Review has been expanded and now includes abstracts from the principal papers presented before other professional and learned societies. This review is separately paged in each Journal so that it may be bound and independently preserved.

It had been the plan to have The Journal contain the Transactions and thus do away with the duplicate publication, but to meet the desires of a substantial number of the membership, the separate issue of Transactions in the 6 by 9 size, bound in half morocco, will be continued for the present.

Membership. The net increase of 1004 in the membership is shown in the diagram on the following page.

On October 1, 1914, the membership in the different grades numbered as follows: Honorary Members 14, Members 4077, Associate-Members 245, Associates 380, Juniors 1274.

Honorary Membership was conferred upon A. F. Yarrow, of London, England.

Growth of Society since 1880

There have been 41 deaths, 38 resignations and 18 reinstatements. In the list of deaths we record that of George Westinghouse, Past-President and Honorary Member, and Alfred Noble, member of the Council. As a special token of respect and esteem, Mr. Noble's place as manager was left unfilled on the Council during the balance of the year.

The student branches now number 36, showing a total enrollment of 955. Three new branches have been added during this year. The Society is now represented at Armour Institute of Technology, Carnegie Institute of Technology, Case School of Applied Science, Columbia University, Cornell University, Kansas State Agricultural College, Leland Stanford Jr. University, Lehigh University, Massachusetts Institute of Technology, New York University, Ohio State University, Pennsylvania State College, Polytechnic Institute of Brooklyn, Purdue University, Rensselaer Polytechnic Institute, State Agricultural College of Colorado, State University of Iowa, State University of Kentucky, Stevens Institute of Technology, Syracuse University, Throop College of Technology, University of Arkansas, University of California, University of Cincinnati, University of Colorado, University of Illinois, University of Kansas, University of Maine, University of Michigan, University of Minnesota, University of Missouri, University of Nebraska, University of Wisconsin, Washington University, Worcester Polytechnic Institute, Yale University.

The Increase of Membership Committee, I. E. Moultrop, Chairman, has continued the effective work of the past, augmented by hearty response from the membership. Only prominent engineers are approached and are carefully selected by the Committee. The influence of the Society is therefore much increased and at the same time representation in many varieties of industry is secured. Sub-Committees with their respective chairmen, are established at the following centers: Atlanta, Park A. Dallis; Boston, A. L. Williston; Chicago, P. A. Poppenhusen; Cincinnati, J. T. Faig; Cleveland, R. B. Sheridan; Detroit, H. H. Esselstyn: Los Angeles, Orlando J. Root; New Haven, E. H. Lockwood; New York, J. A. Kinkead; Philadelphia, T. C. McBride; Rochester, J. C. Parker; St. Louis, John Hunter; St. Paul, Max Toltz; San Francisco, Thomas Morrin; Seattle, R. M. Dyer; Troy, A. E. Cluett.

Employment Work. The Secretary's office has placed at least 40 members during the year, some in leading positions. We have no means of telling definitely about all positions, as in cases of numerous inquiries received from firms wanting draftsmen for temporary work, or instances which frequently occur where a man applying for one position suits another need of a firm and is engaged for that. The register of available men is made up of members of the Societv. and of non-members who have been personally introduced by members of the Society.

The underlying motive of the Society's work is service to the profession, and it is important for the members in general to be aware of the many ways in which the Society is carrying out this purpose as well as benefiting its members individually. The average number of visitors in the Society rooms is about forty a day.

Membership in the Society should carry with it the opportunity for work and an increasing sense of responsibility and privilege in rendering service rather than any personal advantage which may be derived.

No. 1428

MEETINGS JANUARY—JUNE

MEETINGS IN LOCAL CENTERS

ST. PAUL, JANUARY 7

Lecture, illustrated by lantern slides: The American Railroad Ditcher, by Oliver Crosby.

NEW YORK, JANUARY 9

Joint meeting with the American Institute of Electrical Engineers and the American Electro-Chemical Society. Symposium on Electrolytic Deposition of Metals. Papers: Limitations of the Problem of Electrolytic Deposition, Lawrence Addicks; Sources of Direct Current for Electro-Chemical Processes, by F. D. Newbury, Mem.Am. Inst.E.E.,; and The Power Problem in the Electrolytic Deposition of Metals, by H. E. Longwell.

Mr. Longwell's paper appears in abstract form in The Journal for July 1914.

PHILADELPHIA, JANUARY 17

Joint meeting with the Engineers Club, preceded by a dinner. Paper: Recent Locomotive Development, by Geo. R. Henderson.

CHICAGO, JANUARY 28

Paper: Boiler Tests with Illinois Coal, by Bryant Bannister, Kewanee, Ill. This paper and the discussion were published in abstract form in The Journal for June 1914.

MILWAUKEE, FEBRUARY 3

Paper: Wuest Herringbone Gears, by Percy C. Day, published in Transactions, Vol. 33.

BOSTON, FEBRUARY 4

Joint meeting with Boston Society of Civil Engineers and the American Institute of Electrical Engineers. Topic: Recent Developments and Present Tendencies in Railroad Work; Papers: Rolling Stock, by Henry Bartlett, general mechanical superintendent, Boston

& Maine R. R.; Electrical Equipment, by Frederic D. Hall, electrical engineer, Boston & Maine R. R.; and Permanent Way, by A. B. Corthell, chief engineer, Boston & Maine R. R. Published in abstract form in The Journal for July 1914.

ST. LOUIS, FEBRUARY 4

Lecture: Air Conditioning, by J. Irvine Lyle.

PHILADELPHIA, FEBRUARY 9

Joint meeting with the American Institute of Electrical Engineers. Subject: Business Training for the Engineer, by Dr. Alex. C. Humphreys, and Theodore L. Jones, of the Edison Illuminating Company of Brooklyn, N. Y. An account of the meeting appears in The Journal for March 1914.

NEW YORK, FEBRUARY 10

Meeting under the joint auspices of the New York Committee on Meetings and the Sub-Committee on Railroads. Paper: Brake Performance on Modern Steam Railroad Passenger Trains, by S. W. Dudley, assistant chief engineer, Westinghouse Air Brake Company, Pittsburgh, Pa. This paper is available in pamphlet form; and was also published in abstract form, together with discussion, in The Journal for November 1914.

SAN FRANCISCO, FEBRUARY 10

Topic: Transportation of Crude Oil in Pipe Lines; Paper by E. I. Dyer, engineer-in-chief, Union Oil Company of California. San Francisco, on Notes on the Flow of Oil in Pipes. Published in abstract, together with discussion, in The Journal for July 1914.

MINNEAPOLIS, FEBRUARY 11

Illustrated lecture by C. L. Pillsbury, on the Construction and Mechanical Details of the Minnesota State Prison at Stillwater.

CINCINNATI, FEBRUARY 12

Joint meeting with the Engineers Club. Address, by J. Irvine Lyle, on Air Conditioning.

MILWAUKEE, FEBRUARY 14

Paper: The Newer Types of High Reduction Gears, by Percy C. Day.

ATLANTA, FEBRUARY 18

Meeting of affiliated technical societies, under auspices of the Engineering Association of the South. Paper: The Plaza over the Railroads in Atlanta's Business Center, by C. E. Kaufman, in charge of bridges and buildings in the department of the chief of construction.

BUFFALO, FEBRUARY 26

Address: The Human Factor in Management, by James Hartness, followed by an informal talk on the work of the Society, by Calvin W. Rice.

BOSTON, MARCH 4

Annual dinner of the engineering societies of Boston, held at the Boston City Club. Addresses by Guy E. Tripp, Dr. A. E. Kennelly, C. O. Mailloux, James Hartness, and Dr. M. W. Franklin. A more complete account appears in The Journal for April 1914.

NEW YORK, MARCH 10

Joint meeting with the American Institute of Mining Engineers and the American Electro-Chemical Society. Subject: Color Photography, with papers by F. E. Ives, Westley Allison, C. W. Robinson, and George R. Clifton. An extended account of the meeting is given in The Journal for April 1914.

BOSTON, MARCH 11

Symposium on Welding. Papers: The Oxy-Acetylene Process of Welding, by Henry Cave; Welding of Metals with Liquid Fuel, by W. N. Best; The Thermit Process of Welding, by W. R. Hulbert; and Electric Welding, by W. A. Hodges. An abstract of these papers appears in The Journal for June 1914.

BUFFALO, MARCH 12

Paper: Safety Appliances in Industrial Plants, by John Price Jackson.

PHILADELPHIA, MARCH 14

Joint meeting with the Engineers Club. Paper: Steam Power Plants, by I. E. Moultrop.

CHICAGO, MARCH 18

Topical Discussion: Large Steam Power Plants, by I. E. Moultrop, J. W. Parker, John Hunter and W. L. Abbott. Published in abstract form in The Journal for June 1914.

MILWAUKEE, MARCH 21

All-day meeting. Morning session: Address by Wm. George Bruce, secretary, Merchants and Manufacturers Association of Milwaukee. Papers: Cement and Clay Products Contrasted, by Alfred O. Crozier; Historical Significance of the 1907 Wisconsin Law for the Regulation of Public Utilities, by Prof. R. C. Disque. Afternoon session. Papers: Principles of Illumination, by John Hayes Smith; Principles of Street Lighting, by Arthur J. Sweet and Francis A. Vaughn; Manufacture of Pure Iron Products, by G. F. Ahlbrandt; the Measurement of Gases in Large Quantities, by J. C. Wilson; Modern Machine Tools, by A. Wood; and Development in American Power Plant Machinery, by Prof. A. G. Christie. Evening session: Lecture on Radium, by Dr. Hubert N. McCoy.

BUFFALO, MARCH 26

Address: Mine Safety and Mine Rescue Work, by H. M. Wilson, engineer-in-charge, U. S. Bureau of Mines Experimental Station.

BOSTON, APRIL 8

Symposium: Selective Package and Pneumatic Conveyors. Papers: Conveyors of the Selective Type, by W. O. Hildreth; Pneumatic Conveyors, by F. B. Williams; Machinery for Handling Small Packages, S. L. Haines. Published in abstract form in The Journal for July 1914.

BUFFALO, APRIL 10

Lecture: Industrial Germany, by Prof. L. P. Breckenridge.

CINCINNATI, APRIL 14

Meeting held by the University of Cincinnati Student Branch for the Cincinnati Section. Lecture: Flood Prevention Work in the Great Miami Valley, by K. C. Grant.

NEW YORK, APRIL 14

Paper: Graphic Statistics for the Engineer and the Executive, by Willard C. Brinton.

CINCINNATI, APRIL 23

Joint meeting with the Engineers Club of Cincinnati. Papers: Beginning and Development of the Machine Tool Industry in Cincinnati, by A. L. Jenkins; Reinforced Concrete, by Ludwig Eid.

PROVIDENCE, APRIL 29

Annual joint meeting with the Providence Association of Mechanical Engineers. Addresses by officers of the Society, followed by a lecture on the Manufacture of Tubing, by Harold T. Miller, National Tube Company.

PHILADELPHIA, APRIL 30

Joint meeting with the Franklin Institute. Paper: Locomotive Superheaters and Their Performance, by C. D. Young.

NEW HAVEN, MAY 1

Spring meeting of the New Haven Section. Subject: Aeronautics and the Internal-Combustion Motor.

ST. LOUIS, MAY 4

Entertainment to the Associated Engineering Societies of St. Louis. Lecture: Through Germany with the A.S.M.E., illustrated with photographs taken during the trip, given by Arthur Seubert.

SAN FRANCISCO, MAY 6

Paper: Stationary Diesel Engine, by Herbert Haas.

NEW YORK, MAY 12

Address: Main Drainage and Sewage Disposal Plans for the City of New York, by H. DeB. Parsons. A more complete account appears in The Journal for June 1914.

BOSTON, MAY 13

Topic: Boiler Room Practice, by Chas. H. Manning, W. G. Diman, I. E. Moultrop, James D. Andrew, E. G. Bailey, F. W. Dean, John A. Stevens, and Henry Bartlett.

CHICAGO, MAY 13

Subject: Machine Shop and Machine Tool Practice, by P. W. Gates, Robert W. Hunt, and Arthur M. Houser.

CINCINNATI, MAY 21

Joint meeting with the Engineers Club. Address: Municipal Government under the City Manager Plan, by Henry M. Waite, manager of the City of Dayton.

ST. LOUIS, JUNE 3

Paper: Recent Developments in the Manufacture of the Diesel Engine, by H. R. Setz. Published in The Journal for December 1914.

CINCINNATI, JUNE 4

Joint meeting with the Engineers Club. Address: From Ore to National Pipe, by W. A. Phillis, National Tube Company, Pittsburgh.

THE SPRING MEETING

The Spring Meeting at St. Paul-Minneapolis, the first meeting of the Society to be held in the "Twin Cities," was a decided success. The attendance was unexpectedly large, influenced probably as much by the natural local attractions as by the program of professional papers. The meetings were held from June 16 to 19, with headquarters at the St. Paul Hotel in St. Paul, there being 121 members registered and 279 guests, a total of 400. The professional meetings were held in the ball room of the hotel, with the exception of the Thursday forenoon session, which was held in the Engineering Building of the University of Minnesota in Minneapolis. The usual Friday morning session was replaced by technical excursions which, in line with the present practice of the Committee on Meetings to provide increased opportunity for social attractions at the Spring Meeting, did much to add to the pleasure of the meeting.

The registration started on Tuesday afternoon when a large party of members arrived by special train from the East at 4 o'clock. In the evening there were addresses of welcome by Governor A. O. Eberhardt, representatives of the Chamber of Commerce and the mayor of St. Paul.

At the Wednesday morning business meeting the overshadowing event was the discussion upon the subject of boiler specifications. A tentative draft of the Boiler Code Committee's recommendations had been printed so that its work might be checked up and revised before submitting the report for general discussion. There had been a preliminary discussion of the matter at Chicago on Monday by representatives of various organizations, and this discussion was continued at the opening session on Wednesday morning. The result was a resolution calling for a public hearing to be held in the rooms of the Society in New York on September 15, 1914.

The papers presented at the various technical sessions are given in the program accompanying this report. Three of these papers, given at the session held at the University of Minnesota, were by local engineers, upon the subjects of water power development on the Mississippi, the handling of coal on the Great Lakes and flour milling. At this session, also, addresses were made by Honorable Fred B. Snyder, Senator and Regent of the University, Prof. H. T. Eddy of the faculty of the University and H. G. Reist, representing the Council of the Society.

Immediately after luncheon on this day the members and guests went by special train to the residence of Mr. Gebhard Bohn on Lake Minnetonka where the visitors were delightfully entertained and an elaborate program was carried out.

The usual Wednesday evening lecture was on the subject of ore handling by John Hearding, superintendent of the Oliver Iron Mining Co. of Duluth. A number of reels of films were run off by Mr. Hearding who described in a most interesting manner all phases of iron mining work on the Mesaba Range.

The Local Committee, consisting of Max Toltz, chairman, Chas. L. Pillsbury, vice-chairman, E. J. Heinen, secretary, Paul Doty and W. H. Kavanaugh, had made extensive provision for the comfort and entertainment of the visitors, and the numerous social features, with the various excursions to plants of interest in the vicinity, were thoroughly enjoyed.

PROGRAM

Tuesday Afternoon, June 16

Registration of members and guests at headquarters, Hotel St. Paul.

ST. PAUL

Tuesday Evening

Membership reunion and informal reception. Introductory remarks by the chairman of the Local Committee, Max Toltz. Welcome to Minnesota by Governor A. O. Eberhardt. A response by James Hartness, President, fol-

lowed by a message to the engineering fraternity, especially the mechanical engineering profession, by James J. Hill, former president of the Great Northern System.

Wednesday Morning, June 17

BUSINESS MEETING

Proposed amendments to the Constitution and announcement of ballot on amendments to C-9 and C-11. Discussion of Report of Committee on Flanges. Report of Committee on Boiler Specifications.

PROFESSIONAL SESSION

PULVERIZED COAL BURNING IN THE CEMENT INDUSTRY, R. C. Carpenter.

PULVERIZED COAL FOR STEAM MAKING, F. R. Low.

AN INSTALLATION FOR POWDERED COAL FUEL IN INDUSTRIAL FURNACES, Wm. Dalton and W. S. Quigley.

TOPICAL DISCUSSION ON POWDERED FUEL.

Discussed by C. W. Baker, L. L. Hubbard, J. G. Coutant, C. J. Davidson, J. V. Culliney, W. R. Dunn.

Wednesday Afternoon

PROFESSIONAL SESSION

INDUSTRIAL SERVICE WORK IN ENGINEERING SCHOOLS, J. W. Roe.

Discussed by L. P. Alford, P. F. Walker, H. L. Gantt, C. W. Rice, Paul Doty, James Hartness.

CLASSIFICATION AND HEATING VALUE OF AMERICAN COALS, Wm. Kent.

Discussed by P. F. Walker, A. G. Christie.

THE RAILROAD TRACK SCALE, W. Wallace Boyd.

GEAR TESTING MACHINE, Wilfred Lewis.

Discussed by E. H. Neff, Henry Hess, P. F. Walker, A. G. Christie

A FLOW METERING APPLIANCE, A. M. Levin.

Discussed by S. M. Woodward.

Wednesday Evening

Lecture on Iron Ore Handling, with moving pictures, by John Hearding, superintendent, Oliver Iron Mining Company, Duluth.

MINNEAPOLIS

Thursday Morning, June 18

Opening addresses at University of Minnesota, by Hon. Fred B. Snyder, Senator, and Regent of the University, and Prof. H. T. Eddy, Emeritus Dean of the Graduate School. Remarks by H. G. Reist, representing the Council of the Society.

PROFESSIONAL SESSION

POWER DEVELOPMENT AT THE HIGH DAM BETWEEN MINNEAPOLIS AND ST. PAUL, Adolph F. Meyer.

THE HANDLING OF COAL AT THE HEAD OF THE GREAT LAKES, G. H. Hutchinson.

MINNEAPOLIS FLOUR MILLING, Charles A. Lang.

Thursday Afternoon

Luncheon in the Experimental Engineering Building.

Reception given by Mr. Gebhard Bohn at his home on Lake Minnetonka.

Friday, June 19

Technical excursions in St. Paul and Minneapolis.

No. 1429

REPORT OF COMMITTEE ON CODE OF ETHICS

A GENERAL PRINCIPLES

It is not assumed that this code shall define in detail the duties and obligations of engineers under all possible circumstances. It is an axiom that engineers in all their professional relations should be governed by principles of honor, honesty, strict fidelity to trusts imposed upon them, and courteous behavior toward all. The following sections are framed to cover situations arising most frequently in engineers' work.

It is the duty of engineers to satisfy themselves to the best of their ability that the enterprises with which they become identified are of legitimate character. If an engineer after becoming associated with an enterprise finds it to be of questionable character, he should sever his connection with it as soon as practicable, avoiding in so doing reflections on his previous associates.

B THE ENGINEER'S RELATIONS TO CLIENT OR EMPLOYER

The engineer should consider the protection of a client's or employer's interests his first obligation, and therefore should avoid every act contrary to this duty. If any other considerations, such as professional obligations or restrictions, interfere with his meeting the legitimate expectation of a client or employer, the engineer should so inform him.

An engineer cannot honorably accept compensation, financial or otherwise, from two or more parties having conflicting interests without the consent of all parties. The engineer, in whatever capacity, whether consulting, designing, installing, or operating, must not accept commissions, directly or indirectly, from parties dealing with his client or employer. The only condition under which such commissions may honorably be accepted is when they are given with the full knowledge and approval of all parties concerned.

Recommended by letter ballot of membership, reported at the Spring Meeting, St. Paul-Minneapolis, June 1914, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

An engineer called upon to decide on the use of inventions, apparatus, or anything in which he has a financial interest, should make his status clearly understood by those employing him.

The engineer, in conformity with the practice in other professions, should not offer or execute a bond to guarantee the performance of his work. The client's reliance for the satisfactory execution of his work should be the professional reputation and experience of the engineer.

An engineer in independent practice may be employed by more than one party, when the interests of the several parties do not conflict; and it should be understood that he is not expected to devote his entire time to the work of one, but is free to carry out other engagements. A consulting engineer permanently retained by a party, should notify other prospective clients of this affiliation before entering into relations with them, if in his opinion, the interests might conflict.

Before any consulting engineer takes over the work of another consulting engineer he should ask the client his reasons for desiring to change engineers and unless the consulting engineer is entirely satisfied that the client has good and sufficient reasons for making the change he should confer with the present incumbent before accepting the work.

Consultations should be encouraged in cases of doubt or unusual responsibility. The aim should be to give the client the advantage of collective skill. Discussions should be confidential. Consulting engineers should not say or do anything to impair confidence in the engineer in charge unless it is apparent that he is wholly incompetent or the interests of the profession so require.

Engineers acting as experts in legal and other cases, in making reports and testifying, should not depart from the true statement of results based on sound engineering principles. To base reports or testimony upon theories not so founded is unprofessional.

An engineer should make every effort to remedy dangerous defects in apparatus or structures or dangerous conditions of operation, and should immediately bring these to the attention of his client or employer. As failure of any engineering work reflects upon the whole profession, every engineer owes it to his professional associates as well as to himself that a reasonable degree of safety be provided in all work undertaken.

C OWNERSHIP OF ENGINEERING RECORDS AND DATA

It is desirable that an engineer undertaking for others work in connection with which he may make improvements, inventions, plans, designs or other records should first enter into an agreement regarding their ownership.

If an engineer uses information which is not common knowledge or public property, but which he obtains from a client or employer, resulting in plans, designs, or other records, these should be regarded as the property of his client or employer.

If a consulting engineer uses only his own knowledge, or information, which by prior publication, or otherwise, is public property and obtains no engineering data from a client or employer, except performance specifications or routine information; then in the absence of an agreement to the contrary, the results in the form of inventions, plans, designs, or other records should be regarded as the property of the engineer, and the client or employer should be entitled to their use only in the case for which the engineer was employed.

All work and results accomplished by an engineer in independent practice in the form of inventions, plans, designs, or other records, which are outside of the field of engineering for which a client or employer has retained him, should be regarded as the engineer's property unless there is an agreement to the contrary.

When an engineer or manufacturer builds apparatus from designs supplied to him by a customer, the designs remain the property of the customer and should not be duplicated by the engineer or manufacturer for others without express permission. When the engineer or manufacturer and a customer jointly work out designs and plans or develop inventions, a clear understanding should be reached before the beginning of the work regarding the respective rights or ownership in any inventions, designs, or matters of similar character, that may result.

Any engineering data or information which an engineer obtains from his client or employer, or which he creates as a result of such information, must be considered confidential by the engineer; and while he is justified in using such data or information in his own practice as forming part of his professional experience, its publication without express permission is improper.

Designs, data, records and notes made by an employe and referring exclusively to his employer's work, should be regarded as his employer's property.

A customer, in buying apparatus, does not acquire any right in its design, but only the use of the apparatus, purchased. A client does not acquire any right to the plans made by a consulting engineer except for the specific case for which they were made, unless there is an agreement to the contrary.

D THE ENGINEER'S RELATIONS TO THE PUBLIC

The engineer should endeavor to assist the public to a fair and correct general understanding of engineering matters, to extend the general knowledge of engineering, and to discourage the appearance of untrue, unfair or exaggerated statements on engineering subjects in the press or elsewhere, especially if these statements may lead to, or are made for the purpose of, inducing the public to participate in unworthy enterprises.

Technical discussions and criticisms of engineering subjects should not be conducted in the public press, but before engineering societies or in technical publications.

It is desirable that the first technical descriptions of inventions, or other engineering advances, should not be made through the public press, but before engineering societies or through technical publications.

It is unprofessional to give an opinion on a subject without being fully informed as to all the facts relating thereto and as to the purposes for which the information is asked. The opinion should contain a full statement of the conditions under which it applies.

Engineers engaged in private practice should limit their advertising to professional cards and modest signs in conformity with the practice of other professions.

E THE ENGINEER'S RELATIONS TO THE ENGINEERING FRATERNITY

The engineer should take an interest in and assist his fellow engineers by exchange of general information and experience, by instruction and similar aid, through the engineering societies, the engineering schools, or other means. He should endeavor to protect all reputable engineers from misrepresentation.

The engineer should take care that credit for engineering work is attributed to those who, so far as his knowledge of the matter goes, are the real authors of such work.

Criticism of the work of one engineer by another should be broad and generous with the facts plainly stated. The success or failure of one member reflects credit or discredit on the whole profession.

The attitude of superiors toward subordinates should be that of helpfulness and encouragement. The attitude of subordinates to superiors should be one of loyality and diligent support. The treatment of each by the other should be open and frank.

The attitude of an engineer toward contractors should be one of helpful coöperation. Tact and courtesy should be combined with firmness. An engineer should hold a judicial attitude toward both parties to a contract for the execution of which he is responsible.

An engineer in responsible charge of work should not permit non-technical persons to overrule his engineering judgment on purely engineering grounds.

F INTERPRETATION

If two or more engineers, members of this Society, disagree as to the interpretation of this Code, or as to the proper rules of conduct which should govern them in professional relations to each other, they may agree to refer the matter to a standing committee of the Society on the interpretation of the Code. Each party shall submit a statement of his position in writing, and the committee shall render a decision. A permanent record shall be made of the cases so submitted and decided.

Amendments or additions to this Code may be made by the standing committee on interpretation of the Code, subject to the approval of the Council.

Respectfully submitted,

Charles W. Baker, *Chmn.*
Charles T. Main
E. D. Meier
Spencer Miller
C. R. Richards

Members of Committee on Code of Ethics

No. 1430

REPORT OF THE COMMITTEE ON STANDARDIZATION OF FLANGES

THE AMERICAN STANDARD. RECOMMENDED FOR ADOPTION JANUARY 1, 1914 AND REVISED TO MARCH 7 AND 20, 1914.

The Committee on Standardization of Flanges of The American Society of Mechanical Engineers has presented the following report on a standard for pipe flanges, fittings, and their bolting, together with a recommendation in regard to minimum thickness of wall in cast-iron pipe.

2 This new standard was arrived at after a long series of conferences with the Manufacturers' Committee, and is a compromise, consistent with good engineering practice, between the 1912 U. S. Standard heretofore recommended by the Society's committee and the Manufacturers' Standard adopted in 1912.

3 In addition to the adoption of the compromise standard, the committee, in conjunction with the Manufacturers' Committee, have extended the standard weight or low-pressure sizes from 30 in. to 100 in., in order to provide for the large sizes now called for in connection with steam-turbine installations, etc., and have also extended the extra heavy or high-pressure sizes from 24 in. to 48 in., in order to take care of high-pressure water mains.

4 The Committee believe that the compromise standard here presented combines all the advantages of the 1912 U. S. Standard with the best points in the Manufacturers' Standard, and, owing to the extension from 30 in. to 100 in. in the low-pressure and from 24 in. to 48 in. in the high-pressure sizes, gives much more consistent dimensions and stresses in the larger sizes.

Presented at the Annual Meeting, New York 1913, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS, and subsequently revised.

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Presented at the Annual Meeting, New York 1913, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS, and subsequently revised.

FLANGES AND BOLTS

5 *General.* Generally speaking, in so far as flanges and bolting are concerned, the 1912 U. S. Standard 125-lb. schedule, sizes 1 in. to 30 in. inclusive, remains almost unchanged. Nearly all of the alterations to the flanges and the bolting of the 250-lb. 1912 U. S. Standard, 1 in. to 24 in. inclusive, are the result of compromises with the Manufacturers' Standard, and when taken in connection with new additional sizes, 26 in. to 48 in. inclusive, form a more regular design than would have occurred had the Manufacturers' sizes been accepted without compromise.

6 Fig. 13 shows a curve of bolt stresses for present and additional 250-lb. sizes, 1 in. to 48 in. inclusive, as are now finally worked out. Fig. 16 contains comparative bolt stress curves of 125-lb. size, 1 in. to 30 in., and 250-lb., 1 in. to 24 in., for the Manufacturers' Standard of October 1912, the 1912 U. S. Standard, and the proposed American Standard. It will be plainly seen from the more regular form of curve that the new American Standard is better than either of the other two. The bolt stress curve at the 4-in., 22-in. and 24-in. sizes of the 125-lb. standard have been made less abrupt. The one for the 250-lb. standard at the 14-in., 16-in., 18-in., 20-in., 22-in. and 24-in. sizes shows the compromise more in favor of the 1912 U. S. Standard than that of the Manufacturers', and at the same time, as before stated, connecting better with the curve for new additional sizes.

7 *Bolt Circles.* The only 1912 U. S. bolt circle changed was on the 250-lb. 10-in. size. This was changed from 15¾ in. to 15¼ in. in diameter, as a result of a conference with the Manufacturers' Committee. The Manufacturers' Committee adopted the 1912 U. S. Standard bolt circles for the 250-lb. 14-in., 15-in., 18-in., 20-in., 22-in. and 24-in. pipe sizes, changing in each case their October 1912 Standard to do so.

8 *Flange Diameters.* Regarding flange diameters, the 250-lb. 9-in. and 10-in. sizes were changed to suit the Manufacturers' schedule. Sizes 12-in., 14-in., 15-in., 16-in., 18-in., and 20-in. were also changed and form a fair compromise between the 1912 U. S. and the Manufacturers' Standards. The American Standard flange diameters for the 22-in. and 24-in. pipe sizes are identical with those of the 1912 U. S. Standard, the Manufacturers' Committee changing their own standard to adopt same. Nearly all of these changes were made to suit the changed diameters of bolts before mentioned.

9 *Flange Cross-Sections.* Every effort has been made to grade all sizes as uniformly as was found consistent with sudden changes in the number of bolts necessary to allow of flanges turning on 90-deg. angles.

10 *Bolt Diameters, 125-Lb. Working Pressure.* Changes which were made to the 1912 U. S. 125-lb. Standard are as follows: the 3/4 in. diameter of bolt for the 4-in. size was made 5/8 in., making it conform to the Manufacturers' Standard. The bolts on the 22-in. and 24-in. sizes were increased from 1 1/8 in. to 1 1/4 in. diameter (American Standard). These changes were made to improve the conformity of the stress curve.

11 *250-Lb. Working Pressure.* The changes made to the 1912 U. S. 250-lb. Standard are shown on Fig. 16, as follows: The 1 1/4 in. diameter of bolt for the 14-in. size is now 1 1/8 in. The 1 3/8 in. for the 16-in. and 18-in. sizes is changed to 1 1/4 in. The 1 1/2 in. diameter for the 20-in. size is made 1 3/8 in. In meeting the requirements of the American Standard, the Manufacturers' Committee changed their bolt diameters for the 12-in., 14-in., 15-in., 16-in., 18-in., 20-in., 22-in. and 24-in. pipe sizes.

12 *Changes in Number of Bolts.* The number of bolts on the 22-in. and 24-in. sizes was changed from 28, in the 1912 U. S. and the Manufacturers' Standards, to 24, to agree with the American Standard.

FLANGED FITTINGS

1 In. to 30 In. in Diameter for 125 Lb. and 1 In. to 24 In. for 250 Lb. Working Pressure per Sq. In.

13 The new schedule adopted by the A.S.M.E. Committee will be known as the American Standard (effective January 1, 1914) and is made up of dimensions, many of which are common to both the 1912 U. S. Standard and the Manufacturers' Standard of October 1, 1912. The remaining dimensions were suggested by the Manufacturers' Committee as changes to their own standard of October 1912, in an attempt to approach the 1912 U. S. Standard as closely as possible, and at the same time to admit of making use of many of their present patterns. As the suggestions of the Manufacturers did not involve any question of strength, and as the variations from the 1912 U. S. Standard were, for the most part, slight (as shown by comparative curves of face to face dimensions, Figs. 17-26, inclusive), it was considered advisable by the A.S.M.E. Committee to adopt these suggestions.

14 *Additional Sizes.* Additional sizes of 125-lb. flanged fittings, 32 in. to 100 in. inclusive, and 250-lb., 26 in. to 48 in. inclusive, were worked up in schedule form by the Manufacturers' Committee and presented for the consideration of the A.S.M.E. Committee. The A.S.M.E. additional flange and bolting sizes were all incorporated in the designs for these fittings. Curves of center to face dimensions were then worked up in connection with the present standard sizes and were found by the A.S.M.E. Committee to form a complete and uniform design.

15 *Interchangeability.* On all reducing tees and crosses from 1 in. to 16 in. inclusive, the center to face dimension of the various outlets is the same on fittings of the same size run. For sizes 18 in. and up interchangeability exists in two classes, one for short body and also one for long body patterns.

Example: All center to face dimensions of a 5-in. by 5-in. by 1-in. tee are the same as a 5-in. by 5-in. by 5-in. tee and are interchangeable with any combination of 5-in. cross.

16 *Cast-Iron Pipe Wall Thicknesses.* In connection with the flange and fittings schedules, it was considered desirable to determine a minimum for pipe wall thicknesses, for 125-lb. sizes, 1 in. to 100 in., and 250 lb. 1 in. to 48 in. Accordingly, curves "A," 125 lb., and "C," 250 lb., Fig. 15, were plotted from a formula adopted July 18, 1894, by the Committees of the A.S.M.E. and the Master Steam and Hot Water Fitters Association for 75-lb. and 200-lb. flange schedule. The thicknesses derived from this formula were found to be somewhat thinner than those in use with the manufacturers. The formula was then increased by a constant of 1.2, curves "B" 125 lb., and "D" 250 lb., Fig. 15, showing results. The 125-lb. curve of the Manufacturers' sizes coincides with curve "B" for all standard sizes, except the 30-in., which, together with additional sizes 32 in. to 48 in., call for a gradual increase in thicknesses. However, thicknesses for the American Standard have been taken from curve "B." The 250-lb., curve "D," closely follows that of the Manufacturers, and has also been embodied as part of the new standard. The straight thin lines passing through these curves and intersecting ordinates erected upon a horizontal at points distant from an origin equal to inside diameter of pipes represent the actual formula. The length of each ordinate between the formula and the horizontal lines is the theoretical thickness of each pipe wall.

17 *Pipe Wall Stresses.* The stresses in pipe walls given in the

new American Standard schedules, Tables 1 and 2 (125-lb. and 250-lb.), are calculated by the following formula in customary use for low pressures:

$$S = \frac{D \times p}{2 \times t}$$

where

D = inside diameter of pipe
t = thickness of pipe
p = working pressure per sq. in.

or more simply

$$S = \frac{r \times p}{t}$$

where

r = inside radius of pipe.

18 The highest stress was found to be 2000 lb. per sq. in. on the 250-lb. 46-in. and 48-in. pipe walls, giving a factor of safety of about 10. A comparison of pipe wall stresses corresponding to thicknesses given by curves "A," "B," "C," and "D," Fig. 15, was worked up in logarithmic form based on the formula given above. It will be seen that pipe wall stresses derived from curves of thicknesses "B" and "D" give lower rates of stresses than obtained from curves "A" and "C."

EXPLANATORY NOTES

a Standard and Extra Heavy Reducing Elbows carry same dimensions center to face as regular Elbows of largest straight size.

b Standard and Extra Heavy Tees, Crosses and Laterals, reducing on run only, carry same dimensions face to face as largest straight size.

c If Flanged Fittings for lower working pressure than 125 lb. are made, they shall conform in all dimensions except thickness of shell, to this standard and shall have the guaranteed working pressure cast on each fitting. Flanges for these fittings must be of standard dimensions.

d Where long radius fittings are specified, it has reference only to Elbows which are made in two center to face dimensions and to be known as Elbows and Long Radius Elbows, the latter being used only when so specified.

e All standard weight fittings must be guaranteed for 125-lb. working pressure and extra heavy fittings for 250-lb. working pressure, and each fitting must have some mark cast on it indicating the maker and guaranteed working steam pressure.

f All extra heavy fittings and flanges to have a raised surface of 1/16 in. high inside of bolt holes for gaskets.

Standard weight fittings and flanges to be plain faced.

Bolt holes to be ⅛ in. larger in diameter than bolts.

Bolt holes to straddle center line.

g **Size of all fittings scheduled indicates inside diameter of ports.**

h **The face to face dimension of reducers, either straight or eccentric, for all pressures, shall be the same face to face as given in table of dimensions.**

i **Square head bolts with hexagonal nuts are recommended.**

For bolts, 1⅝ in. diameter and larger, studs with a nut on each end are satisfactory.

Hexagonal nuts for pipe sizes 1 in. to 46 in., on 125-lb. standard, and 1 in. to 16 in. on 250-lb. standard can be conveniently pulled up with open wrenches of minimum design of heads. Hexagonal nuts for pipe sizes 48 in. to 100 in. on 125-lb. and 18 in. to 48 in. on 250-lb. standards, can be conveniently pulled up with box or socket wrenches.

j **Twin Elbows, whether straight or reducing, carry same dimensions center to face and face to face as regular straight size ells and tees.**

Side Outlet Elbows and Side Outlet Tees, whether straight or reducing sizes, carry same dimensions center to face and face to face as regular tees having same reductions.

k **Bull Head Tees or Tees increasing on outlet, will have same center to face and face to face dimensions as a straight fitting of the size of the outlet.**

l **Tees and Crosses 16 in. and down, reducing on the outlet, use the same dimensions as straight sizes of the larger port.**

Size 18 in. and up, reducing on the outlet are made in two lengths depending on the size of the outlet as given in the table of dimensions.

Laterals 16 in. and down, reducing on the branch, use the same dimensions as straight sizes of the larger port.

m **Sizes 18 in. and up, reducing on the branch, are made in two lengths depending on the size of the branch as given in the table of dimensions.**

The dimensions of reducing flanged fittings are always regulated by the reductions of the outlet or branch. Fittings reducing on the run only, the long body pattern will always be used.

Y's are special and are made to suit conditions.

Double sweep tees are not made reducing on the run.

n ***Steel Flanges, Fittings and Valves are Recommended for Superheated Steam.***

19 A series of tables, curves and flange sections, which explain themselves, accompany this report and are listed as follows:

LIST OF TABLES AND CHARTS

Flanges, American Standard, Effective January 1, 1914

125-lb. working pressure

250-lb. working pressure

Comparisons between 1912 U. S. Standard, Manufacturers' Standard October 1, 1912, and American Standard, Effective January 1, 1914

125-lb. and 250-lb. working pressure

Fittings, Comparisons between 1912 U. S. Standard, Manufacturers' Standard October 1, 1912, and American Standard, Effective January 1, 1914

125-lb. working pressure

The Committee recommends the adoption of this American Standard, January 1, 1914.

Respectfully submitted,

H. G. STOTT, *Chmn.*	***Members***
A. C. ASHTON	***of***
A. R. BAYLIS	***Committee on***
WM. SCHWANHAUSSER	***Standardisation***
J. P. SPARROW	***of Flanges***

W. M. MCFARLAND, member of the Committee, heartily concurs in the above report except that he would like to see the principle of interchangeability carried out as far as practicable.

The report as here published is revised to March 7 and 20, 1914.

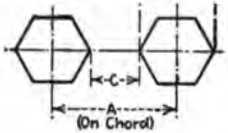
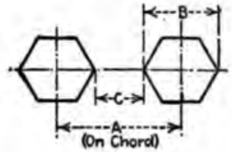
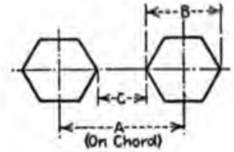
Diameter of Pipe	P = Pressure per Sq. In. Thickness of Pipe = $\left[\frac{P+100}{4\times S}D+0.333\left(1-\frac{D}{100}\right)\right]$ (S = 1800)	Minimum Thickness (Fractions of an In.)	Stress on Pipe per Sq. In.	Diameter of Flange	Thickness of Flange	Width of Flange Face	Diameter of Bolt Circle	No. of Bolts	Diameter of Bolts	Effective Area	Stress per Sq. In. on Bolt	Diameter of Bolt Holes	 A	B	C
1	0.43	7/16	143	4	7/16	1½	3	4	7/16	0.093	264	9/16	2.12	0.91	1.21
1¼	0.44	7/16	178	4½	½	1⅝	3⅜	4	7/16	0.093	412	9/16	2.38	0.91	1.47
1½	0.45	7/16	214	5	9/16	1¾	3⅞	4	½	0.126	438	⅝	2.73	1.00	1.73
2	0.46	7/16	286	6	⅝	2	4¾	4	⅝	0.202	486	¾	3.35	1.21	2.14
2½	0.48	7/16	357	7	11/16	2¼	5½	4	⅝	0.202	750	¾	3.88	1.21	2.67
3	0.50	7/16	428	7½	¾	2¼	6	4	⅝	0.202	1093	¾	4.23	1.21	3.02
3½	0.52	7/16	500	8½	13/16	2½	7	4	⅝	0.202	1488	¾	4.94	1.21	3.73
4	0.53	½	500	9	13/16	2½	7½	8	⅝	0.202	972	¾	2.87	1.21	1.56
4½	0.55	½	562	9¼	15/16	2⅜	7¾	8	¾	0.302	823	⅞	2.96	1.44	1.52
5	0.56	½	625	10	15/16	2½	8½	8	¾	0.302	1016	⅞	3.25	1.44	1.81
6	0.60	9/16	667	11	1	2½	9½	8	¾	0.302	1463	⅞	3.63	1.44	2.19
7	0.63	⅝	700	12½	1 1/16	2¾	10¾	8	¾	0.302	1991	⅞	4.11	1.44	2.67
8	0.66	⅝	800	13½	1⅛	2¾	11¾	8	¾	0.302	2600	⅞	4.50	1.44	3.06
9	0.70	11/16	818	15	1⅛	3	13¼	12	¾	0.302	2194	⅞	3.43	1.44	1.99
10	0.73	¾	833	16	1 3/16	3	14¼	12	⅞	0.420	1948	1	3.69	1.66	2.03
12	0.80	13/16	923	19	1¼	3½	17	12	⅞	0.420	2805	1	4.40	1.66	2.74
14	0.86	⅞	1000	21	1⅜	3½	18¾	12	1	0.550	2915	1⅛	4.86	1.88	2.98
15	0.90	⅞	1072	22¼	1⅜	3⅝	20	16	1	0.550	2510	1⅛	3.90	1.88	2.02
16	0.93	1	1000	23½	1 7/16	3¾	21¼	16	1	0.550	2856	1⅛	4.14	1.88	2.26
18	1.00	1 1/16	1059	25	1 9/16	3½	22¾	16	1⅛	0.694	2865	1¼	4.44	2.09	2.35
20	1.07	1⅛	1111	27½	1 11/16	3¾	25	20	1⅛	0.694	2829	1¼	3.91	2.09	1.82

TABLE 1 SCHEDULE OF STANDARD PIPE FLANGES FROM 1 IN. TO 100 IN. FOR 125-LB. WORKING PRESSURE (Continued)



Diameter of Pipe	P = Pressure per Sq. In. Thickness of Pipe = $\left[\frac{P+100}{4\times S}D+0.333\left(1-\frac{D}{100}\right)\right]1.2$ (S = 1800)	Minimum Thickness (Fractions of an In.)	Stress on Pipe per Sq. In.	Diameter of Flange	Thickness of Flange	Width of Flange Face	Diameter of Bolt Circle	No. of Bolts	Diameter of Bolts	Effective Area	Stress per Sq. In. on Bolt. Metal	Diameter of Bolt Holes	A	B	C
22	1.13	1 3/16	1158	29½	1 13/16	3¾	27¼	20	1¼	0.893	2660	1⅜	4.26	2.31	1.95
24	1.20	1¼	1200	32	1⅞	4	29½	20	1¼	0.893	3166	1⅜	4.62	2.31	2.31
26	1.27	1 5/16	1238	34¼	2	4⅛	31¾	24	1¼	0.893	3096	1⅜	4.14	2.31	1.83
28	1.33	1⅜	1273	36½	2 1/16	4¼	34	28	1¼	0.893	3078	1⅜	3.81	2.31	1.50
30	1.40	1 7/16	1304	38¾	2⅛	4⅜	36	28	1⅜	1.057	2985	1½	4.03	2.53	1.50
32	1.47	1½	1333	41¾	2¼	4⅞	38½	28	1½	1.294	2775	1⅝	4.31	2.75	1.56
34	1.54	1 9/16	1360	43¾	2 5/16	4⅞	40½	32	1½	1.294	2741	1⅝	3.97	2.75	1.22
36	1.60	1⅝	1385	46	2⅜	5	42¾	32	1½	1.294	3073	1⅝	4.19	2.75	1.44
38	1.67	1 11/16	1407	48¾	2⅜	5⅜	45¼	32	1⅝	1.515	2924	1¾	4.43	2.96	1.47
40	1.73	1¾	1428	50¾	2½	5⅜	47¼	36	1⅝	1.515	2880	1¾	4.11	2.96	1.15
42	1.82	1 13/16	1448	53	2⅝	5½	49½	36	1⅝	1.515	3175	1¾	4.31	2.96	1.35
44	1.87	1⅞	1467	55¼	2⅝	5⅝	51¾	40	1⅝	1.515	3136	1¾	4.06	2.96	1.10
46	1.94	1 15/16	1484	57¼	2 11/16	5⅝	53¾	40	1⅝	1.515	3428	1¾	4.22	2.96	1.26
48	2.00	2	1500	59½	2¾	5¾	56	44	1⅝	1.515	3393	1¾	3.98	2.96	1.02
50	2.07	2 1/16	1515	61¾	2¾	5⅞	58¼	44	1¾	1.746	3195	1⅞	4.14	3.19	0.95
52	2.14	2⅛	1530	64	2⅞	6	60½	44	1¾	1.746	3456	1⅞	4.30	3.19	1.11
54	2.20	2 3/16	1543	66¼	3	6⅛	62¾	44	1¾	1.746	3726	1⅞	4.45	3.19	1.26
56	2.27	2¼	1555	68¾	3	6⅜	65	48	1¾	1.746	3674	1⅞	4.26	3.19	1.07
58	2.34	2 5/16	1567	71	3⅛	6½	67¼	48	1¾	1.746	3941	1⅞	4.40	3.19	1.21
60	2.41	2 7/16	1538	73	3⅛	6½	69¼	52	1¾	1.746	3892	1⅞	4.19	3.19	1.00
62	2.47	2½	1550	75¾	3¼	6⅞	71¾	52	1⅞	2.051	3538	2	4.34	3.41	0.93

TABLE 1 SCHEDULE OF STANDARD PIPE FLANGES FROM 1 IN. TO 100 IN. FOR 125-LB. WORKING PRESSURE (Concluded)



Diameter of Pipe	P = Pressure per Sq. In. Thickness of Pipe = $\left[\frac{P+100}{4\times S}D+0.333\left(1-\frac{D}{100}\right)\right]^{1.2}$ (S = 1800)	Minimum Thickness (Fractions of an In.)	Stress on Pipe per Sq. In.	Diameter of Flange	Thickness of Flange	Width of Flange Face	Diameter of Bolt Circle	No. of Bolts	Diameter of Bolts	Effective Area	Stress per Sq. In on Bolt. Metal	Diameter of Bolt Holes	A	B	C
68	2.68	2 11/16	1582	82 1/4	3 3/8	7 1/8	78 1/4	56	1 7/8	2.051	3952	2	4.38	3.41	0.97
70	2.74	2 3/4	1591	84 1/2	3 1/2	7 1/4	80 1/2	56	1 7/8	2.051	4188	2	4.51	3.41	1.10
72	2.81	2 13/16	1600	86 1/2	3 1/2	7 1/4	82 1/2	60	1 7/8	2.051	4136	2	4.33	3.41	0.92
74	2.88	2 7/8	1609	88 1/2	3 5/8	7 1/4	84 1/2	60	1 7/8	2.051	4368	2	4.44	3.41	1.03
76	2.94	2 15/16	1617	90 3/4	3 5/8	7 3/8	86 1/2	60	1 7/8	2.051	4608	2	4.54	3.41	1.13
78	3.01	3	1625	93	3 3/4	7 1/2	88 3/4	60	2	2.302	4325	2 1/8	4.66	3.63	1.03
80	3.08	3 1/16	1633	95 1/4	3 3/4	7 5/8	91	60	2	2.302	4549	2 1/8	4.78	3.63	1.15
82	3.15	3 1/8	1640	97 1/2	3 7/8	7 3/4	93 1/4	60	2	2.302	4779	2 1/8	4.90	3.63	1.27
84	3.21	3 3/16	1647	99 3/4	3 7/8	7 7/8	95 1/2	64	2	2.302	4702	2 1/8	4.68	3.63	1.05
86	3.28	3 1/4	1653	102	4	8	97 3/4	64	2	2.302	4928	2 1/8	4.79	3.63	1.16
88	3.35	3 5/16	1660	104 1/4	4	8 1/8	100	68	2	2.302	4857	2 1/8	4.60	3.63	0.97
90	3.41	3 3/8	1667	106 1/2	4 1/8	8 1/4	102 1/4	68	2 1/8	2.648	4416	2 1/4	4.71	3.83	0.88
92	3.48	3 1/2	1643	108 3/4	4 1/8	8 3/8	104 1/2	68	2 1/8	2.648	4615	2 1/4	4.81	3.83	0.98
94	3.55	3 9/16	1649	111	4 1/4	8 1/2	106 1/4	68	2 1/8	2.648	4817	2 1/4	4.89	3.83	1.06
96	3.62	3 5/8	1655	113 1/4	4 1/4	8 5/8	108 1/2	68	2 1/4	3.023	4401	2 3/8	4.99	4.06	0.93
98	3.68	3 11/16	1661	115 1/2	4 3/8	8 3/4	110 3/4	68	2 1/4	3.023	4587	2 3/8	5.09	4.06	1.03
100	3.75	3 3/4	1667	117 3/4	4 3/8	8 7/8	113	68	2 1/4	3.023	4776	2 3/8	5.20	4.06	1.14

NOTES:—Bolt holes should straddle center lines. Flanges should be plain faced.
Square head bolts with hexagonal nuts are recommended. For bolts 1 5/8 in. diameter and larger stud, with a nut, at each end is satisfactory.
Hexagonal nuts for pipe sizes 1 in. to 46 in. can be conveniently pulled up with open wrenches of minimum design of heads. Hexagonal nuts for pipe sizes 48 in. to 100 in. can be conveniently pulled up with box or socket wrenches.
RULES approximately followed in compiling above data:

Bolt circle = 1.10 D + 3
Flange thickness = 0.0315 D + 1.25 (for sizes 26 in. to 100 in.)
D = inside diameter of pipe

Flanges to be spot bored for nuts for sizes 32 in. to 100 in. inclusive.

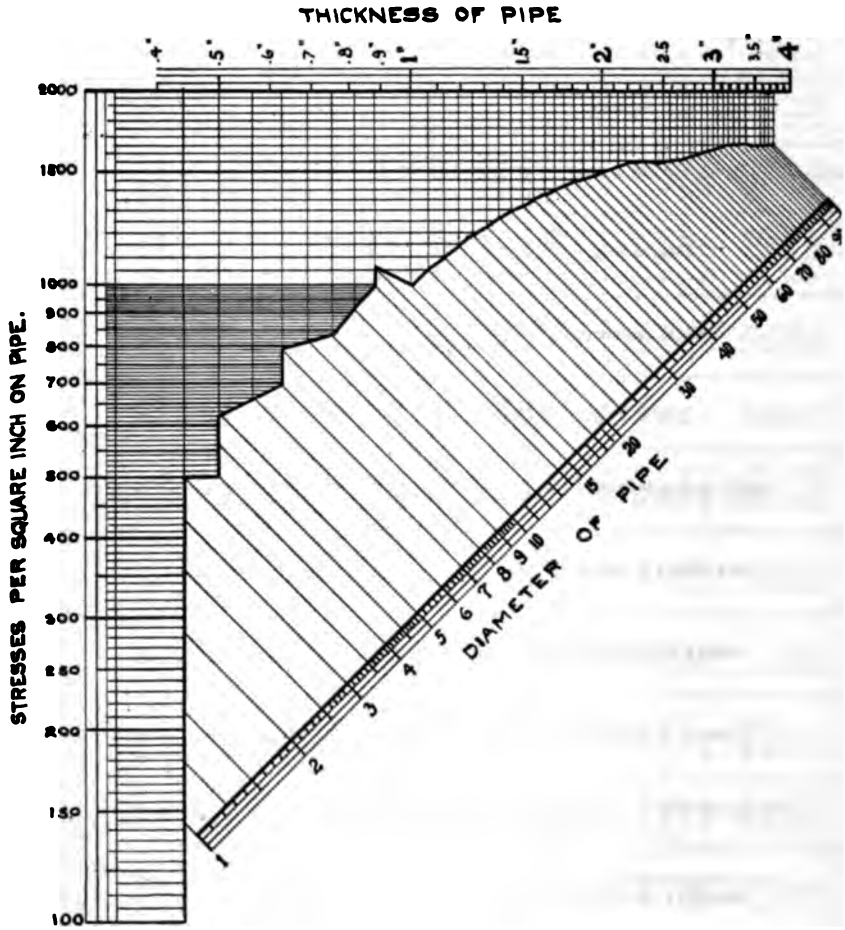


FIG. 1 LOG CHART OF PIPE WALL STRESSES, 125-LB. WORKING PRESSURE PER SQ. IN.

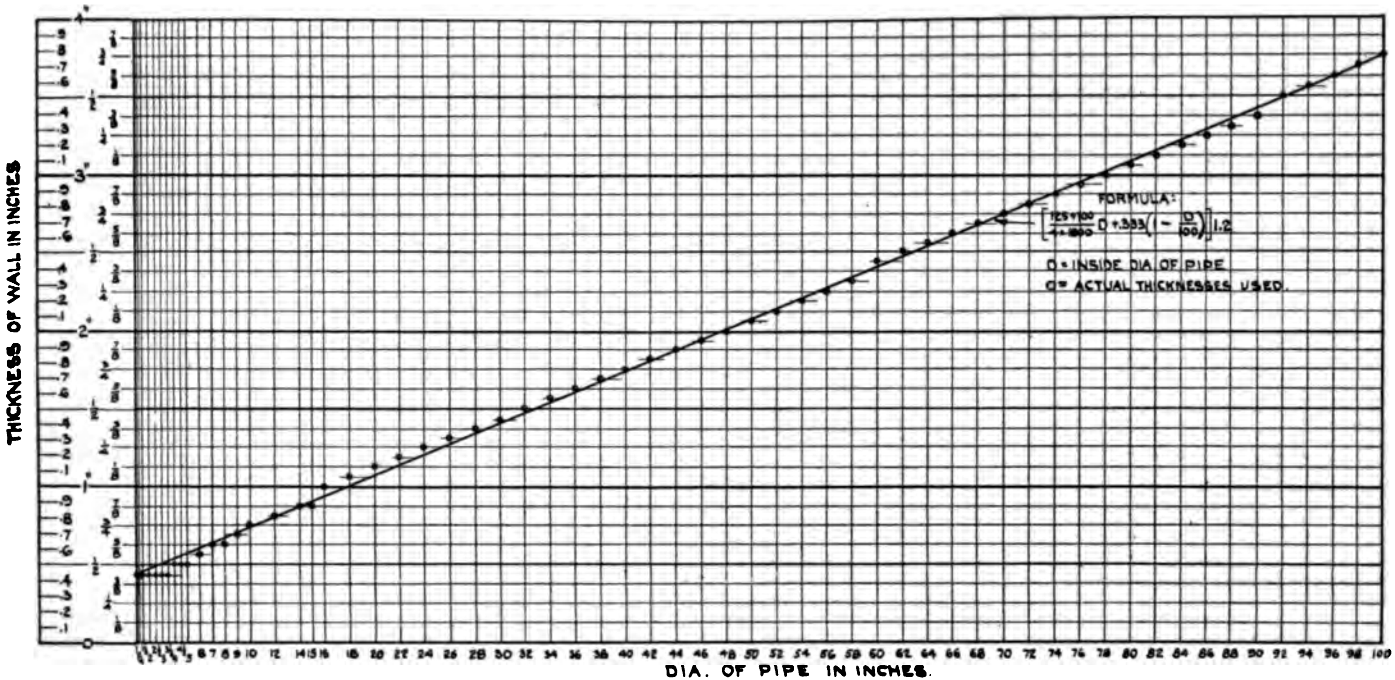


FIG. 2 DIAGRAM OF PIPE THICKNESSES, 125-LB. WORKING PRESSURE PER SQ. IN.

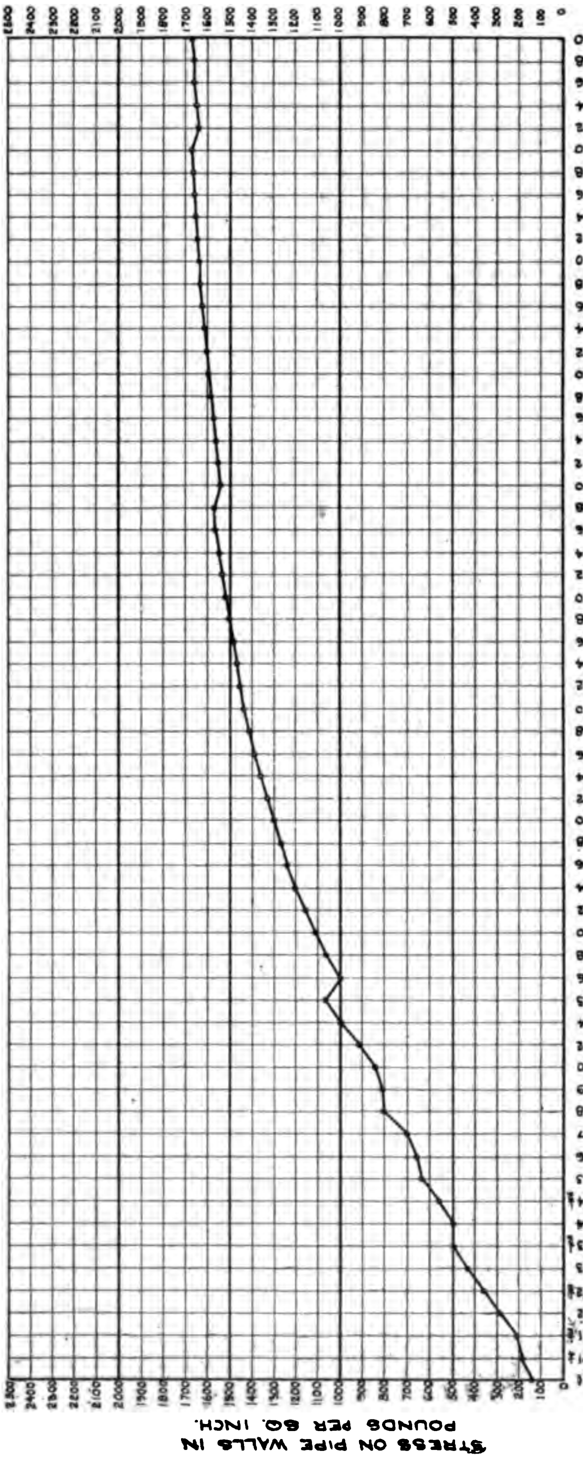


FIG. 3 DIAGRAM OF PIPE WALL STRESSES, 125-LB. WORKING PRESSURE PER SQ. IN.

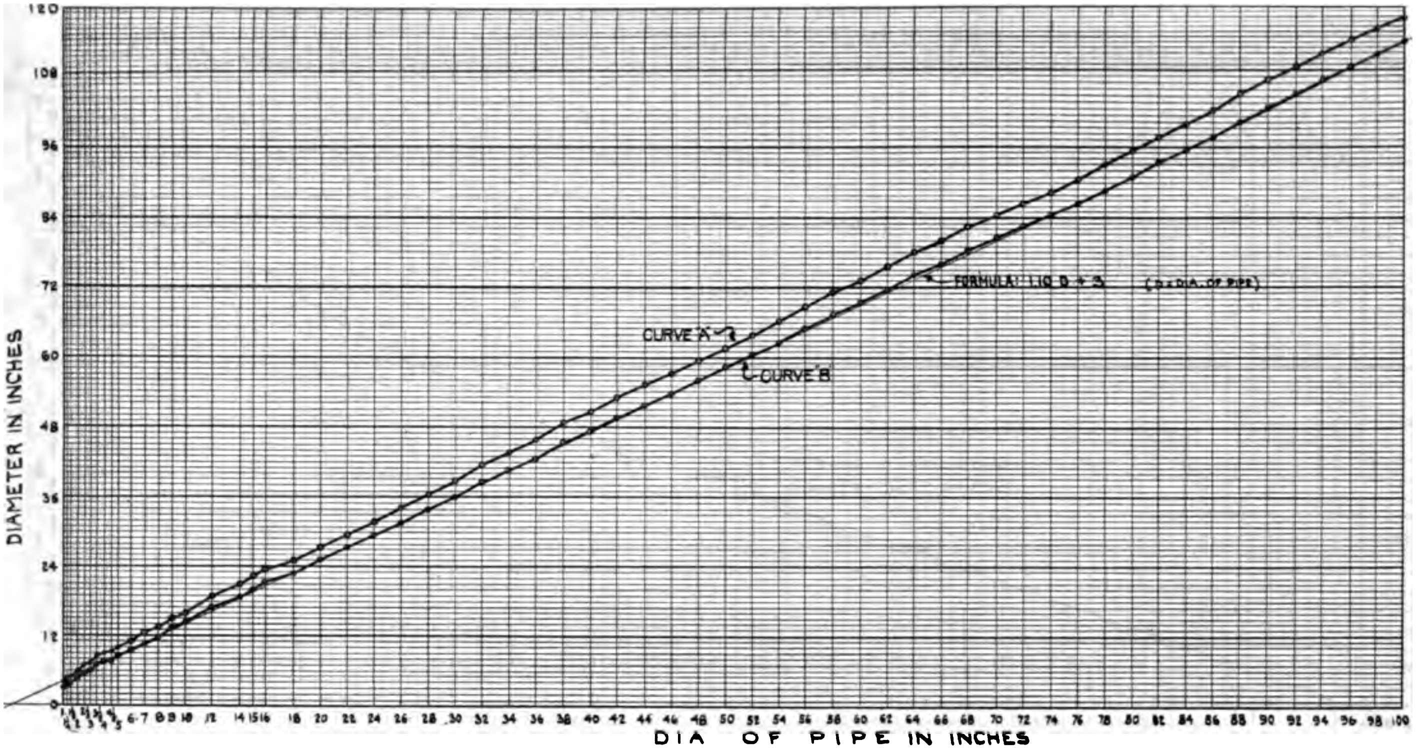


Fig. 4 Diagram of Flange and Bolt Circle Diameters, 125-Lb. Working Pressure per Sq. In.
Curve *A*, Flanges; Curve *B*, B. C. Diameters

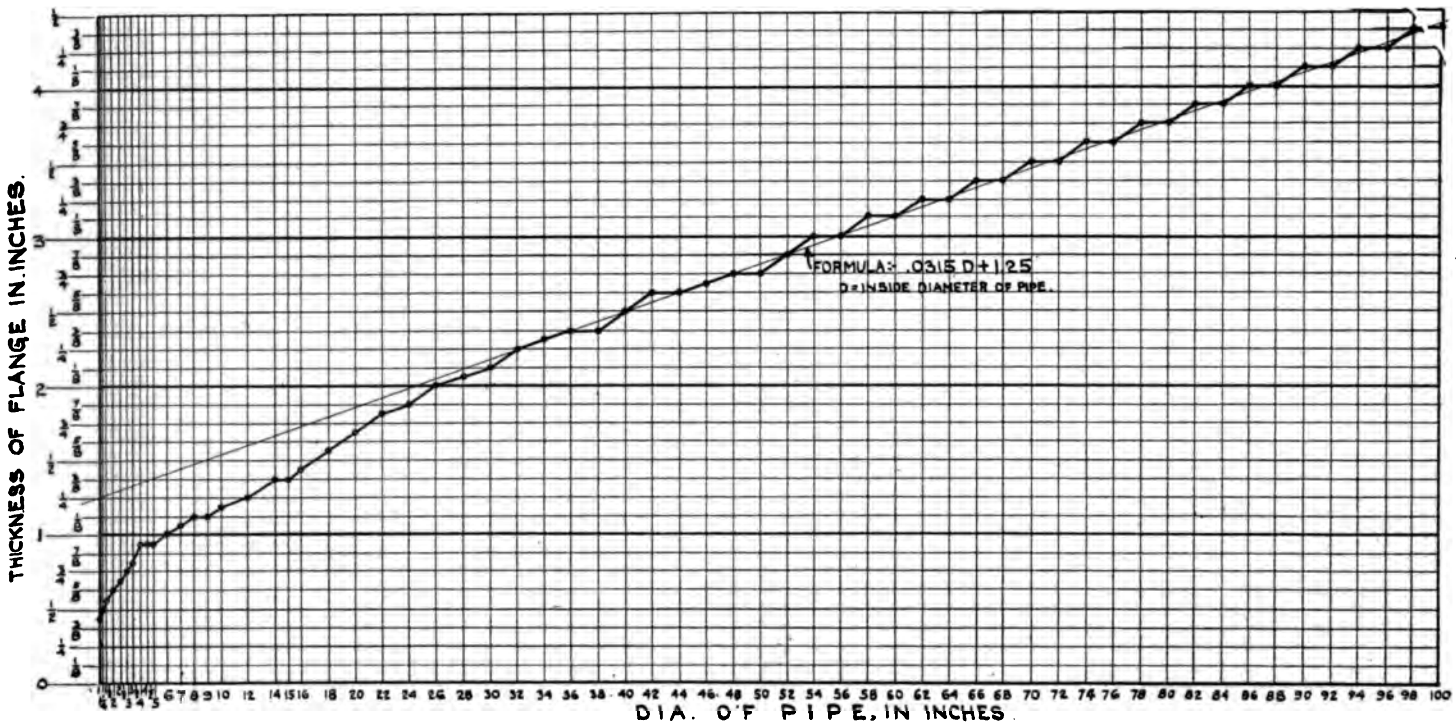


FIG. 5 DIAGRAM OF FLANGE THICKNESSES, 125-LB. WORKING PRESSURE PER SQ. IN.

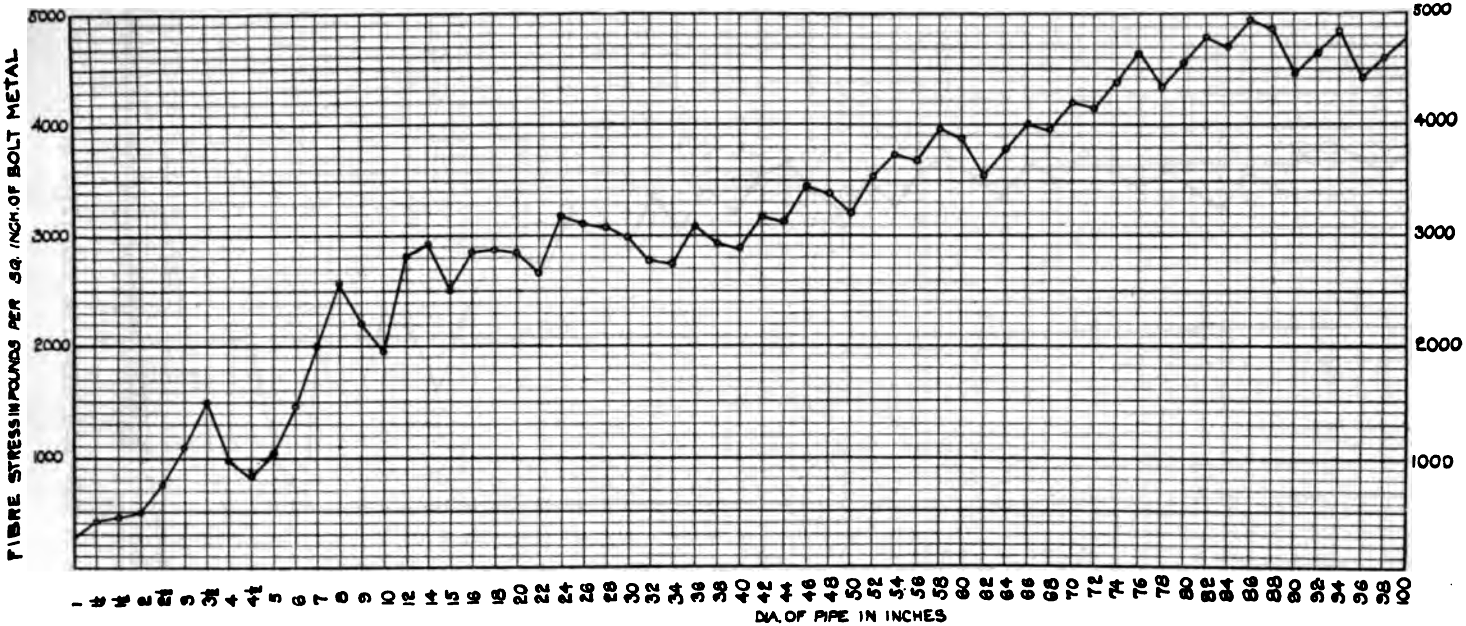


Fig. 6 Diagram of Bolt Stresses, 125-Lb. Working Pressure per Sq. In.

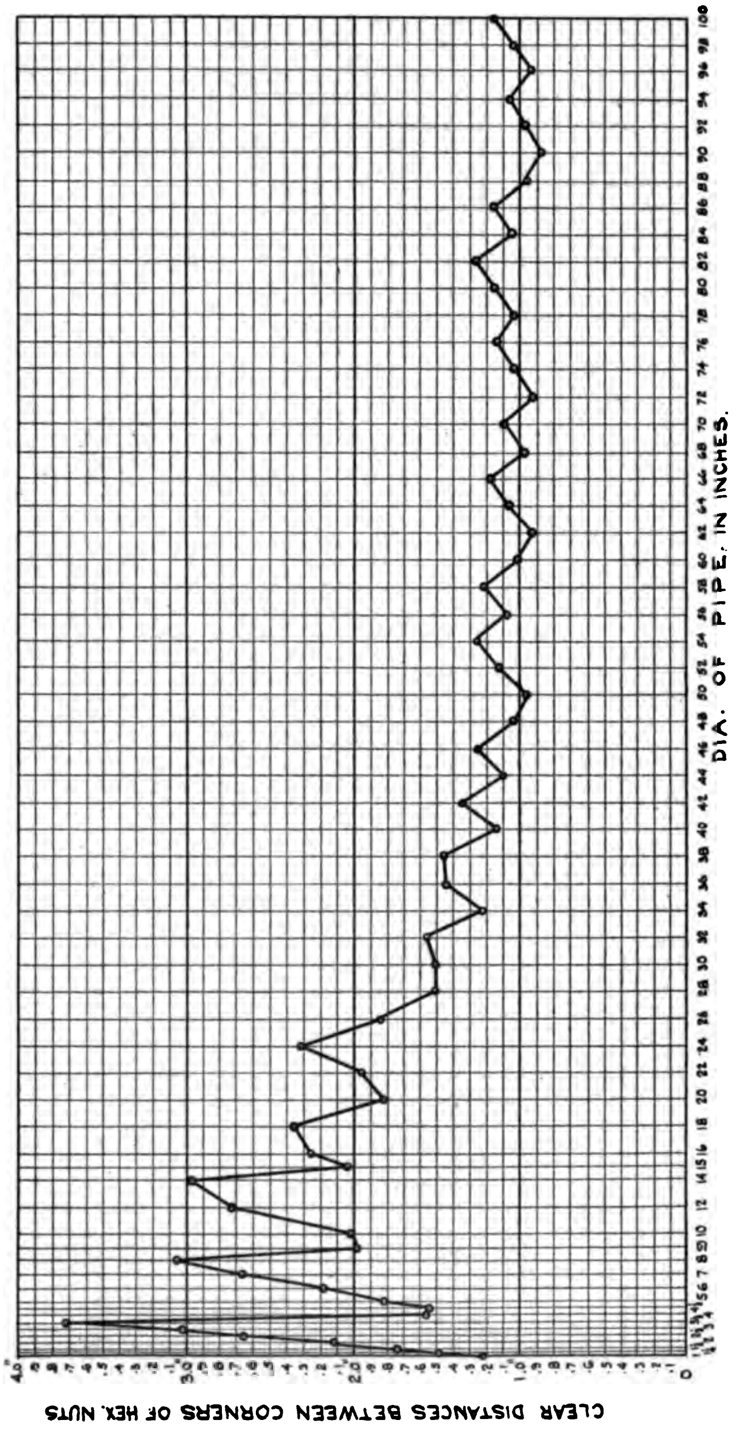
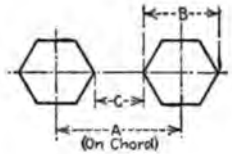
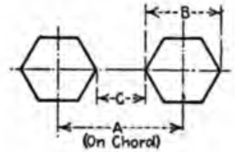

DIA. OF PIPE, IN INCHES.
CLEAR DISTANCES BETWEEN CORNERS OF HEX. NUTS

TABLE 2 SCHEDULE OF EXTRA HEAVY PIPE FLANGES FROM 1 IN. TO 48 IN. FOR 250-LB. WORKING PRESSURE



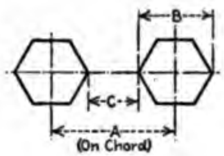
Diameter of Pipe	P = Pressure per Sq. In. Thickness of Pipe = $\left[\frac{P+100}{4\times S}D+0.333\left(1-\frac{D}{100}\right)\right]1.2$ ($S=1800$)	Minimum Thickness (Fractions of an In.)	Stress on Pipe per Sq. In	Diameter of Flange	Thickness of Flange	Width of Flange Face	Diameter of Bolt Circle	No. of Bolts	Diameter of Bolts	Effective Area	Stress per Sq. In. on Bolt Metal	Diameter of Bolt Holes	A	B	C
1	0.45	½	250	4½	11/16	1¾	3¼	4	½	0.126	389	⅝	2.29	1.00	1.29
1¼	0.47	½	312	5	¾	1⅞	3¾	4	½	0.126	609	⅝	2.65	1.00	1.65
1½	0.49	½	375	6	13/16	2¼	4½	4	⅝	0.202	547	¾	3.17	1.21	1.96
2	0.51	½	500	6½	⅞	2¼	5	4	⅝	0.202	972	¾	3.53	1.21	2.32
2½	0.53	9/16	555	7½	1	2½	5⅞	4	¾	0.302	1016	⅞	4.15	1.44	2.71
3	0.56	9/16	667	8¼	1⅛	2⅝	6⅝	8	¾	0.302	731	⅞	2.53	1.44	1.09
3½	0.59	9/16	778	9	1 3/16	2¾	7¼	8	¾	0.302	995	⅞	2.77	1.44	1.33
4	0.61	⅝	800	10	1¼	3	7⅞	8	¾	0.302	1300	⅞	3.01	1.44	1.57
4½	0.64	⅝	900	10½	1 5/16	3	8½	8	¾	0.302	1646	⅞	3.25	1.44	1.81
5	0.67	11/16	909	11	1⅜	3	9¼	8	¾	0.302	2032	⅞	3.53	1.44	2.09
6	0.72	¾	1000	12½	1 7/16	3¼	10⅝	12	¾	0.302	1950	⅞	2.75	1.44	1.31
7	0.78	13/16	1077	14	1½	3½	11⅞	12	⅞	0.420	1909	1	3.07	1.66	1.41
8	0.83	13/16	1230	15	1⅝	3½	13	12	⅞	0.420	2493	1	3.36	1.66	1.70
9	0.89	⅞	1285	16¼	1¾	3⅝	14	12	1	0.550	2410	1⅛	3.62	1.88	1.74

TABLE 2 SCHEDULE OF EXTRA HEAVY PIPE FLANGES FROM 1 IN. TO 48 IN. FOR 250-LB. WORKING PRESSURE (Continued)



Diameter of Pipe	P = Pressure per Sq. In. Thickness of Pipe = $\left[\frac{P+100}{4\times S}D+0.333\left(1-\frac{D}{100}\right)\right]^{1.2}$ (S = 1800)	Minimum Thickness (Fractions of an In.)	Stress on Pipe per Sq. In.	Diameter of Flange	Thickness of Flange	Width of Flange Face	Diameter of Bolt Circle	No. of Bolts	Diameter of Bolts	Effective Area	Stress per Sq. In. on Bolt Metal	Diameter of Bolt Holes	A	B	C
10	0.94	13/16	1333	17½	1⅞	3¾	15¼	16	1	0.550	2231	1⅛	2.97	1.88	1.09
12	1.05	1	1500	20½	2	4¼	17¾	16	1⅛	0.694	2546	1¼	3.46	2.09	1.37
14	1.16	1⅛	1555	23	2⅛	4½	20¼	20	1⅛	0.694	2773	1¼	3.17	2.09	1.08
15	1.21	1 3/16	1579	24½	2 3/16	4¾	21½	20	1¼	0.893	2473	1⅜	3.36	2.31	1.05
16	1.27	1¼	1600	25½	2¼	4¾	22½	20	1¼	0.893	2814	1⅜	3.52	2.31	1.21
18	1.37	1⅜	1636	28	2⅜	5	24¾	24	1¼	0.893	2968	1⅜	3.23	2.31	0.92
20	1.48	1½	1666	30½	2½	5¼	27	24	1⅜	1.057	3096	1½	3.52	2.53	0.99
22	1.59	1 9/16	1760	33	2⅝	5¼	29¼	24	1½	1.295	3058	1⅝	3.81	2.75	1.06
24	1.70	1⅝	1846	36	2¾	5¾	32	24	1⅝	1.515	3110	1¾	4.18	2.96	1.22
26	1.81	1 13/16	1793	38¼	2 13/16	6⅛	34½	28	1⅝	1.515	3126	1¾	3.86	2.96	0.90
28	1.91	1⅞	1866	40¾	2 15/16	6⅜	37	28	1⅝	1.515	3629	1¾	4.14	2.96	1.18
30	2.02	2	1875	43	3	6½	39¼	28	1¾	1.746	3615	1⅞	4.38	3.19	1.19
32	2.13	2⅛	1882	45¼	3⅛	6⅝	41½	28	1⅞	2.051	3501	2	4.64	3.41	1.26
34	2.24	2¼	1889	47½	3¼	6¾	43½	28	1⅞	2.051	3952	2	4.87	3.41	1.46

TABLE 2 SCHEDULE OF EXTRA HEAVY PIPE FLANGES FROM 1 IN. TO 48 IN. FOR 250-LB. WORKING PRESSURE (Concluded)



Diameter of Pipe	P = Pressure per Sq. In. Thickness of Pipe = $\left[\frac{P+100}{4\times S}D+0.333\left(1-\frac{D}{100}\right)\right]^{1.2}$ $(S=1800)$	Minimum Thickness (Fractions of an In.)	Stress on Pipe per Sq. In.	Diameter of Flange	Thickness of Flange	Width of Flange Face	Diameter of Bolt Circle	No. of Bolts	Diameter of Bolts	Effective Area	Stress per Sq. In. on Bolt Metal	Diameter of Bolt Holes	A	B	C
36	2.35	2⅜	1894	50	3⅜	7	46	32	1⅞	2.051	3877	2	4.50	3.41	1.09
38	2.46	2$\frac{7}{16}$	1948	52¼	3$\frac{7}{16}$	7⅛	48	32	1⅞	2.051	4320	2	4.70	3.41	1.29
40	2.56	2$\frac{9}{16}$	1953	54½	3$\frac{9}{16}$	7¼	50¼	36	1⅞	2.051	4255	2	4.38	3.41	0.97
42	2.67	2$\frac{11}{16}$	1953	57	3$\frac{11}{16}$	7½	52¾	36	1⅞	2.051	4691	2	4.59	3.41	1.18
44	2.78	2$\frac{13}{16}$	1955	59¼	3¾	7⅝	55	36	2	2.302	4587	2⅛	4.79	3.63	1.16
46	2.89	2⅞	2000	61½	3⅞	7¾	57¼	40	2	2.302	4512	2⅛	4.49	3.63	0.86
48	3.00	3	2000	65	4	8½	60¾	40	2	2.302	4913	2⅛	4.76	3.63	1.13

NOTES:—Bolt holes should straddle center lines. Flanges should have $\frac{1}{16}$-in. raised face for gaskets.

Square head bolts with hexagonal nuts are recommended. For bolts 1⅝ in. diameter and larger stud with a nut at each end is satisfactory.

Hexagonal nuts for pipe sizes 1 in. to 16 in. can be conveniently pulled up with open wrenches of minimum design of heads. Hexagonal nuts for pipe sizes 18 in. to 48 in. can be conveniently pulled up with box or socket wrenches.

RULES approximately followed in compiling above data:

Bolt circles = $1.171\,D+3.75$

Flange thickness = $0.0546\,D+1.375$ (for sizes 10 in. to 48 in.)

D = inside diameter of pipe

Distance between inside edge of bolt holes and raised face to be $\frac{1}{16}$ in.

Thickness of flange given in table includes raised face.

Flanges to be spot bored for nuts.

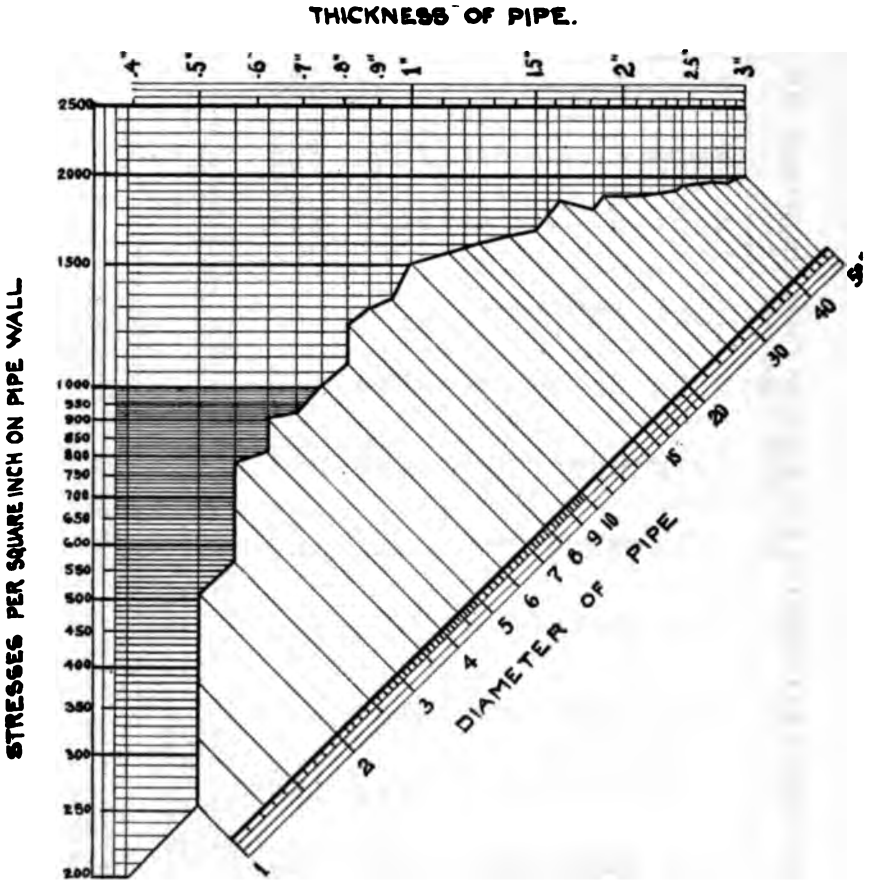


FIG. 8 LOG CHART OF PIPE WALL STRESSES, 250-LB. WORKING PRESSURE PER SQ. IN.

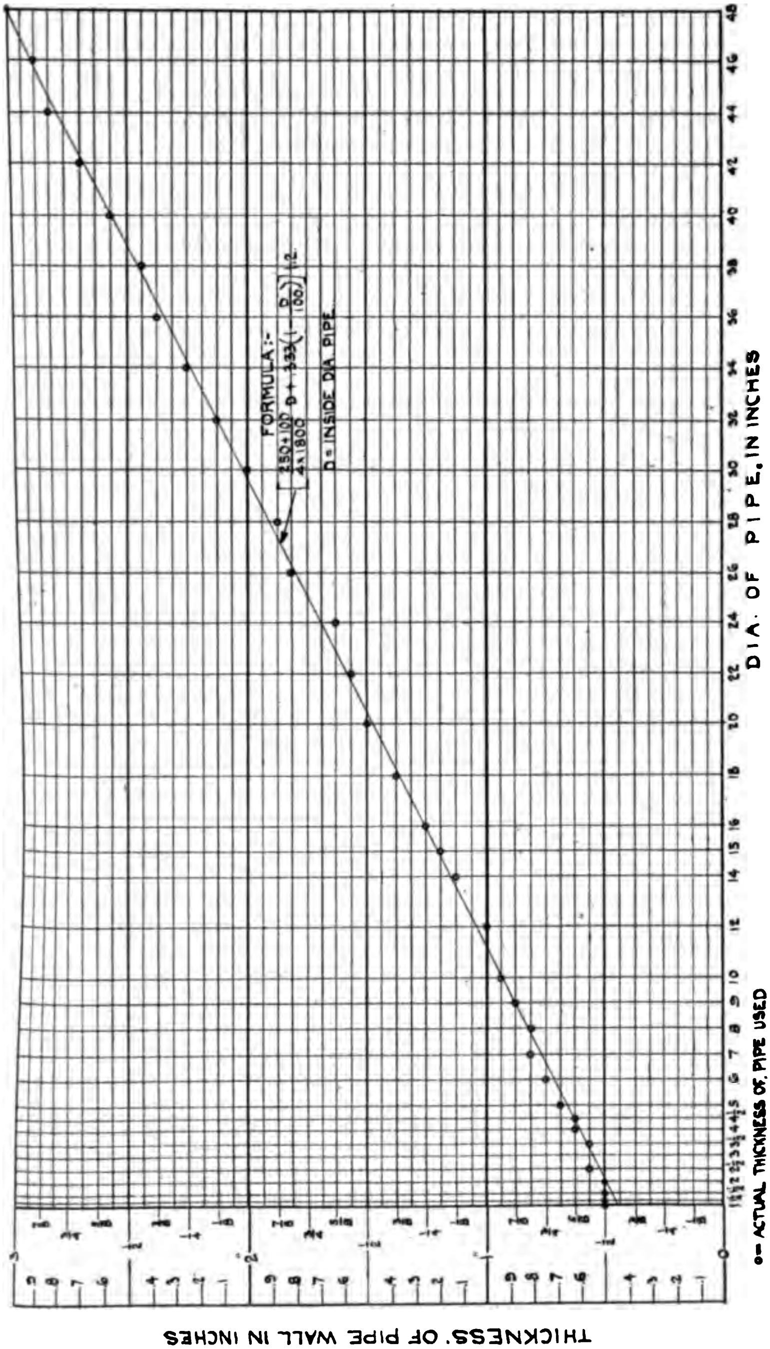


FIG. 9 DIAGRAM OF PIPE WALL THICKNESSES, 250-LB. WORKING PRESSURE PER SQ. IN.

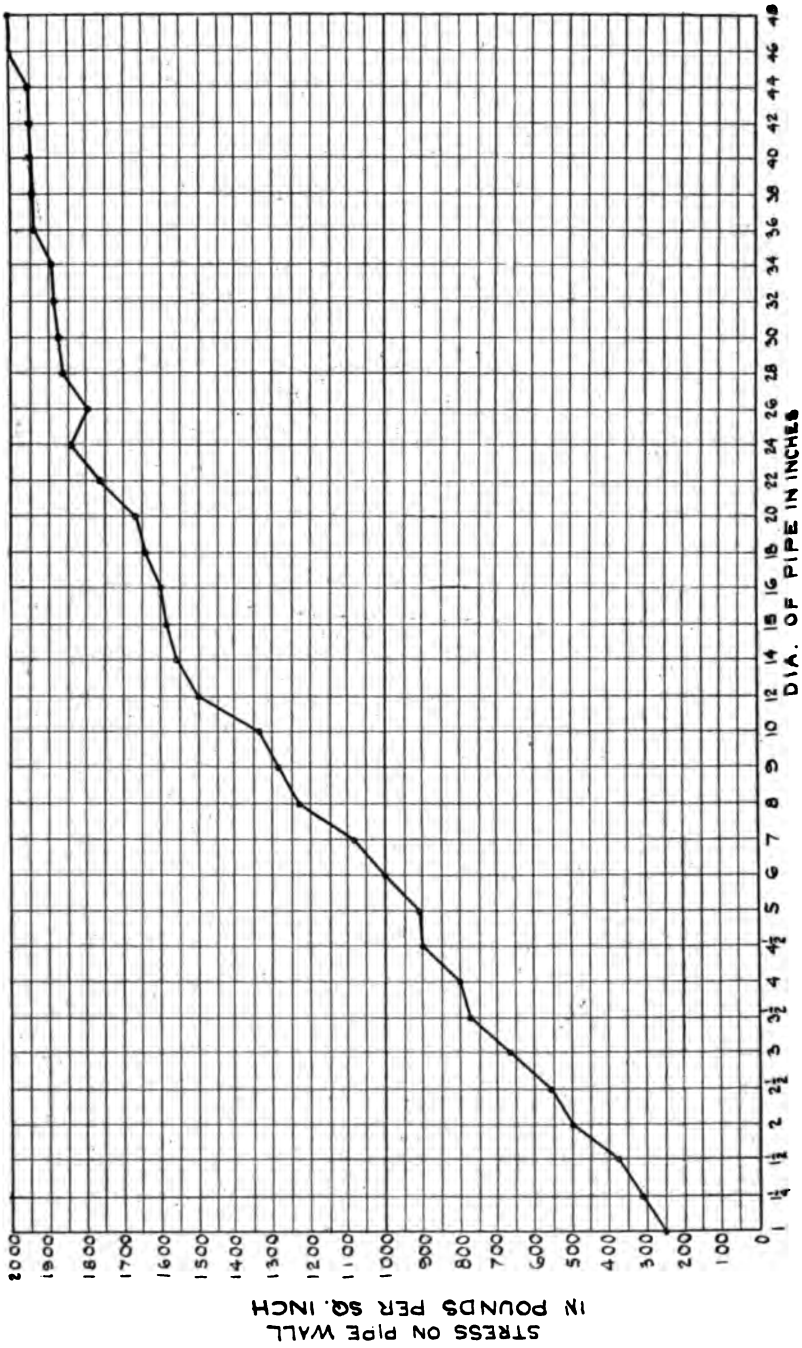


FIG. 10 DIAGRAM OF PIPE WALL STRESSES, 250-LB. WORKING PRESSURE PER SQ. IN.

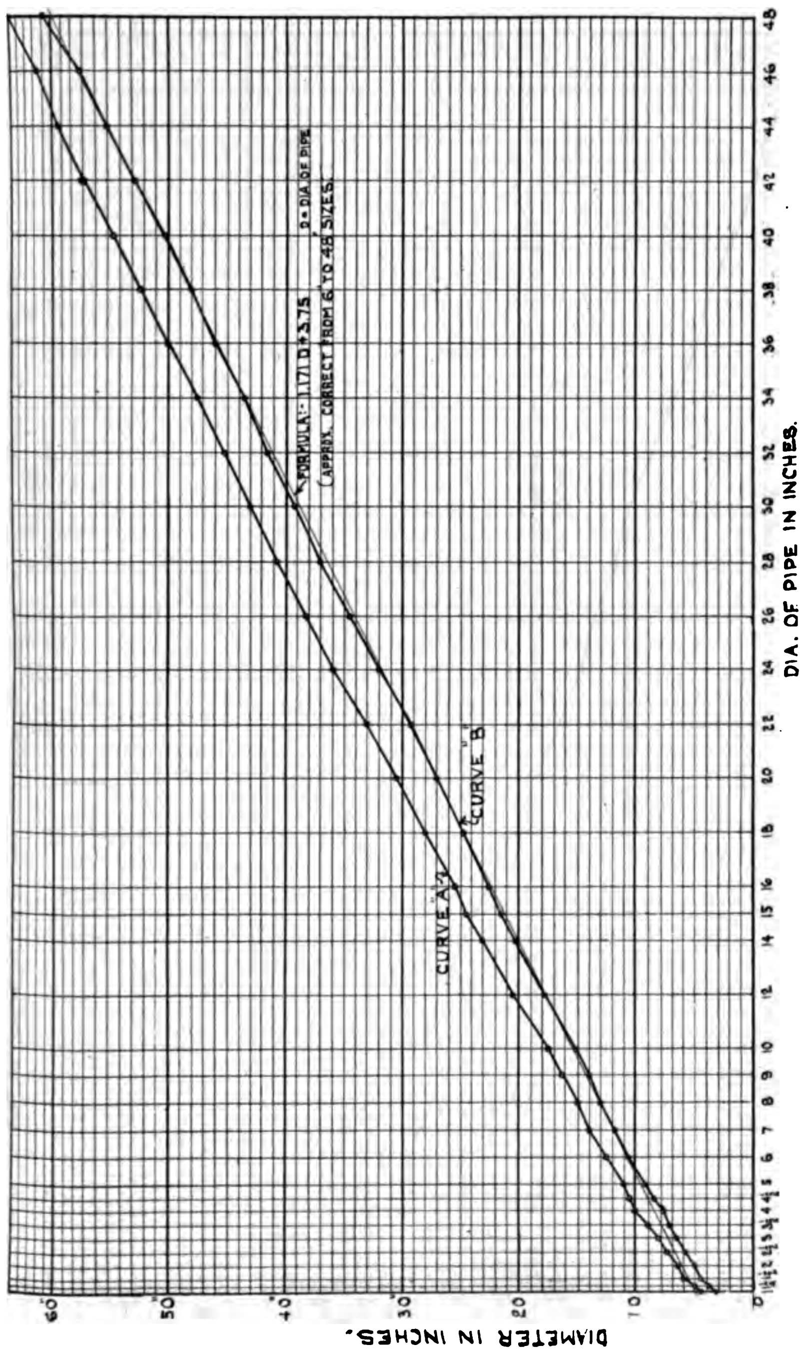
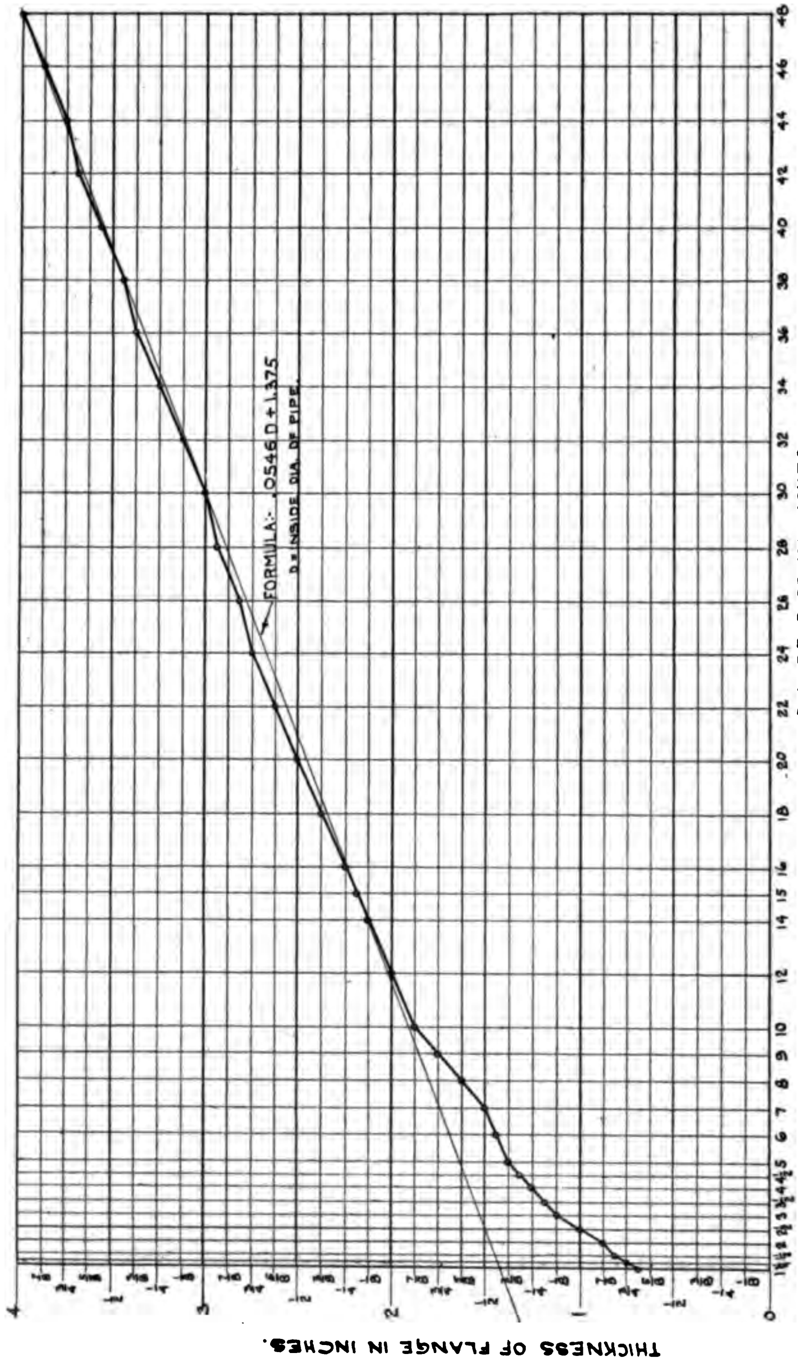


FIG. 11 DIAGRAM OF FLANGE AND BOLT CIRCLE DIAMETERS, 250-LB. WORKING PRESSURE PER SQ. IN.
CURVE *A*, FLANGES; CURVE *B*, B. C. DIAMETERS


FORMULA: .0546 D + 1.375
D = INSIDE DIA. OF PIPE.
DIA. OF PIPE IN INCHES.
THICKNESS OF FLANGE IN INCHES.

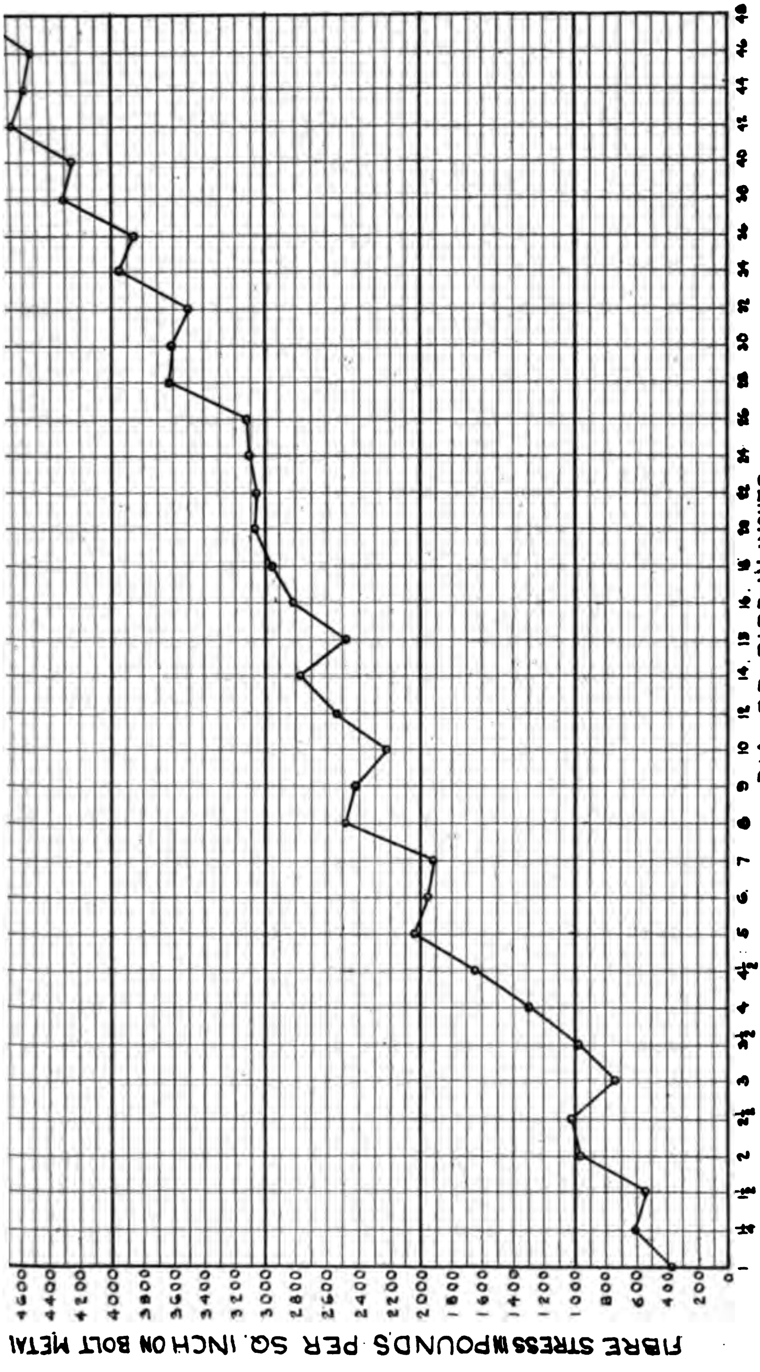
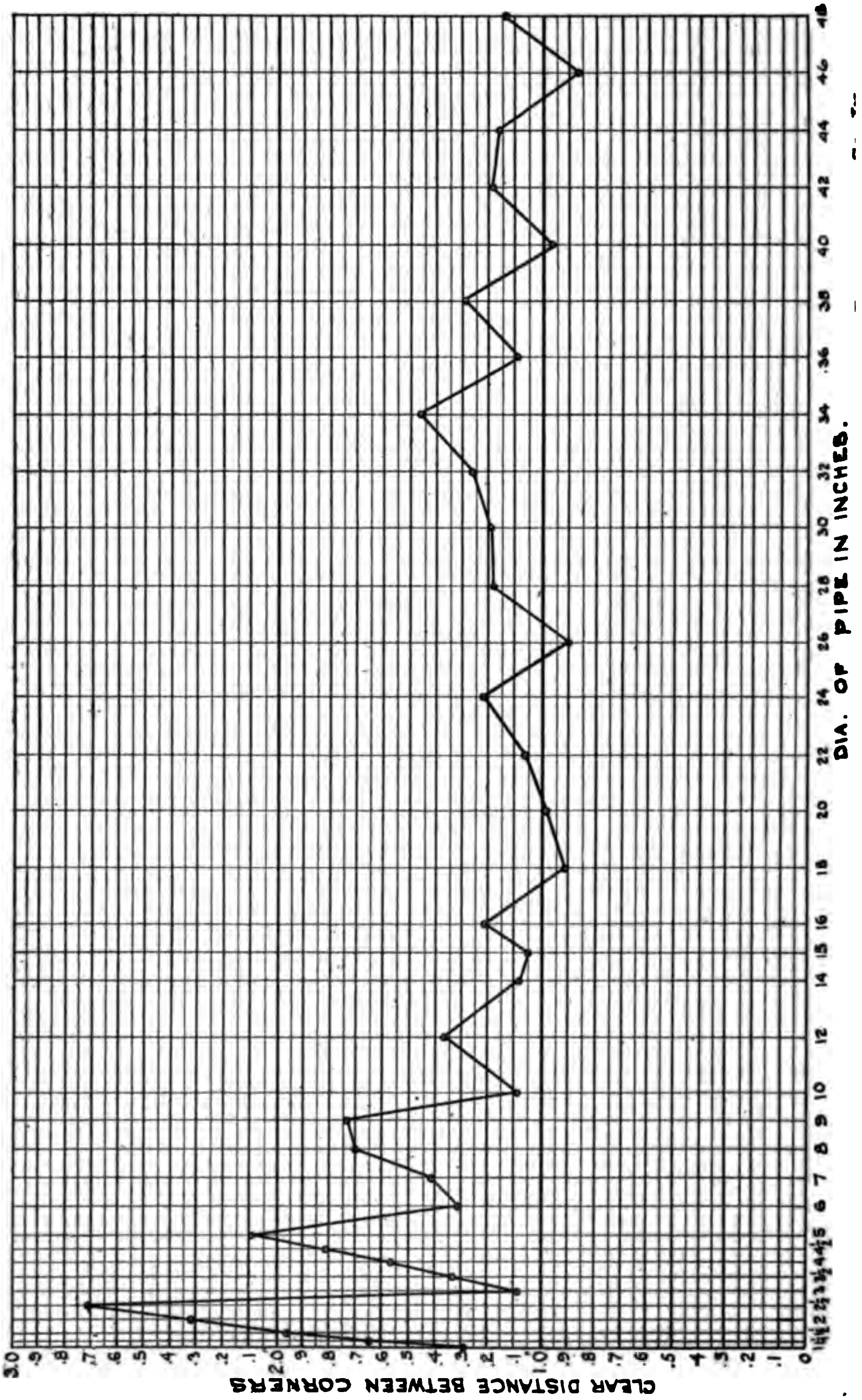


Fig. 13 Diagram of Bolt Stresses, 250-Lb. Working Pressure per Sq. In.


DIA. OF PIPE IN INCHES.
CLEAR DISTANCE BETWEEN CORNERS

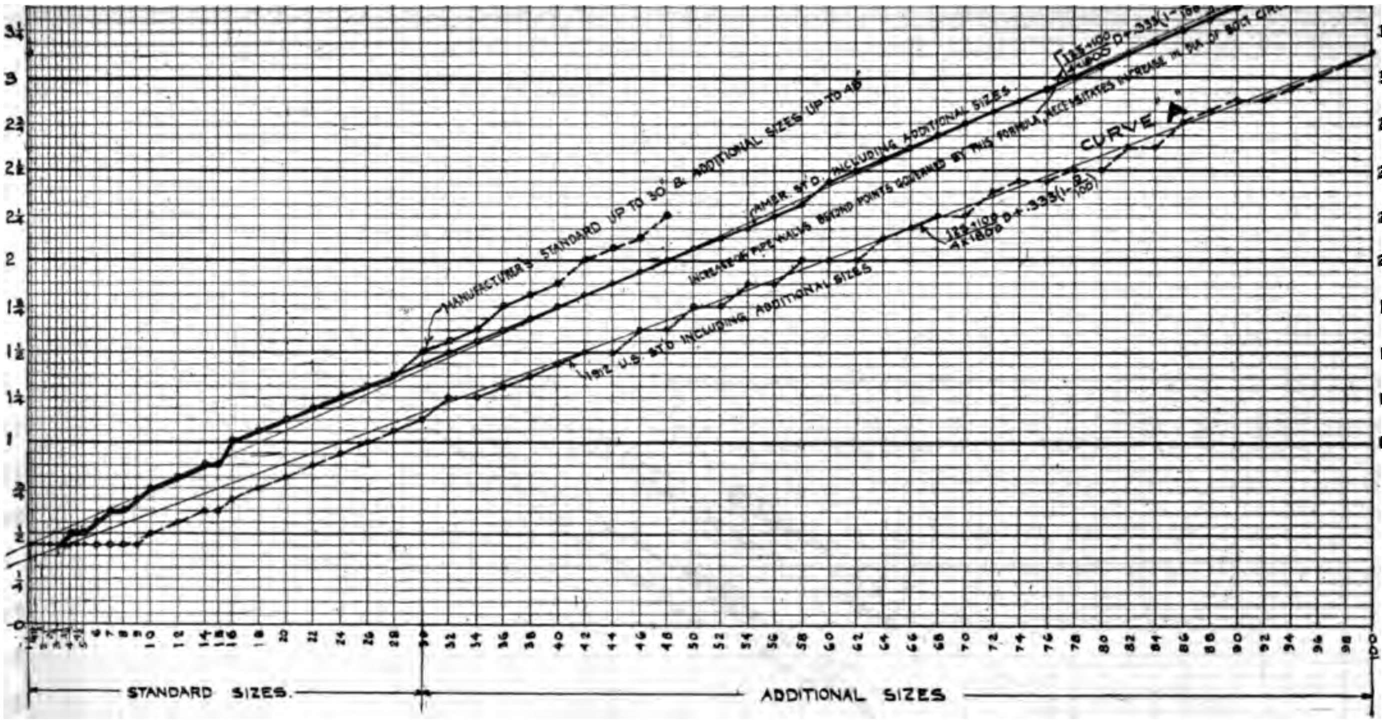


Fig. 15A Comparison of American Standard, 1912 U. S. Standard and Manufacturers Standard, Pipe Thicknesses, 125-Lb. Working Pressure per Sq. In.

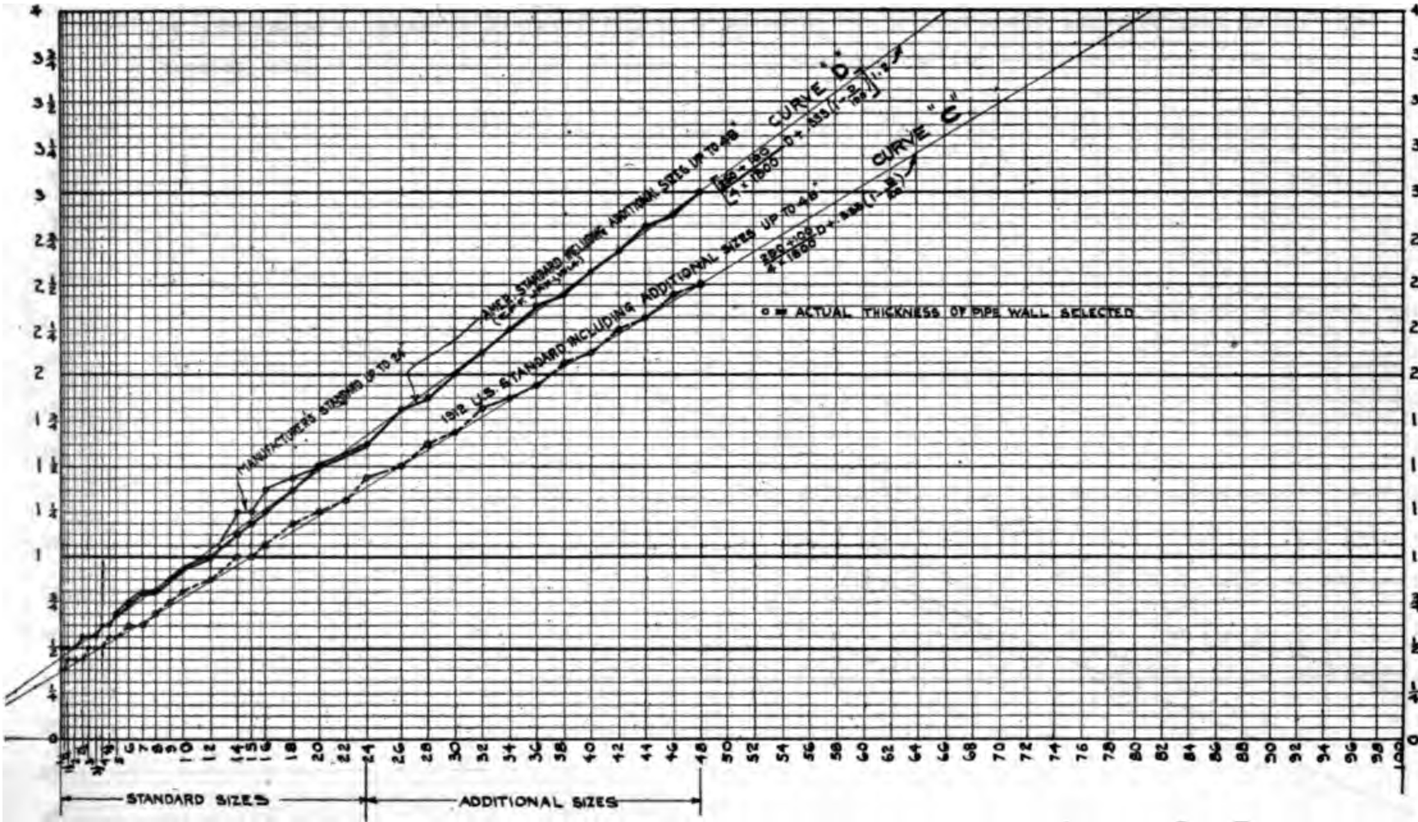


Fig. 15B Comparison of American Standard, 1912 U. S. Standard and Manufacturers Standard, Pipe Thicknesses, 250-Lb. Working Pressure per Sq. In.

TABLE 3 AMERICAN STANDARD, 125-LB. WORKING PRESSURE PER SQ. IN. STANDARD FLANGED FITTINGS, STRAIGHT SIZES—See Fig. 16

	Size	1	1¼	1½	2	2½	3	3½	4	4½	5	6	7	8	9	10	12	14	15	16	18
A-A	Face to Face	7	7½	8	9	10	11	12	13	14	15	16	17	18	20	22	24	28	29	30	33
A	Center to Face	3½	3¾	4	4½	5	5½	6	6½	7	7½	8	8½	9	10	11	12	14	14½	15	16½
B	Center to Face of Long Radius Ells	5	5½	6	6½	7	7¾	8½	9	9½	10¼	11½	12¾	14	15¼	16½	19	21½	22¾	24	26½
C	Center to Face of 45-Deg. Ells	1¾	2	2¼	2½	3	3	3½	4	4	4½	5	5½	5½	6	6½	7½	7½	8	8	8½
D	Face to Face Laterals	7½	8	9	10½	12	13	14½	15	15½	17	18	20½	22	24	25½	30	33	34½	36½	39
E	Center to Face	5¾	6¼	7	8	9½	10	11½	12	12½	13½	14½	16½	17½	19½	20½	24½	27	28½	30	32
F	Center to Face	1¾	1¾	2	2½	2½	3	3	3	3	3½	3½	4	4½	4½	5	5½	6	6	6½	7
G	Face to Face Reducer	..	..	..	..	..	6	6½	7	7½	8	9	10	11	11½	12	14	16	17	18	19
	Diameter of Flange	4	4½	5	6	7	7½	8½	9	9¼	10	11	12½	13½	15	16	19	21	22¼	23½	25
	Thickness of Flange	7/16	½	9/16	⅝	11/16	¾	11/16	15/16	15/16	15/16	1	1 1/16	1⅛	1⅛	1 3/16	1¼	1⅜	1⅜	1 7/16	1 9/16
	Diameter of Bolt Circle	3	3⅜	3⅞	4¾	5½	6	7	7½	7¾	8½	9½	10¾	11¾	13¼	14¼	17	18¾	20	21¼	22¾
	No. of Bolts	4	4	4	4	4	4	4	8	8	8	8	8	8	12	12	12	12	16	16	16
	Diameter of Bolts	7/16	7/16	½	⅝	⅝	⅝	⅝	⅝	¾	¾	¾	¾	¾	¾	⅞	⅞	1	1	1	1⅛
	Minimum Metal Thickness of Body	7/16	7/16	7/16	7/16	7/16	7/16	7/16	½	½	½	9/16	⅝	⅝	11/16	¾	13/16	⅞	⅞	1	1 1/16

TABLE 3 AMERICAN STANDARD, 125-LB. WORKING PRESSURE PER SQ. IN. STANDARD FLANGED FITTINGS, STRAIGHT SIZES (Continued)—See Fig. 16

	Size	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58
A-A	Face to Face	36	40	44	46	48	50	52	54	56	58	60	62	64	66	68	70	74	78	82	84
A	Center to Face	18	20	22	23	24	25	26	27	28	29	30	31	32	33	34	35	37	39	41	42
B	Center to Face of Long Radius Ells	29	31½	34	36½	39	41½	44	46½	49	51½	54	56½	59	61½	64	66½	69	71½	74	76½
C	Center to Face of 45-deg. Ells	9½	10	11	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
D	Face to Face Laterals	43	46	49½	53	56	59	...	...	...	...	...	...	...	...	...	...	...	...	...	...
E	Center to Face	35	37½	40½	44	46½	49	...	...	...	...	...	...	...	...	...	...	...	...	...	...
F	Center to Face	8	8½	9	9	9½	10	...	...	...	...	...	...	...	...	...	...	...	...	...	...
G	Face to Face Reducer	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58
	Diameter of Flange	27½	29½	32	34¼	36½	38¾	41¾	43¾	46	48¾	50¾	53	55¼	57¼	59½	61¾	64	66¼	68¾	71
	Thickness of Flange	1 11/16	1 13/16	1⅞	2	2 1/16	2⅛	2¼	2 5/16	2⅜	2⅜	2½	2⅝	2⅝	2 11/16	2¾	2¾	2⅞	3	3	3⅛
	Diameter of Bolt Circle	25	27¼	29½	31¾	34	36	38½	40½	42¾	45¼	47¼	49½	51¾	53¾	56	58¼	60½	62¾	65	67¼
	No. of Bolts	20	20	20	24	28	28	28	32	32	32	36	36	40	40	44	44	44	44	48	48
	Diameter of Bolts	1⅛	1¼	1¼	1¼	1¼	1⅜	1½	1½	1½	1⅝	1⅝	1⅝	1⅝	1⅝	1⅝	1¾	1¾	1¾	1¾	1¾
	Minimum Metal Thickness of Body	1⅛	1 3/16	1¼	1 5/16	1⅜	1 7/16	1½	1 9/16	1⅝	1 11/16	1¾	1 13/16	1⅞	1 15/16	2	2 1/16	2⅛	2 3/16	2¼	2 5/16

TABLE 3 AMERICAN STANDARD, 125-LB. WORKING PRESSURE PER SQ. IN. STANDARD FLANGED FITTINGS, STRAIGHT SIZES (Continued)—See Fig. 16

	Size	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100
A-A	Face to Face	88	90	94	96	100	102	106	108	112	116	118	120	124	126	130	134	136	138	142	146	148
A	Center to Face	44	45	47	48	50	51	53	54	56	58	59	60	62	63	65	67	68	69	71	73	74
B	Center to Face of Long Radius Ells	79	81½	84	86½	89	91½	94	96½	99	101½	104	106½	109	111½	114	116½	119	121½	124	126½	129
C	Center to Face of 45-deg. Ells	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
D	Face to Face Laterals	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
E	Center to Face	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
F	Center to Face	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
G	Face to Face Reducer	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100
	Diameter of Flange	73	75¾	78	80	82¼	84½	86½	88½	90¾	93	95¼	97½	99¾	102	104¼	106½	108¾	111	113¼	115½	117¾
	Thickness of Flange	3⅛	3¼	3¼	3⅜	3⅜	3½	3½	3⅝	3⅝	3¾	3¾	3⅞	3⅞	4	4	4⅛	4⅛	4¼	4¼	4⅜	4⅜
	Diameter of Bolt Circle	69¼	71¾	74	76	78¼	80½	82½	84½	86½	88¾	91	93¼	95½	97¾	100	102¼	104½	106¼	108½	110¾	113
	No. of Bolts	52	52	52	52	56	56	60	60	60	60	60	60	64	64	68	68	68	68	68	68	68
	Diameter of Bolts	1¾	1⅞	1⅞	1⅞	1⅞	1⅞	1⅞	1⅞	1⅞	2	2	2	2	2	2	2⅛	2⅛	2⅛	2¼	2¼	2¼
	Minimum Metal Thickness of Body	2 7/16	2½	2 9/16	2⅝	2 11/16	2¾	2 13/16	2⅞	2 15/16	3	3 1/16	3⅛	3 3/16	3¼	3 5/16	3⅜	3½	3 9/16	3⅝	3 11/16	3¾

NOTES:—Figures given are for center to face and for face to face finished dimensions. Where necessary manufacturers will make suitable allowances in patterns before casting.

Laterals do not extend beyond the 30-in. size at the present time. Box wrench to be used on bolting for large sizes.

Square head bolts with hexagonal nuts are recommended. 1⅝ in. diameter and larger stud with a nut at each end is satisfactory.

Hexagonal nuts for pipe sizes 1 in. to 46 in. can be conveniently pulled up with open wrenches of minimum design of heads. Hexagonal nuts for pipe sizes 48 in. to 100 in. can be conveniently pulled up with socket wrenches.

Flanges to be spot bored for nuts for sizes 32 in. to 100 in. inclusive.

TABLE 4 AMERICAN STANDARD, 250-LB. WORKING PRESSURE PER SQ. IN., EXTRA HEAVY FLANGED FITTINGS, STRAIGHT SIZES—See Fig. 16

	Size	1	1¼	1½	2	2½	3	3½	4	4½	5	6	7	8	9	10	12	14
A-A	Face to Face	8	8½	9	10	11	12	13	14	15	16	17	18	20	21	23	26	30
A	Center to Face	4	4¼	4½	5	5½	6	6½	7	7½	8	8½	9	10	10½	11½	13	15
B	Center to Face of Long Radius Ells	5	5½	6	6½	7	7¾	8½	9	9½	10¼	11½	12¾	14	15¼	16½	19	21½
C	Center to Face of 45-deg. Ells	2	2½	2¾	3	3½	3½	4	4½	4½	5	5½	6	6	6½	7	8	8½
D	Face to Face, Laterals	8½	9½	11	11½	13	14	15½	16½	18	18½	21½	23½	25½	27½	29½	33½	37½
E	Center to Face, Laterals	6½	7¼	8½	9	10½	11	12½	13½	14½	15	17½	19	20½	22½	24	27½	31
F	Center to Face, Laterals	2	2¼	2½	2½	2½	3	3	3	3½	3½	4	4½	5	5	5½	6	6½
G	Face to Face, Reducer	....	....	....	....	....	6	6½	7	7½	8	9	10	11	11½	12	14	16
	Diameter of Flange	4½	5	6	6½	7½	8¼	9	10	10½	11	12½	14	15	16¼	17½	20½	23
	Thickness of Flange	11/16	¾	13/16	⅞	1	1⅛	1 3/16	1¼	1 5/16	1⅜	1 7/16	1½	1⅝	1¾	1⅞	2	2⅛
	Diameter of Bolt Circle	3¼	3¾	4½	5	5⅞	6⅝	7¼	7⅞	8½	9¼	10⅝	11⅞	13	14	15¼	17¾	20¼
	No. of Bolts	4	4	4	4	4	8	8	8	8	8	12	12	12	12	16	16	20
	Diameter of Bolts	½	½	⅝	⅝	¾	¾	¾	¾	¾	¾	¾	⅞	⅞	1	1	1⅛	1⅛
	Minimum Metal Thickness of Body	½	½	½	½	9/16	9/16	9/16	⅝	⅝	11/16	¾	13/16	13/16	⅞	15/16	1	1⅛

TABLE 4 AMERICAN STANDARD, 250-LB. WORKING PRESSURE PER SQ. IN., EXTRA HEAVY FLANGED FITTINGS, STRAIGHT SIZES (Continued)—See Fig. 16

	Size	15	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48
A-A	Face to Face	31	33	36	39	41	45	48	52	55	58	61	65	68	71	74	78	81	84
A	Center to Face	15½	16½	18	19½	20½	22½	24	26	27½	29	30½	32½	34	35½	37	39	40½	42
B	Center to Face of Long Radius Ells	22¾	24	26½	29	31½	34	36½	39	41½	44	46½	49	51½	54	56½	59	61½	64
C	Center to Face of 45-deg. Ells	9	9½	10	10½	11	12	13	14	15	16	17	18	19	20	21	22	23	24
D	Face to Face, Laterals	39½	42	45½	49	53	57½	...	...	...	...	...	...	...	...	...	...	...	...
E	Center to Face, Laterals	33	34½	37½	40½	43½	47½	...	...	...	...	...	...	...	...	...	...	...	...
F	Center to Face, Laterals	6½	7½	8	8½	9½	10	...	...	...	...	...	...	...	...	...	...	...	...
G	Face to Face, Reducer	17	18	19	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48
	Diameter of Flange	24½	25½	28	30½	33	36	38¼	40¾	43	45¼	47½	50	52¼	54½	57	59¼	61½	65
	Thickness of Flange	$2\frac{3}{16}$	2¼	2⅜	2½	2⅝	2¾	$2\frac{13}{16}$	$2\frac{15}{16}$	3	3⅛	3¼	3⅜	$3\frac{7}{16}$	$3\frac{9}{16}$	$3\frac{11}{16}$	3¾	3⅞	4
	Diameter of Bolt Circle	21½	22½	24¾	27	29¼	32	34½	37	39¼	41½	43½	46	48	50¼	52¾	55	57¼	60¾
	No. of Bolts	20	20	24	24	24	24	28	28	28	28	28	32	32	36	36	36	40	40
	Diameter of Bolts	1¼	1¼	1¼	1⅜	1½	1⅝	1⅝	1⅝	1¾	1⅞	1⅞	1⅞	1⅞	1⅞	1⅞	2	2	2
	Minimum Metal Thickness of Body	$1\frac{3}{16}$	1¼	1⅜	1½	$1\frac{9}{16}$	1⅝	$1\frac{13}{16}$	1⅞	2	2⅛	2¼	2⅜	$2\frac{7}{16}$	$2\frac{9}{16}$	$2\frac{11}{16}$	$2\frac{13}{16}$	2⅞	3

Notes:—Figures given are for center to face and for face to face finished dimensions. Where necessary manufacturers will make suitable allowances in patterns before casting.

Laterals do not extend beyond the 24-in. size at the present time. Box wrench to be used on bolting for large sizes.

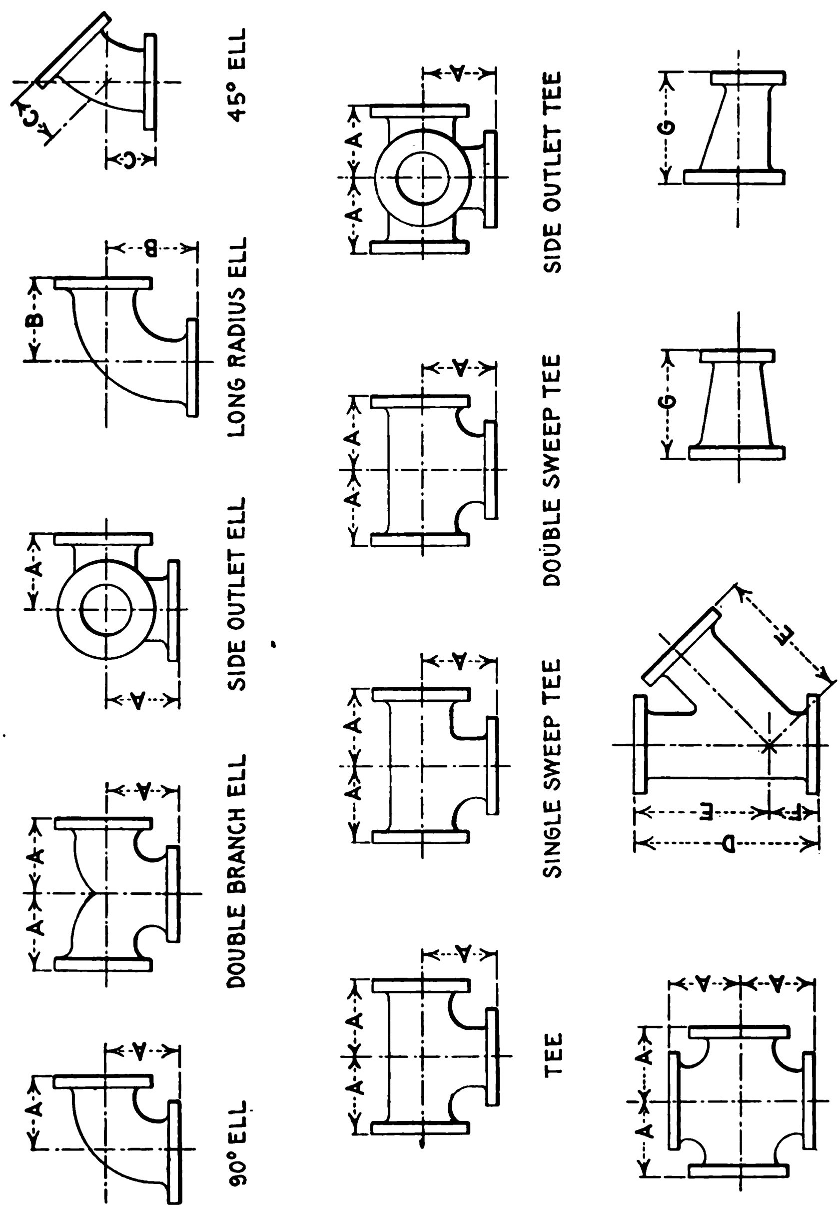
Square head bolts with hexagonal nuts are recommended. 1⅝ in. diameter and larger stud with a nut at each end is satisfactory.

Hexagonal nuts for pipe sizes 1 in. to 16 in. can be conveniently pulled up with wrenches of minimum design of heads. Hexagonal nuts for pipe sizes 18 in. to 48 in. can be conveniently pulled up with socket wrenches.

Distance between inside edge of bolt holes and raised face to be $\frac{1}{16}$ in.

Flanges to be spot bored for nuts.

Thickness of flanges given in table includes raised face.



90° ELL
DOUBLE BRANCH ELL
SIDE OUTLET ELL
LONG RADIUS ELL
45° ELL
TEE
SINGLE SWEEP TEE
DOUBLE SWEEP TEE
SIDE OUTLET TEE
A
B
C
D
E
F
G

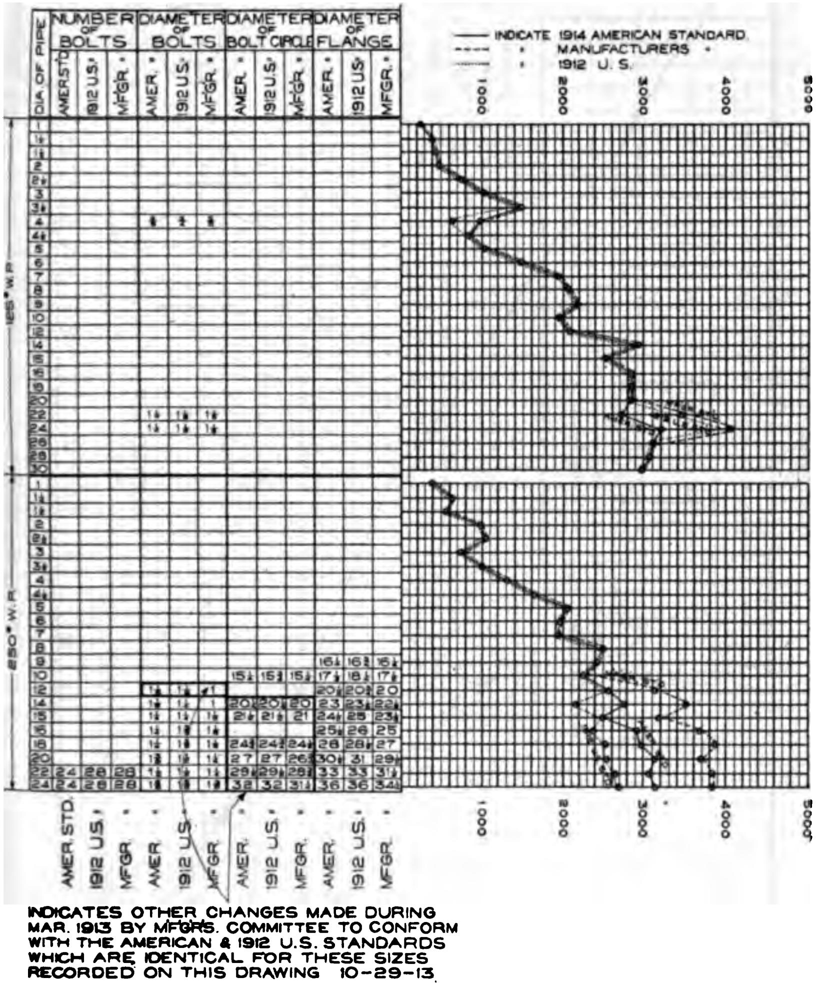


Fig. 17 Comparison of American Standard, 1912 U. S. Standard and Manufacturers Standard, showing where Differences Occur

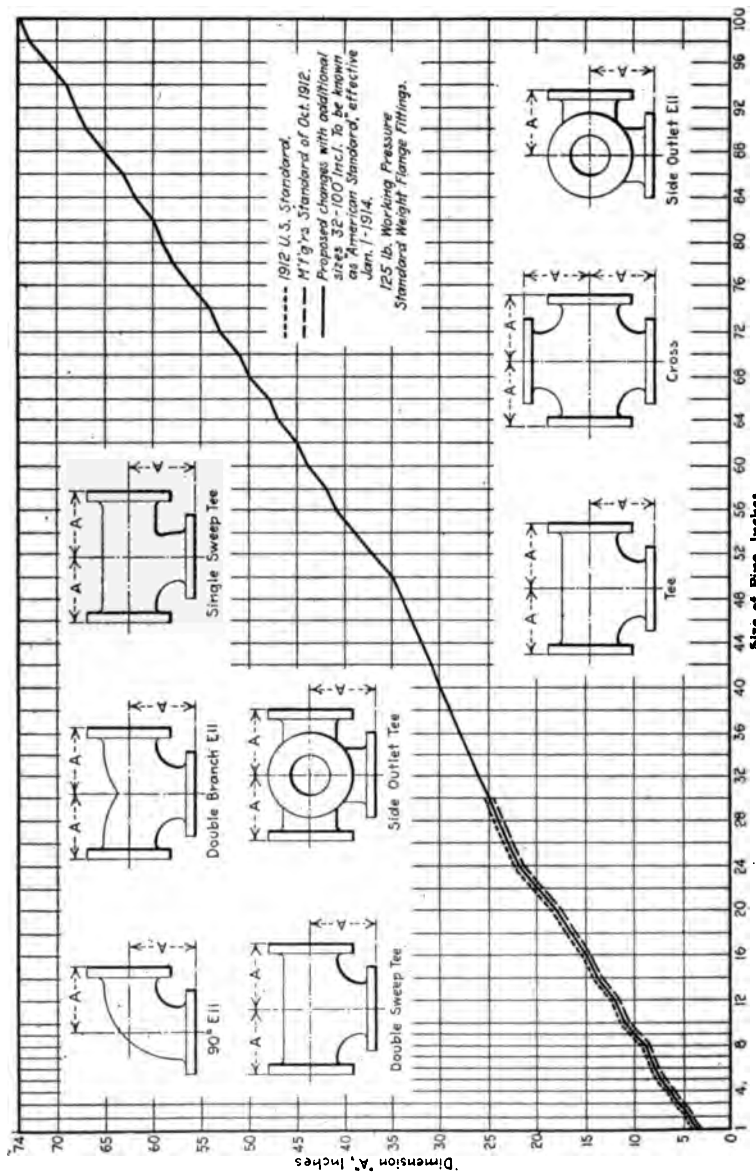


Fig. 18 Comparison of 1912 U. S. Standard, Manufacturers Standard and Proposed Changes in Center to Face Dimensions, Ells, Tees and Crosses, 125-Lb. Working Pressure per Sq. In.

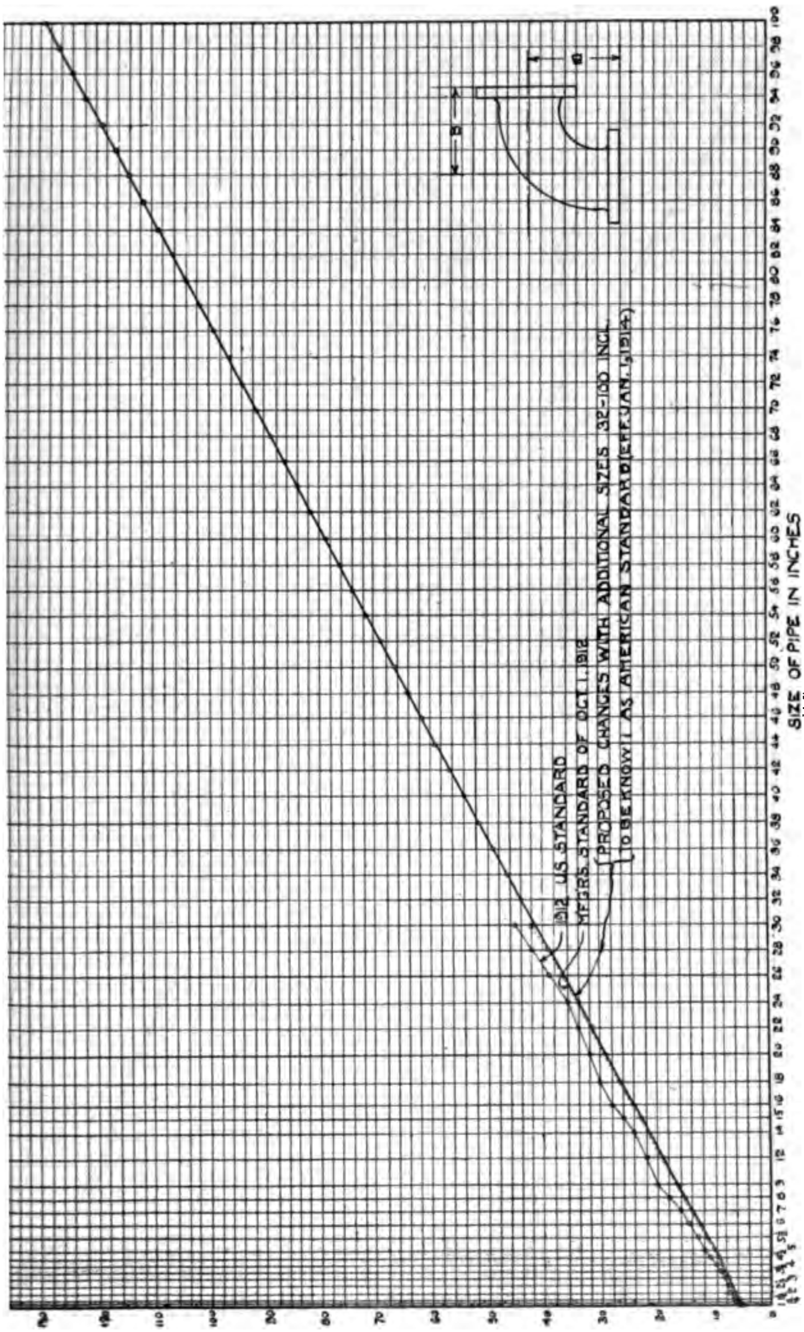
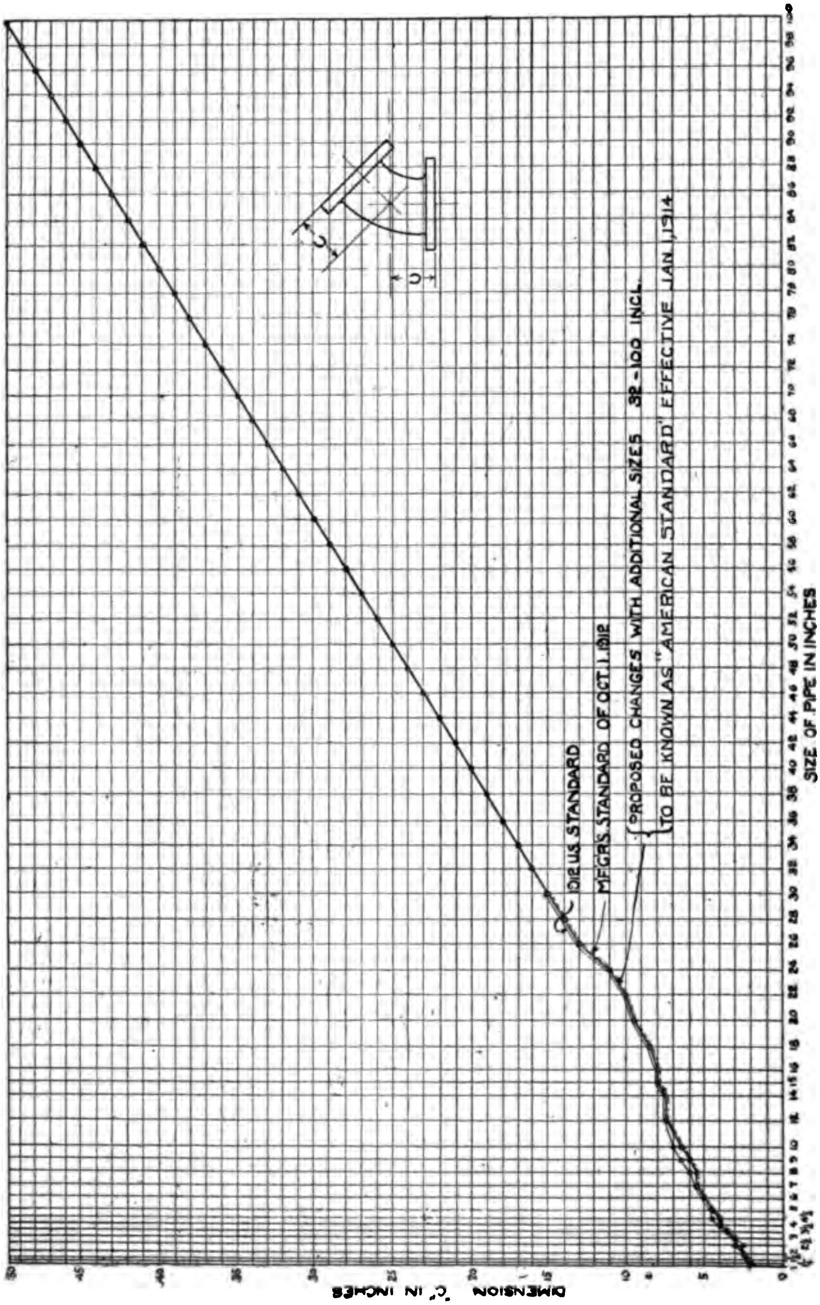


FIG. 19 COMPARISON OF 1912 U. S. STANDARD, MANUFACTURERS STANDARD AND PROPOSED CHANGES IN CENTER TO FACE DIMENSIONS, LONG RADIUS ELLS, 125-LB. WORKING PRESSURE PER SQ. IN.


1912 U.S. STANDARD
MFGRS. STANDARD OF OCT. 1, 1912
PROPOSED CHANGES WITH ADDITIONAL SIZES 32-100 INCL.
TO BE KNOWN AS "AMERICAN STANDARD" EFFECTIVE JAN. 1, 1914
SIZE OF PIPE IN INCHES
DIMENSION "C" IN INCHES

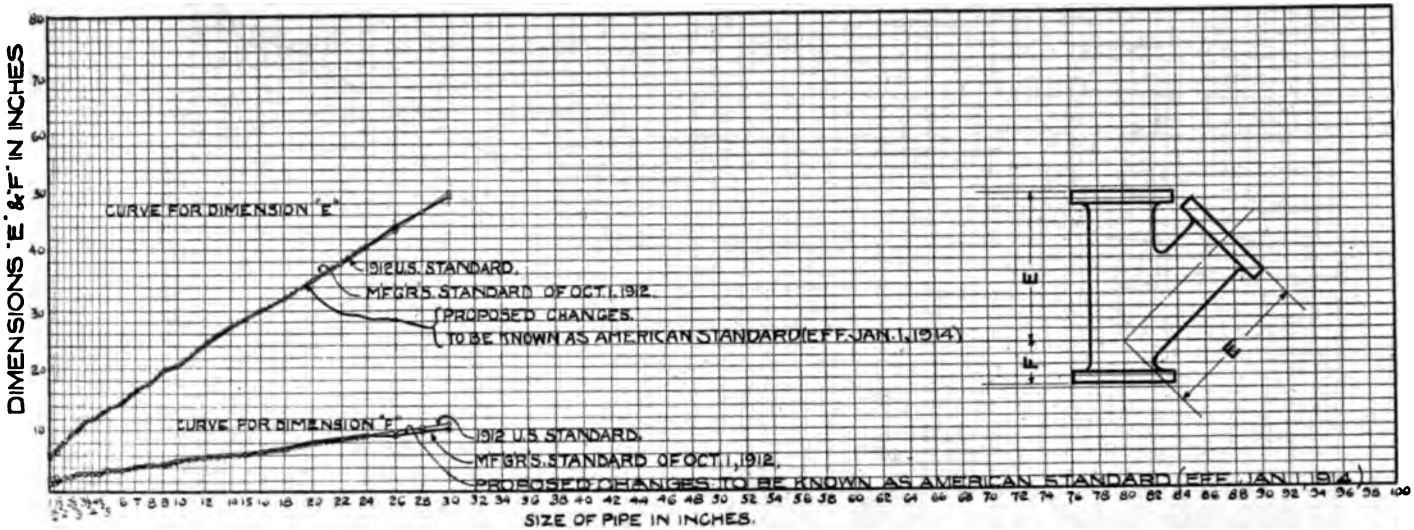


Fig. 21 Comparison of 1912 U. S. Standard, Manufacturers Standard and Proposed Changes in Center to Face Dimensions, Laterals, 125-Lb. Working Pressure per Sq. In.

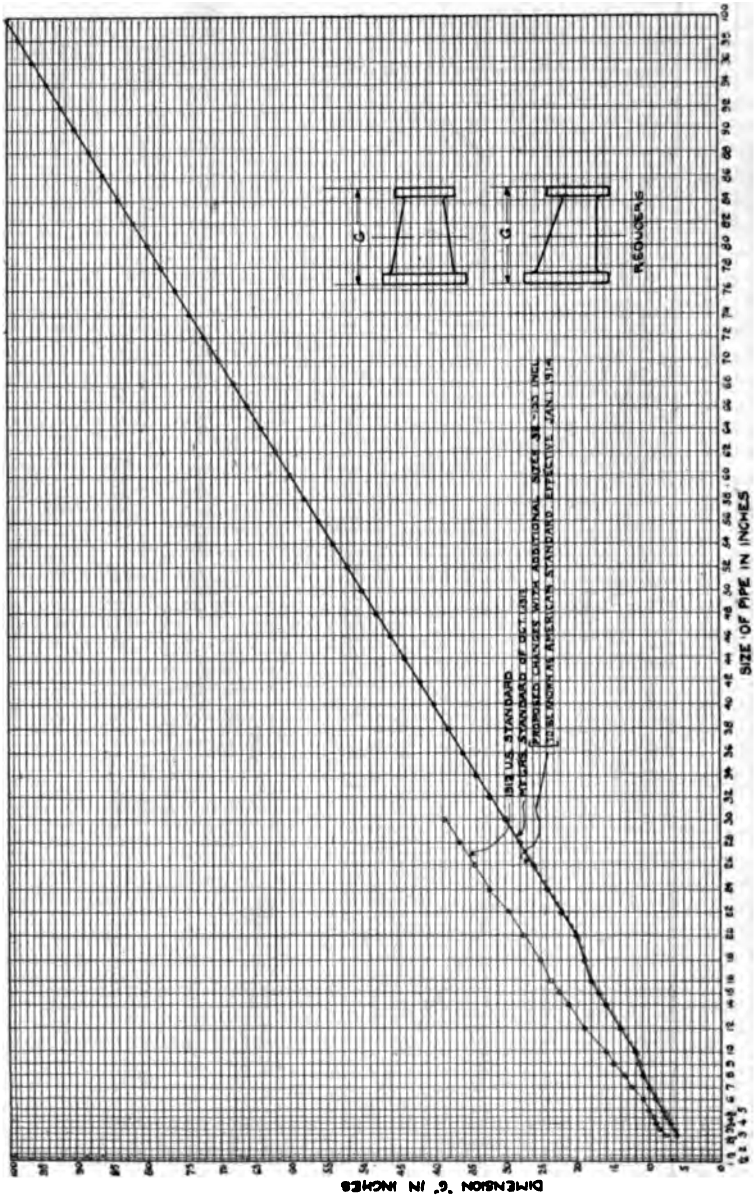


Fig. 22 Comparison of 1912 U. S. Standard, Manufacturers Standard and Proposed Changes in Center to Face Dimensions. Reducers. 125-Lb. Working Pressure per Sq.

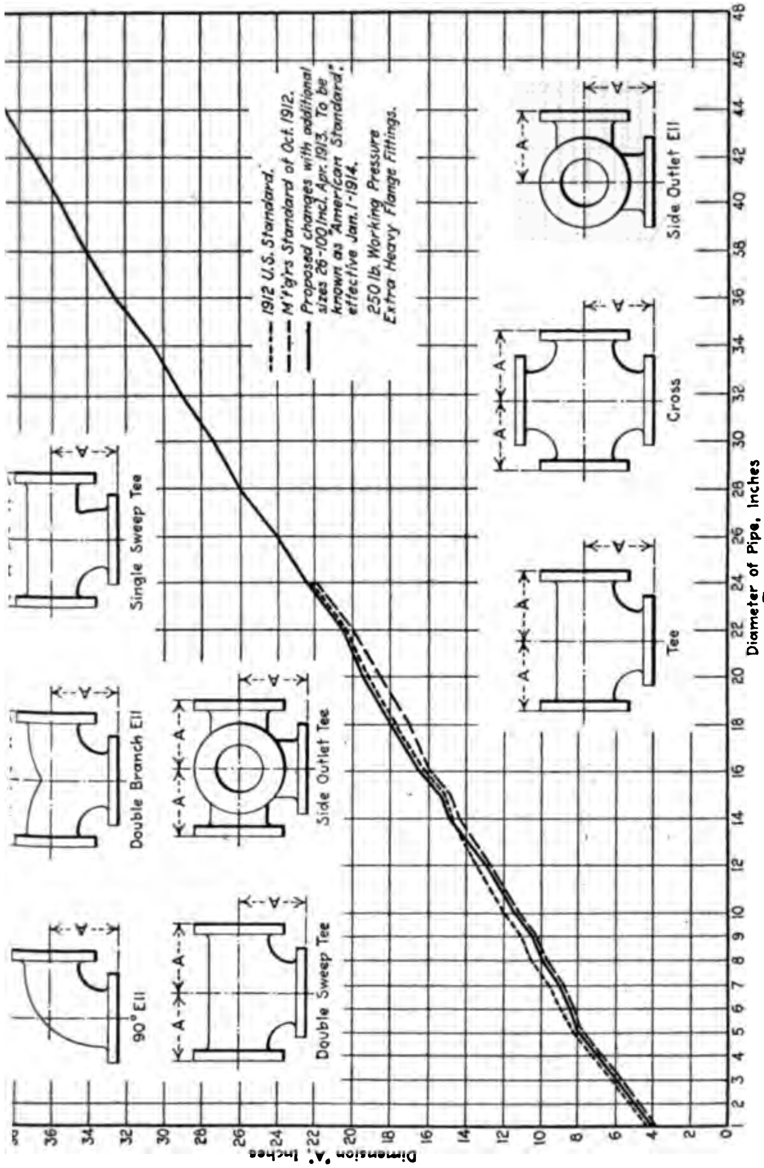
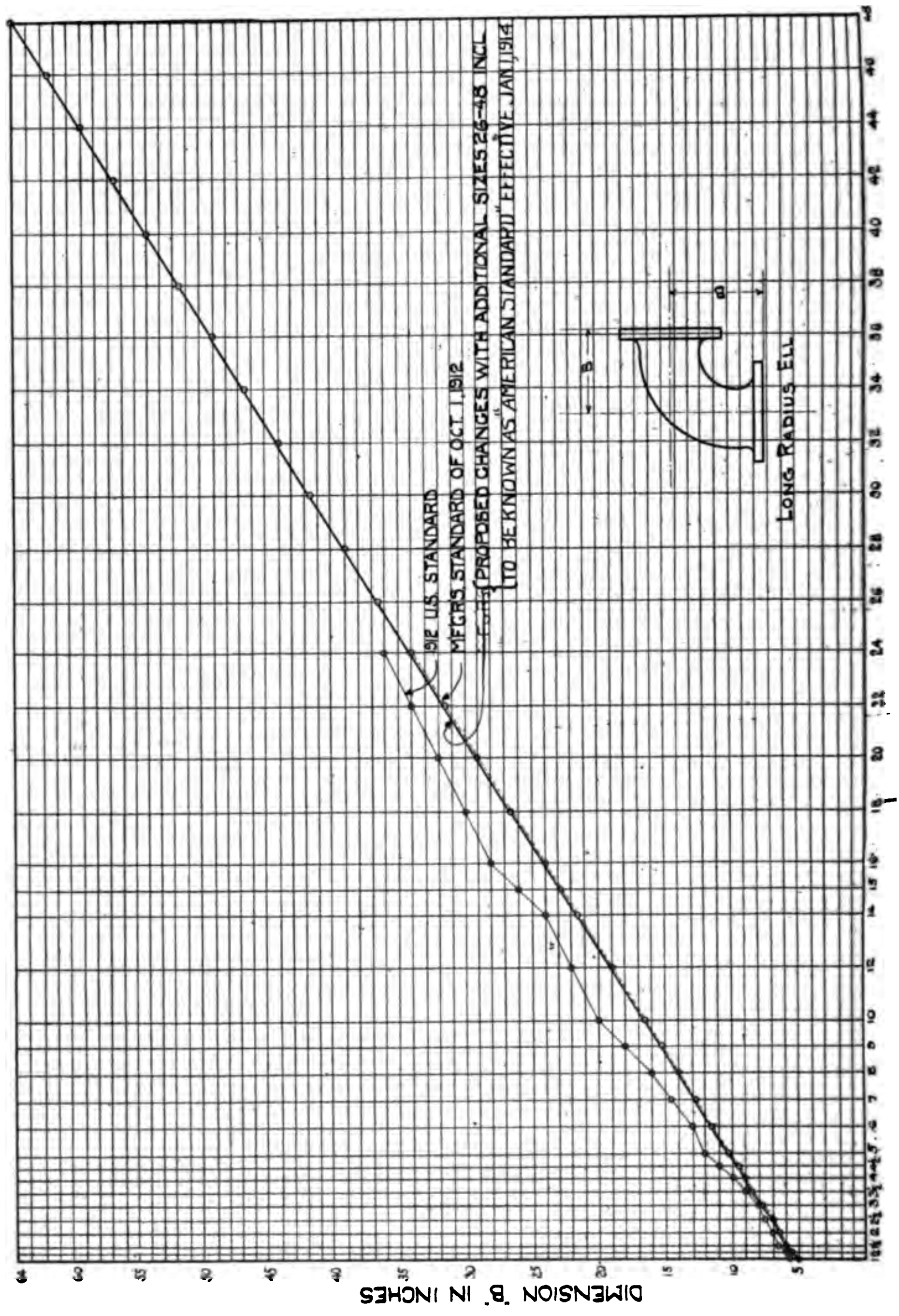


FIG. 23 COMPARISON OF 1912 U. S. STANDARD, MANUFACTURERS STANDARD AND PROPOSED CHANGES IN CENTER TO FACE DIMENSIONS, ELLS, TEES AND CROSSES, 250-LB. WORKING PRESSURE PER SQ. IN.


1912 U.S. STANDARD
MFGRS. STANDARD OF OCT. 1, 1912
PROPOSED CHANGES WITH ADDITIONAL SIZES 26-48 INCL.
TO BE KNOWN AS "AMERICAN STANDARD" EFFECTIVE JAN. 1, 1914
LONG RADIUS ELL
B
DIMENSION "B" IN INCHES

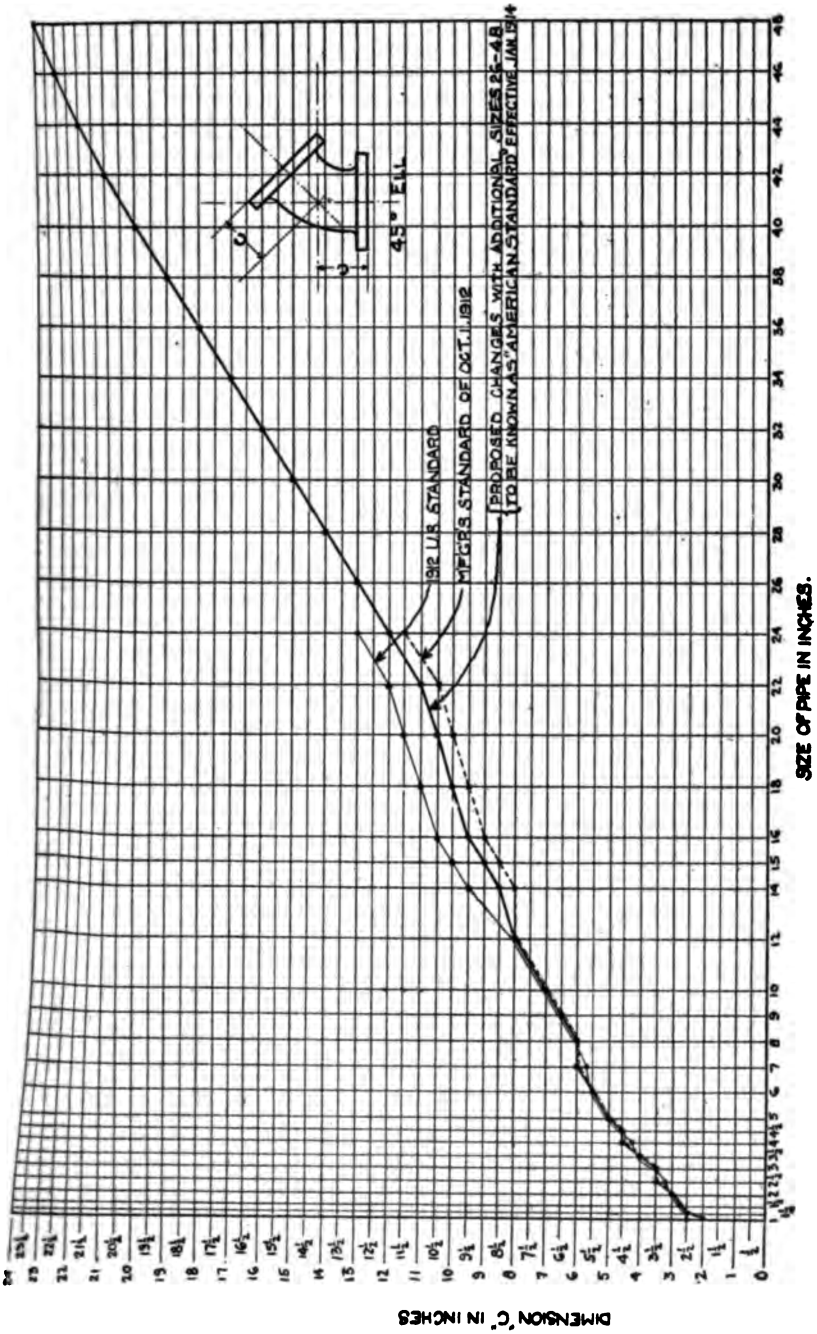


FIG. 25 COMPARISON OF 1912 U. S. STANDARD, MANUFACTURERS STANDARD AND PROPOSED CHANGES IN CENTER TO FACE DIMENSIONS, 45-DEG. ELLS, 250-LB. WORKING PRESSURE PER SQ. IN.

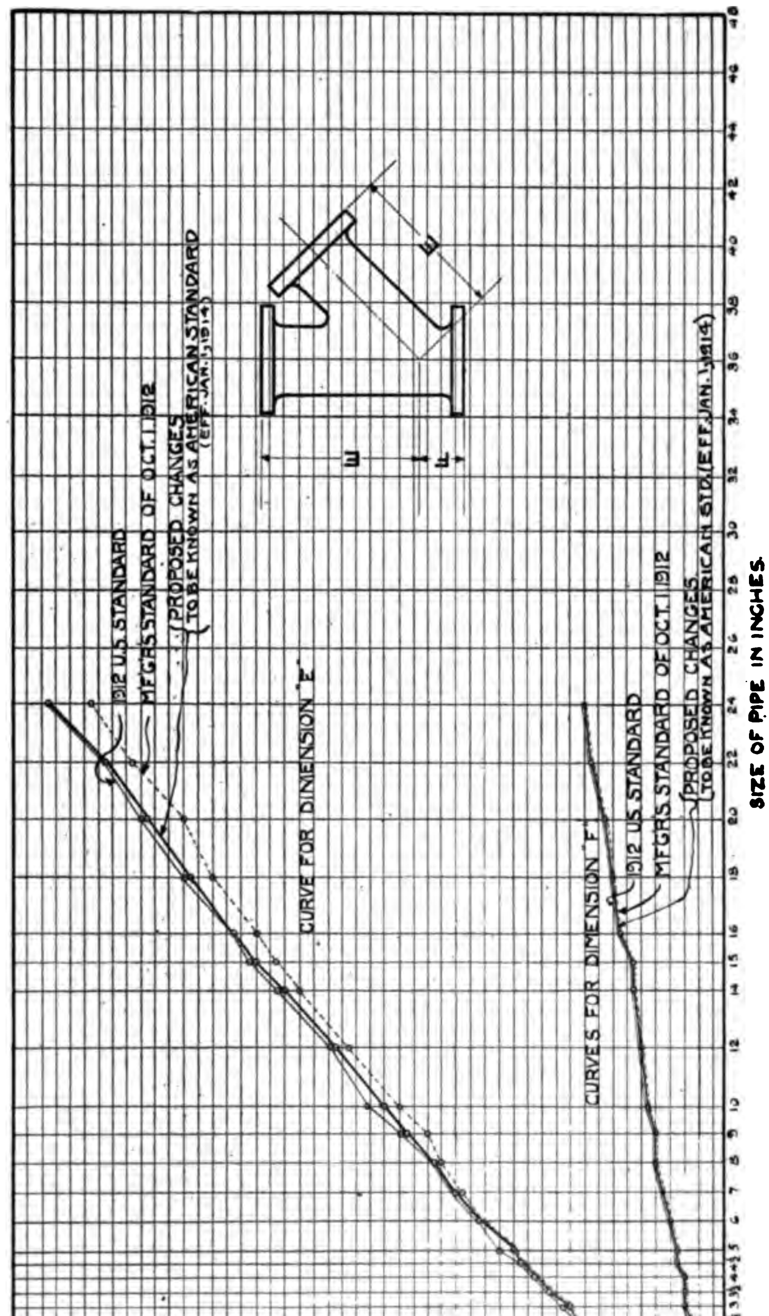


FIG. 26 COMPARISON OF U. S. STANDARD, MANUFACTURERS STANDARD, AND PROPOSED CHANGES IN CENTER TO FACE DIMENSIONS, LATERALS, 250-LB. WORKING PRESSURE PER SQ. IN.

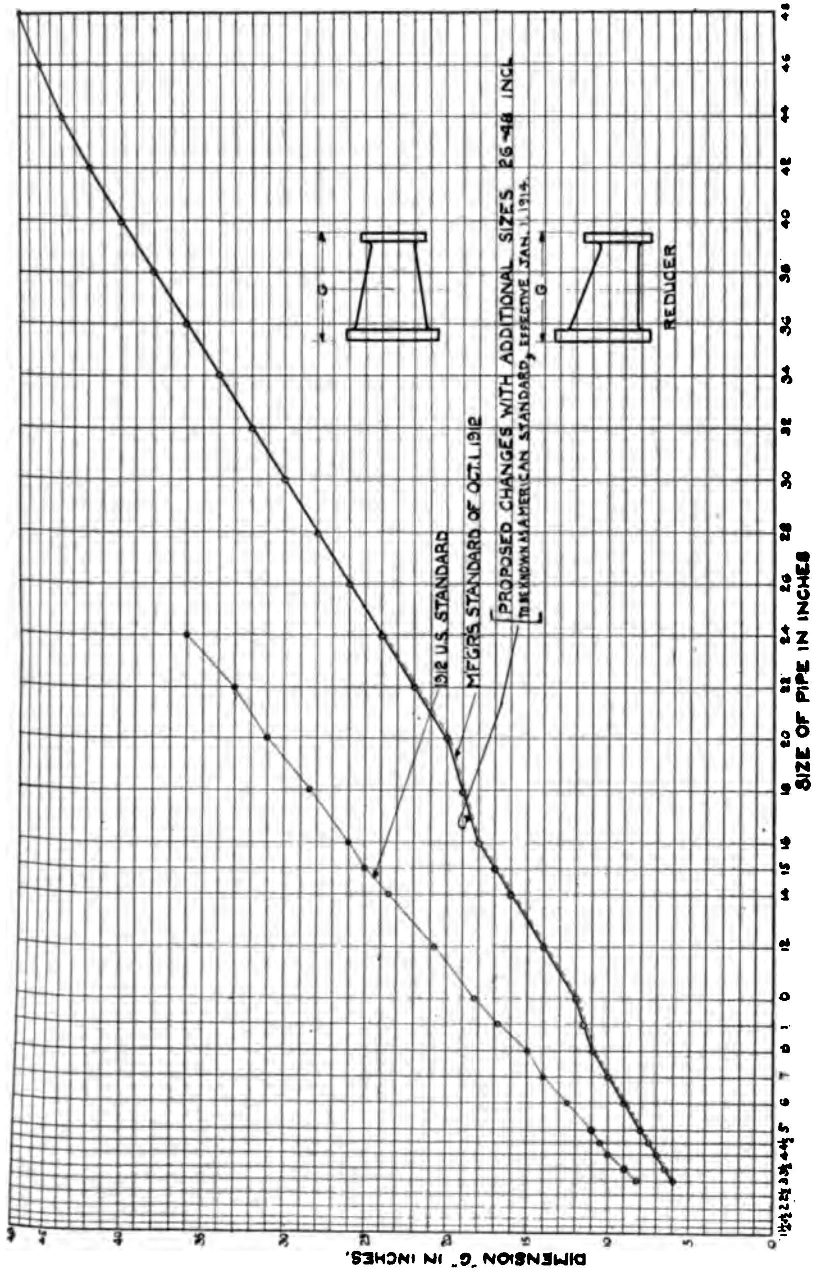


FIG. 27 COMPARISON OF U. S. STANDARD, MANUFACTURERS STANDARD AND PROPOSED CHANGES IN CENTER TO FACE DIMENSIONS, REDUCERS, 250-LB. WORKING PRESSURE PER SQ. IN.

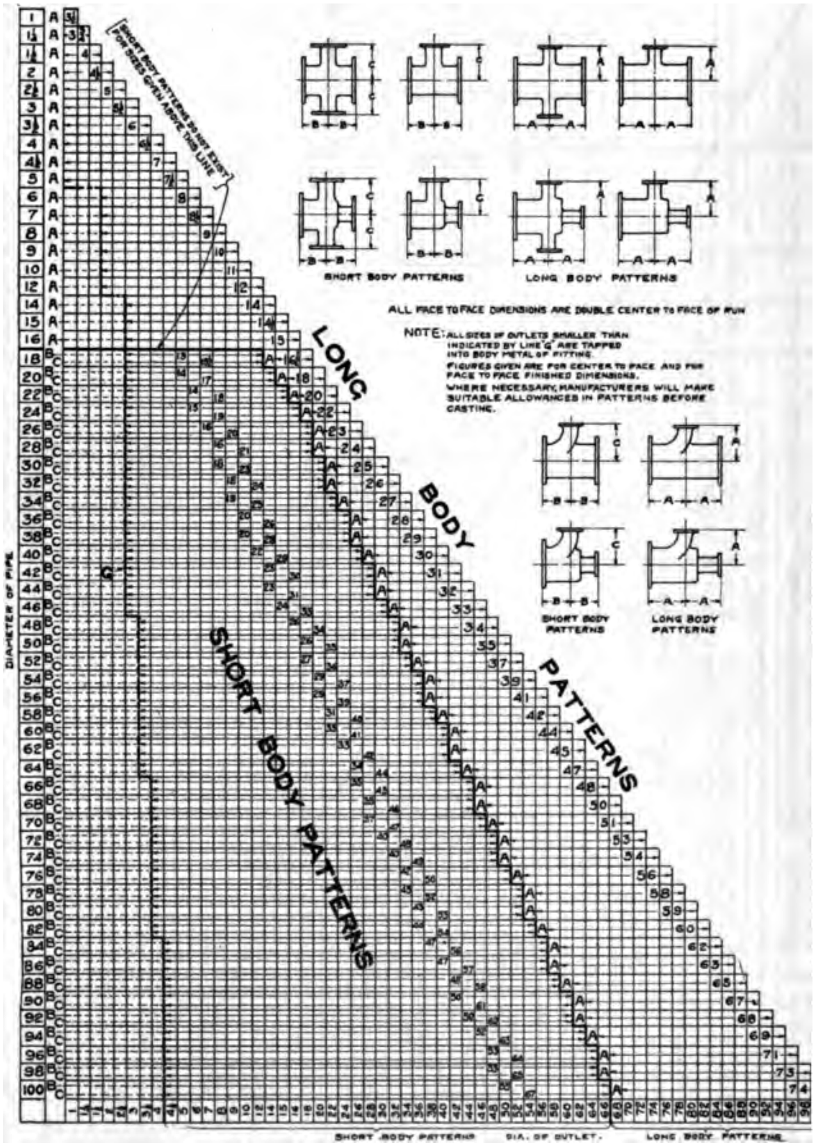


FIG. 28 REDUCING TEES AND CROSSES, LONG AND SHORT BODY PATTERNS, 125-LB. WORKING PRESSURE PER SQ. IN.

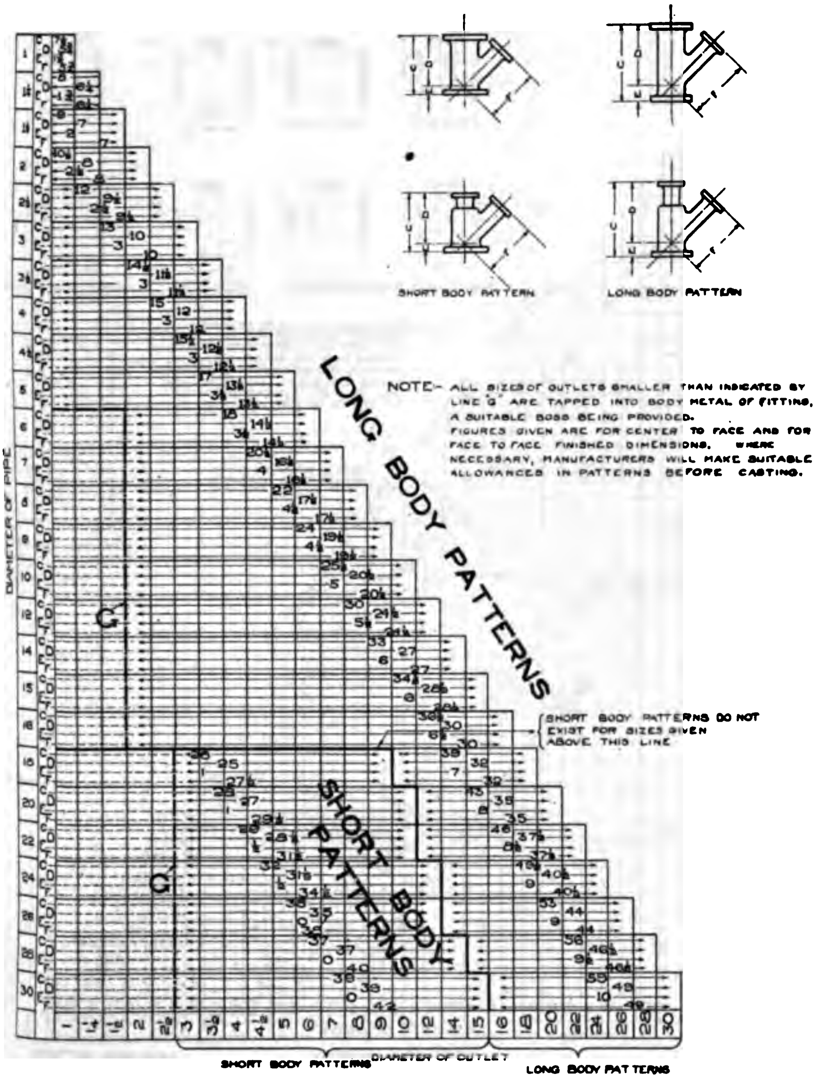


Fig. 29 Reducing Laterals, Long and Short Body Patterns, 125-Lb. Working Pressure per Sq. In.

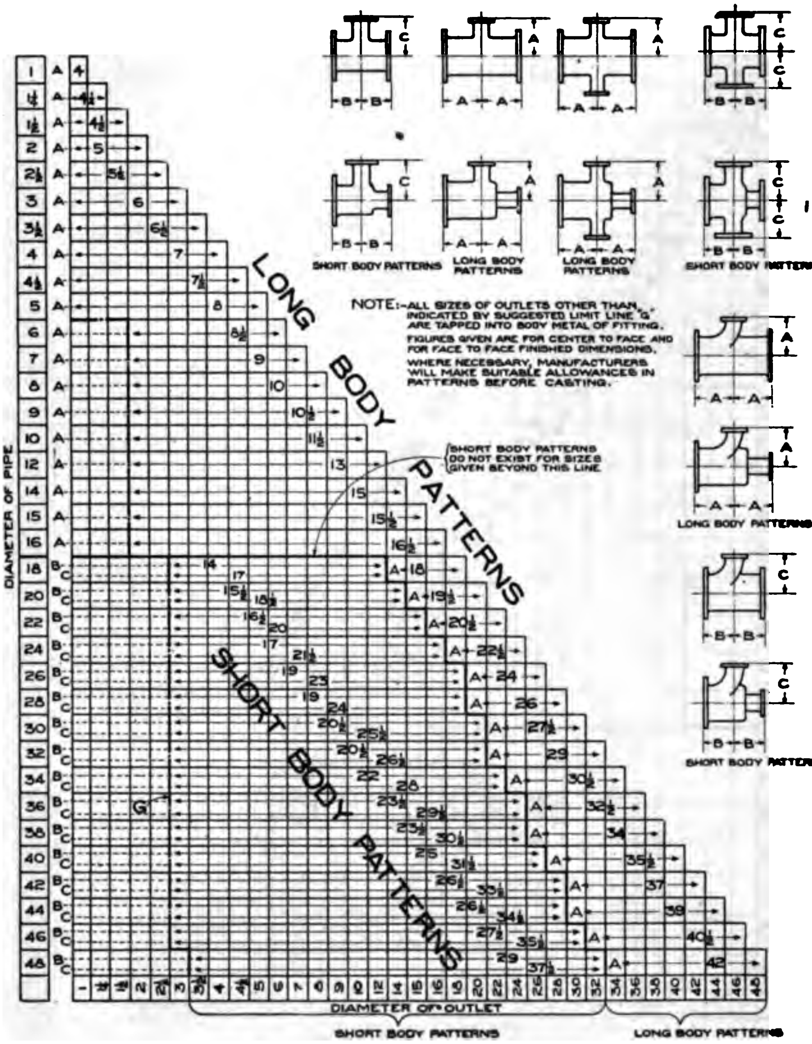


Fig. 30 Reducing Tees and Crosses, Long and Short Body Patterns, 250-Lb. Working Pressure per Sq. In.

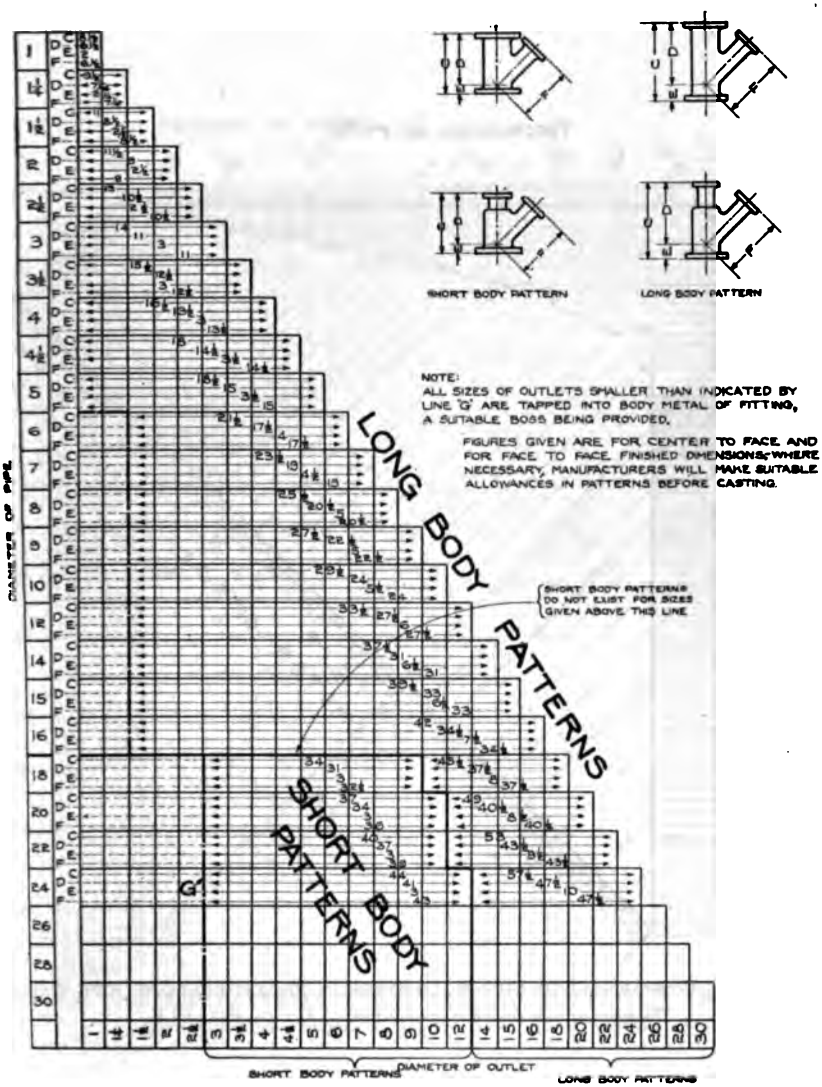


Fig. 31 Reducing Laterals, Long and Short Body Patterns, 250-Lb. Working Pressure per Sq. In.

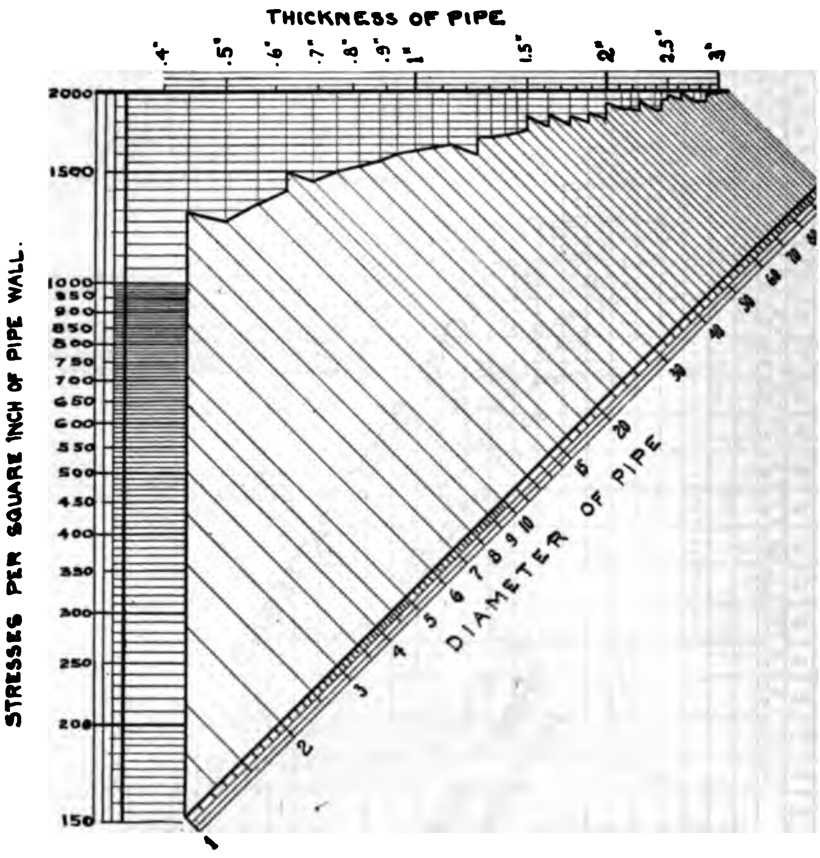


FIG. 32*A* COMPARISONS OF PIPE WALL STRESSES CORRESPONDING TO PIPE WALL THICKNESSES SHOWN BY CURVE "A" IN FIG. 15*A*

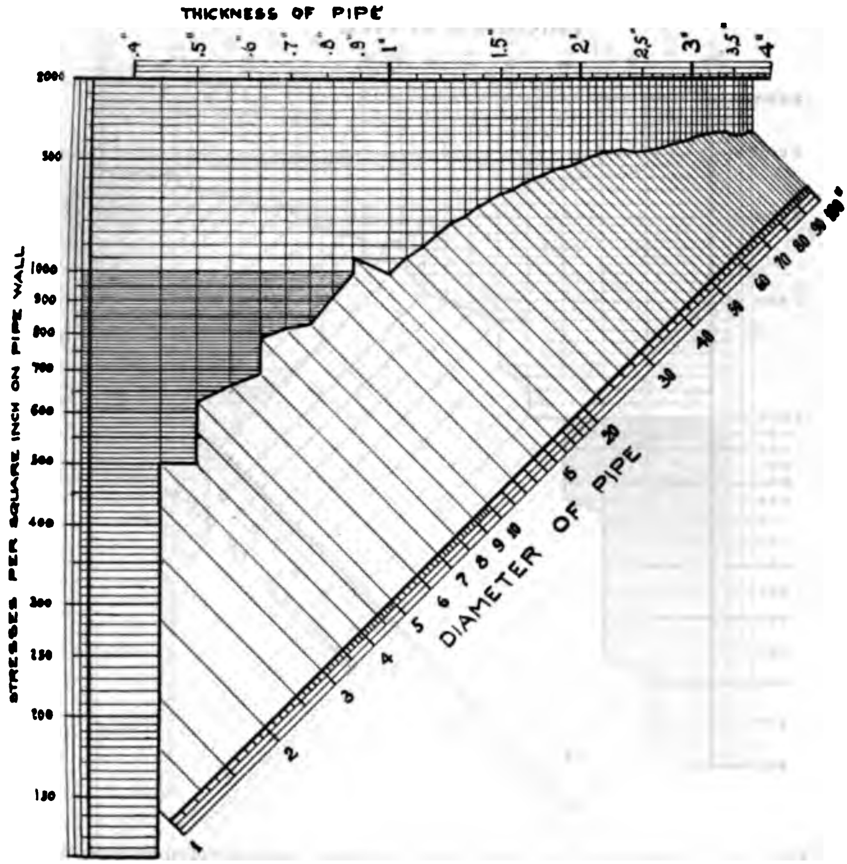


FIG. 32B COMPARISONS OF PIPE WALL STRESSES CORRESPONDING TO PIPE WALL THICKNESSES SHOWN BY CURVE "B" IN FIG. 15A

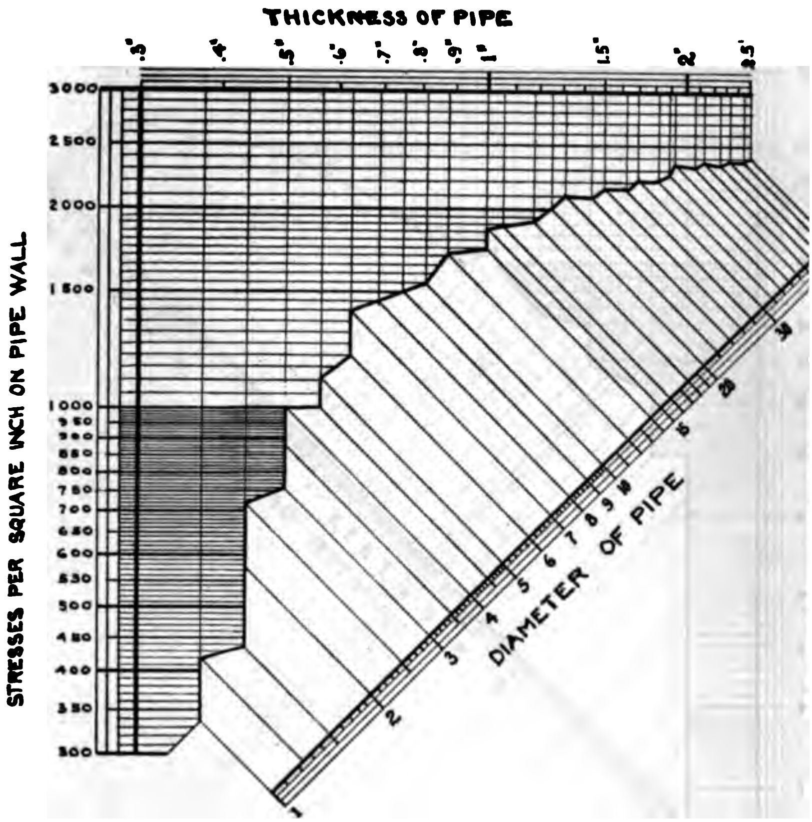


FIG. 32C COMPARISONS OF PIPE WALL STRESSES CORRESPONDING TO PIPE WA THICKNESSES SHOWN BY CURVE "C" IN FIG. 15B

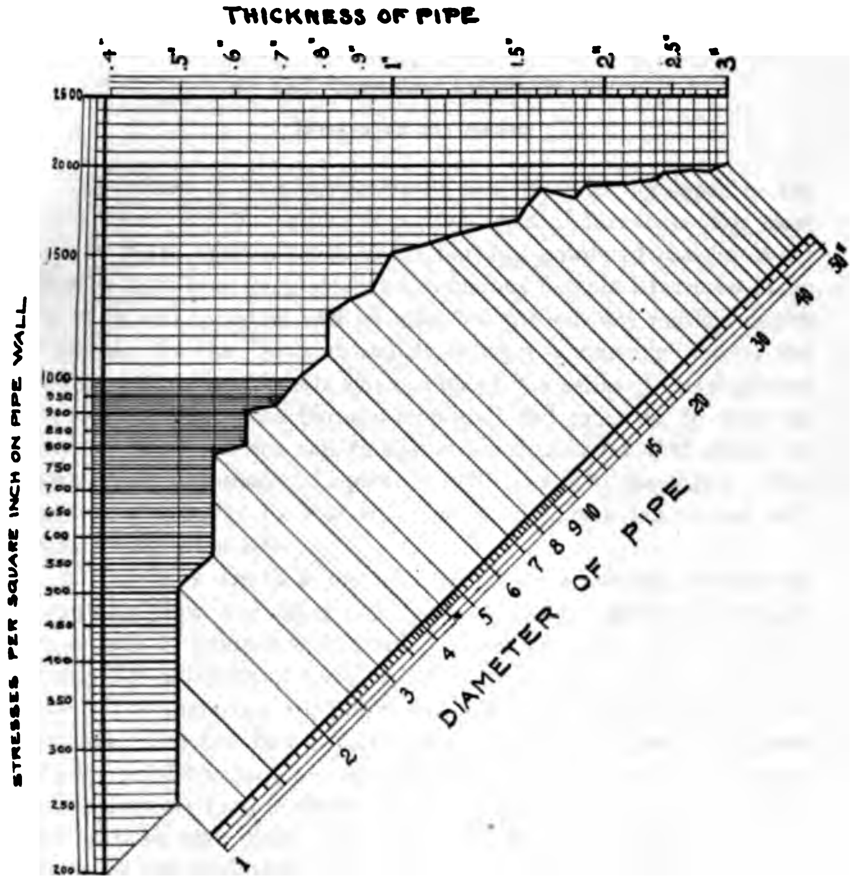


Fig. 32D COMPARISONS OF PIPE WALL STRESSES CORRESPONDING TO PIPE WALL THICKNESSES SHOWN BY THE CURVE "D" IN FIG. 15B

SYMPOSIUM ON POWDERED FUEL

No. 1431 *a*

PULVERIZED COAL BURNING IN THE CEMENT INDUSTRY

By R. C. Carpenter, Ithaca, N. Y.

Member of the Society

The process of burning powdered coal has been developed in but few arts and only in relation to certain types of furnaces. For more than 30 years various schemes for burning powdered coal in boiler furnaces have been suggested and numerous patents have been taken out on various processes and burners, but without any marked degree of success. In the Portland cement industry commercial success was attained more than 15 years ago as a result of a series of investigations and experiments. The furnace employed had much to do with the practical success which was finally attained, and for that reason its construction and mode of operation will be briefly described. This furnace is familiar to Portland cement engineers but is not well known in the other arts.

2 Portland cement is manufactured from a mixture of materials containing lime and silica which are brought together in definite proportions to produce a chemical combination. The raw material is principally carbonate of lime, or limestone in some form, and clay or shale. The materials are pulverized raw and mixed in proper proportions. The raw mix is introduced into a kiln either in the form of a dry powder or in a wet and plastic condition where it is subjected to an extremely high temperature and in which the required chemical combinations take place. The material discharged from the kiln is known as cement clinker; it is pulverized in various forms of grinding mills and reduced to a powder so fine that 90 parts or more will pass through a sieve having 100 meshes to the inch. This paper has to do only with the combustion process which takes place in the kiln. In the early days of the art fixed kilns were employed, but at the present time the rotary kiln is almost universally used.

Presented at the Spring Meeting, St. Paul-Minneapolis, June 1914, of The American Society of Mechanical Engineers.

THE ROTARY KILN

3 The rotary kiln in its essential features was patented l Siemens in 1869 and, in combination with a gas burner and oth appliances, by Ransome in 1885. It was not found successful in En land for cement burning, but was adopted by the Atlas Company America about 1890 and was improved and developed by that compa and other American companies to such a degree that it practical replaced every other method of burning Portland cement.

4 The modern rotary cement kiln consists of a slightly incline steel cylinder mounted on rollers and arranged so that it can l revolved. The upper end is connected to a stack or chimney for tl escape of the discharge gases and is provided with means for suppl ing the raw cement material in the form of dust or slurry. At tl lower end of the cylinder is a stationary hood which performs tl function of affording a discharge opening for the burned materi and which also acts as a support for the fuel supplying devices. Tl rotary cylinders are of various dimensions. The tendency has bee continually to increase the size of the cylinder. Thus, for instanc in 1890 the rotary kilns were in some instances 4 ft. in extern diameter and 40 ft. in length. From 1895 to 1902 the kiln dimensio were quite generally 6 ft. in diameter and 60 ft. long. At tl present time kilns 10 ft. in diameter and 150 to 200 ft. long a common. The Atlas plant at Hudson is equipped with kilns 12 f in diameter and 275 ft. long. In most of the late installations tl kilns are true cylinders having the same diameter at top and botto but in many plants kilns are to be found with the diameter at tl top about one foot less than at the bottom, the two parts being co nected by a tapered section.

5 The rotary kiln is lined throughout with a fire-brick linin except in rare cases where a very wet slurry is employed, in whic case the lining for a short distance from the upper end is omitte The temperatures required in the combustion chamber for burnir cement clinker are from 2800 to 3000 deg. fahr. To withstand tl high temperature, a lining having high refractory qualities must l employed. It must also have the quality of withstanding decompos tion by the chemical action taking place in the kiln. The proble of kiln linings is a very serious one since no lining has been foun that will stand for a great length of time under the conditions operation. The lower part especially has to be repaired frequentl unless the conditions are unusually favorable. The kiln is operate

so as to keep the lining coated with the cement mixture for the purpose of protection. The lining problem, except as it bears on the combustion of powdered fuel, has no place in this paper and will not be discussed further.

6 A diagram of a cement kiln in elevation and plan is shown in Fig. 1. This diagram shows the general features and the arrangement of the various operating parts with reference to each other. In the diagram the rotary kiln is shown at *C*, the flue for discharge gases at *B*, the supporting rolls at *DD*, the stationary hood at the lower end at *E*, the rotary clinker cooler at *G*, the clinker pit at *F*, the blower for supplying compressed air at *H*, the coal bin at *K*, the feeding injector for coal dust at *J*, the conveyor for delivering coal to the fuel tank at *L*, the dust bin for raw material at *A*, and the kiln stack at *S*. The hood *E* is usually mounted on rolls so as to be easily moved for repairing of the kiln. It is customary to supply a separate stack for each kiln, although in some cases one stack receives the discharge from two kilns. In a large installation it is customary also to supply the air for several burners with one blower. In the installation shown in Fig. 1 the blower draws in air which has been warmed by passing through a rotary clinker cooler.

DEVELOPMENT OF THE BURNING PROCESS

7 During the early years of the Portland cement industry in this country, oil was employed as a fuel. This was sprayed into the lower end of the furnace with a jet of compressed air or steam. The oil was employed successfully, but due to the increasing cost after 1895 its use was very expensive. From 1897 to 1900, the increase in price was such as to make the use of oil nearly prohibitive from a commercial standpoint, and was the principal incentive for developing the use of pulverized coal.

8 In 1894, a series of experiments relating to the use of pulverized coal were started by the Atlas Company, in charge of Messrs. Hurry & Seaman, chief engineer and superintendent respectively. These experiments led to many discoveries, the invention of various parts, and finally to the commercial development of the art. Hurry & Seaman are entitled to the credit of the first successful use of powdered coal in the cement industry. This use was begun in 1895 by the Atlas Company and has never been discontinued. Other engineers along independent lines worked out the problem a few years later although possibly receiving some assistance from information

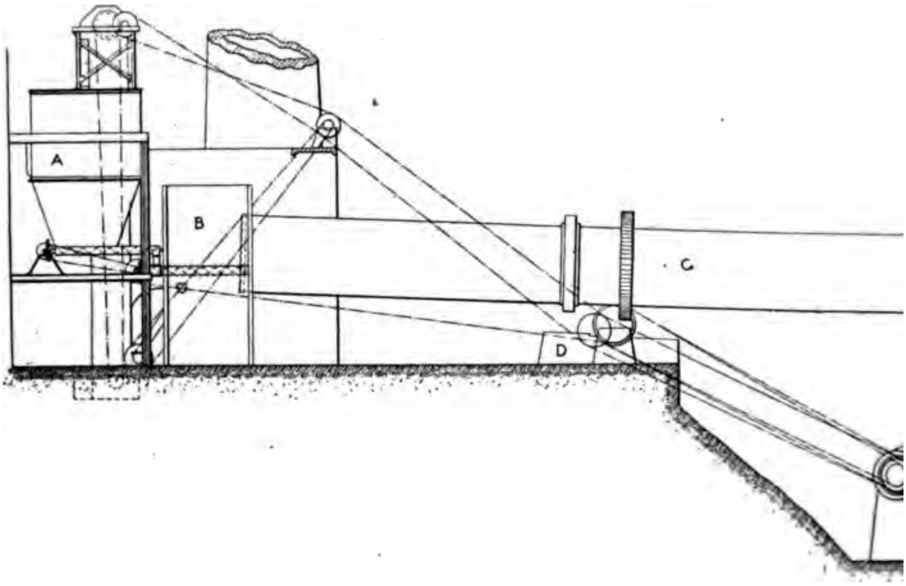
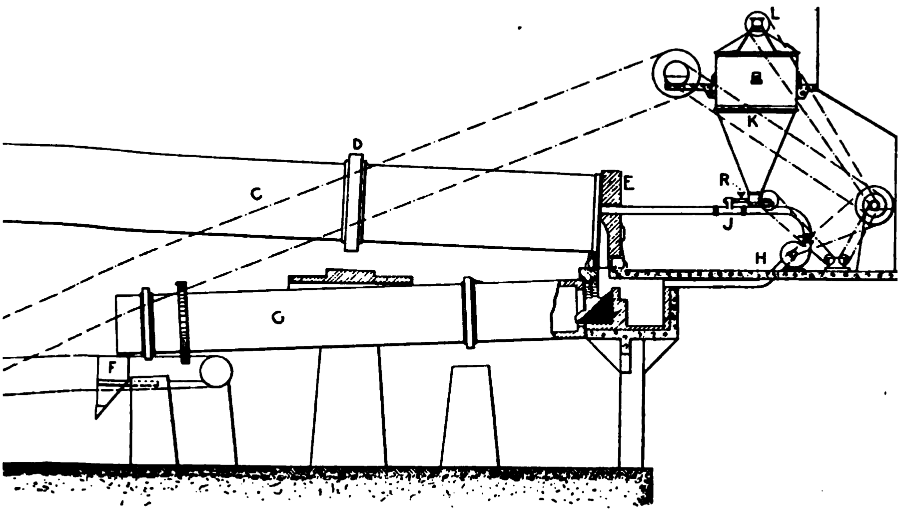


FIG. 1 DIAGRAM OI

disseminated throughout the industry relating to the results obtained by Hurry & Seaman. It may be stated that at the particular date referred to, every mill in the industry jealously guarded every detail of manufacture as a valuable trade secret, consequently little or no direct information as to details of process or machinery employed was common in the different mills. The information which leaked out at that time respecting details of operation or machinery was generally inaccurate and based on speculation or rumors. The success of the process of burning pulverized coal in the Atlas plant was not generally known in other mills until about 1900 when the process was put in successful operation in various plants by independent investigators.

9 The art as at present developed consists of a process for delivering to the kiln the powdered fuel or fuel dust by a jet of air which impinges on the fuel dust in some type of injector with force enough to discharge the dust into the kiln. The process, with details of mechanism, is illustrated in Fig. 1 in relation to a kiln. Fig. 2[1] gives an idea of the character of the combustion which takes place in

[1]Supplied by Duncan & Duncan.



INSTALLATION, 8 FT. BY 145 FT.

the burning of pulverized fuel. The compressed air may be obtained from a fan or compressor as may be more convenient; the diagrams indicate both schemes.

10 The injector varies greatly in different constructions but it performs the function of injecting the coal dust into the kiln by a jet of air and it does not require sufficient air for combustion. The additional air needed for combustion enters the kiln principally through openings in the hood and through the discharge duct for clinker. Such openings are shown in Fig. 2 by arrows at points marked *a*. The amount of air supplied by the compressors or fans should be sufficient merely to carry the dust into the kiln without producing an explosive mixture. The fuel dust enters the combustion chamber of the kiln in the form of a black cloud and burns in the form of an elongated torch, as indicated in Fig. 2. The length of the flame in actual kiln constructions is generally from 25 to 40 ft., although this is affected by conditions. The diameter of the flame in some places may very nearly equal that of the combustion chamber. Under best conditions of burning the flame does not perceptibly im-

pinge against the sides of walls of the kiln, and the heat utilized is practically all given off by radiation.

THE POWDERED FUEL PROBLEM

11 The problem is one of combustion under peculiar conditions. The burning of pulverized coal differs from the burning of solid fuel, from a theoretical standpoint, principally in one particular. In the combustion of coal of commercial sizes lying on the grate, the air for combustion passes between the pieces of coal and the products of combustion pass off in the flues. Coal dust does not burn under such conditions, as the particles are so fine that sufficient air for combustion does not reach the coal through the crevices between the

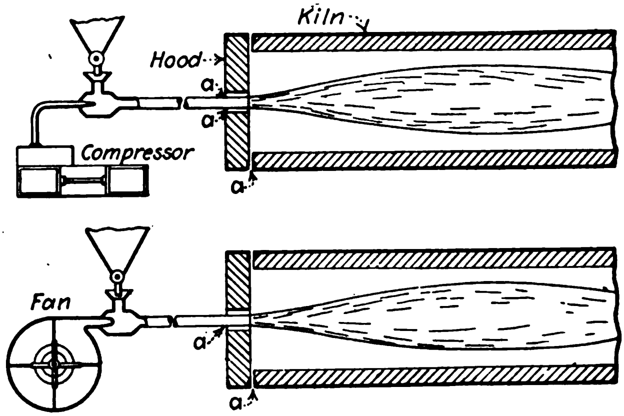


FIG. 2 DIAGRAMS OF BURNER AND KILN FOR POWDERED FUEL

particles. To burn powdered coal successfully, it must be burned while in suspension in the air. In such a position each particle is surrounded by air which supports the combustion. The form of the furnace used in the Portland cement art is favorable for combustion in suspension since it is very long and affords plenty of room for such combustion.

12 Contact of the particles of coal dust with other bodies results generally in the lowering of temperature to such an extent as to make combustion impossible. The result is the virtual loss of any fuel which falls down onto the lining or onto the clinker. The time of combustion is evidently increased as the size of the dust particle is

increased, from which it follows that the finer the grinding, everything else being equal, the quicker and more perfect the combustion.

13 In the early days of the development of the process of coal burning, ignorance of the necessity of fine grinding was the cause of many failures in burning coal dust. In the cement industry special devices for regulating the supply of air for injecting the fuel are supplied, but no special controlling apparatus is supplied for the air which enters the kiln through the various openings around the hood. It would be difficult indeed to control the admission of such air. By increasing the fuel charge, it is possible to bring the air supply down to nearly theoretical, or to any relative proportion desired. I have found from tests in the cement art that best results are obtained when there is a slight deficiency rather than an excess of air. This is denoted by a short carbon monoxide flame at the base of the stack and also by analysis of the escaping gases.

14 *Novelty of the process.* Patents taken out many years ago for the burning of powdered coal under boilers and in various arts show various kinds of pulverizers and feeding devices, and also the idea of delivering powdered coal into the furnace by a jet of air or steam. Crampton suggested a pulverized coal flame for use in his type of rotary Portland cement furnace. No one, however, previous to Hurry & Seaman, seems to have comprehended the necessary underlying principle for successfully burning pulverized coal which requires the burning of the coal while in suspension and the utilization of the radiant heat of combustion without substantial impingement of the flame. The failure to recognize such requirements is, in my opinion, in a large measure responsible for the practical failure of the burning of pulverized fuel in boiler furnaces, although such furnaces, because of form and proportion, make difficult the problem of burning coal dust in suspension. In practically all of the devices which have been tried under boilers the coal dust has impinged on bridge wall or sides of the furnace or on portions of the boiler before the combustion could be completed, resulting in waste, lack of capacity, and destruction of fire-box and fire-brick linings and other portions on which the flame impinged.

FUEL

15 The fuel available for burning in Portland cement kilns can have a wide range of quality. The best bituminous coals are preferable, but those of quite poor quality are in successful use. I have

known of the successful use of anthracite coal but it is difficult to pulverize and needs a high temperature for combustion.

16 The fuel used in the Eastern portions of the country is generally obtained in the bituminous mines of Pennsylvania, Maryland, Virginia or West Virginia. The coal employed in mills in the Western part of the country is frequently that most convenient to the plant and the cheapest in price on the heat unit basis.

17 Before the coal can be ground it is necessary that it be dried so that the moisture content will be less than 1 per cent, as the water in coal seriously affects the operation of pulverizing. It also has a detrimental effect on feeding and on the capacity of the kiln. The effect of the moisture, however, depends upon the kind of coal, so that no limit can be definitely stated as essential to success in advance of a trial.

18 *Capacity and Efficiency.* The weight of pulverized coal required per barrel varies somewhat with the character of the kiln and the character of the process. In the dry process of manufacture the weight of fuel per barrel varies from about 22 to 26 per cent of the weight of cement produced, i.e., from 83 to 100 lb. of coal per bbl. In the wet process the coal varies from about 35 to 50 per cent of the finished product, i.e., from 133 to 190 lb. of coal per bbl. The theoretical amount of coal required, neglecting the heat due to the formation of silicates of line and alumina, is probably not far from 30 lb. per bbl., provided 10,000 B.t.u. per lb. of coal is utilized. The continuous stationary kilns are reported as consuming 12 to 16 per cent of fuel or from 45 to 60 lb. per bbl. of cement.

19 The capacity, in barrels per 24 hours, of the modern kiln when operating on dry material with flue gases about 1000 deg. fahr., can be approximately expressed by the following formula

$$C = \frac{D^2 L}{24}$$

where

C = capacity in 24 hours in bbl. of 380 lb.

D = outside diameter in ft.

L = length in ft.

20 The economy of the kiln has been increased by increasing its length, probably due in part to a change in the process of burning whereby the CO_2 is driven off from the material before it reaches the combustion zone in the kiln, and in part to a reduction in losses. The saving due to the use of the 150-ft. kiln in place of the 60-ft.

kiln has exceeded 20 per cent in fuel and in addition has cut down the labor required in operation more than one-half. Kilns can be operated with a stack temperature less than 1000 deg. fahr. but in that event the capacity is lessened and the result is generally an increase rather than a decrease in cost.

21 Richard K. Meade, in his book on Portland cement, makes the following theoretical calculations as to the heat necessary per 100 lb. of raw material.

		B.t.u.	
Heat required			
	Decomposition of 75 lb. $CaCO_3$ = 75×784 =	58,800	
	Decomposition of 4 lb. $MgCO_3$ = 4×384 =	1,536	
			60,336
Heat supplied			
	Burning of 0.3 lb. sulphur = 0.3× 4,050 =	1,215	
	Burning of 0.8 lb. carbon = 0.8×145,450 =	11,632	12,847
	Balance to be supplied by fuel.............		47,489

About 600 lb. of raw material are needed per bbl. so that the total heat per barrel required would be 284,934 B.t.u., neglecting the effect of the silicates. The combination of the silicates and lime gives off heat. This amount is in doubt as the exact resulting composition of the silicates is not known. A certain combination might produce 44,700 B.t.u. per 100 lb. of raw material, which is hardly possible as it would reduce the theoretical heat to be supplied to 2789 B.t.u. per 100 lb. raw material, or to 16,734 B.t.u. per bbl. of cement.

22 The principal cause of lack of economy in the rotary kiln appears to be due to excessive flue loss. Dr. Joseph W. Richards,[1] has reported the following distribution of heat losses in a 6 x 60 kiln:

36 per cent excess air in chimney gases
36.1 per cent necessary products of combustion
10.7 per cent in hot clinker
12.8 per cent in radiation and convection

The above investigation indicates about 72 per cent flue loss of which about one-half is due to poor operation and is preventable.

23 In order to utilize the waste heat in the stack, I arranged in the Cayuga Lake plant to pass the discharge gases of two kilns through a boiler and an economizer, the draft being maintained by a fan. I also arranged to heat the air entering the kilns by drawing it

[1]Engineering Record, Feb. 27, 1904.

through the hot clinker discharged from the kilns. The kilns w
60 ft. in length and 7.5 ft. in diameter at the lower end and 6.5
at the upper end. The results are shown in Table 1.

24 From these data Table 2 has been computed showing the proximate distribution of heat throughout the process.

TABLE 1 DATA (TWO KILNS) PER HOUR, KILN 7½ AND 6½ x 60

Coal consumed per hour, lb.	
Clinker specific heat, 0.2	
Clinker produced per hour (CaO = 62 per cent), lb.	
Weight $CaCO_3$ per hour, computed, lb.	
Moisture in raw material 3.1 per cent	
Weight CO_2 per hour from material, lb.	
Weight of air supplied per lb. of coal, 44 per cent excess, lb.	
Total weight of air supplied per hour, lb.	3
Weight of air supplied by coal feeders per hour, lb.	
Total weight of gases discharged per hour, lb.	3
Heat discharged per lb. of gas, 0.23 (1800—100), B.t.u.	
Area of outside of kiln, sq. ft.	
Area of hood exposed, sq. ft.	
Air entering kilns, deg. fahr.	
Air leaving kilns, deg. fahr.	
Air leaving boiler, deg. fahr.	
Air leaving economizer, deg. fahr.	
Temp. of kiln by optical pyrometer, lower third, deg. fahr.	2350 to
Temp. of kiln by optical pyrometer, upper part, deg. fahr.	2960 to

TABLE 2 APPROXIMATE DISTRIBUTION OF HEAT

	B.t.u.	Per
Heat entering kilns from clinker cooler	2,041,000	
Heat entering kilns from comb. of coal	26,450,000	
Heat produced from chemical reactions	632,206	
Total heat supplied	29,123,206	1
Discharged from kiln to boiler	14,859,859	
Discharged with clinker (8018 × 2 × 500)	4,409,540	
$CaCO_3$ decomposed (8875 lb. at 765)	6,789,375	
126 lb. sulphuric anhydride liberated	238,140	
252 lb. water evaporated	303,200	
Radiation and unaccounted for	2,523,092	
Radiation per sq. ft. of surface of kiln per hour	974	
Heat absorbed by boiler from kiln gases	8,798,328	
Heat absorbed by economizer from kiln gases	1,178,998	
Stack loss and boiler radiation	4,882,533	

25 This investigation showed that about 50 per cent of the heat was discharged into the stack and of that amount about 68 per cent could be utilized in a boiler and economizer so that the ultimate flue loss was reduced to about 17 per cent of the fuel.

26 In the cement industry very few attempts have been made to utilize the heat of the escaping gases. So far as I know, the only successful installation of that kind is that in the plant at Kosmosdale, Kentucky. The reason why the waste heat has not been utilized to a greater extent is no doubt due to the difficulties of arranging and maintaining the waste heat boilers in good condition. I am satisfied, however, that such difficulties are not so serious as to prevent a good return on the investment. It is doubtful if the difficulties are more serious than have been overcome in the steel industry.

27 Since 1902 the present methods of burning Portland cement have been in successful use, and without further reference to prior methods I will give a brief description of the machines employed, without going into minute details, so that they can be made a permanent part of the records of the Society. The operations required for burning pulverized coal consist in (*a*) drying, (*b*) pulverizing, (*c*) conveying, (*d*) storage, and (*e*) feeding. All these operations are provided with special machines and will be discussed later in the paper.

DRYING

28 Previous to drying, the coal is crushed by passing through rolls plain or toothed, or through crushers, to break up the large pieces. For the purpose of drying, rotary cylinders of the general character illustrated in Fig. 3, are generally employed, provided with an external furnace. The rotary cylinder of the dryer is frequently subdivided by partitions, or else provided with Z-bars, which raise the coal upward as the cylinder revolves and bring it into better contact with the heat and gases.

29 In some of the coal dryers, as Fig. 4, which is a dryer constructed by the Vulcan Iron Works, the discharge gases from the external furnace are arranged to pass through the dryer.

30 The coal to be dried is fed into the upper end of the cylinder *C*, through the hopper *K*, or other convenient means, and is discharged through the stationary hood *H*, at the lower end of the cylinder. An external furnace is located at *AA*, from which the hot gases pass to the rotating cylinder *C*, through the stationary hood *H*. There is a by-

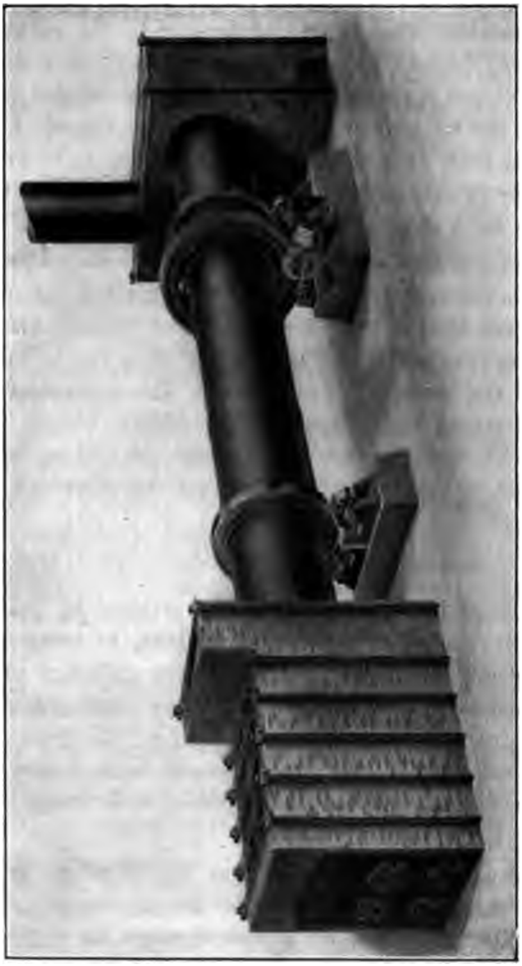


Fig. 3 General View of Rotary Dryer with Stationary Firebox

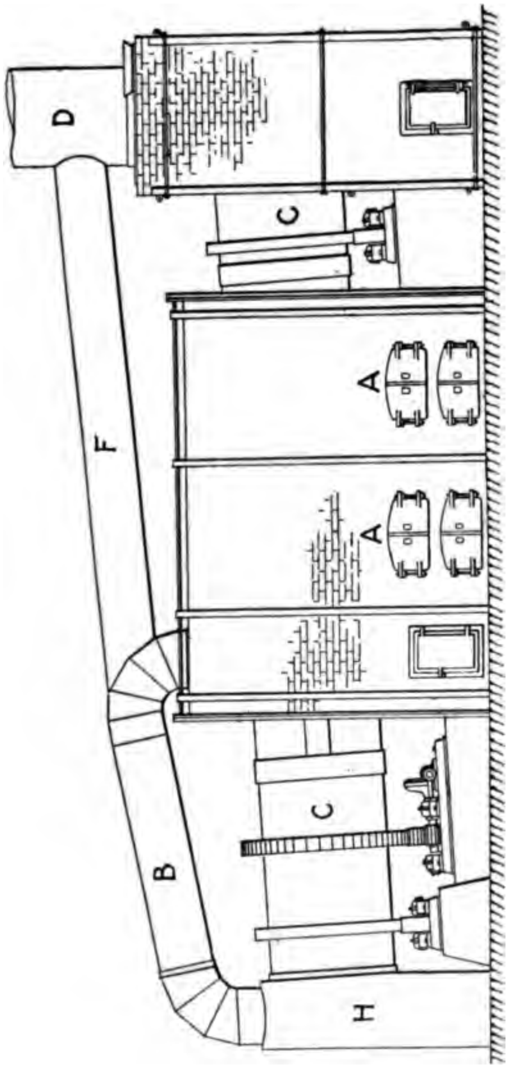


FIG. 4 COAL DRYER WITH HEATED GASES PASSING THROUGH CYLINDER

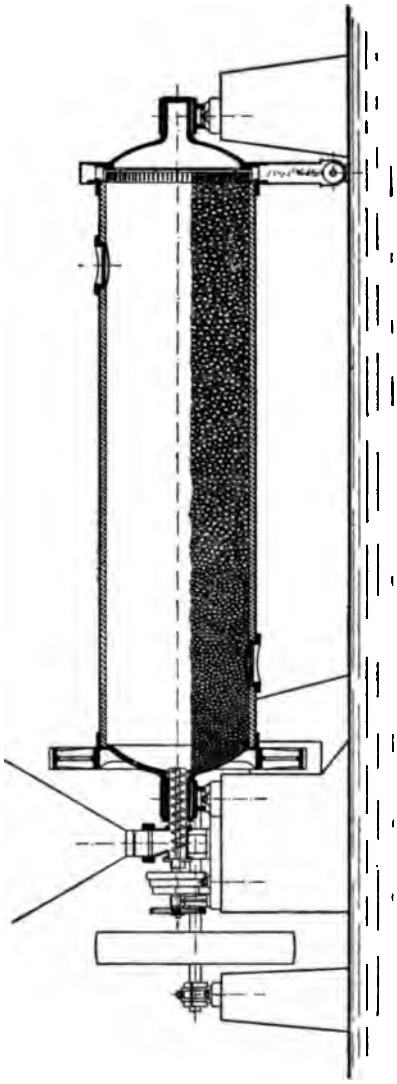


Fig. 5 Section of Tube Mill

30-in. mill, 2 tons per hour............35 h.p.
40-in. mill, 4 tons per hour............65 h.p.

The 30-in. Griffin mill is in extensive use but is no longer manufactured.

42 The tube mill is extensively used for grinding coal, also for grinding rock and finished material in cement mills, and is constructed by several manufacturers. It consists essentially of a large cylinder mounted on hollow trunions at the ends, a section of which is shown in Fig. 4. The cylinders vary in diameter from 4 to 6 ft. and have a length varying from 22 to 30 ft. The material to be pulverized is fed through a hollow trunion at one end and is discharged at the opposite end. The cylinder is filled about 40 per cent full with hard silicious pebbles usually somewhat elliptical in form and having diameters not greatly different from 2 in. The mill is lined with some tough materials which can be readily replaced, such as silica blocks or plates of steel. The rotation of the cylinder lifts the load of pebbles and material being pulverized and causes the pebbles to roll and slide over the material to be ground as it passes through the mill. The result is an extremely fine product. The 50-in. tube mill 22 ft. in length has a capacity of about 4 tons of coal per hour and requires about 75 h.p. The tube mill is practically dustless and noiseless. It requires very dry coal to be successful.

43 The Fuller mill is probably the most extensively used of any grinding mill for coal in the Portland cement industry in this country. This mill is a comparatively new one and is manufactured by the Lehigh Car Wheel & Axle Works, at Fullerton, Pa. In this mill the pulverizing element consists of four steel balls which roll in a stationary horizontal concave-shaped grinding ring. The four balls are propelled around the inside of the grinding ring by means of four pushers. Directly above the pulverizing zone is a separating chamber which is completely encircled by a screen of woven wire cloth. The material is thrown against the screen by a fan keyed direct to the main shaft and revolving with it. Outside of the screen and separated from it by several inches of space is an outside casing through which all the finished material passes. There is also an exhaust fan beneath the pulverizing zone which induces a discharge through the screen and also tends to facilitate the discharge of the ground material. The material to be pulverized is fed from a hopper at the top of the mill by special feeding mechanism to the pulverizing

zone. The mill is driven by pulley or gears attached to the main shaft below the pulverizing zone.

44 The Fuller mill is constructed in two sizes, 33 in. and 42 in. The capacity of the 33-in. mill is given as 2 to 2.5 tons per hour for an expenditure of from 30 to 35 h.p., and of the 42-in. mill as 4 to 6 tons per hour with an expenditure of 45 to 50 h.p.

45 In addition to the pulverizing mill described in this paper, other mills are employed to a limited extent. The Atlas Portland Cement Company employ Huntington mills for coal grinding which they manufacture in their own shops. The Huntington mill is in structure much like the Griffin mill but it is provided with three pulverizing rolls instead of one.

CONVEYING MACHINE

46 I shall make no attempt to describe the conveying machinery employed in modern cement mills for conveying the coal to the various parts of the mill. This machinery differs greatly in the different mills. In the great majority of mills screw conveyors are employed for moving the coal horizontally and bucket and chain elevators encased in dust-proof housings of steel for moving it vertically. In other mills belt conveyors and pan conveyors are used.

47 The requisite for safe conveying is the prevention of an explosive mixture of pulverized coal and air. Neglect of this precaution has caused the loss of many lives and the destruction of a great deal of property in the Portland cement industry. The present practice endeavors to keep the pulverized coal from mixing with air so that if it should happen to catch fire it would burn showly without producing disastrous explosions.

STORAGE OF PULVERIZED COAL

48 Storage capacity for pulverized coal, because of the element of danger, should be as small as possible consistant with the continuous operation of the mill. It is customary to provide for each kiln a storage bin with a capacity of from 6 to 10 hours of operation. Such bins are usually located 15 to 20 ft. from the lower end of the kilns where they do not interfere with the operation. Each bin is supplied by a conveyor leading from the pulverizing machine. The ordinary location with reference to the kiln is illustrated in Fig. 1. In this drawing the coal bin, shown at *K*, is of a cylindrical form with a cone-shaped bottom. The pulverized coal is supplied to the

bin through a screw conveyor at the top of the bin, shown at *L*. It is discharged from the bottom of the bin by means of a screw. Coal storage bins of rectangular cross section are equally serviceable.

FEEDING THE COAL

49 Powdered coal is fed from the bottom of the bin by adjustable feeding arrangements generally consisting of a double-threaded screw conveyor having a variable feed, one type of which is illustrated in

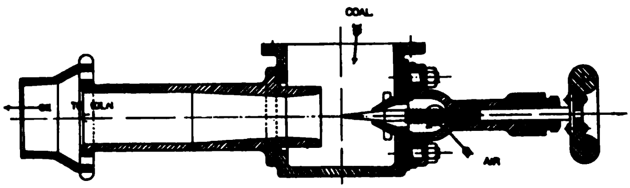


FIG. 6 SECTIONAL VIEW OF ATLAS BURNER

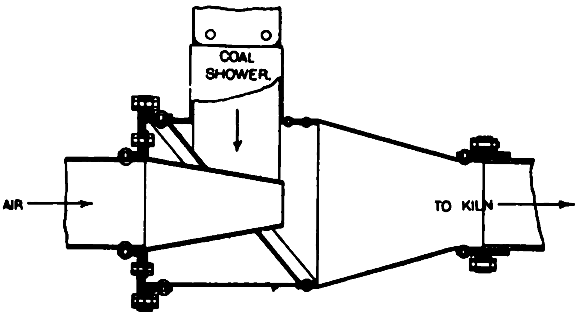


FIG. 7 LOW-PRESSURE BURNER

Fig. 1. The coal dust is blown into the kiln by a jet of air with some type of injector. In some of the plants compressed air of from 30 to 40-lb. pressure is employed for delivering the pulverized coal; in other plants air is obtained from a rotary fan at about 2 ounces pressure. Fig. 6 illustrates a type of high pressure burner extensively employed by the Atlas Company. The drawing clearly shows the construction and mode of operation. Fig. 7 shows a common type of low pressure injector. The drawing shows the construction of the injector, and its mode of operation will be readily understood.

50 The coal feeding injectors are located in front of the stationary hood and arranged to deliver the jet of coal dust axially

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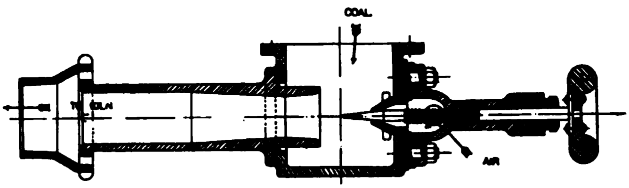

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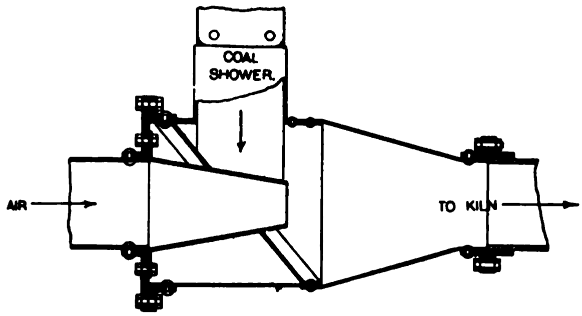

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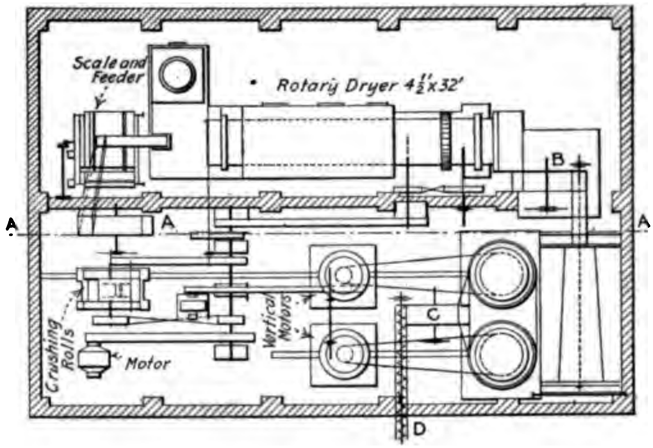

FIG. 8 40-FT. BY 60-FT. COAL MILL, MACHINERY PLAN

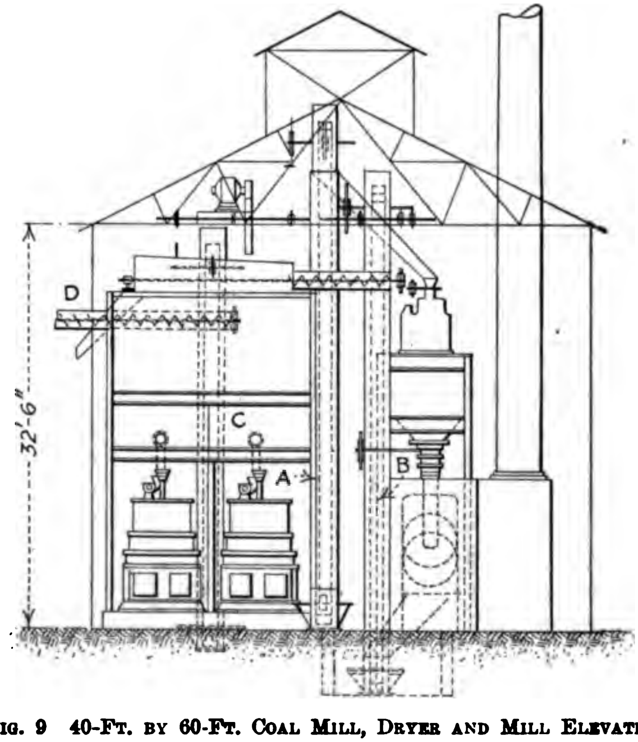

FIG. 9 40-FT. BY 60-FT. COAL MILL, DRYER AND MILL ELEVATION

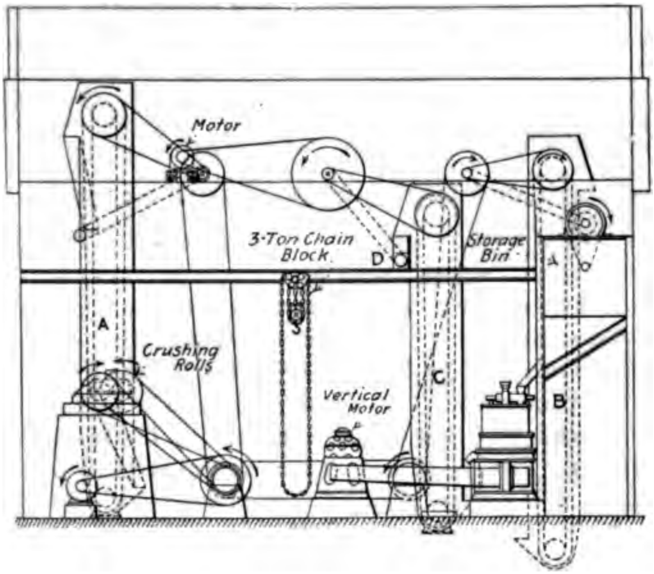

FIG. 10 40-FT. BY 60-FT. COAL MILL, ELEVATION SHOWING FULLER MILLS

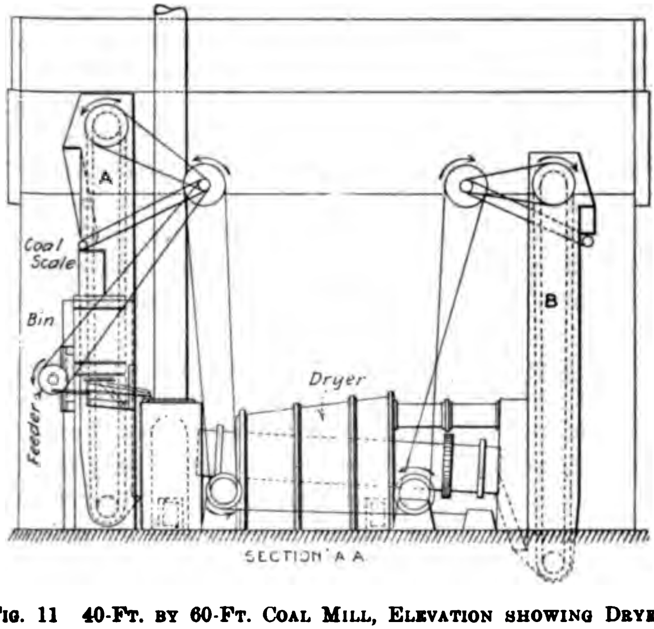

FIG. 11 40-FT. BY 60-FT. COAL MILL, ELEVATION SHOWING DRYER to the kiln. Practice has proved that it is unnecessary to use more than one jet to a kiln, although in some of the constructions two jets are used. The detailed construction of injectors for feeding the pulverized fuel differ in the various plants, but all embody the features illustrated in Figs. 6 and 7.

COMPLETE INSTALLATION OF PULVERIZING MACHINERY

51 I present a set of drawings which show a complete installation of coal pulverizing machinery having a capacity of about 8 tons per hour. These drawings I have selected as illustrating simply and completely the machinery needed for a coal pulverizing equipment. They were prepared by the Lehigh Car Wheel & Axle Works and are submitted by permission. They appear as Figs. 8 to 11 in connection with this article. Fig. 8 is a plan view showing the arrangement of the machinery. Figs. 9, 10 and 11 are vertical sections which show the locations in a vertical plane of various machines. By reference to these drawings it will be noted that machinery is provided for crushing the coal in crushing rolls, elevating the crushed coal in a dust-proof elevator *A,* to the top of the mill where it discharges by gravity through a coal scale and then into the upper end of a rotary dryer. The coal passes through the dryer which removes the moisture, then it is discharged into a dust-proof elevator *B,* and raised to a height sufficient to fall by gravity into the storage bin for dried coal located at a higher level than the pulverizing mills. From these storage bins the coal is drawn by gravity into the pulverizing mills. The pulverized coal is then raised by a dust-proof elevator *C,* to a point where it is discharged into a screw conveyor *D,* leading to the storage bins near the kilns. The drawings show the various machines as driven by electric motors, which is customary in the art. The rotary dryer is of the general type of one already described in this article and has a rotary cylinder 4 ft. 6 in. in diameter by 32 ft. in length.

52 The paper is intended to give an idea of the difficulties overcome and the results attained in the burning of pulverized coal in the cement industry without referring to many details of construction. The process of burning in the cement kiln is described quite at length in order that the reader may understand the peculiar character of the problem involved in the cement industry and the differences of the combustion processes in that art and in the steam boiler furnace. It is hoped that a full discussion will give additional information on

this subject which will tend to improve the efficiency of combustion in all arts.

In the preparation of this article, information has been supplied by the Atlas Portland Cement Company, H. J. Seaman, general superintendent, A. G. Croll, assistant superintendent; the Universal Portland Cement Company, Edward M. Hagar, president; the Helderberg Portland Cement Company, F. W. Kelley, general manager; the Cayuga Lake Portland Cement Company, M. E. Calkins, president; the Allentown Portland Cement Company, J. W. Fuller, president. Valuable information and drawings have also been received from the following manufacturers of cement machinery: Allis-Chalmers Company, Milwaukee; Bradley Pulverizer Company, Boston; Lehigh Car Wheel & Axle Works, Catasauqua, Pa.; Power & Mining Machinery Company, Milwaukee; Thomas Prosser & Son, New York; F. L. Schmidt & Company, New York; Vulcan Iron Works, Wilkes-Barre.

No. 1431 *b*

AN INSTALLATION FOR POWDERED COAL FUEL IN INDUSTRIAL FURNACES

By William Dalton, Schenectady, N. Y.

and

W. S. Quigley, New York

Members of the Society

At the works of the American Locomotive Company, Schenectady, N. Y., there have been in use oil furnaces for heating the blanks for drop forgings and general small forge work and hand-fired coal furnaces for the heavier work in the hammer shop. The equipment is now being changed to burn powdered coal fuel and a milling building has been erected to contain the coal drying and pulverizing apparatus.

2 The advance in the price of fuel oil in 1912 and the refusal of the oil companies to guarantee deliveries or to renew contracts for any considerable length of time led to an investigation in order to determine what fuel would be a satisfactory substitute for oil.

3 The apparatus installed was that developed by the American Iron and Steel Manufacturing Company at their Lebanon and Reading works and now handled by the Quigley Furnace and Foundry Company, New York. The plant was built and started in May 1913, and while there has been the usual amount of trouble in getting a new fuel system to run smoothly, the results have been satisfactory.

4 The coal milling and distributing plant is motor-driven and centrally located in a building of non-combustible construction. At present it has a capacity of 5 tons an hour and is so arranged that by duplicating the dryer and pulverizer its capacity can be doubled.

5 This plant has a concrete hopper placed under an elevated track where it can be served either by discharging directly into it from the car or from the stock pile by means of a traveling crane and grab bucket. The concrete car hopper discharges into a rotary crusher

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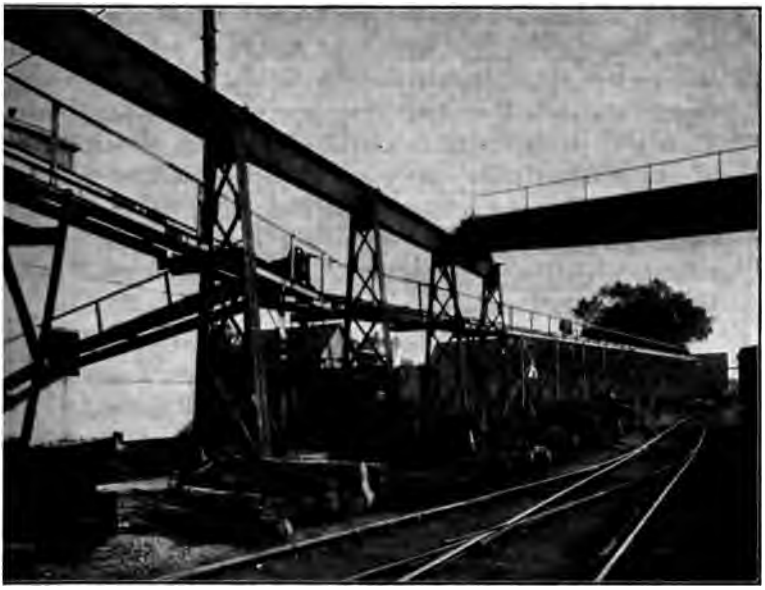
Presented at the Spring Meeting, St. Paul-Minneapolis, June 1914, of The American Society of Mechanical Engineers.

FIG. 1 MILLING BUILDING, SHOWING BINS, DRIER, PULVERIZER, ETC.

FIG. 2 VIEW FROM OPPOSITE SIDE OF MILLING BUILDING



3 CONVEYOR SYSTEM FROM MILLING BUILDING SUPPLYING LINES RUNNING TO HAMMER AND DROP-SHOPS

. 4 THREE-DOOR FURNACE WITH WASTE-HEAT BOILER, ON WHICH TESTS WERE RUN capable of reducing 20 tons per hour of run-of-mine coal to ¾-in. cubes, from which it is carried by means of a bucket elevator to a storage bin which discharges by means of chutes and reciprocating feeder into an indirect-heat type dryer of 6 tons per hour capacity. From here it is elevated to a dried coal storage bin arranged to feed by chutes directly into the pulverizer, then elevated to a pulverized coal storage bin, from which it is distributed by screw conveyors to the drop forge and hammer shops. The plans permit of further extension to the blacksmith shop, power plant and other departments later (Figs. 1, 2 and 3).

6 The milling building is detached, well-ventilated, and built in conformity with the underwriters' requirements and accepted by them on a par with buildings containing equipment for fuel oil or gas for industrial purposes. There has been no trouble whatever from spontaneous combustion, or fires from other causes, and there appears to be no reason to expect trouble from this source if ordinary precaution is used, as required with any other kind of fuel.

7 To insure the best results, the coal should be of high volatile and low ash and should be dried so as to contain not over ½ of 1 per cent of moisture, care being taken in drying to avoid overheating and so driving off any of the volatile content. The coal should be pulverized to a fineness that will permit 93 per cent to 95 per cent to pass through a 100-mesh sieve, and for some classes of work even a greater degree of fineness has been found desirable.

8 In the burning of powdered coal, the fuel controlling device is the most essential element in the successful operation of the system as a uniform and controllable supply of the powdered coal must be supplied to the burner at all times. The controller used in this installation shown in Fig. 9 was developed by the American Iron and Steel Manufacturing Company, and used successfully by them for seven years.

9 The device is motor driven and consists mainly of two screws, the upper located so as to propel the powdered coal from the bin forward to a point where it falls in a stream past an opening through which a cross current of low pressure air (a small portion of the total amount of air required for combustion) is directed, so as to force the desired quantity to the burner through suitable pipes. The lower or return screw is of greater pitch than the upper and returns the excess coal to the base of the hopper. By this method a continuous stream of coal passes the opening and any portion up to the capacity of the

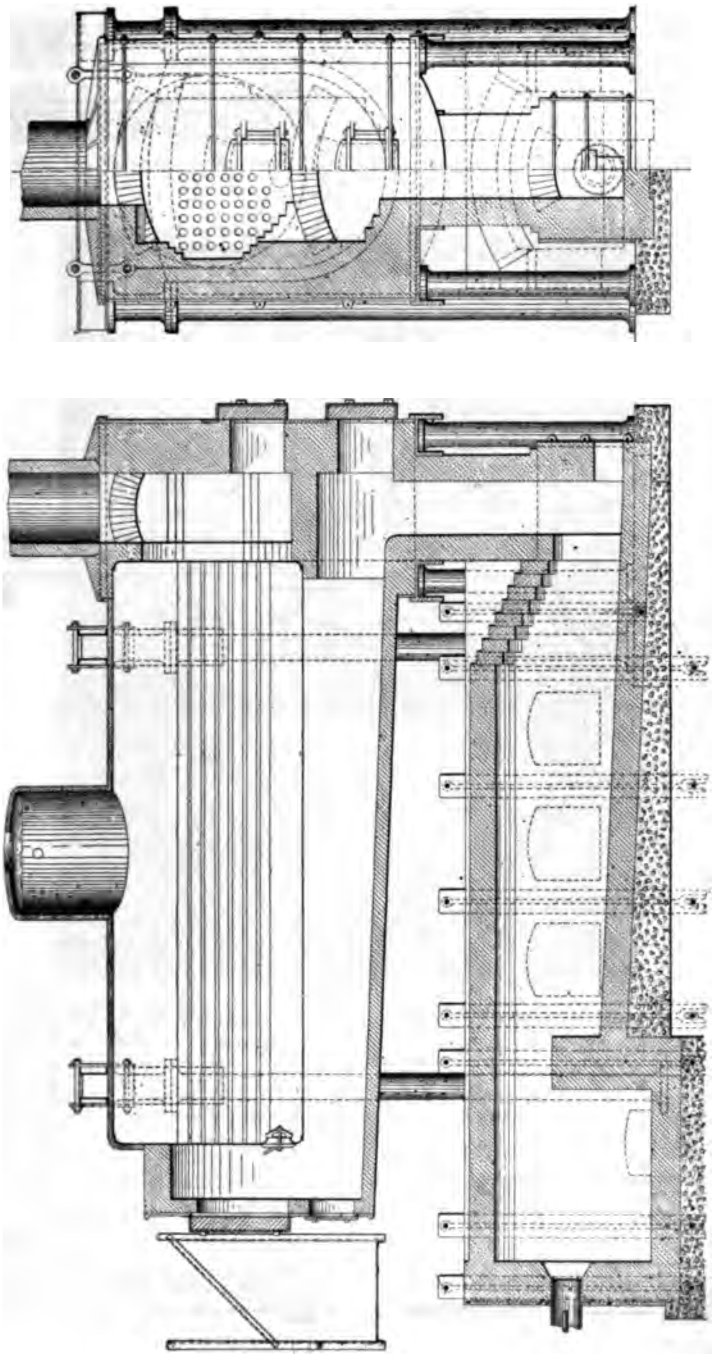


FIG. 5 DIAGRAM OF THREE-DOOR FURNACE WITH WASTE-HEAT BOILER, SHOWN IN FIG. 4

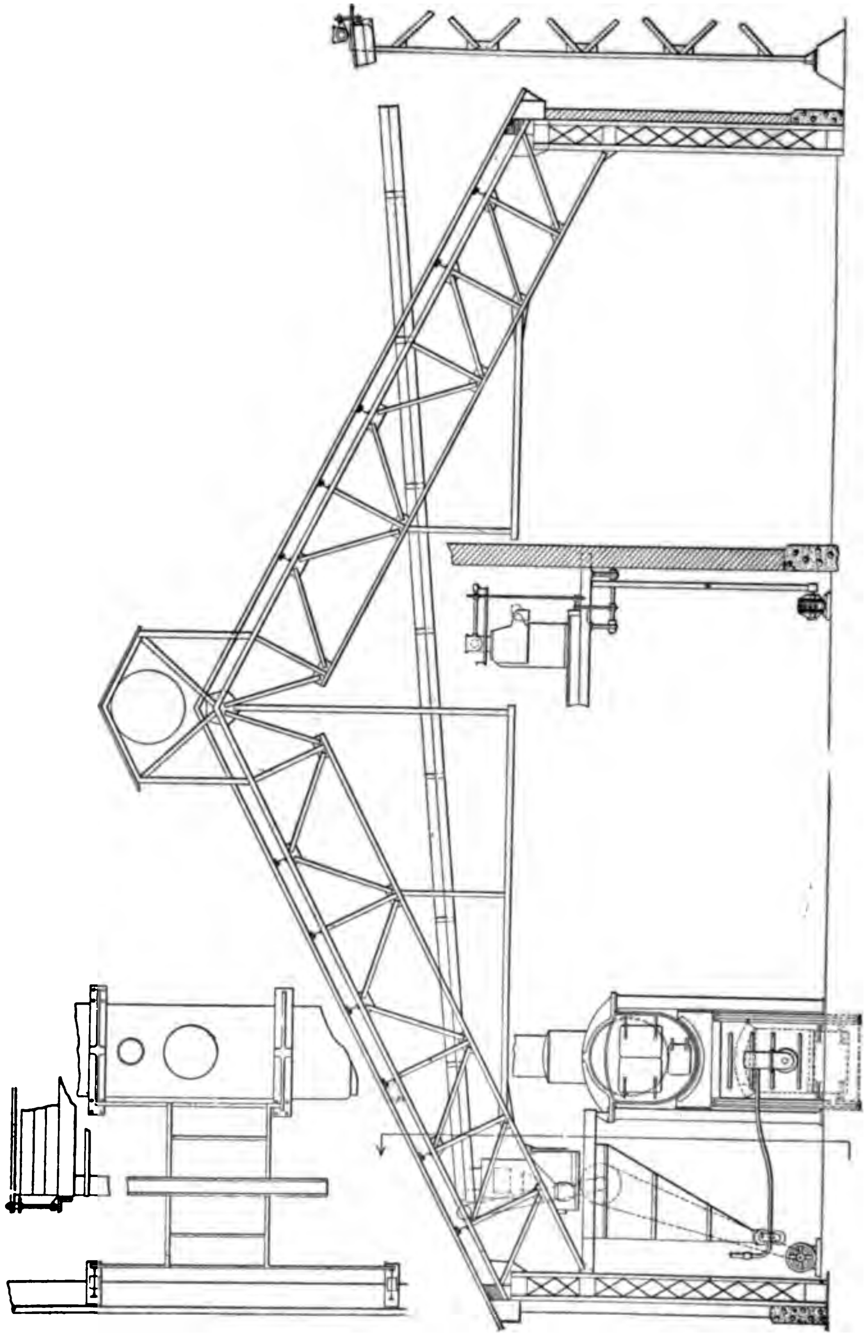


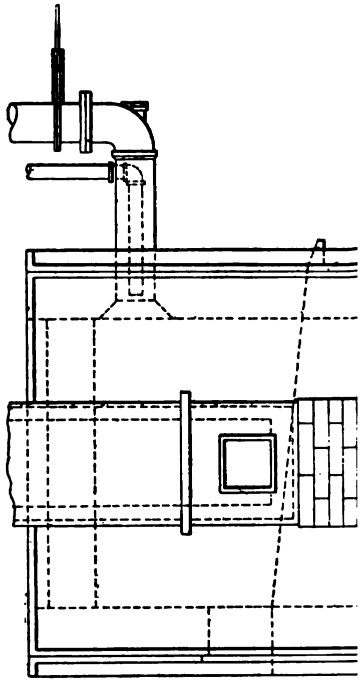
Fig. 6 Cross-Section of Hammer Shop Showing Location of Cross Conveyor, Scale, Powdered Coal Hopper, Etc.

upper screw may be utilized by increasing or decreasing the cross jet, and as the lower screw has a greater capacity than the upper it is impossible to clog the device in case of stopping the consumption of coal altogether.

10 The furnaces in the drop shop are rebuilt oil furnaces and

FIG. 7 FURNACE HEATING BLANKS FOR DROP FORGING, ON WHICH TESTS WERE RUN

those in the hammer shop are rebuilt hand-fired coal furnaces, and it should be emphatically stated that it is a serious mistake to attempt to apply powdered coal to existing furnaces without rebuilding them in a manner best suited to that fuel, since rapid and economical operation, as well as the elimination of the ash, cannot be accomplished without properly designing the furnaces for the new fuel. Coal has been burned in this plant with an ash content as high as 18 per cent



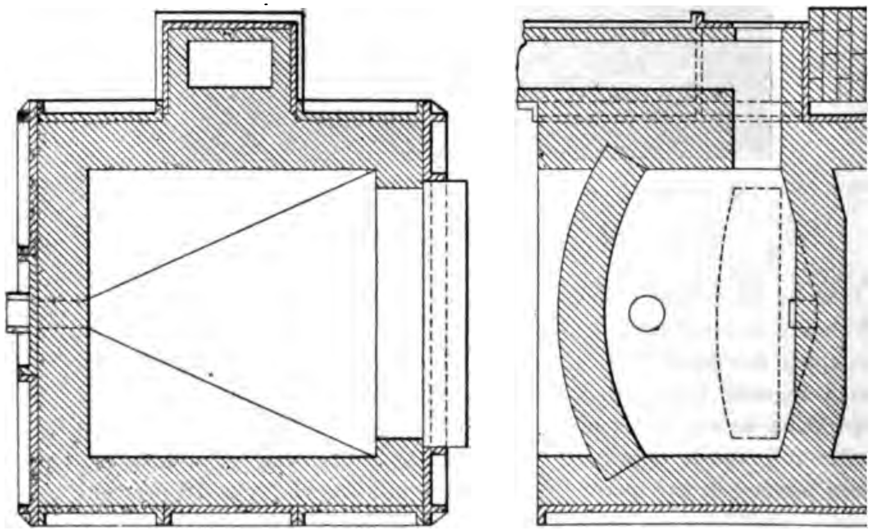


FIG 8 DIAGRAM OF FURNACE, SHOWN IN FIG. 7

with uniformly good results, although the high ash causes considerable annoyance where open furnaces, such as are used for heating small forgings, rods, etc., without doors, are used or where doors are not wholly closed during operation, unless efficient hoods or an exhaust system for properly disposing of the small particles of escaping ash are installed.

11 The foregoing gives in a general way a description of the important features of the plant. After the first two furnaces were

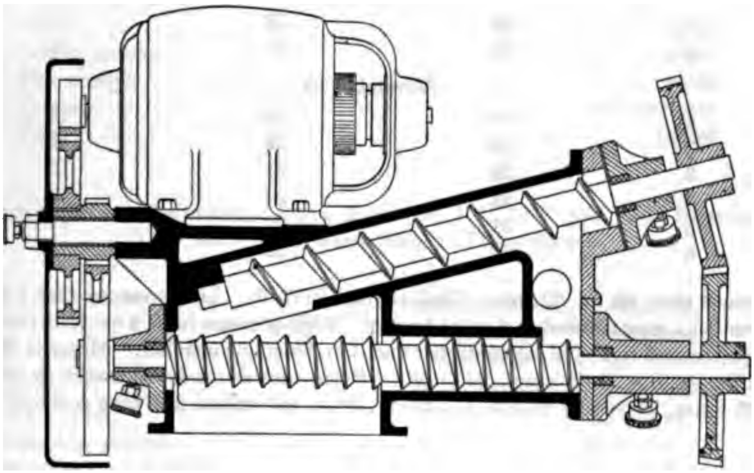


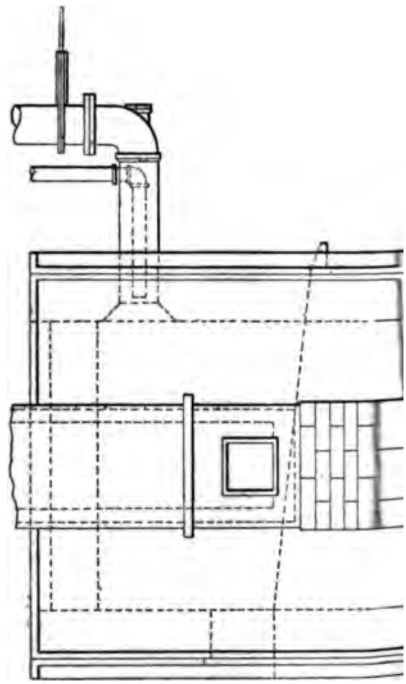
FIG. 9 MOTOR-DRIVEN CONTROLLER

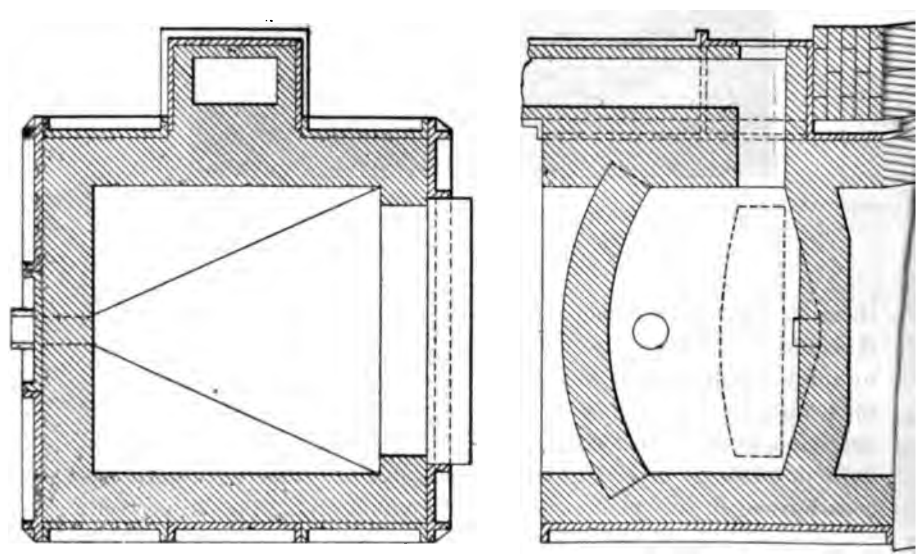
equipped in the drop shop and one in the hammer shop, tests were made to determine the savings effected with the use of powdered fuel as compared with fuel oil and hand-fired coal practice; and also as to what changes needed to be carried out in the alterations upon the other furnaces. The results of the tests upon these first furnaces are given on the following page.

12 The coal was measured as follows: Started with coal at a marked level in the hopper and after the test filled the hopper to the starting mark with coal weighed in bags, weight of bags subtracted.

13 The oil was measured as follows: There were two tanks with gage glasses at the bottom, so that the exact level of oil could be determined; the tanks were so connected that one could be filled with oil while the other supplied oil to the furnaces. The tanks were accurately calibrated and the oil consumption computed accordingly.

FIG 8 DIAGRAM OF FURNACE, SHOWN IN FIG. 7





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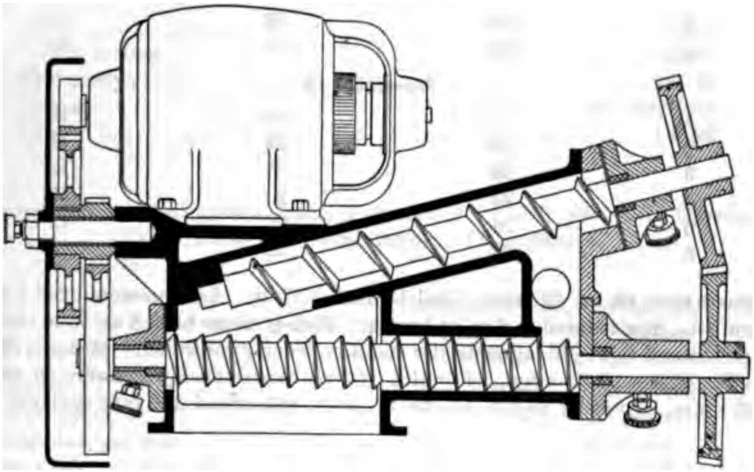

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TEST ON POWDERED COAL FURNACE No. 3335

Nov. 12, 1913: Started 12 m., ran to 4:07 p.m. Heat in at 12:30.
Nov. 13, 1913: Started 6:15 a.m., ran to 12:30 p.m. Heat in at 7:28.
Furnace ran eleven heats, five heats of 10 pieces and 6 heats of 12 pie Worked on pedestal die wedge.

HEATS	TIME, MINUTES	FORGING TIME, MINUTES	PIECES
		November 12	
1	23	19	10
2	24	18	10
3	23	17	10
4	28	18	10
5	21	17	10
		November 13	
1	41	20	12
2	22	29	12
3	24	21	12
4	23	22	12
5	24	22	12
6	22	22	12

Actual time 10 hr. 22 min. Coal burned 2177 lb. Low-pressure blast 1 from 8-in. pipe reduced to 6 in. at burner. High-pressure blast 8 oz. from 4½ pipe reduced to 1½ in. at controller and 2 in. leaving controller. Motor on c troller ⅜ h.p., 1.85 amp., 230 volts. 50-in. blower on low-pressure air r 825 r.p.m., driven by 10-h.p. a.c. motor, 20-in. galvanized iron pipe connectio

TEST ON OIL FURNACE No. 5078

Nov. 14, 1913: Test started 6:10 a.m., ran to 3:35 p.m.
Furnace ran eleven heats, 12 pieces to each heat. Worked on pedestal wedge.

HEATS	TIME, MINUTES	FORGING TIME, MINUTES	PIECES
1	31	18	12
2	25	18	12
3	20	16	12
4	21	19	12
5	23	18	12
6	21	17	12
7	40	22	12
8	28	16	12
9	21	16	12
10	23	17	12
11	31	16	12

Actual time 9 hr. 25 min. Oil used 1238 gal. Blast on oil burner 6½ oz. fr 6 in. pipe reduced to 4 in. at burner. 120 h.p. a. c. motor runs three No. Sturtevant blowers for blast. Blast, 1½ h.p. per hr.

14 The powdered coal furnace ran 57 min. longer than the oil furnace. However, 30 min. were lost because of failure to charge furnace on November 12 and 18 min. were lost on November 13, because plate for heating dies was not put in at the proper time.

15 The work was on pedestal die wedges, which are of iron. The blocks weigh 25 lb. and the forgings 16 lb. The time lost on the pulverized coal furnace would more than allow for making the

COAL ANALYSIS

Ash	14.12
Volatile matter	20.28
Fixed carbon	64.60
Fineness	98.4 per cent
B.t.u	13,220

COMPARISON OF PULVERIZED COAL FURNACE NO. 3335 AND OIL FURNACE NO. 5078 (BOTH SAME SIZE) IN DROP SHOP

	PULVERIZED COAL FURNACE NO. 3335	FUEL OIL FURNACE NO. 5078
Hours run	10 hr. 22 min.	9 hr. 25 min.
Fuel consumed	2177 lb. coal	138 gal. oil
Average time per heat	25.1 min.	25.8 min.
Average time per forging	1.87 min.	1.47 min.
Actual forgings	122	132
Forgings to be counted	132	132
Cost of fuel at contract price	$2.82 ($2.56 ton)	$6.69 (4.8c gal.)
Cost of fuel delivered to the furnace	$3.31	$6.89

12 forgings, so that the amount turned out by each furnace should be considered equal as indicated in the foregoing table.

16 Some weight should be given the fact that the oil costs were probably kept at a minimum, as the heater was thoroughly familiar with oil and was able to obtain the maximum heat with the minimum amount of fuel oil. The same men ran each furnace and the only factor of importance was that the ram used on the hammer at the oil furnace was about 500 lb. heavier than the ram on the hammer at the coal furnace. This did not affect the time of heats, but allowed a quicker forging time and there was less time lost with nothing in the furnace.

17 It will be noticed from the coal analysis that the coal contained over 14 per cent of ash, which is too high for the efficient use of pulverized coal. The volatile matter analyzed low, but as this coal has been running above 30 per cent in volatile matter it is believed there must have been some fault in the analysis in this respect and investigations are now being made regarding it.

18 The above results show that the cost of operating the furnace on pulverized coal during these tests was 48 per cent of operating it on fuel oil at the present price.

COMPARISON OF TESTS ON LARGE 3-DOOR FORGE FURNACES OF SAME SIZE UNDER WASTE HEAT BOILERS NOS. 45 AND 61

No. 45, old style furnace burning mine run coal, hand-fired. Nov. 12, 1913
No. 61, new furnace equipped to burn pulverized slack coal. Nov. 21, 1913

	BOILER NO. 45 MINE RUN COAL	BOILER NO. 61 PULVERIZED COAL
Hours ran	10 hr. 5 min.	9 hr. 30 min.
Fuel consumed	4630 lb.	3200 lb.
Average time per heat	117 min.	120 min.
Cost of fuel actually delivered	$6.69	$4.14
Tonnage per furnace	9920	9920
Cost of milling, conveying and blast	$0.48	$1.04
Total cost of fuel burned	$7.17	$5.18
Cost per ton output	$1.45	$1.05

19 Both furnaces ran under favorable conditions and the men on both hammers turned out a fair average day's work. Both furnaces were on the same class of work and heated the same amount of material.

20 In comparing the coal the analysis given below shows that there is too high a percentage of ash in the slack coal, otherwise the samples are representative of the two grades of coal used.

21 The blast and rate of feed on pulverized coal was properly handled and heats came out at proper temperature of working.

22 In comparing the maintenance of the two styles of furnaces, the pulverized coal furnace had not been run long enough to make an accurate comparison, but indications are that the maintenance of the pulverized coal will not exceed that on the old style and will probably run less. The saving in labor with the pulverized coal furnace is shown to be:

Three men on ashes at $1.75	$5.25
Three men on fires nights at $2.10	6.30
Per 24 hours run	$11.55

23 Based on the shop running at average capacity there would be a labor saving of $11.55. This allows for men to start furnaces in the morning and wheel away ashes and slag.

Coal Analysis, Boiler No. 45

Sulphur	1.26
Ash	5.52
Volatile matter	29.17
Fixed carbon	65.31
B.t.u	13,826

Stack temperature 340 deg. fahr.
Blast on furnace 9½ oz.

Coal Analysis, Boiler No. 61

Sulphur	1.27
Ash	13.72
Volatile matter	30.18
Fixed carbon	56.10
B.t.u.	13,132

Stack temperature 240 deg. fahr.
Blast on furnace 1 oz.
Blast on coal 6 oz.

24 From these reports it will be noted that the air pressure required for burning powdered coal is materially less than that used on either oil or hand-fired coal furnaces. Owing to this decrease it was found necessary to lengthen the stack on the waste heat boiler to increase the draft and afford a better circulation.

No. 1431 *c*

PULVERIZED COAL FOR STEAM MAKING

By F. R. Low, New York City

Member of the Society

Numerous attempts have been made in the past quarter century to use pulverized coal as a boiler fuel. The published accounts of the various trials are full of promise and apparent accomplishment. but few of the processes have persisted, and only a small proportion of the coal used in steam making is fired in this way.

2 There have been three broad types of apparatus produced: that of which the Pinther (Fig. 1) is typical, where the prepared coal is emptied into a hopper above a feed-controlling mechanism and carried into the furnace by the natural draft; that having a mechanical feed, as the revolving brush of the Schwartzkopff apparatus (Fig. 2); and that in which the coal is blown into the furnace, as in the Day or Ideal apparatus (Fig. 3).

3 With the first type efficiencies of from 75 to 80 per cent were obtained, but the capacity was limited. When sufficient draft was applied to introduce a considerable amount of fuel, the velocity was such as to carry unconsumed particles of coal into the back connection and tubes. When fuel is introduced into a powdered fuel furnace at a rate which will give the full rated capacity of the boiler, a particle will remain in the combustion zone of an ordinary furnace less than half a second.

4 The first installation that I ever saw for burning pulverized coal under a boiler was of the rotary brush type. It was promoted by Mr. Bradley, an extensive fertilizer manufacturer, I should say in the late nineties. It was but a step from pulverizing fertilizer to pulverizing coal. The apparatus was applied to a horizontal-return tubular boiler at Quincy, Mass., set in the usual way. The brush injector was placed at the furnace door and upon the grate was a thin fire composed of coal of about the size of hickory nuts. There was no way of feeding coal to this fire and none was necessary.

Presented at the Spring Meeting, St. Paul-Minneapolis, June 1914, of The American Society of Mechanical Engineers.

Enough of the coal failed to be consumed in suspension, and fell and agglomerated itself upon the fuel bed to keep it supplied. The powdered coal was brought in bags and dumped into the hopper above the brush. The chimney was smokeless, the fire box cloudy, but the combustion chamber full of clean white flame. It looked very promising, but never reached the publication stage.

5 When it is suggested that an air blast be used to introduce the fuel, the apprehension of an excess of air is natural. The relative volumes of equal weights of coal and air are about 1 : 990. It would

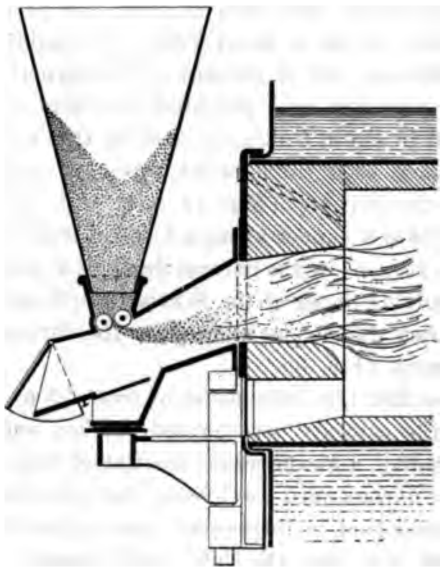


Fig. 1 Pinther Type of Apparatus

hardly be expected to use less than 15 lb. of air per pound of coal, so that the relative volumes of coal and air introduced would be

$$1 : (990 \times 15) = 1:14{,}850$$

6 The diameter of the globe of air which would accompany each tiny particle of fuel into the furnace would be $\sqrt[3]{14{,}850}$ or over 24 times the diameter of the particle of coal, so it will be seen that plenty of air may be used for fuel injection purposes without exceeding the supply required for complete combustion. In all of the systems at present in use, the fuel is introduced in this way, the blower usually being so combined with the pulverizer that the pul-

verized coal is blown into the furnace as fast as it reaches the necessary degree of fineness.

7 That the subject has not been neglected by inventors is evidenced by the fact that during the past 20 years there have been 23 United States patents issued for pulverized coal apparatus.

8 The earlier attempts to utilize pulverized coal were in connection with metallurgical processes. J. S. Dawes used it in England, in 1831, in blast furnaces, injecting it with the air through the tuyeres. It was proposed or tried in iron works by Desboissierres, in 1846, by

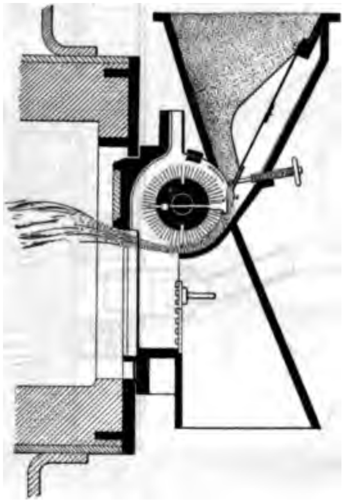


FIG. 2 SCHWARTZKOPF APPARATUS

Mouchel, in 1854, and by Mushet, in 1856. Somewhat later, Crampton tried it in locomotive and other boilers.

9 In the Engineering and Mining Journal of 1876, Chief Engineer B. F. Isherwood, U.S.N., described a test made by naval engineers under his direction in 1867 and 1868 at South Boston, upon an apparatus devised by James D. Whelpley and his partner, Storer, for firing a boiler in part with pulverized fuel. The boiler was of the horizontal two-flue type having only 299 sq. ft. of heating surface and 13½ sq. ft. of grate. A coal fire was maintained upon the grate and the pulverized fuel fed in above it, a fire arch being used to maintain the furnace temperature when the powdered fuel was used, but not with the grate alone.

10 Tests were made both with anthracite and semi-bituminous coal. The highest rates of combustion attained were 13.8 lb. per sq. ft. of grate per hour for the anthracite, and 14.9 for the bituminous, referring all the coal burned, pulverized as well as solid, to the grate area. Mr. Isherwood's conclusions were that, including the cost of pulverizing, the anthracite did a good deal better and the

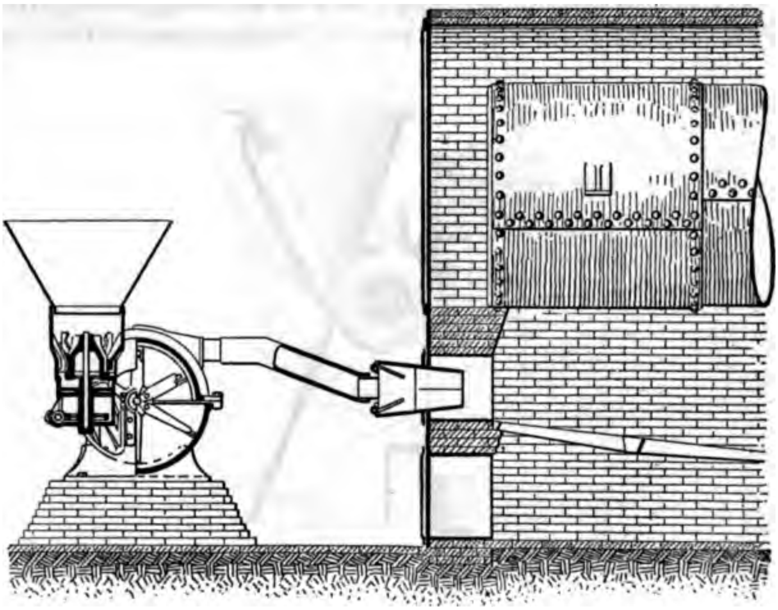


FIG. 3 DAY OR IDEAL APPARATUS

semi-bituminous a little better, when burned upon the grate in the ordinary way than when burned in part in the pulverized condition.

11 In the late nineties, D. Wegener brought out in Europe and tried in this country a natural draft system. Tests showed boiler efficiencies of from 75 to 80 per cent.

12 In 1910, J. E. Blake, of the Blake Pulverizer Company, installed, under a 300-h.p. water-tube boiler, at the Henry Phipps power plant in Pittsburgh, the arrangement shown in Fig. 4. The pulverizer served as its own blower, sending the pulverized fuel mixed with air to the furnace, where, in this installation, it was introduced by a series of nozzles extending across the width of the furnace. A

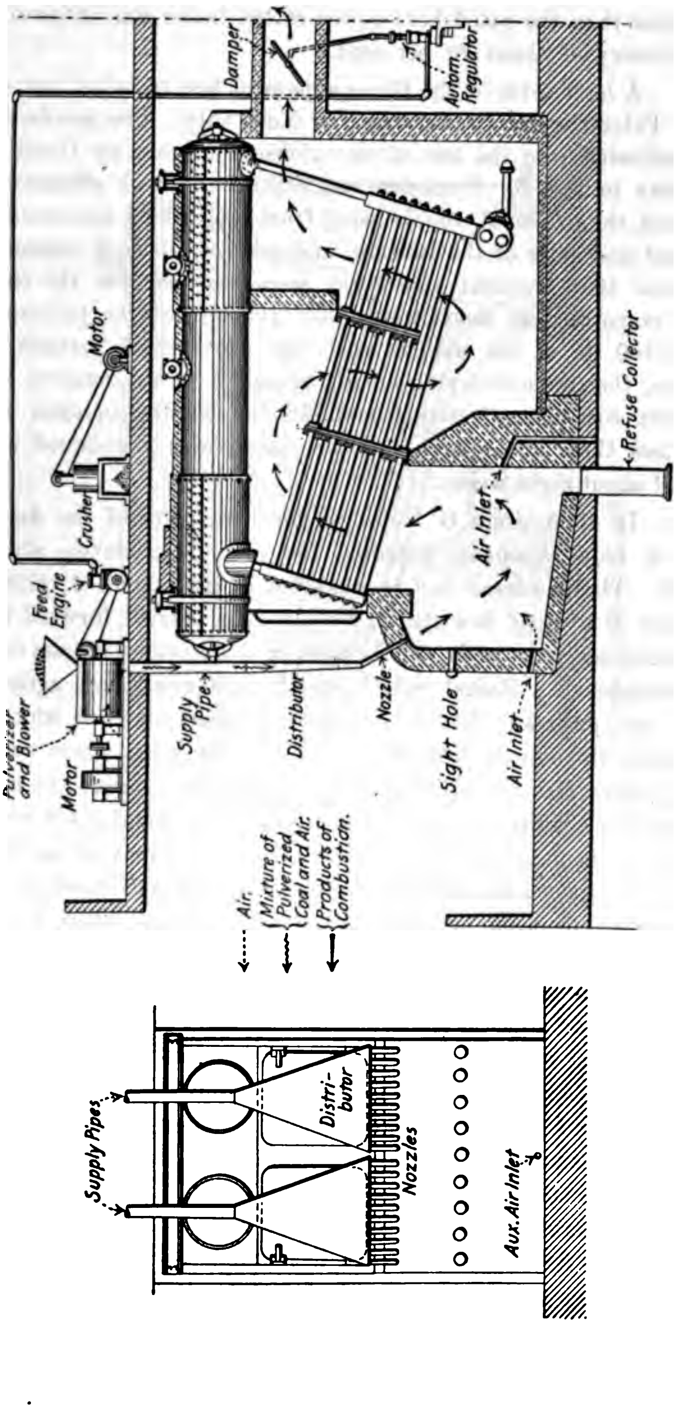


FIG. 4 BLAKE AND PHIPPS INSTALLATION

little less than the rated horsepower of the boiler was obtained with an efficiency of about 79 per cent.

13 A later form of the Blake apparatus was installed last winter at the Peter Doelger Brewery in New York City. The powdered coal was delivered into the top of an extension furnace or Dutch oven, as shown in Fig. 5. Smokeless combustion and high efficiency were obtained, the principal trouble being from slag, which accumulated on the roof and sides of the furnace, and piled up in such masses upon the floor that frequent shutdowns were required for its removal. They evaporated as much water with 1000 lb. of the pulverized as with 1400 lb. of the natural coal, but the cost of furnace maintenance, the frequent laying off of the boiler for the removal of slag and the cost of pulverizing counteracted in the opinion of the operators these advantages and the system was abandoned after a trial of about eight weeks.

14 In 1905, John B. Culliney, superintendent of the American Steel & Iron Company, patented the controlling device shown in Fig. 6. The powdered fuel is deposited in the hopper *A*, filling the chamber *B* directly beneath it, whence it is carried forward by the horizontal screw conveyor and dropped in a continuous stream through the chamber *C*. Radial rods upon the conveyor shaft agitate the mass, and push any foreign or uncomminuted material which may have been introduced with the fuel out to the sides, where swinging cover plates *DD* are provided for its removal. Connected to each side of the chamber *C* is a blast pipe *E*, the opening for which is shown in the longitudinal section at *F*. A current of air flowing through the pipe and across the falling stream of pulverized coal picks up a portion of it and carries it to the larger pipe *G*, where it is taken up by another air current and carried into the furnace. About one-seventh of the total air is supplied at the smaller pipe under a pressure of about 6 oz., the remainder of that necessary to complete combustion being supplied by the larger pipe under a pressure of $1\frac{1}{2}$ oz. or less. The part of the coal which is not taken up by the blast is returned to the upper chamber by the inclined screw of coarser pitch, and carried forward again through the same process. Regulation of the speed of the conveying screws, and of both air supplies, gives the operator complete control of the rate of feeding and character of the flame. This system has found a wide application, not only for large metallurgical work, but for many furnaces where oil

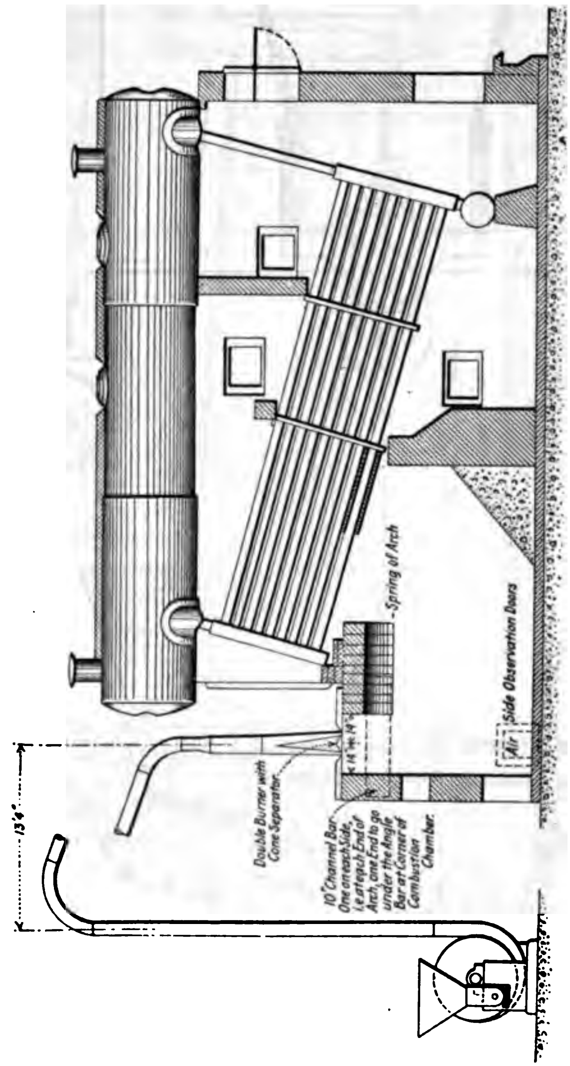
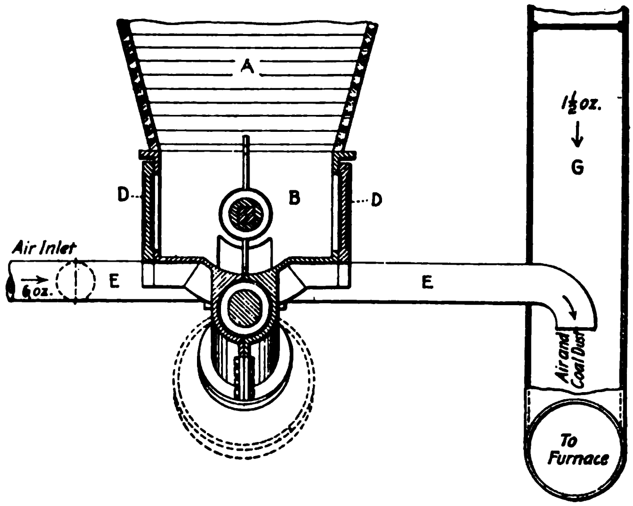


FIG. 5 DOELGER INSTALLATION

and producer gas were formerly used, and was used for a numb of years under boilers at the works of the Erie Malleable Iron Cor



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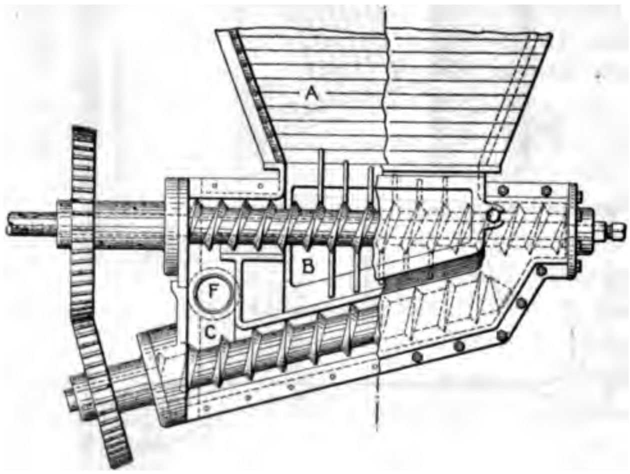

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FIGS. 6a AND 6b CULLINEY FEEDING

pany until the purchase of current from the electric company ma the operation of the boilers no longer necessary.

15 This system has been for some time in successful use f

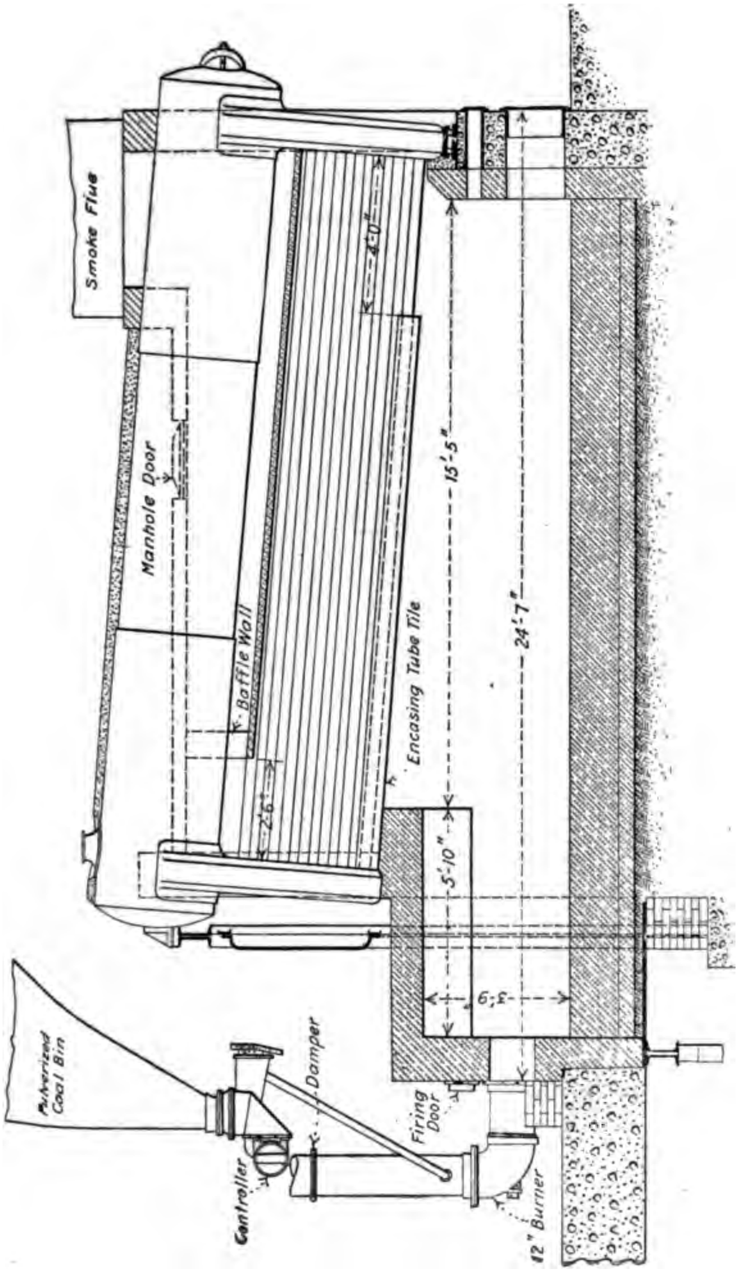
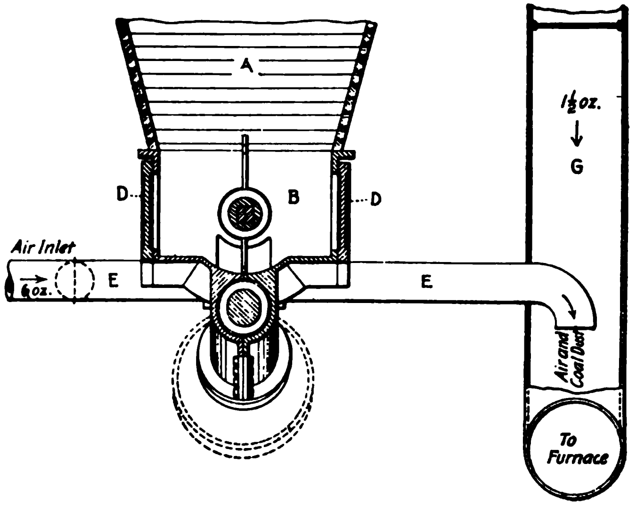


Fig. 7 300-H.P. Franklin Boiler, American Locomotive Company and producer gas were formerly used, and was used for a numb of years under boilers at the works of the Erie Malleable Iron Cor



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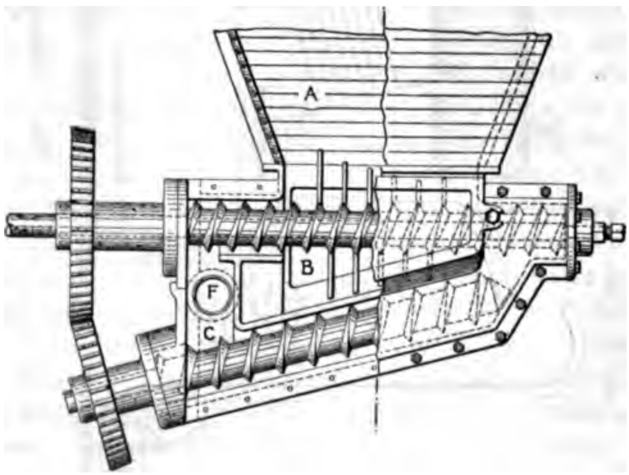

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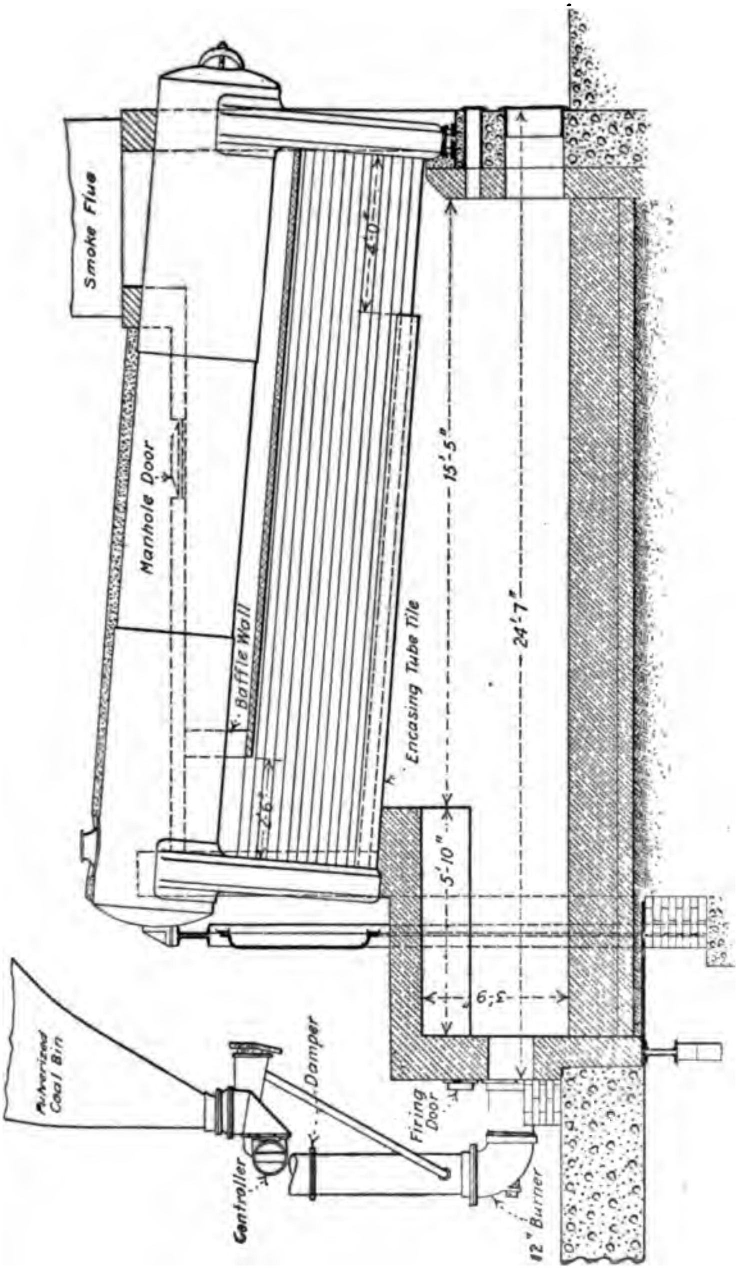


FIG. 7 300-H.P. FRANKLIN BOILER, AMERICAN LOCOMOTIVE COMPANY

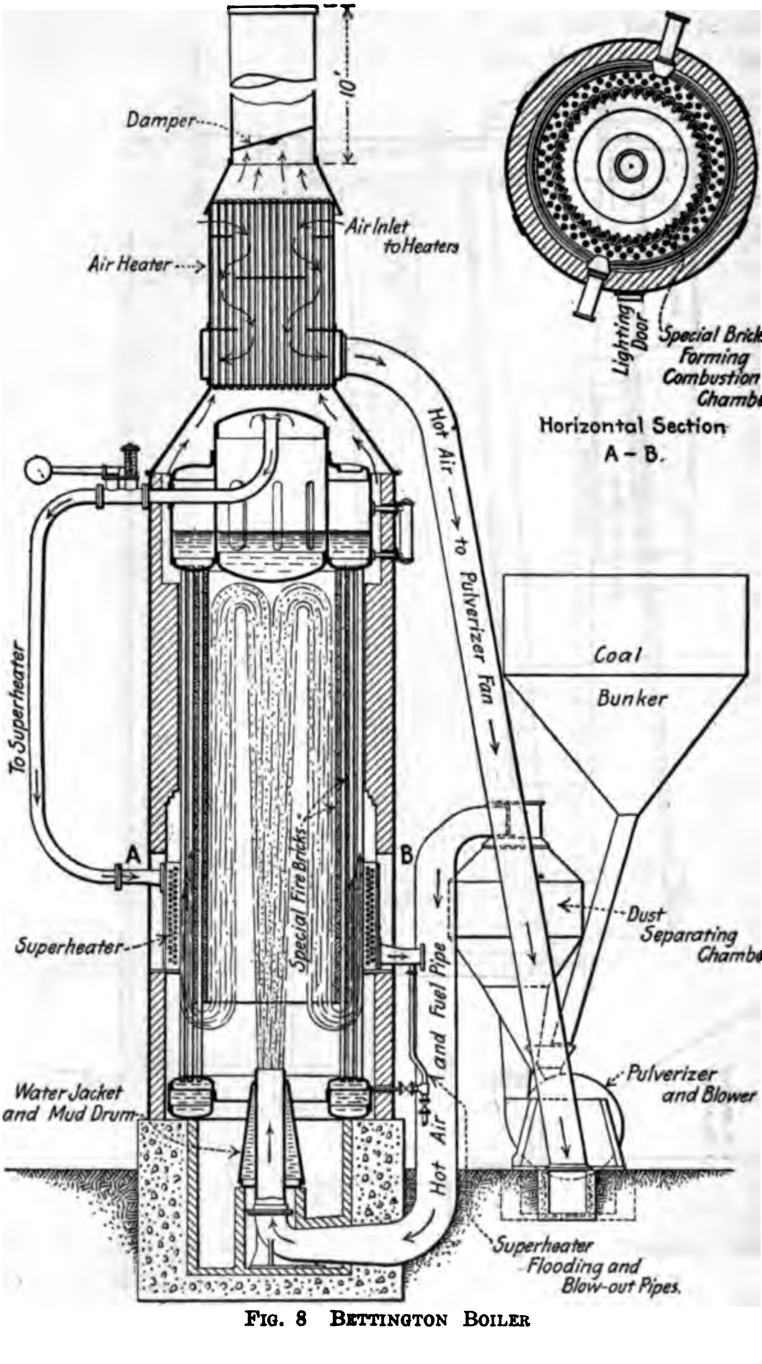


FIG. 8 BETTINGTON BOILER

shop processes at the Schenectady works of the American Locomotive Company, and has recently been installed for steam making purposes under a 300-h.p. Franklin boiler. The arrangement is shown in Fig. 7. The results, up to this writing, have been complete smokeless combustion, no slag, several furnace linings melted down. but inability to get full boiler capacity. This is laid to limited controller capacity, and larger controllers are being installed. It is hoped that further information will be available before the date of the meeting.

16 Claude Bettington of Johannesburg, South Africa, where the price of coal is high, attacked the problem by designing a boiler especially for use with pulverized fuel. He took out his first patent in the United States, but his boiler was first commercially exploited in England. He met his death in an aeroplane accident some two years ago. In his boiler the feed is upward, as shown in Fig. 8, through a water-jacketed nozzle in the center of a vertical furnace. The pulverizer acts as a blower, and the air supply is preheated. From the pulverizer the coal passes to a separator, where the larger particles settle out and return to be again treated, the finer passing on to the burner. The blast, about 2 in., opposing gravity, tends to keep the coal in suspension, and as a particle would have to pass twice the length of the furnace (upward and downward) to escape, there is no difficulty in obtaining complete combustion.

17 The flame does not lift more than 10 per cent under the highest rate of feed which it is practicable to employ, the temperature of the furnace and of the enveloping gases being increased enough to offset the greater velocity of ingress. The tubes of the inner row of the circular furnace are covered with a special refractory covering to within a short distance of the bottom header, making a brick-lined combustion chamber. The special bricks are placed loosely around the tubes, but soon become coated with molten ash and slag, which welds them into a solid wall, and closes the crevices between the lining and the top header. The ash which is not so slagged to the furnace surfaces, or carried out by the draft, drips into the ashpit below the lower header. The destructive effect of the impinging flame upon the brickwork is avoided by taking it upon the lower head of the central drum, or upon the accumulation of gas in the upper end of the chamber, the region of greatest heat intensity being in the core, while the tubes and shell are subjected to the lesser temperature of the somewhat cooled gases, which have not yet got away. The radiant heat is, however, effective upon them and the metal surfaces must be

kept perfectly clean, and particular care taken as to the water level. One of these boilers having 2606 sq. ft. of heating surface has been running for over four years at the works of the builders. It evaporates regularly 14,000, and has been worked up to 22,000 lb. of water per hour. These rates, however, (5.4 and 8.4 lb. per sq. ft. of heating surface) are attained with stoker fired boilers.

18 A contributor to Power who has had two of these boilers in charge says that the steel head of the upper drum burned through at one time, probably due to dirt collecting upon it; that in spite of the cooling effect of the tubes the special bricks forming the furnace quickly burn away, and frequent renewals are necessary. Care must be taken lest the lining burn through and the gas be short-circuited. Although this boiler will burn low-grade fuel successfully, and while under steam is easily managed, one fireman being able to look after several boilers, these advantages are largely offset in his opinion by high cleaning and maintenance charges.

19 The makers say their experience has been that a lining will last about two years, and that even large holes will automatically seal up. The parts which require most frequent renewal are the beaters and liners of the pulverizer. These are of manganese steel, and can be replaced in about two hours. The makers claim an approximate life for the beaters of 1500, and for the liners of 2000 tons of coal handled. A user, after 10 months' experience, says that the blades run from 1000 to 1200 hours per set, and that the second set of liners was still in use. The use of heated air in the pulverizer allows coal having 15 per cent or more of moisture to be handled successfully; a separate heater is recommended for large boilers. They allow 2 to 3 per cent of the boiler capacity for pulverizing. There was some trouble from leaky water jackets putting the flame out, but this has been overcome by the use of welded jackets.

20 A number of these boilers are in use in South Africa, in Great Britain and Canada. Tests of one of the Rand boilers show an efficiency of 82.6 per cent, the coal having 2.15 moisture, 22.8 volatile, 57.55 fixed carbon, 17.5 ash. The CO_2 is carried at 15 per cent in regular practice.

21 With the ordinary method of burning coal, the grate with its bed of solid incandescent fuel more or less encumbered with ash and clinker, offers a considerable, a varying, and an uneven resistance to the passage of air, rejects the incombustible residuum with some difficulty and allows some of the unburned fuel to sift to the ashpit or to

be fused in with the clinker. If the fuel can be burned in suspension, many of these difficulties disappear and the draft-producing apparatus is reduced to that which will remove the products of combustion and allow enough air to enter to burn the required amount of fuel. There still remains, however, the difficulty of getting rid of the incombustible. With 10 per cent ash there will be 200 lb. of refuse to be got rid of with each ton of coal burned. If this is kept in a pulverized form it is carried into the back connection, the tubes and stack, and scattered about the neighborhood. If it is fused it attaches itself to the surfaces of the furnace and welds itself into masses, occasioning damage to the brickwork in its removal and comparatively frequent layoffs for cleaning. In one instance the molten slag formed in sheets and ridges upon the sides and in stalactites upon the roof of the furnace, while the floor was covered with a plastic mass, which cooled when the door was opened for its removal, and could hardly be got out without material damage to the furnace.

22 The possibility of getting an adequate supply of oxygen to the finely comminuted carbon allows perfect and smokeless combustion with a minimum air supply, but with the rates of combustion demanded in present practice, the result is a high temperature with erosive and reducing characteristics which, however good they may be for metallurgical processes, are not favorable to the longevity of a boiler furnace. If this temperature is kept down by feeding less fuel, the capacity is limited, while if it is kept down by using an excess of air the economic advantage just cited is sacrificed.

23 There have been several disastrous explosions of the prepared fuel outside of the furnace, but these can be easily guarded against. Coal, however finely comminuted, does not contain the elements necessary for its own combustion, and if ignited will burn only slowly if kept in a compact mass. It is only when it is diffused in a cloud that the oxygen of the atmosphere can get to it quickly enough to make the rate of combustion dangerous. The pulverized fuel can be safely conveyed en masse in suitable holders, in screw conveyors, or even in cars and barrows if care is taken that it shall not be blown or sifted about in a finely disseminated state. In those systems where the pipe back of the blower is filled with an explosive mixture of coal and air, the rate of flow must exceed that of the propagation of flame in such a mixture, and in shutting down the coal supply should be shut off first. The pulverized mass will run like water, so that the pitch of

chutes, conveyors, etc., must be so set as to provide against the flowing of their contents.

24 While anthracite dust can be used it burns more slowly than coal having a higher percentage of volatiles, and must be very finely pulverized. For most systems practically all of the coal should go through a screen having 100 meshes to the inch, and for coals having a small percentage of volatile or where very rapid combustion is imperative the coal is ground to a fineness, which will permit the greater part of it to pass through a 200-to-the-inch sieve. Low-grade coals and coals having a large percentage of ash can be burned in this way, but there is a limit to the proportion of slate and bone that one can afford to grind, and an increasing proportion of ash means increased trouble from dust and slag. The earlier practice of taking up the impingement of the flame on a checkerwork or a heap of brickbats is out of favor. It simplifies the process of keeping the burner lighted, but burns up too much firebrick and makes a locus for the building of a slag heap. With an ordinary firebrick furnace well heated up there is no trouble in maintaining the flame steady and it will re-ignite after having been turned out for several minutes.

25 The cost of pulverizing and the large initial cost of the drying, pulverizing, conveying and feeding apparatus, together with the fact that coal of practically all grades can be burned with a tolerable degree of smokelessness in the cheaper apparatus in common use with a degree of efficiency which leaves little margin to cover the increased expenditure, have combined to restrict the use of pulverized coal for boiler purposes to special instances.

No. 1431 *d*

TOPICAL DISCUSSION ON POWDERED FUEL

Following the presentation of the papers upon Pulverized Fuel, there was a topical discussion for which contributions had been prepared by J. L. Agnew, W. P. Barba, H. G. Barnhurst, John V. Culliney, W. R. Dunn, William A. Evans, Edw. J. Kelley, A. W. Raymond. These contributions were sent to the Society in response to an invitation to furnish data upon the following selected topics:

(1) Grades of coal successfully used—analysis
(2) Experiences with coal high in ash and sulphur
(3) Essentials of storage bin for powdered fuel—troubles from storage
(4) Necessity for drying coal before grinding
(5) Fineness of grinding
(6) Cost of grinding and handling, including upkeep
(7) Danger from particles of dust floating in air
(8) Essentials of a good burner
(9) What troubles are likely to occur with burners in general
(10) Special features required in powdered fuel furnaces
(11) Air pressure used and effect of stack draft on combustion
(12) Experiences with ash or slag in furnace
(13) What temperatures are maintained in furnaces—influence of temperature on formation of slag
(14) Experiences with checkerwork in metallurgical furnaces
(15) Life of furnace as compared with furnaces using other fuels
(16) Items of expense or economy in the plant as a whole, due to use of powdered fuel

The contributions are as follows:

(1) *Grades of Coal Successfully Used—Analysis.*

A good average analysis of the coal used here is as follows:

Volatile matter	39
Fixed carbon	53
Ash	8
Sulphur	2
B.t.u.	13,600

Presented at the Spring Meeting, St. Paul-Minneapolis, June 1914, of The American Society of Mechanical Engineers.

The amount of volatile matter present is probably of considerable importance, but we are not able to say from our own experience how high the fixed carbon could go and the coal still be successfully used in the powdered form, though it is stated that anthracite and even coke has been used.—J. L. AGNEW.

The kinds we have used successfully are high-grade gas coals and gas slacks where the volatile has run about 35 per cent to 40 per cent, ash 6 per cent to 8 per cent and the sulphur low.—W. P. BARBA.

Coal most suitable for kiln furnaces and other types of metallurgical furnaces is that which runs about 35 per cent in volatile combustible matter, 8 per cent or lower in ash, and 1½ per cent or lower in sulphur. Good results are being obtained, however, on coals which vary considerably from the above percentages.—H. G. BARNHURST.

The grade of coal successfully used in heating and puddle furnaces has a composition closely approaching the following:

Volatile matter	33
Fixed carbon	56
Moisture	1
Ash	9
Sulphur	1
	100

—J. V. CULLINEY.

What is technically known as gas slack is the grade most generally used, particularly in the portland cement industry. This is cheaper than run of mine gas coal, and in its fine state dispenses with the use of preliminary crushing machinery prior to going to the dryer. The coal should be high in volatile matter. Its range in this respect should vary from 28 per cent upward. The higher the volatile content, the more readily will the coal ignite, provided, of course, the fineness be the same. The volatile matter is driven off after the small percentage of moisture. It is readily ignited by the heat of the furnace, and, if the coal has been sufficiently reduced in fineness and properly mixed with air, the burning coal dust will approach the condition of an approximate gas. A typical analysis of a high-grade gas coal would be as follows, figured on a dry basis:

Volatile matter	34.50
Fixed carbon	57.00
Ash	8.50
Total	100.00
Sulphur	1.20

The value of a coal for a particular industry will depend greatly upon the character of the particular furnace and especially upon the material to be heated. For example, a coal high in sulphur may be used without deleterious effect in one industry, while in another it would cause a great deal of harm to the material being treated. Coals high in sulphur invariably give trouble, due to spontaneous combustion. This is especially true with some of the high sulphur coals of Indiana and Illinois.—W. R. DUNN.

Furnaces have been operated using coal with ash as high as 18 and 20 per cent, but the successful use of such coal is limited to those furnaces in which the deposit of ash on the charge of material does not seriously affect the product. For most furnaces of the rotary type and for heating furnaces, moderately good coal will do, that is coal containing 8 to 10 per cent ash. On furnaces for the more refined treatment of metals, such as the open hearth steel and copper refining furnaces, exact specifications should be enforced, limiting the ash to 3 or 4 per cent. Copper matt furnaces producing less refined copper than the above will stand a high percentage of ash. This ash, if deposited on the charge, is drawn off with the other slagged impurities. The one essential of coal for powdered coal burning is high volatile content. This should be above 20 per cent.
—WILLIAM A. EVANS.

The type of furnace is the deciding factor in the choice of the coal. Following are two analyses which have given very satisfactory results in open hearth practice:

	No. 1	No. 2
Ash	10	5
Sulphur	1	½
Volatile matter	37	unknown
Moisture	1½	1
Cost per ton delivered	$2.50	$3.35

The following coal has been used for a period of about 10 years for heating annealing ovens:

Ash	19.05
Sulphur	3.53
Volatile matter	24.62
B.t.u.	11,000

This coal was obtained for $1.70 delivered. Comparison of the above analyses will show the fallacy of predicting just what grades of coal can, and cannot be burned. The consumer will have to decide for himself what coal will give the highest economy, and can probably arrive at no conclusion without actual tests. One user of the coal given in the second analysis has, after a period of 10 years of success with it, decided to change to a coal containing a much lower percentage of ash, and consequently higher calorific value. The reasons given are, less accumulation of ash in the furnace, and therefore the elimination of much of the expense of handling it, through the saving of the cost of pulverizing and otherwise preparing the useless ash, and that due to the higher calorific value of the fuel. This would seem to indicate that a more expensive coal containing less ash and having higher calorific value will decrease annealing costs; just how far this theory can be carried into actual practice depends on the local plant conditions and can probably be determined only by experiment.—A. W. RAYMOND.

(2) *Experiences with Coal High in Ash and Sulphur.*

The amount of sulphur present in coal used for reverberatory smelting is of little or no importance as the charge to the furnace always contains a large amount of sulphur. The ash, however, is of great importance. At different times we have used coal containing from 5 per cent to 10 per cent ash. When the coal is burned, part of the ash sticks at the throat of the furnace in a pasty condition, and when there is as much as 10 per cent ash, it tends to build up here and eventually interferes with the smelting. Usually, however, it can be kept barred off without much difficulty.

Another portion settles in a fine pulverulent condition in the flue chamber beyond the throat. This simply requires drawing out periodically with hoes through small side doors built in for that purpose. The amount obtained when burning about 70 tons of coal per 24 hours is 400 or 500 lb.

The greatest portion of the ash, however, settles on the bath in the furnace and forms part of the liquid slag. It is drawn off in that form and of course causes no difficulty whatever, only increasing somewhat the amount handled.

As coal ash is high in silica it is quite evident that a basic slag will combine with it most readily and in such a case the ash might be valuable as a flux. On the other hand, an addition of this high silica ash to a slag already high in silica might easily raise the melting point sufficiently to cause a good deal of trouble and interfere seriously with the working of the furnace.—J. L. AGNEW.

We find the ash rather troublesome, but this would not have been enough to condemn the coal had the price been low enough to warrant some extra trouble. In trying a gas slack of 12 per cent ash and 2 per cent to 3 per cent sulphur, we found trouble with both the ash and the sulphur, the latter throwing off very disagreeable fumes in the plant.—W. P. BARBA.

Coals running as high as 25 per cent ash, 5 per cent sulphur, have been used with success in cement manufacture.—H. G. BARNHURST.

The higher the percentage of volatile matter, the better the results obtained. In metallurgical furnaces the percentage of ash and sulphur should always be kept as low as possible, although the sulphur in the coal does not appear to be absorbed by the iron to any great extent; no more so than in the regular hand-fired puddle and heating furnaces. The ash causes very little trouble in furnaces maintaining a temperature of 2500 deg. fahr. or over, and in puddle and heating furnaces, having waste heat boilers located above them, part of the ash is deposited in the combustion chamber, part in the furnace proper, while the remainder is deposited beneath the boilers.

Very little ash passes up the stack. The ash deposited in the combustion chamber is removed by dropping the bottom or through the combustion chamber door. The bottom is made up of easily removable grate bars, upon which rests a layer of fine ash, which together with the furnace brick forms a pasty slag. This slag becomes hard and brittle when cool.

It is possible to remove this pasty slag through the combustion chamber door several times a day without difficulty and to clean this chamber entirely once a week, by pulling out the grate bars. The ash which is carried over the bridge wall runs off with the slag and the remainder of the ash is deposited under the boiler and removed at the end of each week.—JOHN V. CULLINEY.

In the cement industry, a coal high in ash may increase the formation of clinkers, particularly if the raw materials fed to the kiln are deficient in silica. Otherwise, a coal having a high percentage of ash causes only a slight inconvenience, due to the removal of larger quantities of fine ash from the dust settling chambers. In some cases where the ash has a low fusing temperature, trouble may be caused by the formation of an excessive amount of slag. Generally the presence of sulphur in large or small percentages is the cause of a great many difficulties.

Where the coal is used in drying furnaces, such as rotary dryers, the presence of sulphur in the coal will cause no ill effects, but where powdered coal is used to reduce nickel ores, copper ores, etc., especially in the refining end of the industry, the question of sulphur in the coal should receive careful attention. It has been claimed that if the sulphur in the coal is first burned off to the dioxide form SO_2, there is very little danger of it combining with a molten mass of metal having a strong affinity for sulphur. If, on the other hand, the powdered coal is not supplied with the requisite amount of air causing incomplete combustion and burning the sulphur to the monoxide form SO, there is a great tendency of the sulphur to unite with the molten metal, particularly so because it is present in an atmosphere of CO and free carbon, and has no chance to take on more oxygen. I believe that even where there is great danger of sulphur absorption, a furnace can be constructed so that little or no sulphur in the coal will unite with the metal in the furnace, that is the sulphur will be burned to sulphur dioxide and there will be an oxidizing rather than a reducing flame.—W. R. DUNN.

High ash coal often introduces insurmountable difficulties. The ash accumulates so rapidly in the combustion chamber and clings so tenaciously to the walls that it is almost impossible to remove it.

—W. A. EVANS.

The presence of sulphur in the coal is important only as it affects the material treated in the furnace. In this case a coal of low enough sulphur content must be used to keep the sulphur content in the finished product below the maximum allowed by specification. The relation of the sulphur content in the finished product to that in the fuel is about the same in the case of pulverized coal as of producer gas.—A. W. RAYMOND.

(3) *Essentials of Storage Bin for Powdered Fuel—Troubles from Storage.*

Our storage bins hold about 60 tons of powdered coal and are kept practically full all the time. The dust will take fire very easily, even a lighted match often being enough to ignite it, but it simply smolders away harmlessly. The best way in such a case is to shut off the supply of fresh coal and use up what is already in the bin.—J. L. AGNEW.

The sides of the storage bins should be of very sharp slope in order to have the coal flow freely. It has been apparent that more clogging takes place if the moisture is allowed to go over 1 per cent than if it is kept below. Probably the interior smoothness of the bins has much to do with the coal flowing down as required. A great deal of moisture will form in the first bin in which the coal is stored after drying, if the time of storage is long, the moisture often running down through the coal and dripping out at the bottom of the bin. In the bin where the pulverized coal is stored we have found by experience that by the end of 96 hours combustion is likely to take place; and also that such has occurred in several cases in less than that length of time.—W. P. BARBA.

It is advisable, in storing large piles of coal, to have the coal under roof, with at least two sides of the building open, in order to allow part of the moisture to evaporate, thereby lessening the work of the dryer.

Pulverized coal which is damp should never be stored for any great length of time, as spontaneous combustion is likely to occur. Dry coal can, however, be stored indefinitely.

All hoppers to hold pulverized coal should be made with two sides vertical and the other two sloped, at an angle of about 30 deg. with the vertical. This is done to prevent the coal from arching. The greater the percentage of moisture in the coal, the greater the tendency to arch.—JOHN V. CULLINEY.

A good storage bin for powdered coal should be free from pockets or corners where the coal is likely to lodge and remain stored for some time. Powdered coal stored for some length of time is apt to ignite, due to spontaneous action. The bin should be of ample capacity, not too large, and should hold coal sufficient for 12 to 18 hours' use. It should be covered with a sheet iron cover to protect the feeding mechanism against foreign matter falling into the bin and getting into the working parts of the feeder; a cover also prevents the accidental introduction of sparks or fire. It should by all means be constructed of fire resisting material. Sheet iron bins are very serviceable, especially when the coal stored is in a dry condition and not allowed to absorb moisture from the air. Wet coal, if it contains a large amount of sulphur, generally causes rapid corrosion of the sheet metal plates. Dry powdered coal is exceedingly hygroscopic and it is necessary that the coal in the bin should be kept as free as possible from contact with the atmosphere of the room.—W. R. DUNN.

The bin should be of a size to carry over 14 or 16 hours without refilling, thus giving plenty of time for such repairs as may be required without shutting down the furnace. It also permits of operation of grinding plant during the day, giving enough storage to carry through night service. The only trouble that can come from storage of powdered coal is spontaneous combustion, when coal is allowed to stand too long in bins. Powdered coal should always be kept moving, not allowed to stand more than one day in case of a temporary shutdown of the plant. For any greater length of time, the powder should all be drawn out of the bins. Spontaneous combustion is more likely to take place with powdered coal than with ordinary slack because of the heat accumulated during the grinding.
—WILLIAM A. EVANS.

The essentials are proper capacity and shape of bin. The capacity should be large enough to permit of sufficient coal storage to carry the furnace operation through any shutdown which may occur in the grinding room. With the proper equipment a 24-hour storage is generally sufficient and absolutely safe. Pulverized coal when properly prepared has been stored without any occurrence of fire for periods of from a week to ten days. Storage for such a long time as this can only be accomplished without fire danger if the coal is delivered to the bins in a thoroughly dry condition and at a comparatively low temperature.

The bins should be made and kept as air-tight as possible. A very frequent difficulty experienced in the storage bin is a tendency for powdered coal to bridge over at the bin outlet, and consequently stop flowing into the feeder. Such a condition is sometimes very hard to overcome. One very large and successful user of the fuel claims to have eliminated this annoyance by a peculiar construction of the bin. The ordinary cone-shaped hopper is replaced by a trough of triangular cross-section and a small conveyor is run directly through the coal along the bottom of the trough. This conveyor can replace the one generally used to control the amount of coal fed to the furnace, and the equipment consequently becomes as simple and inexpensive as the one previously used.—A. W. RAYMOND.

(4) *Necessity for Drying Coal before Grinding.*

Coal as received runs from 4 per cent to 8 per cent moisture, which should if possible be reduced to 1 per cent or less. This is not an easy matter. A small lump of coal may be ignited on the surface and still not be dry throughout. Moisture is detrimental because (*a*) it reduces the capacity of the grinder, (*b*) it tends to pack in the storage bins, (*c*) it lowers the possible attainable temperature, and (*d*) it lessens the efficiency.—J. L. AGNEW.

It is essential to have the coal dried to at least 1 per cent of moisture, both for the ease of pulverizing as well as for ease of screening in the pulverizer.—W. P. BARBA.

When high temperatures are required, a higher degree can be obtained by the use of dried rather than wet coal, as the temperature of combustion will decrease with the increased percentage of moisture. For instance, a coal containing 3 per cent moisture, as it frequently does, if passed through a dryer would give approximately a temperature of 3200 deg. fahr. when burned with 25 per cent excess air, whereas the same coal containing 10 per cent moisture would give only 3000 deg. when burned with 25 per cent excess air. In addition to the above, wet coal clogs the screens of certain types of pulverizers considerably, decreasing the output of the pulverizers and also affecting its quality. Wet coal will stick in bins and in burners.

Coal should be dried to 1 per cent or less before pulverizing, if pos sible.—H. G. BARNHURST.

If it is desired to obtain conditions such that the coal will ignit instantly, the moisture content should not exceed one-half of 1 pe cent. The coal on its way to the furnace, after it has been driec absorbs additional moisture, and by the time it is ready to be use it may contain as much as 0.7 of the 1 per cent moisture. Dr coal is desired because it can be more intimately mixed with the ai and fed more regularly to the furnace. Wet coal or damp coal wi clog the feeding mechanism and ejector tubes, and in addition to thi it is apt to form coke in the furnace and the furnace temperature wi not be so high as when dry coal is used.—W. R. DUNN.

The necessity for drying coal is controlled by two factors, th design of the grinding machine and the capacity of the plant. Th first factor concerns machines that depend upon screens for regu lating the fineness of the coal. Where screens are used coal mus be dried. With moist coal screens clog up. Machines that depen upon air separation for regulating the fineness of coal have no suc difficulty. They do, however, consume more power when grindin moist coal.

The other factor, viz. capacity of plant, is important as it has als to do with economy in building a small plant. Where but 20 or 3 tons a day are to be used it is possible so to select coal as to kee its moisture down to under 5 per cent. This can be secured by ship ping in boxed cars and carrying in dry storage a sufficient quantity t last ten days or two weeks. Where large quantities are used and whe it is impossible to carry enough storage to insure a continuous suppl of commercially dry coal a dryer is absolutely necessary.

It will be argued that there are plants using coal that has not bee dried. Where this is done in large quantities it will be found tha the same plant has other furnaces or other means of using up the we coal that comes to the plant and is able to select the driest for use i the machines in question. The writer has used coal containing 2 per cent moisture. Although it is possible to struggle through for short time under this condition, it is so troublesome that it can b put down as a good rule as not possible. Wherever undried coal is use it is in the direct delivery system, where the coal is fired direct fro the pulverizer to the furnace. The storage system will not work o moist coal; caking and arching of the coal in the bins interrupts th uniformity of feed.—W. A. EVANS.

Burning wet coal introduces moisture or steam into the furnace, where its presence is always sure to prove a hindrance to efficient combustion, and consequently prevent the attainment of highest economy.

Coal containing more than 1½ per cent of free moisture will require more horsepower when being pulverized, and the pulverized product will contain a much lower percentage of impalpable powder. Therefore, it is axiomatic to say that drying the coal will prove economical.—A. W. RAYMOND.

(5) *Fineness of Grinding.*

The finer the coal is ground the more complete will be the combustion. The standard practice of 95 per cent to pass through a 100-mesh screen, and 80 to 85 per cent to pass through a 200-mesh screen is good practice, and one to which we endeavor to adhere.
—W. P. BARBA.

It is customary in the cement industry to grind coal to such a degree of fineness that 95 per cent will pass through a 100-mesh screen. The finer the coal the greater its moisture absorbing properties. Fine coal is also more liable to spontaneous action than the same coal more coarsely ground.—W. R. DUNN.

Standard practice was for some time to attain a fineness such that 90 per cent would pass through a 100-mesh screen. This has gradually been increased to a present standard of 95 per cent through a 100-mesh screen; with 80 per cent passing a 200-mesh screen. Finer grinding would be very desirable except for the much increased cost for power.—W. A. EVANS.

It is generally accepted that coal which contains less than 95 per cent of material which will pass a 100-mesh test sieve and less than 82 per cent which will pass a 200-mesh sieve cannot be burned with the highest efficiency of combustion and the greatest economy. In direct contradiction to this is the experience of one of the oldest users of the fuel in annealing ovens. In this particular case the coal is pulverized so that only 60 per cent will pass a 100-mesh sieve and only 37 per cent will pass a 200-mesh sieve.

It is futile to expect a decrease in the cost of fuel by pulverizing coarser than 95 per cent through the 100-mesh sieve. I think it will be agreed that coal must contain no particles which will not pas through a 40-mesh sieve, and when this requirement is met ther will always be at least 95 per cent of 100-mesh goods in the finishe product. Consequently an attempt to pulverize coal so that it wi all pass a 40-mesh sieve and, at the same time, contain less tha 95 per cent which will pass a 100-mesh sieve, means the addition c special machinery whose maintenance cost is high and there is there fore no gain in economy in the preparation of the coal. As we car not reasonably expect a coarse degree of pulverization to show an added efficiency in the furnace over a finer degree, there is no hor of obtaining higher economies by pulverizing coarser than 85 pe cent through a 100-mesh. In fact, if the proper equipment is use it will be found less expensive to produce a coal containing 95 pe cent of 100-mesh goods and from 82 to 85 per cent of 200-mesh good than that of any other fineness.

As for coal of a higher degree of fineness, we can undoubtedl expect a higher efficiency of combustion and there will also be less ar noyance from the ash, due to the fact that it is in a more finely divide state. To offset this, on the other hand, there is the added cost c preparation.

I believe the only way the question can be answered satisfactoril is by experiments with coals of various finenesses. From my know edge of pulverizing costs I can say that the degree of pulverization ca be absolutely limited to 98 per cent through the 200-mesh. This de gree can be attained with a comparatively small increase in prepar tion, but to go further increases the cost excessively. All that we kno at present are the limits of the field in which to investigate, viz: th coal must contain not less than 95 per cent through the 100-mesh an not more than 98 per cent through the 200-mesh.—A. W. RAYMONI

(6) *Cost of Grinding and Handling, including Upkeep.*

The average cost of grinding and delivering the coal to the fu naces is about 45 cents per ton, and is made up as follows:

	Cents
Labor	15
Power	10
Repairs	14.5
Coal for drying	5.5
	45.0

These figures represent an average for 5 months from April to August, 1913.

The item "repairs" includes all repairs to coal crackers, grinders, conveyors, fans, belting, etc. Three men on one 10-hour shift are all that are necessary to prepare and deliver 70 or 80 tons to the furnace per day.—J. L. AGNEW.

The cost depends largely upon the amount of coal operated upon. Based on 200 tons in 24 hours, with coal at $1 per ton and same coal being used for power, the expense would be, fuel for drying the coal, power, labor, supplies and repairs, approximately 17.6 cents per ton; at $2, about 21.8 cents per ton; at $3, about 23.9 cents per ton. These figures, however, do not include overhead charges, interest or depreciation—in other words, the cost of preparing depends upon the quantity to be pulverized, as well as cost of labor, power, etc., entering into the operation. Repairs to dryers and mills should not exceed 2 cents per ton, and the power required for this operation should not exceed 17-h.p-hr. per ton.—H. G. BARNHURST.

In a mill having an average output of 150 tons per day, the cost is about 40 cents per ton.—JOHN V. CULLINEY.

The figures given herewith are taken from a plant capable of grinding 140 tons of coal per 24 hours. As the plant was built about 16 years ago, it contains more refinements and larger storage space than is considered good practice to-day. The average cost per ton of 2000 lb. for pulverizing coal (including interest on investment, 5 per cent for depreciation and 5 per cent for obsolescence) is:

	Cents
Labor operating department	15.64
Labor repairs to machinery	1.70
Supplies, fuel, power, etc	14.71
Oils and waste	1.25
Repairs	4.54
	37.84
Interest, depreciation and obsolescence	1.35
Total	39.19

—W. R. DUNN.

TABLE 1 COST FOR PULVERIZING COAL

Capacity of Grinding Room, Tons per Hour	Percentage through 100 Mesh	Percentage through 200 Mesh	H.P. at ¾ Cents, Kw-Hr.			Labor		Cost per Ton for Maintenance	Total Cost per Ton
			Total H.P. Required	Hours per Ton	Cost per Ton	Men at $2 per Day	Cost per Ton		
1	99	95	45	45.0	22.5	1	20.0	6.66	49.16
2	95	82	45	22.5	11.25	1	10.0	3.33	24.58
2	99	95	60	30.0	15.0	1	10.0	3.40	28.40
3	95	82	60	20.0	10.0	1	6.66	2.22	20.88
3	99	95	85	28.0	14.0	1	6.66	2.40	23.06
4	95	82	75	19.0	9.5	1	5.0	1.70	16.20
5	95	82	85	17.0	8.5	1	4.0	1.20	13.70
6	99	95	170	28.0	14.0	1	3.33	2.40	19.73
10	95	82	170	17.0	8.5	1	2.0	1.20	11.70
10	99	95	255	28.0	14.0	2	4.0	2.40	20.40
25	95	82	425	17.0	8.5	2	1.7	1.20	11.40
25	99	95	680	28.0	14.0	3	2.4	2.40	18.80

TABLE 2 FUEL REQUIRED TO DRY COAL

Percentage of Moisture in Coal	Coal Consumed per Hour in Pounds in Operating Dryer *					
	160	230	350	540	715	900
	Capacity of Dryer in Tons per Hour.					
1	19.5	28.1	43.2	66.8	88.9	113.0
2	15.3	25.1	33.5	51.8	68.9	86.3
3	12.7	18.2	27.5	42.4	56.4	70.6
4	10.7	15.5	23.6	36.4	48.4	60.6
5	9.3	13.3	20.3	31.3	41.6	52.2
6	8.1	11.7	17.7	27.4	36.4	45.7
7	7.2	10.4	15.7	24.1	32.1	40.2
8	6.5	9.4	14.3	22.0	29.3	36.7
9	5.9	8.5	12.8	19.8	26.4	33.0
10	5.4	7.8	11.8	18.4	24.4	30.4
11	5.0	7.1	10.8	16.7	22.2	27.8
12	4.6	6.6	10.0	15.3	20.2	25.2
13	4.2	6.1	9.3	14.4	18.9	24.0
14	3.9	5.7	8.6	13.3	17.7	21.9
15	3.7	5.3	8.0	12.3	16.3	20.2

* Coal to have 14,000 B.t.u. per lb.

The cost is very well established to be between 40 and 45 cents per ton, which, when replacing mine run coal, is just about taken care of by the possible use of slack coal at 50 cents per ton less than what the mine run costs.—W. A. Evans.

The cost will vary with the local plant conditions, the variable factor being, of course, the cost of handling. The pulverizing cost naturally depends upon the degree of pulverization, and the amount of coal consumed. Table 1 will give some idea of how this cost varies, and forms a basis on which to calculate this cost for any particular installation. The figures are applicable only when the Raymond system of pulverizing is used, and are obtained from actual experience covering a period of over five years. Table 2, from the Ruggles-Coles Engineering Company, will be of service in calculating drying costs.—A. W. Raymond.

(7) *Danger from Particles of Dust Floating in Air.*

The grinders, conveyors and bins are all enclosed and very little dust escapes. We have used open fires continuously in the building where the grinding is done and never have had an explosion or an accident of any kind due to dust in the atmosphere.—J. L. Agnew.

There is a real danger from dust and particles of powdered coal suspended in the air. Consequently, we have the building in which the pulverizing is done largely open at the bottom and open louvers at the top. Also we make it a practice to keep the plant clean and free from accumulations of loose dust.—W. P. Barba.

Only when floating or mixed with air will pulverized coal puff or explode, if ignited. Explode, however, is too strong a term to use unless large quantities are involved, in which case the progressive rise in temperature and heat during the puff might increase the violence to an explosive degree. Coal being carried from pulverizers to bins should be handled as a solid material, and not in the shape of a dust cloud, since any firing would engage the whole volume. Aerial propulsion for transfer of pulverized coal should be avoided. Leakage should be guarded against to prevent dirt or accumulations in inaccessible places. Explosions occur only when the mixture of air suffices to supply oxygen enough to support combustion. A pulverized coal plant should be kept clean, and it can be. Accumulations of dust on beams or projections when dislodged may in theor make an explosive mixture with the air, but such explosions are rare Explosion is only combustion intensified. It is only through careless ness that any explosion in the handling of pulverized coal could occu to-day.—H. G. BARNHURST.

Coal dust is dangerous only in a suspended state, that is, sur rounded by sufficient air to cause instant deflagration. Many pul verized coal plants will be found that have coal dust floatin around in the air, surrounding the pulverizing machinery. Ther is, however, no excuse for this, since a pulverizing equipment may b compared to a steam plant. If a steam boiler can be kept from leakin under a pressure of 100 lb., surely a pulverizer can, in which there i practically no pressure.—JOHN V. CULLINEY.

There is always danger of fire from particles of any kind of dus floating in air in a confined space if fire or sparks are allowed in tha space. In the case of powdered coal there is no excuse for dus escaping except in the grinding room, which is bound to be some what dirty. The protection is to insist upon no sparks or fire in th grinding room. Danger is absolutely eliminated in the case of th direct delivery system, for there is then no powder escaping.—W. A EVANS.

Coal dust which is finer than 200 mesh may be considered ex tremely dangerous. Very finely divided particles are liable to ignit spontaneously. Coals which ignite below a temperature of 150 deg within one hour are dangerous. The liability of coal dust to ignit spontaneously is dependent upon the temperature of self-ignition an the time of heating necessary, and increases in proportion to th percentage of oxygen present in the coal.

Coal dust which is suspended in air can be ignited without the pres ence of inflammable gas. The presence of moisture lessens the prob ability of explosion, and therefore dust should be dampened wit sprinklers. The use of stone dust has been suggested for preventin explosions, but its value in that connection is doubtful.

Coal dust containing any uncombined hard material, like silica is very dangerous to health, usually producing a fibroid condition o the lungs.

In plants where particles of dust are floating about in the air, i is advisable therefore to use the following precautions: (a) permit n smoking; (*b*) prohibit the use of matches; (*c*) do not use naked gas lights; (*d*) have no girders or open beams on which the coal dust may possibly lodge; (*e*) use only incandescent electric lamps for lighting; (*f*) be sure that all machinery, floors and walls are kept clean; (*g*) prevent the escape of dust by providing a short and direct discharge to the furnace.—EDWARD J. KELLEY.

When the atmosphere in the grinding room becomes impregnated with coal dust, a condition exists which may result in a very serious explosion. This is, practically, the only danger which occurs in the handling of pulverized coal, and it is entirely eliminated by the use of equipment in which the coal can be prepared without allowing any dust to leak out and permeate the surrounding air in the room.—A. W. RAYMOND.

(8) *Essentials of a Good Burner.*

Only one type of burner has been used here. It has given no trouble. One essential of a good burner is that the air and coal supply must be under complete control.—J. L. AGNEW.

The essentials are regular feed, ease and accuracy of control and regulation. If these requirements are complied with in any type of burner, it should be satisfactory.—W. P. BARBA.

In a good burner there should be absolute control over the flow of pulverized coal to the burner pipe. In other words, it should be so devised that the clearance around the screw, or other means of transfer, should be small, so as to prevent any rush of coal by vacuum formed by blower in the burner pipe. Pulverized coal when mixed with air flows easily. There are a large number of so called burners on the market which are in reality fuel controllers, and do not have anything to do with the actual burning of the fuel. In other words, they feed the coal to the burner pipe only. In burning pulverized coal absolute control must be had for regulating the quantity of air for controlling the temperatures.—H. G. BARNHURST.

The essentials are: (*a*) uniform feed, (*b*) proper mixture of coal and air, (*c*) proper control, ability to vary coal supply, (*d*) simplicity, (*e*) compactness.—JOHN V. CULLINEY.

A burner should thoroughly and intimately mix the coal dust and air. It should feed the coal with absolute uniformity to the furnace to which it is attached, and be so constructed that the air or blast pressure can be varied to suit the requirements. The feeding mechanism should respond instantly to the demands made upon it by the operator. All parts should be accessible and readily removed for renewals and repairs with very little inconvenience, and be so proportioned that the velocity of the coal leaving the burner is not excessive. It should be capable of burning coal to within one-half inch of the extreme burner tip, and so constructed that the tendency to choke up is reduced to a minimum. Should such choking occur, due to the accidental introduction of foreign matter, it should be so made that it can be readily cleaned.—W. R. DUNN.

The difficulties in the way of obtaining easily the essentials of uniform feed of both air and coal, through mixture of the two, and exact control of both, have been the tendency of powdered coal to flush through any opening uncontrolled and also to cake and to arch over at the point of delivery from the storage hopper.

There are two general types of powdered coal burners in use, those depending upon varying the speed of a screw conveyor for control, and upon varying the quantity of air blowing through a stream or small mass of coal. The control by air rather than that by screw conveyor of variable speed seems to work out to the best advantage, for the reason that any speed control is bound to be bungling and not of sufficiently fine adjustment. On the other hand, the quantity of powder picked up by a blast of air in passing through either a falling stream of coal or forcing its way through a small body of the powder has a constant ratio to the air blast and is subject to very exact control. A good burner should operate within 3 per cent variation in quantity of coal for any number of 5-minute intervals for any given setting of its controller. In the case of the air control the blast of air operating at about 6 oz. picks up more coal than it can furnish with oxygen, so additional air has to be provided for combustion. Two air blasts are therefore provided, one for control of the quantity of coal and for conveying the coal from the controller up to the furnace. The other air supply is for furnishing the additional amount of air for combustion, usually at about 1/2 oz. pressure.—W. A. EVANS.

The supply of coal should be absolutely under control and the mixture of the coal in the air uniform. There are several burners on the market which very nearly approximate this result. They are either of the syphon type, in which the supply of coal is controlled by air suction, or the more common screw conveyor type, which depends on a variable-speed screw for regulating the flow of the coal. One very good way to insure a uniform mixture of coal and air is to make the coal dust travel through a horizontal pipe at least 6 or 8 ft. long, after it is fed to the air and before entering the furnace.

—A. W. RAYMOND.

(9) *What Troubles are Likely to Occur with Burners in General.*

Stoppage of the burner is the usual trouble, which may be caused by small foreign substances and occasionally by the powdered coal arching over in the bin, due possibly to dampness or other causes, and then falling with a sudden avalanche effect, which, in some cases, stops the burner or blows a fuse, and in other cases sends a heavy charge into the furnace and the powdered coal which cannot be burned forms a heavy smoke.—W. P. BARBA.

No troubles should occur with burners of proper design, if the coal is thoroughly dried and properly pulverized.—H. G. BARNHURST.

The troubles found with most controllers are: (*a*) inability to mix coal and air properly, (*b*) irregular feed, (*c*) choking up, and (*d*) inability to control for small furnace use.—JOHN V. CULLINEY.

Intermittent and non-uniformity of feed, choking up of air passages, the accumulation of foreign matter in the interior of the burner, too high velocity through the discharge pipes, and unreliability of feeding device are troubles that may occur.—W. R. DUNN.

The troubles that can occur are interruption from caking and arching over as previously spoken of and the flushing of coal through openings and along screw conveyors if used as part of the burner. Uniformity of feed is also possible of some improvement. These troubles are entirely overcome by the use of a direct delivery system where the control is all obtained, while the coal is still coarse and easily kept within control. Burners must be placed within 5 ft. of the furnace, for otherwise the coal will settle out from the air and the thorough mixture will be disturbed.—W. A. EVANS.

(10) *Special Features Required in Powdered Fuel Furnace.*

No special features used need be introduced in a reverberatory

furnace to make it suitable for use with pulverized coal. All that is necessary is to omit the usual firebox entirely and extend the bridge wall to the roof. Holes of course will be left in the bridge wall for the burners to pass through. Fig. 1 shows the inside of a reverberatory furnace before being put into commission looking towards the end at which the pulverized coal is introduced.—J. L. AGNEW.

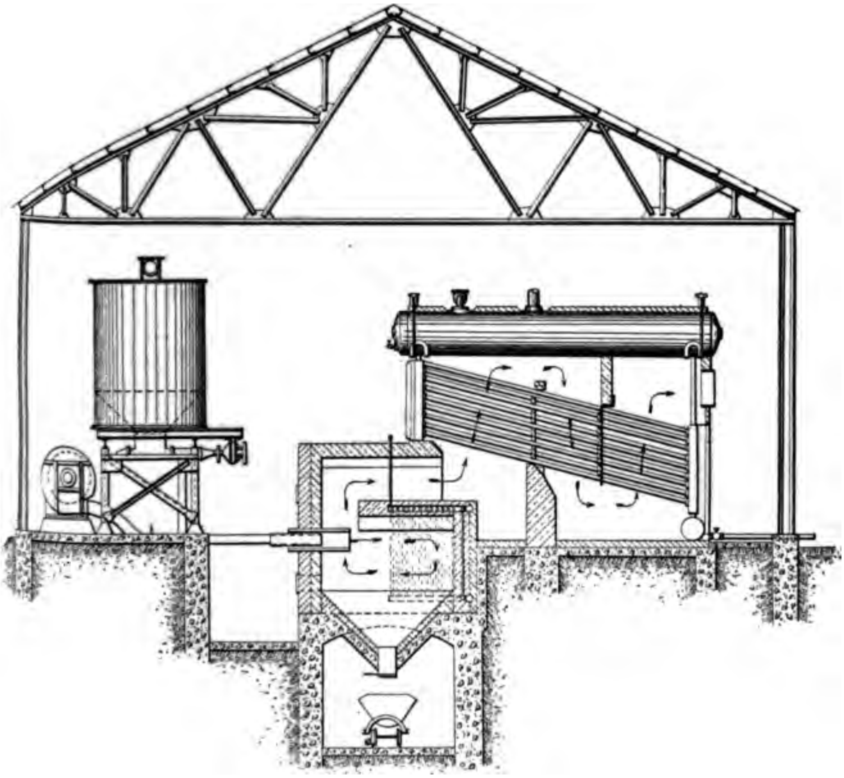
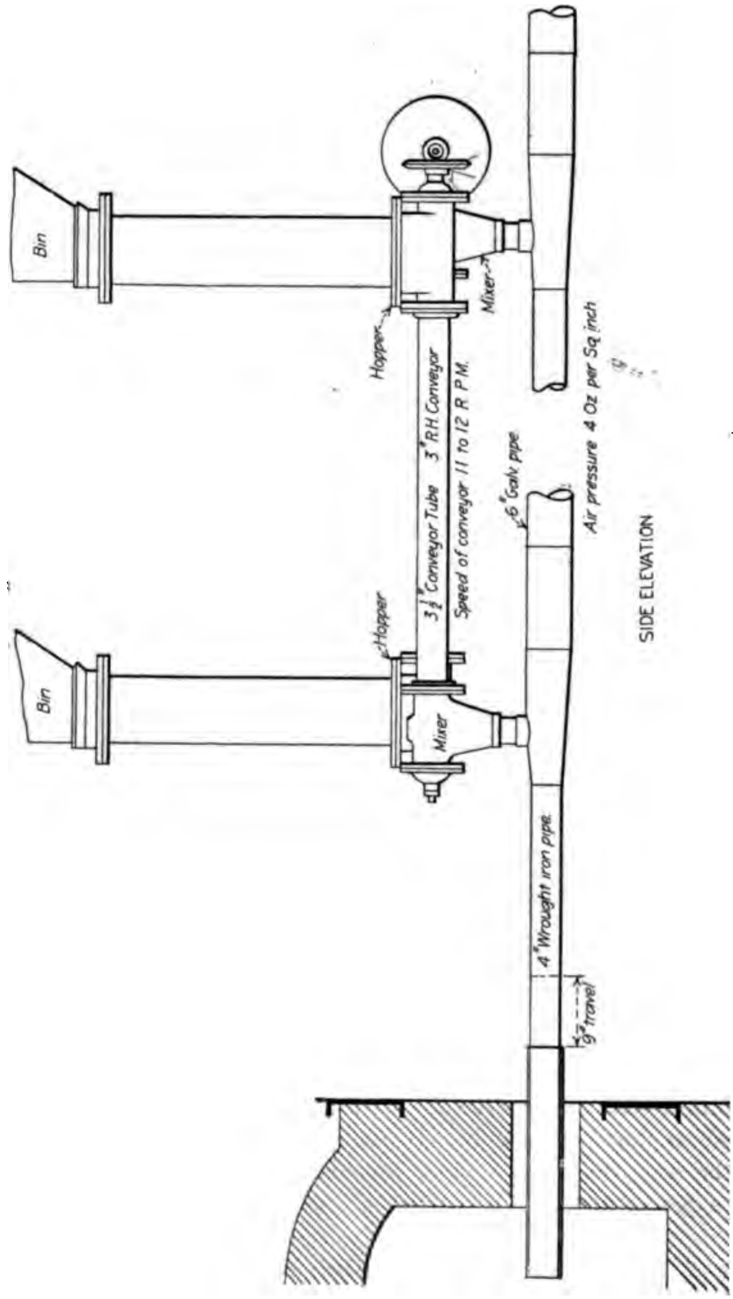


FIG. 2 DESIGN OF FURNACE FOR BURNING LOW-VOLATILE, HIGH FIXED-CARBON FUELS

A proper distance between the burner and a bridge wall must be designed so that combustion may take place, the flame impinging upon the wall causing a certain amount of the ash to settle and giving a proper distribution of heat on the hearth.—W. P. BARBA.

Fig. 2 shows a design of a furnace for burning low volatile, high fixed-carbon fuels, such as anthracite, coke breeze, etc. In


Bin
Bin
Hopper
Hopper
Mixer
Mixer
3½" Conveyor Tube 3" R.H. Conveyor
Speed of conveyor 11 to 12 R.P.M.
6" Galv. pipe
Air pressure 4 Oz per Sq inch
4" Wrought iron pipe
9" travel
SIDE ELEVATION

these furnaces the blast passes down and up and over an arch, thereby surrounding the incoming fuel and supplying the heat necessary for the initial ignition. The main principle governing the design of a furnace for burning pulverized coal is that it must be sufficiently large so that coal when burned will have time to complete its combustion before leaving the furnace. In open hearth furnace practice the same condition exists as in rotary kilns, i.e., the fuel must be projected and burned directly over the bath. Furnaces to suit fuel requirements for any individual operation should be designed especially for the work in question.—H. G. BARNHURST.

In puddle, heating, forge and like furnaces the high pressure air blast should range between 4 and 6 oz., the low pressure or volume air blast from 1 to 2 oz. In all experimental cases with air blast it is always advisable to begin with too low a pressure and slightly increase it until proper pressure is reached, rather than to begin with a high pressure and work down.—JOHN V. CULLINEY.

Fig. 3 shows a burner fitted to a reverberatory furnace. No change whatever was made in the furnace, which was formerly heated with oil. The burner tip is so constructed that it is readily adjustable. In starting the furnace, the burner tip is extended the full length and after ignition takes place it is gradually withdrawn so that it becomes flush with the inner wall.—W. R. DUNN.

(*Topics 10 and 12*) The essential features for furnaces for burning powdered fuel are emphasized in the almost complete failure to secure success under boilers. The essentials are temperature of at least 2000 deg. fahr. throughout the entire furnace and large combustion space, at least 1 cu. ft. for each 3 lb. of coal burned per hour. The boiler is essentially a low temperature furnace, seldom going over 1500 deg. fahr., and in no case does it offer sufficient space for combustion out of contact with the boiler surface. An idea of the space required under a water tube boiler running at modern high ratings is indicated in Fig. 3. This is almost prohibitive, at least for application to any existing plants. It would require a vertical height of 15 ft. below the tubes of a 600-h.p. boiler subject to peak loads of 1800 h.p. Horizontal return tubular boilers do not present the difficulty of space, for they are seldom run over rating, and are normally built with much larger combustion space throughout their entire length than is provided with any water tube boiler. They do, however, give difficulty from low temperature. The writer has never been able to maintain combustion under a return tubular boiler except with the assistance of an auxiliary igniting flame, and after protecting the flame from the chilling effect of the boiler surface by a brick arch, run a considerable distance back, as shown in Fig. 4. The auxiliary igniting flame was arranged as also shown in Fig. 4. It consisted of two 15-in. square steel boxes 5 ft. long, firebrick lined, leaving about 12 in. square inside, and with grate bars in the bottom. These were set directly in front of the two fire doors of the boiler. Coal fire carried on the grates provided the necessary igniting flame and was assisted by the close contact of the white-hot brick lining.

Aside from the difficulty of building combustion space large enough

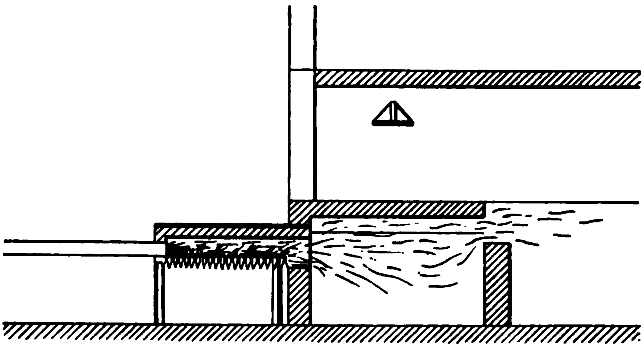


FIG. 4 BRICK ARCH USED TO PROTECT THE FLAME FROM THE CHILLING EFFECT OF THE BOILER SURFACE

and of maintaining combustion, there is little chance for powdered coal coming into general use on water tube boilers. The cost of grinding eats up any possible small advantage in economy it might have over the very efficient operation of mechanical stokers. The 95 to 97 per cent furnace efficiency of the latter leaves a very narrow margin for improvement; certainly not as much as 40 cents, the cost of grinding each ton of coal. That leaves the field for powdered fuel boiler firing possibly to horizontal return tubular boilers and to a few special conditions, such as waste fuel or a fuel that cannot be burned on stokers. The writer suggests a use that, to his knowledge, has not been tried. It is for peak loads. Powdered coal used only to supply the peak loads to heavily overloaded boilers would very much increase their capacity, would be in use only for short periods, would be entirely automatic, and might prove of untold value.

The writer's experience has been that wherever ash has a chance to deposit within the range of the flame, slag will form and be of such a sticky, sluggish nature that it is next to impossible to remove it. It chills solid at 1800 deg., or as soon as any door is opened to break it out. It is suggested that a flux be used to make the slag more fluid, so as to allow it to be drawn off in its fluid state. The writer has never tried this.

A patent was recently issued to a Pittsburg concern involving the use of a furnace with its bottom side slanting down towards the front, as shown in Fig. 5. A narrow opening at the lower end is supposed to

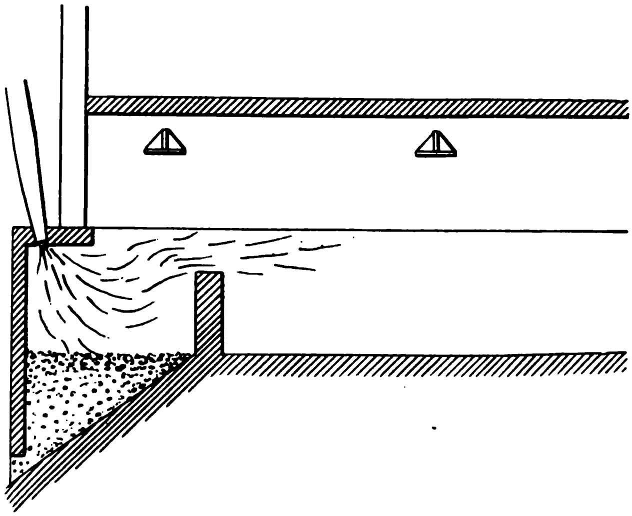


Fig. 5 Design of Furnace with Bottom Side Slanting down towards the Front

permit of drawing off ash at the same rate as it deposits on the top surface. This does, however, crust over on the top surface so that the slag does not settle down to the opening.

Another patent recently applied for involves the use of a moving side to a furnace such as a horizontal chain grate (Fig. 6), this grate to carry a bed of cinders or other protecting material, or even coal. Such a moving side or chain grate would continually remove the slag as fast as deposited, and the projecting material would form a very desirable indestructible impinging surface. This same arrangement with coal used on grate would permit of the coarser grinding of the powdered coal, allowing the coarse particles to drop to the grate, tl insuring complete combustion regardless of the coarser grindi —W. A. EVANS

(11) *Air Pressure Used and Effect of Stack Draft on Combustion.*

Coal is blown into the furnace with air under 6 or 8 oz. pressu This air supplies only a portion of the oxygen required for cc bustion, the balance being drawn into the furnace through openi around or near the burners. The amount of air drawn through th openings is dependent entirely on their area and the stack dra The latter should be under control by means of a damper. T

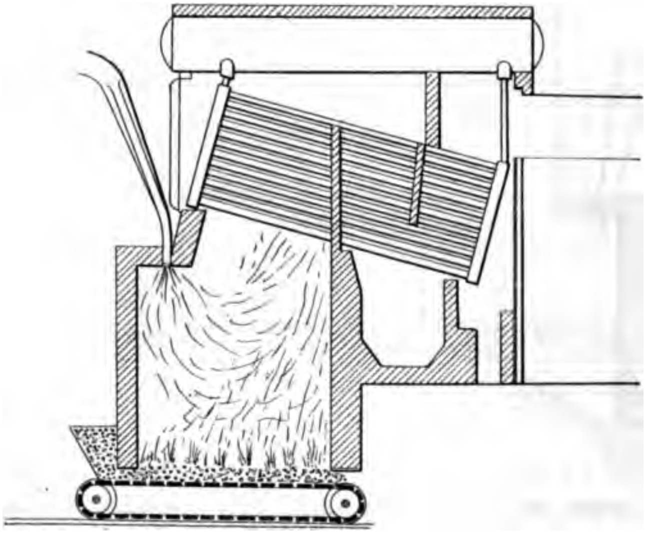


FIG. 6 DESIGN OF FURNACE WITH MOVING SIDE OR CHAIN GRATE

draft, at the throat of the furnace where the area is about 40 sq. is usually between 1.0 and 1.2 in. of water—J. L. AGNEW.

The air for atomizing the powdered coal which we have used under 4 to 6 oz. pressure, but we believe this to be higher than sirable. The air for combustion should be very low in volume. T stack apparently has little effect upon the combustion but is necess to carry off ash and gases.—W. P. BARBA.

In furnaces and in the pipes conveying the coal from the b there should be at all times a slight vacuum maintained so that leakage of any sort should be toward and not from the furnace. In other words stack draft should be sufficient to create a slight vacuum in furnace, and strong enough to take care of all the products of combustion.—H. G. BARNHURST.

It has been found advisable to place a damper on the top of the stack, keeping it almost closed during heating. With the damper in this position and the neck of the furnace as small as allowable, one obtains the best results with pulverized coal, both in the saving of coal and increase of furnace temperature and decrease of stack temperature.—JOHN V. CULLINEY.

The air pressure generally used is 7 to 9 oz. per sq. in. The stack draft should be sufficient to carry off the products of combustion.—W. R. DUNN.

There is a great variance of opinion among the various users of powdered coal as to whether it should be fed into the furnace by air from an ordinary blower or by compressed air. There is no doubt that the use of blast air increases the life of a furnace, as the flame does not seem to be quite so intense, and because of the lower velocity a more complete combustion is obtained in the combustion chamber. Those who uphold the use of compressed air say that it is necessary in order to obtain high temperatures.—A. W. RAYMOND.

(12) *Experiences with Ash or Slag in Furnace.*

The ash deposits largely in the combustion chamber, falling in front of the bridge wall as well as the hearth and tail of a continuous furnace. The slag is formed on the hearth which is removed by bars without a great deal of trouble. In the tail of the furnace the ash is soft and is usually pulled out with bent bars.—W. P. BARBA.

The ash from the ordinary anthracite does not slag even though allowed to remain in the furnace for a considerable length of time. Soft coal ash, however, in most cases will settle down to the bottom of the furnace and if allowed to remain too long will slag. Most of the ash where pulverized coal is burned, passes out to the air above the chimney; what remains, if promptly removed, is easily cared for.
—H. G. BARNHURST.

In regard to ash trouble, it might be said that only in furnaces operating at a temperature of 2000 deg. fahr. or less, is there any trouble of this kind. This difficulty is overcome by placing hoods over the door of the furnaces and connecting them to a suction fan which deposits the ash into a collector of the cyclone separator type.
—JOHN. V. CULLINEY.

In the portland cement industry the formation of slag in the furnaces is unknown. The ash is generally collected in a dust chamber in the rear housing of the kiln.—W. R. DUNN.

(13) *What Temperatures are Maintained in Furnaces—Influence of Temperature on Formation of Slag.*

The working temperature of the furnace at its hottest part is about 2800 deg. fahr. This could be readily increased if desired but the brickwork of the furnace would then suffer too severely When working at the above temperature from 5 to 6 tons of materia are smelted by 1 ton of coal. The kind of slag formed is determined by the nature of the charge and should preferably run about 33 per cen to 35 per cent silica. Such a slag will flow from the furnace perfectly liquid at the prevailing temperature and also allow of a good separation from the matte.—J. L. AGNEW.

Furnace temperatures can be controlled from 1800 to 3500 deg fahr. If the air is preheated, there is no doubt but that considerably lower temperatures can be readily controlled, provided the temperature of furnace is above the kindling temperatures of the fuel. Slag is formed more easily with high temperatures than with low. Hence with thorough control of the burning mixture, serious results can be avoided.—H. G. BARNHURST.

The highest temperature in a rotary cement kiln is approximately 2600 deg. fahr. Temperatures high enough to melt nickel readily have been obtained with pulverized coal in reverberatory furnaces.
—W. R. DUNN.

(14) *Experience with Checkerwork in Metallurgical Furnaces.*

None is used here, but the waste heat is utilized for generating steam in a boiler set in the flue. It is estimated that about 500 h.p. could be obtained in this way from the waste heat of one furnace when burning about 70 tons per day.—J. L. AGNEW.

In regard to this item the only furnaces which we have had experience with, where checkerwork would enter into the construction, are those in connection with open-hearth furnaces, and it has been found that no serious trouble arose with the checkerwork or baffle walls. Checkerwork should be so designed that there are no horizontal or level places on which the ash could settle. We have not heard of any serious complaints with checkerwork—in fact, we know of one open hearth furnace where 152 consecutive heats were obtained before furnace brick work necessitated shutting down for repairs, and there was no serious closing up of the checkerwork. The furnace brick work gave out before the checkerwork was choked up in any way.—H. G. BARNHURST.

In small singeing furnaces, a system of checkerwork acted as a bar to complete combustion and resulted in the formation of a considerable quantity of coke.—W. R. DUNN.

(15) *Life of Furnace as Compared with Furnaces using Other Fuels.*

The life of a reverberatory furnace is not adversely affected by the use of pulverized coal. As a matter of fact it is probably prolonged. On account of the uniformity of the heat, the contractions and expansions, which are unavoidable when grate firing is used, are done away with completely and consequently the furnace is much more likely to have a long life.—J. L. AGNEW.

It is our opinion, without definite data to substantiate it, that the life of a furnace running with powdered coal is greater than that of a furnace using oil. We may safely say at least that the use of powdered coal does not appear noticeably to injure the furnace.
—W. P. BARBA.

The life of furnaces using pulverized coal naturally depends upon the type of furnace. Rotary kilns using pulverized coal, where the heat is being carried out with the out-going clinker and is not cumulative in its effect, have linings which last from 8 months to 16 months; the lining, however, is subject to erosion by raw materials and clinker. The life of furnaces using pulverized coal is equal to that of hand-fired or oil-fired furnaces. With proper furnace control and using pulverized coal properly prepared the brick work should last just as long as when using any other kind of fuel.—H. G. BARNHURST.

The life of the furnace is about the same as the life of a furnace using fuel oil. I have known of cases where rotary kilns in the portland cement industry have retained their original lining for a period exceeding 26 months.—W. R. DUNN.

Pulverized coal furnaces operated at low air pressures will last longer than the ordinary hand-fired furnaces. By using too high air-pressure the bridge wall and roof of the furnace are destroyed and also the furnace waste is increased.—JOHN. V. CULLINEY.

(16) *Items of Expense or Economy in the Plant as a Whole, due to Use of Powdered Fuel.*

The main item of expense in the use of pulverized coal is the installation of the necessary plant for grinding the coal and distributing the dust to the points where it is to be burned. Next to this would come the power required and the repairs.

To offset these items of expense the labor required is less with dust firing than with the usual method. The latter would require at least double the number of men and the work would be of a much more trying kind. There would also be a considerable amount of ash and clinker to dispose of each day and an unavoidable loss of partly burned coal would occur in this material.

The great advantage, however, of pulverized coal firing is in the efficiency. The heat is uniform and under perfect control, the combustion is complete and takes place where it will do most good, but above all there is no delay for grating with an accompanying drop in temperature. The furnace is always working, and working at a uniform rate, both of which points are essential to efficiency.—J. L. AGNEW.

Under the maximum production in a powdered coal installation it is probable that a good economy can be obtained. In our own case, on account of slackness in manufacture for which the powdered coal plant was installed, we have been unable to run economically or get any data on what we may expect under the best conditions.—W. P. BARBA.

The economy of an installation for preparing pulverized coal as a fuel naturally depends upon the price of other fuels obtainable. The economy, however, obtained in the use of pulverized coal as against hand-fired furnaces in certain types of furnaces is remarkable.

In furnaces for heating billets, from 20 to 25 per cent has been saved; in open-hearth furnaces in comparison with producers, from 30 to 40 per cent; in puddling furnaces, from 33 to 50 per cent; in heating and busheling furnaces, 20 to 25 per cent. These figures are authentic and can be verified. The principal items of expense are naturally the cost of preparing pulverized coal. The advisability of making a pulverized coal installation naturally depends on whether the saving obtained by increased efficiency of burning will overcome the additional cost of preparing the fuel.—H. G. BARNHURST.

GENERAL DISCUSSION ON POWDERED FUEL

CHAS. WHITING BAKER. This discussion on burning powdered coal throws light on the question, once much discussed in technical literature, as to whether the presence of water vapor in a boiler furnace, such as is furnished, for instance, by a steam jet blower, adds to or detracts from the efficiency of the furnace. The weight of scientific opinion has always been that the admission of water to the furnace, whether as moisture in the coal as steam from a blower, or otherwise, is detrimental to efficiency. It has been claimed, however, that where the water was admitted in such a way as to be decomposed to form water gas, which was later burned to CO_2, a more complete combustion of the coal was attained and there was less loss due to incomplete combustion.

The universal testimony in these papers and discussions, however, is that with powdered coal the moisture in the coal must be reduced to the lowest point to facilitate the distribution of the dust by the blast, and further, that this dried coal burns perfectly to CO_2, notwithstanding the absence of moisture.

LOREN L. HEBBARD (written). It has been brought out in the paper on Pulverized Coal for Steam Making, that the most important features or difficulties encountered are the disposal of incombustibles and the maintenance of the furnace. When these troubles are sidestepped by the use of excess air other serious faults are introduced; first, the incombustible in the form of dust is either deposited through the boiler passes or is carried out the stack; second, the efficiency and capacity suffers to such an extent that the system may become an economic failure.

It would therefore seem that the trend of experimentation shoul be to develop a furnace and a refractory material to withstand th heat. Under such conditions the ash would be slagged and the desig must necessarily provide for its frequent removal. When these con**ditions are satisfied then high capacity and efficiency will necessaril follow. No doubt past investigators have satisfied themselves th this is impossible, but that does not prove that it will not be a complished.**

Of the various types of apparatus described in this paper it woul appear that the Bettington boiler is a big step in the right directio and will lead eventually to successful results.

J. G. Coutant. The American Iron & Steel Manufacuring C have a dust collecting system installed in connection with all sma furnaces, which embraces hoods over all furnaces so arranged as t collect all dust and gases issuing from the front of the furnaces ov the work. The hoods are all connected with a heavy galvanized iro pipe through which the gases and dust are exhausted by a steel pla fan which discharges into a cyclone type dust collector. The gase suddenly admitted into the enlarged area lose most of their veloci and escape through an opening in the top to a stack; while the heavi dust and ash matter falls through the discharge orifice into a bi With this system gases of 500 deg. to 600 deg. fahr. are handled a 3 oz. vacuum and about 500 lb. of ash collected daily.

Chas. J. Davidson. It has occurred to me that in attemptin to make the use of powdered fuel general, particularly in boiler fu naces, there is a serious obstacle, which apparently has not receive serious consideration. I refer to the ash in finely divided particle which is carried up the stack with the products of combustion, an thereafter falls on the roofs or surrounding buildings and other objec which are exposed, and in the streets. In cement mills, lime kiln etc., this probably is not a serious consideration. But, should an a tempt be made to use this form of fuel in cities, while there migh be no visible smoke, the residue referred to is, generally speakin much more objectionable than smoke so-called, and might become great nuisance and be legally prohibited. I would appreciate it ve much if those who have had experience along this line would elucida their ideas relative to this detail of the subject.

John V. Culliney. The saving by the use of pulverized coal made up largely of (*a*) practically perfect combustion, (*b*) no han ling of coal or ash, (*c*) no poking or clinkering, and (*d*) constant and uniform heat, resembling a gas fire and as easily controlled.

One other item which might be mentioned is the use of preheated air. By passing preheated air into a furnace at, say 600 deg. fahr., the number of B.t.u. required to heat this air, in the combustion chamber, from room temperature to 600 deg. fahr. is saved. The saving is not made up of this item alone but also by the increase of furnace efficiency. That is (*a*) more heats per hour, (*b*) higher furnace temperature, (*c*) uniform temperature, (*d*) less ash deposited on hearth of furnace.

In furnaces having waste heat horizontal boilers above them, wrought-iron pipes are placed in the boiler setting underneath the boiler. This robs the boiler of very little heat and at the same time causes a saving of about 15 per cent in the amount of coal used.

In small furnaces the pre-heated pipes are placed underneath hearth.

The American Iron & Steel Manufacturing Company have forging furnaces operated daily for the last nine years on pulverized coal. These furnaces range in size from 20 in. by 36 in. to 7 ft. by 16 ft., and are used for heating bolt, nut, spike and rivet bars and also for puddling, bushelling and heating. Drop forge for both small and large hammers.

Operating under normal conditions, we use about 260 tons (gross) of pulverized coal per day.

W. R. Dunn. The chief item of economy in the use of powdered coal is the enormous saving effected as compared to the use of fuel oil. Another item of economy is the saving, due to a large elimination of labor expense.

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No. 1432

INDUSTRIAL SERVICE WORK IN ENGINEERING SCHOOLS

By Joseph W. Roe, New Haven, Conn.

Member of the Society

A social force has been at work in our engineering schools for the past few years which materially affects the attitude of students, on leaving college, towards working men. It concerns a steadily growing portion of the membership of The American Society of Mechanical Engineers,—that in the Student Branches. As many of these members will be called on for leadership in this Society in the coming generation, whatever helps or hinders their broadest professional training should have its careful consideration.

2 In the winter of 1907-1908 some engineering students of the Sheffield Scientific School at Yale started an activity which for want of a better name, has been called industrial service work. It consisted of a study of welfare activities, living and working conditions in American industries, and a definite attempt to render some useful service to workingmen in the city. As a large industrial center, New Haven has many thousands whose greatest need is a knowledge of the English language. It was felt that to help meet this need was the most practical service the students could render. A system of instruction in English was evolved, based on the familiar phases of everyday life, which did not require a knowledge of the foreign language on the part of the teacher. Groups were organized in various parts of the city wherever they could be gathered, the general plan being that the students should go to the men rather than to attempt bringing the men to any school or institutional buildings. The plan worked well from the start. The classes were full and many newly arrived immigrants were reached who would not have come near a public night school.

3 In connection with this teaching work, which was the main activity, a series of talks on industrial subjects was given to the

Presented at the Spring Meeting, St. Paul-Minneapolis, June 1914, of The American Society of Mechanical Engineers.

students by such speakers as John F. Stevens of the Panama Canal, S. B. Thorne of the Buck Run Coal Company, Charles Stelzle, Miss Gertrude Beeks, Prof. Edward A. Steiner, Charles R. Towson, and others. A small library on immigration and industrial conditions was set at work and some of the books became well worn.

4 The hold which it took on the better type of student, as well as its effect, on him were interesting and significant. The work was wholly voluntary and done in their own free time, yet many gave two or more evenings a week throughout the whole winter to it. The word "mucker" dropped from their vocabulary. The "wop," the "hunkie" and the "dago" became people, acquired names, and sometimes commanded their genuine respect. Students and workmen were coming, often for the first time, into direct and friendly contact and finding out for themselves how the others lived, worked and thought. From the knowledge so gained, there came an attitude of frank goodwill and friendliness on the part of both. The following winter a number of other engineering schools undertook a similar work with equal success. Under the leadership of the industrial and student departments of the Y.M.C.A. it has spread rapidly throughout the country until now, only seven years later, more than 3000 students are engaged in it and are coming into contact with about 50,000 workmen.

5 In a general way the activities of the student are: (*a*) reading and investigation of the general principles involved; and (*b*) a personal contact with workmen in some line of service. The latter takes many forms, but chiefly that of teaching. In all industrial centers there are a large number of men whose greatest need is English. Without it they cannot get a job alone, buy their own supplies, understand instructions for their work or even for their own personal safety; hence the padrone and labor contractor. With a knowledge of English, an opportunity of becoming industrially independent is opened up to them. Other subjects, of course, are taught, such as first aid to the injured, elementary mathematics, drawing, and civics, but English is the greatest need.

6 The service is not, however, confined to instruction nor to foreigners. Any sound basis of contact is utilized. Wherever possible the classes or groups are kept small, not over five or six men to a teacher, in order to insure the element of personal contact. The work is done independently of the college curriculum, on a voluntary basis, and without pay, as this basis is by far the best in its effect on the

student. In some cases the faculty has coöperated by taking over that portion of the program relating to speakers and has arranged a course of industrial lectures for all upper classmen. This has been done recently at the Sheffield Scientific School with good success. The advantages of industrial service work are felt by the employer, the workman, the student, and the community.

7 Employers, some of whom were at first critical, welcome it for its direct benefit and support it by giving access to the workmen, by furnishing places for teaching and in many cases paying the small necessary expenses. They see, too, its effect on the student. An employer recently said: "Two college men of equal training worked

FIG. 1 INDUSTRIAL SERVICE AT WORK
Teaching English at a Construction Camp. The Lesson is Posted on the Side of the Car. The Breaking Down of Class Feeling is Clearly Present

in my shop last summer. One of them 'knew it all,' was despised by the men and got fired. The other became 'one of the men' and learned from them, and nearly every evening some of the working men went to his room and he helped them in mathematics, mechanics, plain reading, etc. That fellow has a big job waiting for him because he has learned how to handle men to his advantage."

8 Some of the advantages to the workman have been pointed out above. He is given nothing which pauperizes him or lowers his self-respect. Usually he is suspicious at first of the student as a representative of the capitalistic class. He finds, however, by a contact which he has in almost no other way, that at least these boys are clean-cut, fair-minded and friendly. Those who are familiar with the attitude of workmen know their latent feeling of contempt for the young

college engineer who comes among them, possibly strong in things which they little appreciate, but weak in practical things, where they are strong. We have all seen, however, the loyalty with which old, hard-headed workmen will serve young college men who have *won their confidence* and made good with them. Their distrust gives way to a feeling of pride in their successes such as they might have for their own sons who have been given advantages they themselves have not had. This change in attitude of the workman has been clearly

Fig. 2 Another Phase

A Noon-Day Class in a Foundry in First Aid to the Injured. Practically all of these Men are English-Speaking

marked, and shows a breaking down of social antagonism—a help to all (see Fig. 1).

9 The gain to the student, while not obvious, is quite as great. More than half the value of an executive engineer lies in his capacity to understand and work with his men. No amount of technical proficiency can make up for the absence of it. One of the greatest weaknesses of the college-trained engineer is the unconscious attitude of assumed superiority which he sometimes has, for a time at least, after graduation. It seriously limits his usefulness and his capacity for learning. The ability to understand and to work with

men is the most valuable asset he can have. This our colleges, as colleges, cannot teach, for it is based on a knowledge of human nature and there is no textbook on human nature. It can be learned only by personal contact; and genuine personal contact is possible only on a basis of mutual respect and friendliness. The students are learning much more that the possibilities and limitations of welfare work. They are acquiring a personal attitude toward fellow workmen which starts them out right.

10 It is possible to give here only a few expressions of how this work is held by students of the stronger type. One says: "It's a wonderful, and sometimes a humiliating revelation to a fellow to get up against some of these foreign men. It just makes a fellow readjust a good deal of his previous thinking." Another, one of the best known college athletes of the day said a few months after graduation: "Remembering what I learned in this movement at Yale, when I became foreman I treated my gang of Italians as men and not as dogs, and it was really pitiful to see the way they returned the little kindnesses I showed them. Each day I was met with cheery words of greeting. When the job was complete, the men came to me in a bunch, thanked me for the fair way I had treated them and said they would like to work for me always." Another, a football captain, said a short time ago: "This industrial work is the livest thing that's struck college since I've been here. It's a real job and it's practical. Everyone of us who goes into it is bound to acquire an experience in dealing with men which the curriculum cannot give, and we need it."

11 Last year one graduate, who went into the office of a bituminous coal mine, gathered together a class of seven men to prepare them for examinations as fire bosses and underground foremen (see Fig. 3). With this instruction the men passed the examinations and their potential earning capacity per year was increased an average of $266.40 per man. As a result, this year 40 men applied for similar instruction and as this was beyond his capacity, arrangements were made for paid night instruction in one of the public school buildings which has been carried on by others under his supervision. Without multiplying instances we find results like this wherever men go who have had this industrial service training.

12 The advantage to the community needs but little emphasis. When one considers the type of Americanism with which the immigrant first comes into contact, it is no wonder that his social standards remain low. The only Americans that many a Pole or Italian meets

are the saloon keeper, the ward heeler, and the grafter. Contact with clean-cut, wholesome, educated college boys opens up to him a type of Americanism which he sees in no other way. It raises his standards and kindles his ambition. The men come to the students with all sorts of questions which indicate a hunger for information and improvement.

13 As the industrial service movement has developed it is quite distinct from ordinary social welfare work. It has two clearly defined objectives. The first one is immediate benefit to the laborer whom the

FIG. 3 A RESULT OF INDUSTRIAL SERVICE TRAINING
An Evening Class in Practical Mining. The Teacher in Charge is a Young Assistant Superintendent who Became Interested in Industrial Work while at Yale

student may be teaching; the second, less obvious, but main purpose, is the subjective effect upon the student himself, the developing of an attitude of mind, and a knowledge of the social aspects, the responsibilities, and the opportunities of his engineering profession. While the latter should not be over-emphasized to the student, it is never lost sight of by those directing his activities.

14 Such briefly is the development and nature of industrial service work. In appraising its value it is well to look at it broadly. The work which these students are doing is part of a general trend, of a changing of social standards, and of a development away from the industrial individualism of a hundred years or even fifty years

ago. The probability is that this tendency will increase rather than diminish during the coming generation.

15 Industrial history shows nothing more clearly than the fact that while tools of production make high social development and physical welfare possible, they by no means insure them. The series of inventions of Hargreaves, Arkwright, Eli Whitney, Watt, and other great inventors from 1760 to 1800 resulted in a tremendous readjustment of social conditions. In England, where this change was felt first and most severely, tens of thousands of artisans found their handicrafts supplanted. They drifted into the new industrial centers and found work as best they could. The resulting conditions are a matter of history. The industrial leaders had little or no sense of responsibility for conditions of labor and living which would not be tolerated today. Operatives were crowded together under unsanitary and dangerous conditions, working hours were long, and wages were governed solely by the supply and demand of an overcrowded labor market. This indifference on the part of the employers was soon met by violence and industrial warfare. At length, from various reasons, conditions began to adjust themselves. Under the leadership of such men as Lord Ashley, Robert Owen, an industrial conscience came into existence, and year by year, partly through labor legislation, partly through labor unions, partly through voluntary improvement by the employers, conditions have steadily improved, and are now better than before the introduction of machinery.

16 The situation was never as acute in this country as it was in England, but we know that even today we have in America industries with the most highly developed machinery where child labor and dangerous or unsanitary working conditions still exist. While conditions as a whole are by no means ideal, there has come a general acceptance of the fact that reasonable hours, good light and air, safety, and a fair wage are best not only for the worker but for the employer. Men do not agree, by any means, as to just what constitutes reasonable hours and a fair wage; but none now deny the general principle.

17 At the beginning of this century a new force came in, the rapidly developing art of industrial management. It is still in its infancy, yet enough has been done to show that old methods of management have been wasteful and that great increases in production are possible when the right methods have been found and put into successful operation. The invention of machinery vastly increased the workman's production by giving him new and efficient tools. The new

force opens up a further increase, through the higher efficiency of th workman himself and of methods of industrial management. Th effect in both cases is the same. The advent of machinery produce a profound social readjustment accompanied by widespread distres and friction. The readjustments due to the application of improve methods of management will not in all probability be as great, ce tainly not as drastic. Standards are far higher today than whe machinery was first introduced a hundred years ago and workme now have means of defence. Moreover, the social changes possible a probably not as radical or far reaching as in the earlier developmen

18 The development and application of the highest types of i dustrial management, however, is going to be difficult and delica work, if the results are to be made a permanent benefit to society a whole. Those who personally direct this development will largel determine the efficiency with which "efficiency" itself is applied. I the attempt is made by those in charge to seize all the benefit of th improved methods and to crowd the advantage of the employer the will either defeat or indefinitely postpone the advance. They mu be experienced men, wise, fair, thoroughly conversant with possibiliti and free from sentimental idealism. This means not only a know edge of machinery, systems, and time study, *but of human nature an the rights and real needs of industrial workers.*

19 The executive engineer will be at the focus of this situatio He alone is in direct personal contact with the two great element involved, capital and labor. His thorough understanding of both o these forces will prove one of the greatest elements in progress. I the man in actual charge has little knowledge of, or sympathy wit the workman, serious missteps are certain. If on the other hand t a thorough technical training and knowledge of the resources an responsibilities of the employer, he adds an attitude of fairness an friendliness, and a personal understanding of the workman involve the new force will work out to the good of all concerned. Scientifi management offers an opportunity to pay better wages, but it wi require strength and wisdom to apportion the economic gain fairl and to maintain a just distribution of it.

20 Welfare work in various forms has been going on for man years, ranging all the way from improvement in the small details o working conditions to the planning and building of whole mode cities. Some of these enterprises, conceived in a spirit of genuin good will, have met with no response from the workmen and in spit

of the great sums of money and much thought spent on them, have ended in bitterness and disappointment. In other cases welfare work has been developed quietly and wisely, each move being tested out as it was tried and has deeply influenced the lives and social standards of the whole community. In the record of these enterprises there is a glaring discrepancy of success and failure. Most of the failures have gone onto the rocks from violation of the fundamental principles of human nature. About some there has been a fine flavor of condescension; others have been made an advertisement; others have been imposed upon workmen by authority. A workman, no matter how crude his social standards, has a right to his own personality and sooner or later he will assert it. As one of their leaders put it to the writer: "Some of these employers roll their good intentions into a big bolus and jam it down the workmen's throats saying 'Here, take that; it's good for you.'" No welfare work will ever be effective unless it is preceded by a square deal, is wrought out gradually and patiently, and is the product of mutual confidence, experience and good sense.

21 While thousands have been invested in welfare enterprises, we know that the purpose behind them is being accomplished in scores of industrial organizations, without any special equipment, by the personal influence of some man or men in charge. These men seem to have a genius for understanding and developing the best in those under them. They have no fixed rule or system. It is a question of attitude and personality. They create an atmosphere of confidence instead of suspicion and distrust. Their influence permeates a whole factory, kindling ambition and developing better workmen and better industrial conditions. Such men can accomplish wonders without any welfare equipment. Given a welfare equipment they make it successful and beneficial to all. Their value to the employer, to the workman, and to the community can hardly be overestimated; the new art of management under the direction of such men will prove a permanent success. The development of just such men as these is the aim of the industrial service movement.

22 We have tried to sketch briefly the spirit of this movement, its main activities, and its relation to the general industrial situation. It seems sound. There are at present about 30,000 students in the engineering courses of the various schools and colleges throughout the United States. Of these, perhaps 5000 to 7000 graduate each year. About 20 to 25 per cent of the students become sufficiently inter-

ested in this work to get the benefits of it. What will it mean to the employer and workman in the next generation to have coming into the management of industrial enterprises 1000 or 2000 men a year, who inspire good will and confidence and have the right point of view from the start?

23 So far the industrial service work has been guided by experts from the industrial and student departments of the international committee of the Y.M.C.A. These men have given it special study and have directed its activities. They have kept it free from fads, and its rapid growth is perhaps the best evidence of the wisdom with which it has been directed. Although the motive which lay behind it was a religious one, it has attracted many men who took but little interest in the ordinary forms of religious activity. Many of these have found in the progress of this work that this motive and the unselfish social one are not so far apart.

24 In this industrial service movement, we have a large body of students giving a reasonable portion of their time voluntarily, and outside of their regular studies, to work which is an immediate benefit to others and to themselves as coming industrial leaders. It has been suggested by members of the Society that this work might be fostered as one of the activities of the Student Branches. If so, it should be wisely and carefully directed. The experience and training which its present leaders have acquired would be available and can be called on to help organize and guide it. The work of the Student Branches is good, but they have much greater possibilities than we have yet realized. At present their main, if not sole, activity has been to arrange a series of engineering lectures, which is well as far as it goes Some such work as this industrial service in addition would strengthen their usefulness and bring in the human element which the curriculum cannot give.

DISCUSSION

L. P. ALFORD. Professor Roe asked me to make one suggestion in his name in regard to the work of the Student Branches. It is that there might well be some person connected with the Secretary's office charged with the duty of visiting the Student Branches as often as necessary with this purpose. The members of this Society are employers of cadet engineers. The Student Branches are training these young engineers for full membership in the Society after they have reached the proper age and acquired the necessary experience.

Through the medium of this official of the Society working with the Student Branches, it might be possible to modify and improve the training of young engineers to their advantage, to the advantage of their first employers and further to the advantage of members of this Society.

P. F. Walker. With regard to Professor Roe's paper, I think the plan suggested is one that may be readily applied in the cases of sections connected with institutions located in large centers, but those of us who are in institutions located in smaller towns will have to employ different methods. One method which I believe to be workable, is based on the plan of university extension work which Kansas, along with Wisconsin and other western universities, is developing. Vocational courses of study adapted to the needs of boys and young men engaged in the various industries of the state, are outlined. Through these, they receive instruction in the rudiments of mathematics and the sciences related to engineering, together with first principles in their application to construction work. I expect to have two or three of my seniors in mechanical engineering working as instructors in this connection next year. I mention this as a suggestion for those institutions not situated in the large manufacturing centers. The general plan brought out in the paper is a most happy suggestion, and one which may well engage the attention of the Society.

H. L. Gantt. I do not think that the membership at large has any idea of the importance of this paper. The most important problem before the industrial community today is that of the relation between the employer and employee. The reason why this is so is because the employer and employee do not understand each other.

The plan suggested to bring the employer and employee together, is the most promising step that I have seen or heard of. We see in the papers every now and then what somebody in the American Manufacturer's Association says about what the Unions are doing to them. They do not say a word about what they are doing to the Unions. That is because they do not understand each other. Foreigners who come to this country do not understand us; we do not understand them. To many of us, they are simply "Dagoes" or "Hunks," to be treated as somebody in authority sees fit. Now, the activities which Professor Roe has described will bring the engineer of the future in contact with all of these people and give him a knowledge of who they are, what they are, and what they can do. I find that the Hungarian, the Pole or the Italian is very much like anybody else when you really know him.

Workmen are in one class and employers in another, and, as they do not know each other, they cannot, or will not, talk to each other. So long as that condition prevails, we are not going to solve our industrial problems without some connecting link. The work that Professor Roe is doing is going to turn out a lot of young engineers who will learn something about the human nature with which they have to deal and supply this link. In the ordinary college course, the student gets a lot of mathematics and engineering, all from the book end. Then he goes out on a job and sees the mechanical processes. He can learn those mechanical processes a great deal more quickly than he can learn the human beings who have to operate them. You may build the best mechanism in the world, but some human being has to operate it, and if you have not a knowledge of the kind of human being who is to operate it, you are going to get into trouble.

The term scientific management used in this paper means the utilization of scientific methods of investigation in the art of management. You can build up a system of management which is perfect, just as you can build a fine steam engine or automobile, but unless you have the right personality to run it, you are just as likely to wreck it as you are to wreck the automobile or steam engine by putting an incompetent person in to handle it.

In constructing a system of management, one must first have an ideal which must be based on the knowledge of human nature as well as on a knowledge of mechanical operations and appliances. Professor Roe and his co-workers are giving their students the fundamental ideas of how to handle their workmen. It is very much better to have a man who knows how to handle the workmen using a comparatively poor system of management, than it is to have somebody who does not know how to handle the workmen with a fine system of management. The first will get along better than the second, and I want to emphasize that this training of the engineering student in a knowledge of the human nature with which he has to deal, to my mind, ranks in equal importance with strictly engineering training.

CALVIN W. RICE. In response to the suggestion of Professor Roe that the Secretary arrange to visit the Student Branches, your Secretary tries to be up to date in every realm of activity of the members. As soon as I heard, two years ago, of this work of Professor Roe, I wrote a personal letter to every head of a mechanical engineering department in each of the schools in America where it is taught, and you would be pleased to see the magnificent responses that were received, showing that they are all alive to this movement. As a suggestion, I think that speaking for Professor Walker, as representing the Student Branches, he would be glad to have also the members of the Society visit him—men of affairs. I think there is nothing so attractive to the average student as to have a real man with a reputation, come and visit the school and give a talk.

The effect would be two-fold. You would have the interest of more members of the Society in that work and you would have more interest on the part of the Student Branches because men of affairs were interested in them. Now another suggestion has come to me with respect to students, which can be accomplished by every person in the room and by every person with whom you speak when you get home—and that is, the benefit of these conventions. Every person here must be in some organization. You must have men in your employ who are just out of college or who are just starting in your organization, lacking experience. Try to coördinate them with the university in your town or with some organization in your town which is doing this class of work. You will have a two-fold benefit from this interest. First, the men in your employ will become more useful to you because they understand men better, and second, the men in whom they become interested will also become better employees for you.

I want to urge each one of you to take the spirit of this paper of Professor Roe and apply it to your own factory now rather than to think it is something for somebody else to do in some university.

P. F. Walker. There is one other thought in connection with the Student Section and what it may mean in the life and work of the Society, that I would like to lay before you by explaining what we have done at Kansas. Each year, usually in December, we hold our annual meeting. There is no organized local section of the society membership nearer to us than St. Louis, but we are only forty miles from Kansas City where there are nearly twenty members. As many more are scattered in other cities in the state. At these annual meetings of the Student Section, we make a special point of inviting every member of the Society who is within reasonable distance, and some of them always come. I speak of this as a suggestion, indicating what the Society might do in the way of recognizing the Student garian, the Pole or the Italian is very much like anybody else when yo really know him.

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Section centers as nuclei for local sections of the Society for the regions adjacent, when the location is distant from those cities where a full local section organization is practicable.

L. P. Alford. I feel impelled to say another word in the name of Professor Roe. I know that in making this suggestion he has had no thought whatever that there has been a lack of coöperation between the Secretary's office and the Student Branches. It is not that at all. He has been merely trying to point out the possibility of further and new activities and suggesting the way in which some of these can be initiated. Personally, I am most heartily in sympathy with the suggestion of Mr. Rice that some members of the Council or other members of the Society take occasion to visit and address the Student Branches.

Professor Roe's paper does not reveal his personal connection with this great movement. He is its father. He is the man through whose far-sightedness and initiative the work was started. He deserves a generous measure of our esteem and commendation for having inaugurated a social movement in our engineering colleges that promises to be of great benefit to engineers and industry.

H. L. Gantt. To visit these Student Branches and start this work going, will cost something. You cannot do any of these things without money. I feel that many manufacturers would be willing to put up money for the advancement of the Society. Somebody has suggested that we might have manufacturers who are contributing members or something of that kind. This suggestion is well worth considering. The possibilities of the engineer as an economic factor, have been emphasized most clearly within the last twelve hours, but we need money to make them realities. All we need now is to have some way of financing this growth which seems to have started with such a rush.

Paul Doty. I think that most employers, at least modern employers, recognize their obligations in connection with the general subject of welfare work. The thought that "a man is his brother's keeper" does seem to permeate the minds of a good many employers. We have in St. Paul in our company work, an employees' club, formerly called The Technic Club. We have some educational work, some welfare work, we have talks on "safety first," on efficiency, and we also have talks covering good management and some on bad management. We try to make these meetings of employees of vital interest to them. We bring home everyday suggestions—we bring home their work-a-day life. These meetings are held as frequently as necessary, at least once a month, and in addition to the practical side of the work, the construction, the manufacture, the distribution—all the operations of the property—we have the social side, a dance occasionally, a picnic now and then and an excursion during the summer season—something that will maintain the human interest, and bring together the employer and employee.

We try to have a sense of the need of the understanding which Mr. Gantt has referred to. We know that employers without employees could accomplish very little, especially in continuous service business like public utilities when 24 hours a day, 365 days a year, somebody is working somewhere with us, and we need something outside of the mere payment of wages as compensation to the employee. I do not go so far at the present moment as to refer to service pensions or service annuities, or profit sharing, or other form of welfare work as it is understood generally, but all those things we do have in mind.

The educational work is particularly important and is under men like Mr. Walter C. Beckjord and his associates. A few years ago, Mr. Beckjord was a student at the University of Minnesota and came to us as one of our cadet engineers. We have that feature established to bring about the training of the younger men, and through years of faithful service, he is now occupying a position of responsibility and has been president of the branch of our educational work including both the gas and the electrical departments.

We claim no special credit for the work we are trying to do. It is work that is being advocated by the National Electric Light Association. It has been recommended by Mr. Insull, president of the Commonwealth-Edison Company, who has suggested that educational work be carried on in the time of the employer, not only in the time of the employee after hours, when a man perhaps is tired and does not care to come out. That, I think, is a wonderful step forward, when a man recognizes the responsibility to employees to give time for educational work on the company's payroll. The movement is here. It is the coöperative movement and we must, as progressive men, progressive engineers, recognize that there is work for us to do along this line. We are not wholly discharging our obligations by the giving of the pay check or the pay envelope at the end of the week or the two weeks' period.

H. L. GANTT. Professor Roe does not regard this as welfare work. Welfare work, as I understand it, is something done by the employer for the employee. Personally, I am not a tremendous advocate of welfare work as such. As one of their leaders put it to the writer: "Some of these employers roll their good intentions into a big bolus and jam it down the workmen's throats saying, 'Here, take that; it's good for you.'" While I have no idea that Mr. Doty has any reference to welfare work of that character, yet there is a good deal of so-called welfare work that is strictly of that character, sometimes with the best intentions in the world. The work which Professor Roe is doing is not in this class and seems to me to be at the root of our industrial progress. The gap between employer and employee will widen, if we do not do anything to close it up. It is equally important to public interests and to the interests of the employer, the engineer and the employee that this work be done.

JAMES HARTNESS (written). The engineer should be in the forefront of the campaign for bringing people together, not only people of different nations, but people in different walks of life. The trend of the public's social and economic views will begin to turn upward as soon as these various peoples begin to understand each other. But so long as the workman fails to understand the business man, and the business man the worker, the trend of our ideas will be toward anarchy.

The paper should serve as a keynote for many others that will bring out the great importance of this fact, for it is the engineer, who as the director of men, is in the position to put into practical effect many regulations that will lead to a better relation and a better understanding between man and man.

This can be truly called welfare work, but it should not carry with it the impression that it is solely for the laborer or even for the newly arrived immigrant, for it is as truly welfare work among the well-to-do.

Our success as engineers will be greater if we work along these lines and the value of the engineer to his country will be beyond measure if he realizes his obligations and opportunities along the lines stated.

Although the paper sets forth this work in its bearing on the student and the humblest workers, it will carry to every one the message that there are opportunities of this kind not only between the business man and the worker, but also between the workers of different grades when measured according to their skill and knowledge.

He congratulated the writer on presenting this subject to the Society and hoped that it would be followed by others tending to offset the present unfortunate trend of class feeling in this country, for much harm and very little good will be obtained by any scheme that fails to take into consideration the fact that each man has a heart as well as a brain, and that each man may best be directed by someone in whom he has confidence, someone who understands him, and that the physical energies of man must be directed through the man's inner self. It is necessary to get at his inner motive instead of trying to impress his body forcibly into service.

The Author. So far from implying criticism, the suggestion referred to in the discussion sprang from the very effectiveness of Mr. Rice's relations to the Student Branches. No one knows better than the engineering instructor his interest in the Branches, or the value of his visits to engineering schools. But, as the chief executive officer of the Society, the Secretary has the responsibility for many activities, of which the Branches constitute but one. The President and Council members are men of important outside interests. None of the officers of the Society are in a position to give all, or even a large portion, of their time to the Branches, even if they would.

And yet there is a great field there. The Branches are increasing in number and membership. Their value, already demonstrated, may be greatly enlarged; and the good work done by the Society under existing conditions justifies an extension of its activity. The present officers cannot, in justice to their other responsibilities, however, be called on for a much greater contribution of time than they are now giving.

What is suggested, therefore, is a salaried officer of the Society, who should be a college man of experience, wide acquaintance and constructive ability, who would, under Mr. Rice's direction, organize Student Branches and supervise their activities, bring the officers and active members into closer relations with engineering students, assist in arranging schedules of speakers, help students in securing wise summer employment, and inquire into and develop such new activities as this industrial service work, which the writer believes to be of sufficient promise to justify, of itself, the step proposed. But it is a work which is expert in nature and must be guided wisely to keep it free from fads and the mistakes of immature enthusiasm.

This program is merely a suggestion. The right man would materially extend the field as his work progressed. Like the education, with which it would be allied, it would be constructive work for the future and its influence would be more felt in the next generation.

No. 1433

CLASSIFICATION AND HEATING VALUE OF AMERICAN COALS

By William Kent, New York City

Member of the Society

The recent publication by the United States Bureau of Mines in Bulletin No. 22 of over 3000 analyses and results of calorimetric examinations of American coals offers the best opportunity that has ever been had for a study of the long-mooted questions of the classifications of coals and of the relation of their chemical composition to their heating value.

2 The writer has made an attempt at such a study and gives the principal results of it herewith, although they are by no means complete. It was not possible in the limited time at his disposal to take all the analyses of heating values and compare them, but instead he has made a selection of 155 analyses of coals from different states, showing practically the extreme range of composition of heating value of the coals of each of these states, whenever a sufficient number of coals of such states are given in the bulletin. The most important items of the ultimate and proximate analyses were tabulated, viz., the S, H, C, O, and N of the ultimate analysis as referred to the combustible (coal free of moisture and ash), also the volatile matter, the moisture and the ash of the proximate analysis, the moisture and ash being referred to the coal as received, and the volatile matter being referred to the combustible.[1] The fixed carbon was omitted in order to save space. Referred to combustible it is 100 per cent minus the volatile matter of the combustible, and referred to coal as received it is 100 per cent minus the sum of moisture ash and volatile matter.

3 The actual analyses, both proximate and ultimate, were made on air-dried coal, the surface moisture having been first removed.

[1] See Table 1.

Presented at the Spring Meeting, St. Paul-Minneapolis, June 1914, of The American Society of Mechanical Engineers.

The results as given in the bulletin are calculated to three differen bases: (1) as received, (2) dry coal, (3) ash and moisture fre (commonly called combustible); and in many cases to a fourth basis ash, moisture and sulphur-free. For the purpose of comparison however, other information not contained in the bulletin was desired such as the B.t.u. per lb. of coal air-dry, ash-free, and air-dry, asl and sulphur-free. The writer has calculated and tabulated thes omitted items, but it should be stated that the figures which he obtaine relating to B.t.u. calculated to the sulphur-free basis are probably to high in many cases of high sulphur coals, as will be shown later.

4 Having thus tabulated the results, the questions to be solve are (1) how shall the coals be classified; (2) what relation does th heating value of the coals bear to the chemical composition.

5 The earliest published classification of American coals is tha of Persifor Frazer, Jr., in 1874 (Trans. A.I.M.E.). He divide the coals into anthracite, semi-anthracite, semi-bituminous and bituminous, and he used what he called the "fuel-ratio," or the ratio o fixed carbon to the volatile matter in the combustible, as the basis o subdivision between the several classes. The names he used are stil retained, although the figures of fuel-ratio which he gave are n longer accepted as marking the divisions into classes; but the bituminous coals have been divided into two or more classes, a bituminous and lignite, and the lignites have been recently subdivided by the U. S. Geological Survey and the Bureau of Mines into sub-bituminous and lignite.

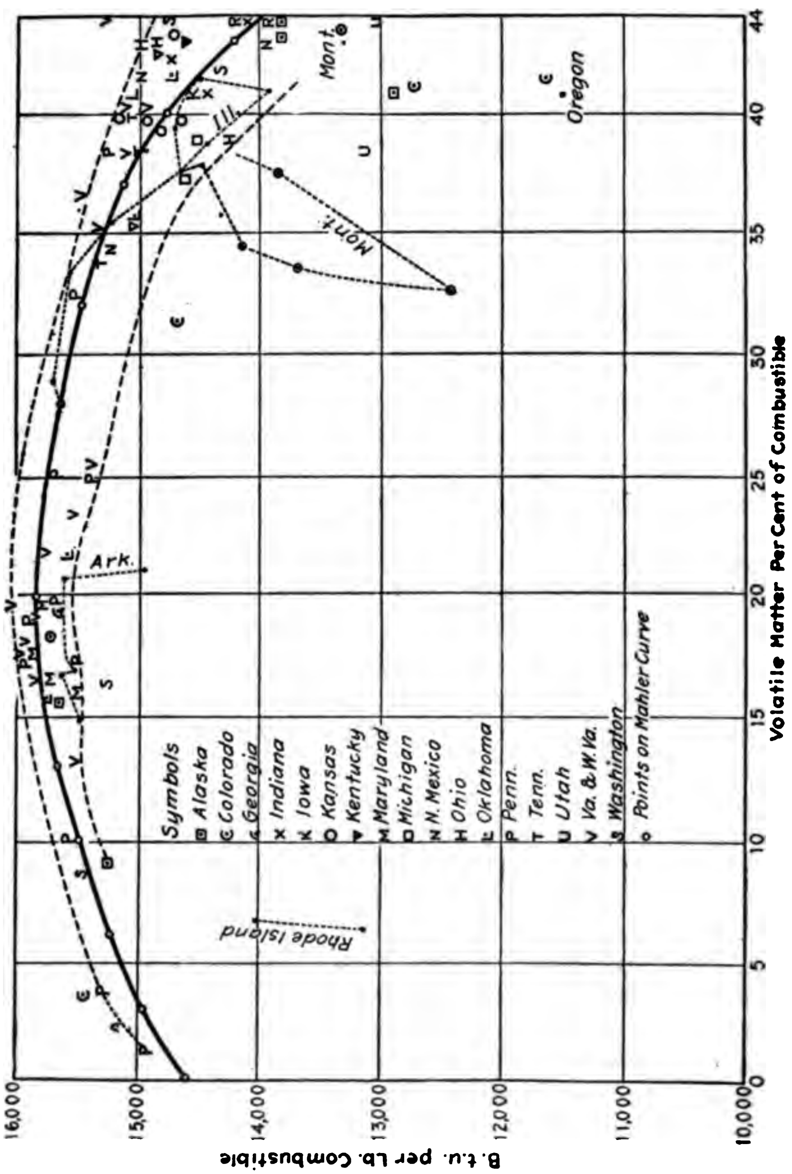
6 Frazer's method of using the ratio of one constituent to another, or of one to the sum of two others, has been followed by several writers, such as David White[1], who uses the ratio $\frac{C}{O+A}$ in which C, O and A are respectively the carbon, oxygen and ash in the dry coal. The expression of the relation of two elements as a ratio is not as convenient for the purpose in view as the expression of the same relation as a percentage, or the ratio of one of the two elements to the sum of the two. Thus by Frazer's method two coals having fuel ratios differing as widely as $\frac{97}{3}=32.3$ and $\frac{92}{8}=11.5$ are

[1]U. S. Geol. Survey, Bulletin 382, 1909. The Effect of Oxygen in Coal. David White.

both anthracites, the first having 3 per cent and the second 8 per cent of volatile matter in the combustible, while two other coals, also differing 5 per cent, viz., one with 48 and the other 53 per cent of volatile matter in the combustible, have fuel ratios that differ but little, or $\frac{52}{48}=1.08$ and $\frac{47}{53}=0.90$. White plots the B.t.u. per lb. dry coal as ordinates and the ratio $\frac{C}{O+A}$ as abscissae, and obtains a curve that begins in a nearly vertical direction, where with coal very high in oxygen and ash the ratio is less than 1, and ends in a direction that is nearly horizontal, becoming actually horizontal when $\frac{C}{O+A}=0$ and the ratio becomes infinity, while if he had plotted the B.t.u. against the ratio $\frac{C}{C+O+A}$, which may be expressed as a percentage, the curve would have become an inclined straight line.

7 In 1892 the writer published an article in Mineral Industry giving the results of a study of Mahler's researches on European coals. By plotting the B.t.u. against the percentage of fixed carbon in the combustible and drawing a curve through the plotted points, he showed that the B.t.u. per pound of combustible of the coal tested by Mahler was related to the percentage of volatile matter in the combustible. Messrs. Lord and Haas published later the results of their tests of Pennsylvania, Virginia, and Ohio coals and stated that they had found no such relation, but on the contrary that the combustible portion of coals of certain districts had remarkably uniform heating values, which were independent of the percentage of volatile mattter. In a discussion of Lord and Haas's paper[1] the writer plotted their results and compared them with the curve derived from Mahler's tests, and showed that the Pocahontas coals fell on the Mahler curve, and that the tests of Pennsylvania and Ohio coals having about 45 per cent of volatile matter fell within the Mahler field, showing a variation of 3 or 4 per cent as maximum from the curve, but that as Lord and Haas said, each coal district had a law of its own, and that two

[1]Trans A.I.M.E., Vol. 27, p. 946.


B.t.u. per Lb. Combustible
Volatile Matter Per Cent of Combustible
Symbols
Alaska
Colorado
Georgia
Indiana
Iowa
Kansas
Kentucky
Maryland
Michigan
N. Mexico
Ohio
Oklahoma
Penn.
Tenn.
Utah
Va. & W. Va.
Washington
Points on Mahler Curve
Rhode Island
Ark.
Mont.
Ill.
Oregon

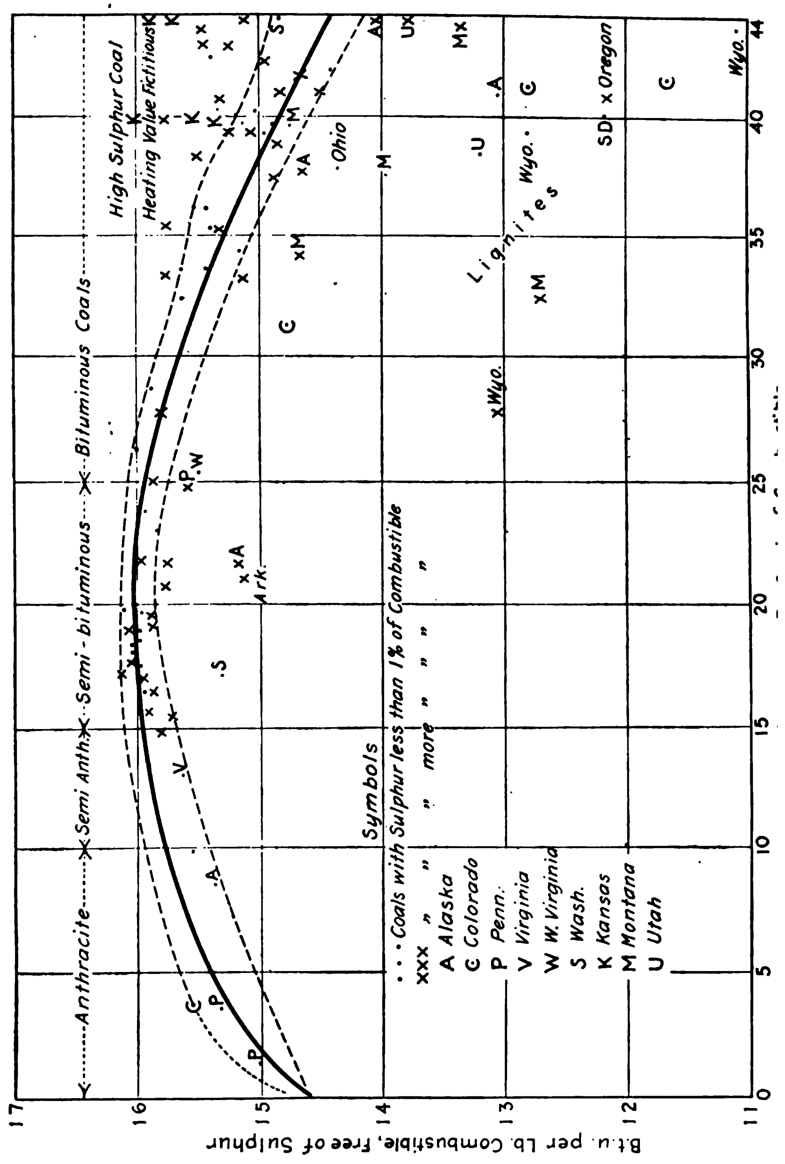
Ohio coals from different districts in the same state each with the same percentage of volatile matter in the combustible might vary 6 or 8 per cent in heating value per pound of combustible.

8 In studying the 155 coals, the writer first plotted the B.t.u. per lb. combustible with the results which are shown graphically in Fig. 1. This plotting shows that all the coals of the Appalachian field come close to the original curve drawn from Mahler's tests of European coals, when the volatile matter in the combustible is 35 per cent or less. For coals higher in volatile matter, and for Western coals generally, the heating value varies over a wide range and appears to have no relation to the volatile matter, but each district has a law of its own. The Illinois coals are all found within the small area shown by dotted lines. Perhaps the most important conclusion from Fig. 1 is that all the semi-bituminous coals of the Eastern states, and those from the Western states and Alaska, with a very few exceptions, have a heating value per pound of combustible that is very close to 15,750 B.t.u. With bituminous coals and lignite containing over 36 per cent of volatile matter in the combustible there appears to be no law connecting the heating value with the percentage of volatile matter, and the plotting is not continued beyond 44 per cent.

9 As many of the coals high in volatile matter are also high in sulphur, it was attempted to find if high sulphur was the cause of some of the variation of the heating value, but the results are negative. When the heating value per pound of combustible is converted for sulphur by the usual method, by subtracting 4050 B.t.u. per lb. S, and dividing by 1 minus (% S÷100), the value thus found is often far higher than the heating value per pound of combustible of coals of the same districts that are low in sulphur. In Fig. 2 the results thus obtained are plotted, the high value referred to being shown at the upper right hand of the diagram, marked "high sulphur coals, heating values fictitious." Lower values for these coals might be found if they were converted by the "unit coal" method of Parr and Wheeler (Bulletin 37, 1909, of the Illinois University Engineering Experiment Station) viz.

$$\text{B.t.u. per pound unit coal} = \frac{\text{Indicated dry B.t.u.} - 5000\,\text{S}}{1.00 - (1.08\,\text{ash} + 0.55\,\text{S})}$$

10 The next attempt at relating the heating value of these coals


Anthracite
Semi Anth.
Semi-bituminous
Bituminous Coals
High Sulphur Coal
Heating Value Fictitious
Lignites
Ohio
Ark.
Wyo.
Oregon
SD
Symbols
· · · Coals with Sulphur less than 1% of Combustible
xxx " " more " " " "
A Alaska
C Colorado
P Penn.
V Virginia
W W. Virginia
S Wash.
K Kansas
M Montana
U Utah
0 5 10 15 20 25 30 35 40 44
17 16 15 14 13 12 11
B.t.u. per Lb. Combustible, Free of Sulphur

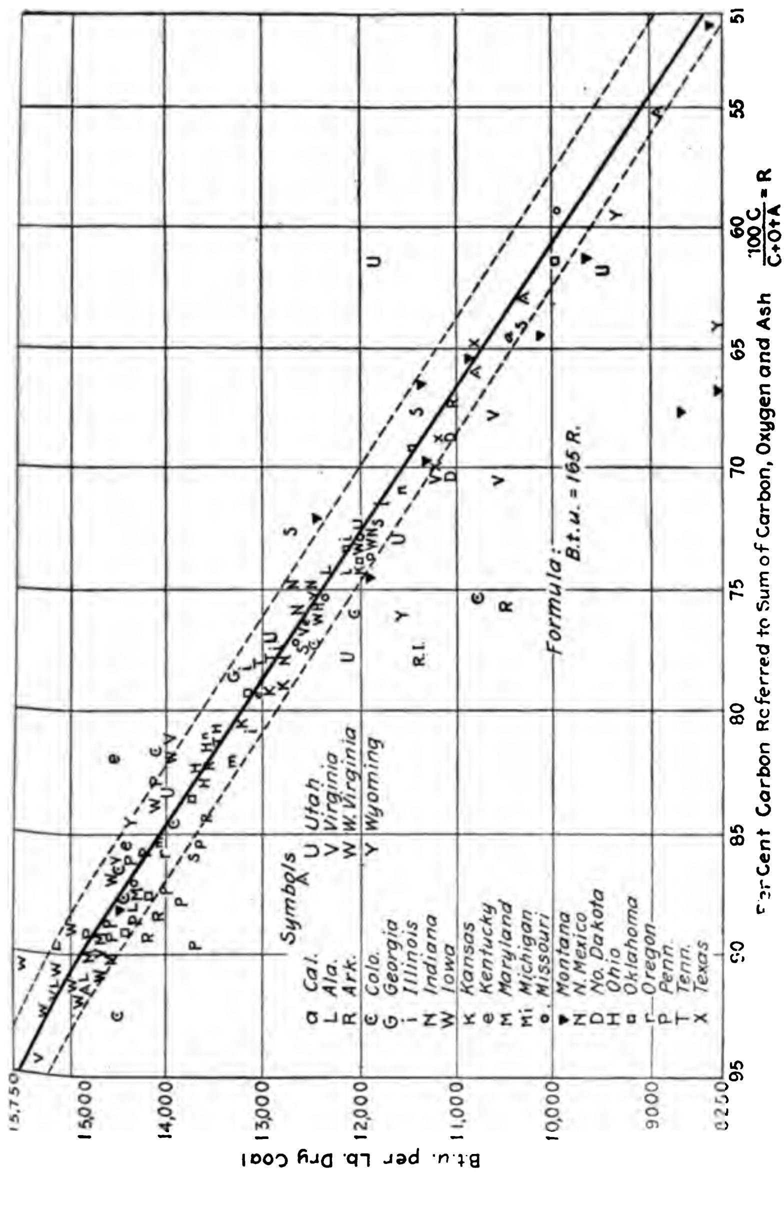
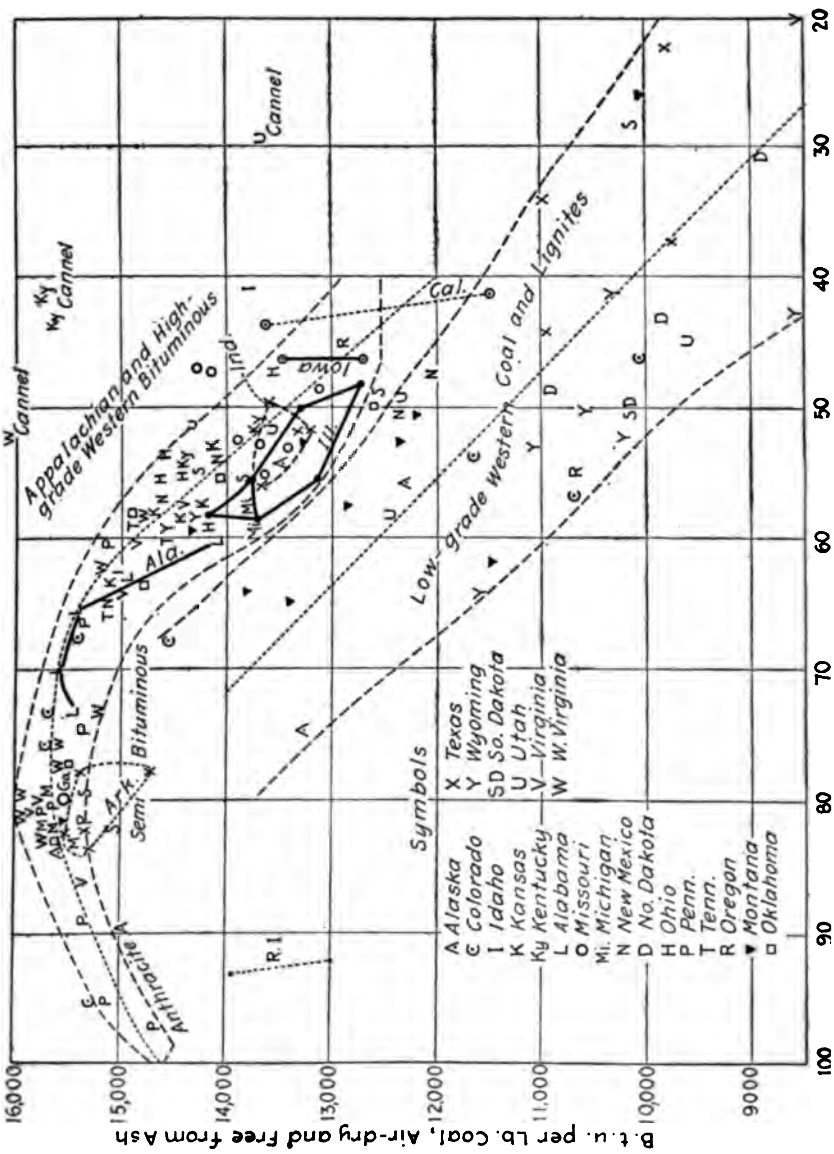


FIG. 3 RELATION OF HEATING VALUE TO CARBON REFERRED TO SUM OF CARBON, OXYGEN AND ASH


B.t.u. per Lb. Coal, Air-dry and Free from Ash
16,000
15,000
14,000
13,000
12,000
11,000
10,000
9000
100
90
80
70
60
50
40
30
20
Anthracite
Semi Bituminous
Appalachian and High-grade Western Bituminous
Low-grade Western Coal and Lignites
Cannel
Ala.
Ind.
Ill.
Iowa
Cal.
Ark.
R.I.
Symbols
A Alaska
C Colorado
I Idaho
K Kansas
Ky Kentucky
L Alabama
O Missouri
Mi. Michigan
N New Mexico
D No. Dakota
H Ohio
P Penn.
T Tenn.
R Oregon
▼ Montana
□ Oklahoma
X Texas
Y Wyoming
SD So. Dakota
U Utah
V Virginia
W W. Virginia

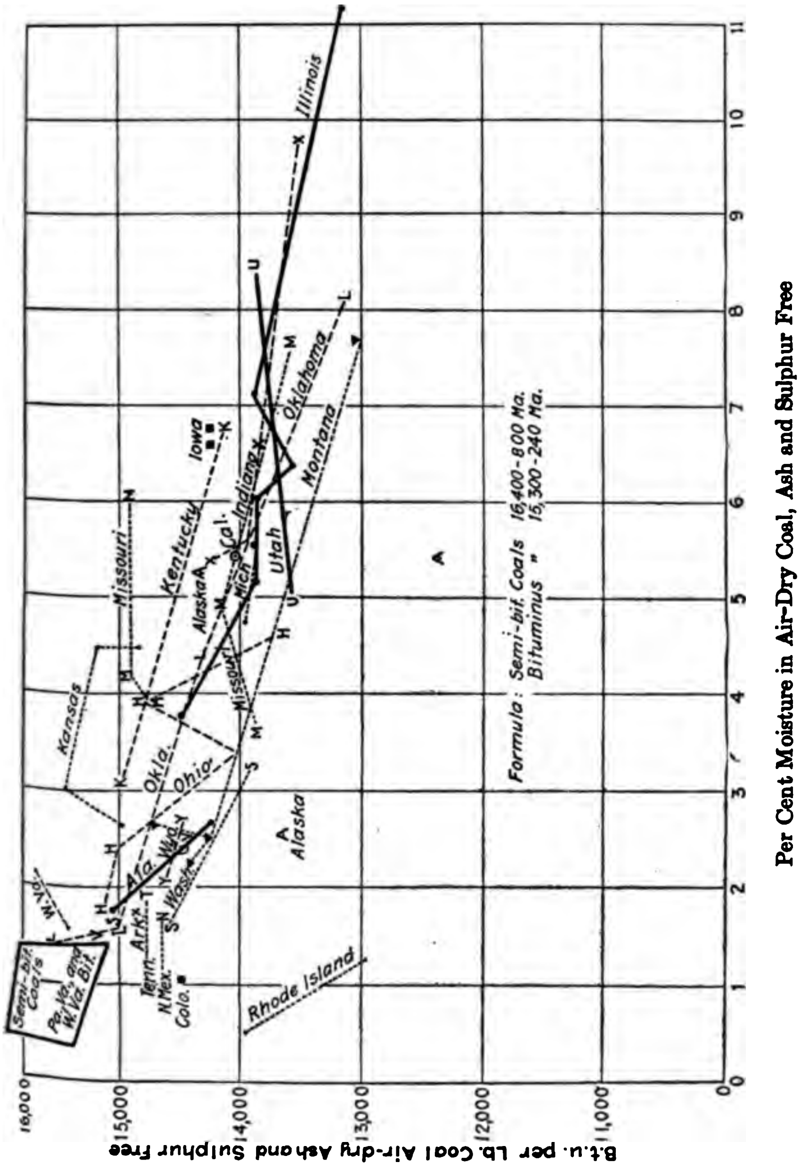


FIG. 5 RELATION OF HEATING VALUE TO MOISTURE IN AIR-DRY COAL, ASH AND SULPHUR FREE

to their chemical composition was by the method of David White, modified by converting his ratio $\frac{C}{O+A}$ into percentage $\frac{C}{C+O+A}$.

A straight line whose formula is B.t.u. $= 16500 \frac{C}{C+O+A}$, may be drawn through the plotted points, but the variations of many of the points from the line indicate that the method is of little if any practical value (see Fig. 3).

11 Fig. 4 shows the result of plotting the B.t.u. per lb. of air-dry coal free from ash to the fixed carbon. By this method the coals are apparently divided into two principal classes: (*a*) high-grade coals including as subdivisions, anthracite, semi-anthracite, and the Appalachian and other good bituminous coals; and (*b*) low-grade Western coals and lignites. The variations from the average lines drawn through the plotted positions are in many cases so great that this method cannot be considered as of any value.

12 Fig. 5 shows the result of plotting the heating value per pound of air-dry coal and ash and sulphur free, against the percentage of moisture in such coal, for those cases in which the moisture does not exceed 11 per cent. The results indicate that this method may prove to be of considerable importance when it is applied separately to the coals of different states or districts, especially the bituminous coals of the Middle West. The high position of the Kansas coals and of one of the Missouri coals may be due to the error of the common method of correcting for sulphur.

13 After studying the coals by the method of plotting as described, Table 2 was constructed, in which a revised classification is attempted. The last five columns show the differences in B.t.u. per lb. between the B.t.u. per lb. given and those that result from calculation by Dulong's formula, by the Mahler curve, or by the average lines of Figs. 3, 4 and 5. The extent of these differences suggests that in some cases the calorimetric determinations, or the analyses, or both, may be in error and indicates the necessity for thoroughly checking the loss in air-drying, the moisture determinations of the air-dried coal, the analyses, proximate and ultimate, and the calorimetric work. The revised classification is as follows:

TABLE 1 CLASSIFICATION OF COALS

	Volatile Matter per cent of Combustible	Oxygen in Combustible per cent	Moisture in Air Dry Coal free from Ash per cent	B.t.u. per Lb. Combustible	B.t.u. per Lb. Coal Air-Dry Ash-Free
I Anthracite.........	less than 10	1 to 4	less than 1.8	14,800 to 15,400	14,600 to 15,400
II Semi-anthracite....	10 to 15	1 to 5	less than 1.8	15,400 to 15,500	15,200 to 15,500
III Semi-bituminous..	15 to 30	1 to 6	less than 1.8	15,400 to 16,050	15,300 to 16,000
IV Cannel*.........	45 to 60	5 to 8	less than 1.8	15,700 to 16,200	15,500 to 16,050
V Bituminous, high grade...........	30 to 45	5 to 14	1 to 4	14,800 to 15,600	14,350 to 15,500
VI Bituminous, medium grade.......	32 to 50	6 to 14	2.5 to 6.5	13,800 to 15,100	13,400 to 14,400
VII Bituminous, low grade...........	32 to 50	7 to 14	5 to 12	12,400 to 14,600	11,300 to 13,400
VIII Sub-bituminous and lignite.......	27 to 60	10 to 33	7 to 26	9,600 to 13,250	7,400 to 11,650

* Eastern cannel. The Utah cannel is much lower in heating value.

TABLE 2 CLASSIFIED LIST OF COALS

	Order in Table 1	Combustible				Air-dry, Ash-free		B. t. u. Greater (+) or Less (—) than Estimated by				
								Combustible		Air-dry, Ash-free		Dry Coal
		Vol.	S.	O.	B. t. u.	Moist	B. t. u.	Dulong Formula	Mahler Curve	F. C. Curve	Moisture Formula	$\frac{C}{C+O+A}$
I. Anthracite												
Alaska	4	8.8	0.73	4.04	15,203	1.55	14,968	— 50	— 76	— 263	+ 87	— 172
Colo	5	3.6	0.87	1.32	15,413	1.08	15,247	— 164	+ 373	+ 305	— 183	— 756
Pa	7	1.3	1.00	2.13	14,882	1.43	14,666	+ 127	+ 172	— 243	......	—1102
Pa	8	3.7	0.68	2.41	15,248	0.83	15,123	— 75	+ 208	+ 193	......	— 693
Wash	5	8.5	0.72	2.67	15,410	0.80	15,367	— 6	+ 20	+ 93	— 385	— 453
II. Semi-Anthracite												
Ark	1	14.8	2.33	2.57	15,496	1.45	15,272	— 21	— 176	— 61	......	— 386
Pa	11	10.0	0.74	2.17	15,457	0.91	15,398	— 193	— 23	+ 15	— 274	— 457
Va	3	13.1	0.82	4.18	15,500	0.90	15,439	— 46	— 160	— 95	— 233	— 58
III. Semi-Bituminous												
Ala	1	28.8	0.59	4.45	15,757	1.15	15,577	— 65	+ 137	— 15	+ 165	+ 99
Ala	2	27.9	1.58	3.42	15,620	0.94	15,475	— 309	— 40	— 147	+ 23	— 176
Alaska	3	15.5	1.29	3.02	15,651	0.60	15,559	+ 13	— 109	+ 9	— 208	— 236
Ark	2	16.7	3.16	1.69	15,624	0.86	15,525	— 176	— 386	— 61	— 21	— 386
Ark	5	17.0	3.57	1.25	15,530	0.92	15,387	+ 1	— 270	— 213	+ 216	— 531
Ark	6	20.7	1.47	4.27	15,602	1.34	15,393	+ 225	— 238	— 288	+ 249	+ 23
Colo	7	23.8	0.58	4.34	15,849	0.83	15,716	+ 195	+ 49	+ 20	+ 55	+ 212
Colo	8	25.8	0.72	2.29	15,939	1.43	15,712	— 295	+ 199	+ 80	+ 443	— 22

Md.	1	16.5	1.13	2.81	15,710	0.90	15,577	− 81	− 90	− 6	+ 36	− 147
Md.	2	16.0	1.02	2.54	15,640	1.10	15,478	− 180	− 140	− 102	+ 72	− 284
Md.	3	19.7	0.94	3.01	15,826	0.80	15,699	− 65	− 14	− 41	+ 163	− 53
Md.	4	17.5	0.98	2.47	15,856	0.66	15,746	− 61	+ 30	+ 145	+ 28	− 100
Mont.	9	18.3	0.96	2.93	15,721	0.61	15,625	+ 49	− 99	+ 1	− 170	− 149
Okla.	2	21.7	1.15	2.87	15,586	0.53	15,504	− 2	− 244	− 176	− 339	− 260
Okla.	3	15.7	1.36	1.87	15,728	0.70	15,619	− 287	− 52	+ 63	− 56	− 287
Pa.	2	19.0	1.87	3.32	15,840	0.99	15,680	+ 85	+ 10	+ 38	+ 300	+ 34
Pa.	3	24.8	1.81	5.50	15,376	0.40	15,316	+ 110	− 394	− 373	− 557	− 28
Pa.	4	25.0	1.50	3.72	15,660	0.86	15,523	− 203	− 110	− 160	+ 20	− 81
Pa.	6	19.5	1.73	1.99	15,683	1.50	15,624	− 411	− 157	− 22	+ 643	− 308
Pa.	9	17.3	1.63	2.82	15,847	0.65	15,744	+ 149	+ 47	+ 140	+ 65	− 59
Pa.	10	17.2	5.09	1.66	15,493	0.76	15,378	− 95	− 307	− 226	+ 217	− 454
Va.	4	19.0	0.68	3.42	15,840	0.54	15,750	+ 9	+ 10	+ 110	− 131	0
Va.	5	17.5	0.68	2.23	15,910	0.64	15,795	− 236	+ 100	+ 157	− 6	− 179
Wash.	6	16.3	0.48	3.97	15,264	1.67	15,013	− 209	− 516	− 588	+ 14	− 251
W. Va.	2	25.3	0.86	4.13	15,399	1.18	15,218	− 370	− 371	− 458	− 314	− 306
W. Va.	3	23.3	0.61	1.68	15,736	0.90	15,597	− 674	− 84	− 103	+ 55	− 348
W. Va.	4	21.8	1.27	5.52	15,781	0.81	15,655	+ 546	− 49	− 29	+ 59	+ 304
W. Va.	7	19.9	0.60	2.80	16,038	0.69	15,998	+ 178	+ 208	+ 270	+ 166	+ 95
W. Va.	8	16.5	0.79	4.56	15,820	0.65	15,804	+ 255	+ 40	+ 134	− 68	+ 168
W. Va.	10	18.1	0.86	1.97	15,919	0.73	15,802	− 145	+ 99	+ 178	+ 100	+ 149

IV. Cannel

Ky.	2	55.5	1.38	7.57	15,800	0.92	15,646	− 153	......	+3046	+ 198	+ 771
Ky.	3	57.0	1.15	7.61	16,013	1.44	15,784	− 91	......	+3439	+ 686	+ 967
W. Va.	1	47.4	0.92	5.34	16,176	0.84	16,042	− 284	......	+2212	+ 433	+ 674
Utah.	6	67.6	2.32	13.68	14,918	8.26	13,686	+ 172	......	+4974	+ 618	+1683

H in combustible; Ky. 2, 7.13; Ky. 3, 7.46; W. Va. 1, 7.13; Utah 6, 7.73. The highest H. in the other coals is 5.78, Mo. 6.

TABLE 2—(Continued)

	Order in Table 1	Combustible				Air-dry, Ash-free		B. t. u. Greater (+) or Less (—) than Estimated by				
								Combustible		Air-dry, Ash-free		Dry Coal
		Vol.	S.	O.	B. t. u.	Moist	B. t. u.	Dulong Formula	Mahler Curve	F. C. Curve	Moisture Formula	$\frac{C}{C+O+A}$
V. Bituminous, High-Grade												
Ala.	3	33.4	1.13	6.99	15,590	1.23	15,400	+ 564	+ 170	— 24	+ 120	+ 361
Ala.	4	35.3	1.07	7.00	15,214	1.77	14,947	— 50	— 76	— 203	+ 87	— 172
Colo.	4	31.3	0.72	9.38	14,681	1.01	14,533	+ 1	— 849	— 967	— 447	— 46
Colo.	6	33.7	0.56	8.77	15,559	0.87	15,423	+ 489	+ 189	+ 54	— 186	+ 633
Ill.	6	40.0	2.82	9.74	14,818	2.34	14,470	......	......	......	......	......
Kan.	2	39.8	6.68	5.26	15,167	2.86	14,734	+ 69	+ 22	+ 24	+ 908	— 54
Kan.	4	39.5	4.93	7.27	14,809	2.49	14,436	+ 28	+ 38	— 234	+ 395	+ 6
Ky.	4	35.3	0.58	8.05	15,328	1.64	15,095	+ 255	+ 38	— 131	— 9	+ 313
N. Mex.	1	41.5	0.74	8.79	14,875	1.64	14,630	— 145	+ 375	+ 40	......	+ 138
N. Mex.	2	34.4	0.96	6.93	15,221	0.80	15,099	— 258	— 139	— 228	......	+ 148
Ohio	1	45.5	4.58	8.10	14,888	1.75	14,626	+ 186	......	+ 586	+ 264	+ 65
Ohio	4	42.9	3.97	7.04	14,965	2.38	14,642	— 12	+ 725	+ 280	+ 330	— 46
Ohio	5	42.8	3.66	9.01	14,832	3.83	14,431	+ 480	+ 572	+ 83	+ 463	+ 131
Okla.	5	35.5	7.36	3.71	15,025	1.38	14,814	— 299	— 185	— 412	+ 450	— 182
Okla.	6	40.8	2.06	7.35	15,061	1.57	14,825	+ 43	+ 461	+ 151	— 73	+ 43
Pa.	1	38.3	1.38	6.94	15,345	1.42	15,127	+ 132	+ 445	+ 165	+ 32	+ 165
Pa.	5	32.4	1.00	7.35	15,511	1.07	15,346	+ 509	+ 31	— 98	— 76	+ 411
Tenn.	1	38.4	1.17	7.94	14,960	1.97	14,665	— 183	+ 60	— 248	— 35	+ 43
Tenn.	2	33.8	0.95	6.70	15,320	1.08	15,137	— 290	— 40	— 211	— 286	+ 168
Tenn.	3	39.8	5.73	5.14	15,125	1.32	14,921	+ 11	+ 365	+ 103	+ 310	— 82
Va.	1	38.3	1.32	8.01	15,156	1.79	14,887	+ 142	+ 136	— 59	+ 77	+ 155
Va.	2	40.2	0.85	12.18	14,918	2.52	14,381	+ 842	+ 158	— 233	+ 88	+ 619

VI. *Bituminous Medium Grade*

Ala.	5	37.7	1.37	10.45	14,467	2.69	14,078	+ 187	— 553	— 858	— 430	+ 26
Alaska	1	44.2	1.83	14.11	13,838	2.55	13,484	— 673	......	— 661	— 923	+ 217
Cal.	2	53.8	4.80	11.47	14,336	5.19	13,593	— 13	......	+1023	+ 51	+ 127
Ill.	2	41.4	1.36	12.02	14,492	5.15	13,745	+ 477	+ 392	— 589	— 179	+ 245
Ill.	3	37.4	1.14	8.46	14,621	6.02	13,742	— 164	— 499	—1016	+ 8	— 241
Ill.	7	39.3	3.10	9.03	14,724	3.71	14,177	+ 160	— 176	— 521	+ 105	+ 85
Ind.	1	40.9	2.88	9.50	14,492	5.48	13,698	— 58	— 108	— 678	+ 19	— 39
Ind.	3	47.3	6.60	9.96	14,305	5.01	13,576	+ 169	......	+ 76	+ 15	+ 37
Ia.	2	51.2	8 53	8.96	14,206	5.35	13,445	+ 104	......	+ 515	+ 609	— 118
Ia.	3	40.6	6.64	8.03	14,555	6.24	13,647	+ 194	— 305	— 701	+ 540	— 128
Kan.	1	44.2	9.94	5.64	14,724	4.09	14,121	— 12	......	+ 81	+ 967	— 224
Kan.	3	39.8	5.22	5.98	14,922	4.30	14,269	— 163	+ 49	— 333	+ 600	— 151
Ky.	1	44.0	4.29	8.90	14,657	6.52	13,702	+ 137	......	— 143	— 570	+ 37
Ky.	5	43.5	5.64	7.46	14,836	2.98	14,394	+ 592	+ 736	+ 174	+ 447	— 41
Mich.	1	38.8	1.53	9.54	14,999	4.70	13,818	— 234	— 401	— 880	— 203	— 7
Mich.	2	37.1	1.11	10.51	14,603	5.59	13,786	+ 118	— 517	—1017	— 52	— 156
Mo.	1	44.8	5.16	9.53	14,351	4.65	13,682	— 2	......	— 208	+ 55	— 32
Mo.	3	44.6	4.96	11.83	13,892	3.42	13,416	+ 165	......	— 624	— 551	— 202
Mo.	4	50.8	6.33	7.73	14,679	3.69	14,136	— 7	......	+1026	+ 433	— 46
Mo.	5	45.3	9.45	6.28	14,476	2.83	13,921	— 158	......	+ 31	+ 618	— 229
Mo.	6	50.2	6.21	6.12	15,134	5.68	14,276	— 66	......	+1241	+ 941	— 72
Mont.	5	34.3	4.86	9.50	14,134	2.42	13,791	— 10	—1226	+ 779	+ 414	— 207
Mont.	8	39.6	0.60	9.77	14,681	2.30	14,342	— 188	— 79	— 428	— 343	— 555
N. Mex.	3	44.3	0.68	12.70	14,539	3.06	14,093	+ 450	......	+ 143	......	+ 404
Ohio	2	37.8	0.63	11.58	14,269	4.69	14,152	— 19	— 751	— 651	— 527	— 111
Ohio	3	47.7	5.74	9.44	14,332	3.30	13,523	— 40	......	+ 128	— 397	— 97
Okla.	4	41.7	2.31	9.26	14,711	4.31	14,075	+ 25	—1000	— 287	+ 60	+ 42
Utah	1	45.6	0.60	13.30	14,245	4.98	13,536	+ 287	......	— 219	— 509	+ 201
Utah	2	47.2	0.62	10.93	14,764	2.47	14,399	+ 190	......	+ 674	— 244	+ 260
Wash.	1	41.8	0.57	12.38	14,348	3.26	13,879	+ 142	— 52	— 553	— 680	+ 257
Wyo.	9	39.6	0.84	9.25	14,793	2.73	14,391	+ 100	+ 32	— 343	— 164	0

TABLE 2—(Continued)

	Order in Table 1	Combustible				Air-dry Ash-free		B. t. u. Greater (+) or Less (−) than Estimated by				
								Combustible		Air-dry, Ash-free		Dry Coal
		Vol.	S.	O.	B. t. u.	Moist	B. t. u.	Dulong Formula	Mahler Curve	F. C. Curve	Moisture Formula	$\frac{C}{C+O+A}$
VII. Bituminous Low Grade												
Alaska	2	40.8	0.94	18.83	12,964	5.42	12,261	— 309	— 40	— 147	+ 23	— 176
Ill	1	46.0	6.33	10.53	14,263	6.75	13,300	+ 270	......	— 245	— 299	+ 79
Ill	4	40.8	5.55	12.02	13,921	6.02	13,084	+ 263	— 679	—1264	— 195	— 3
Ill	5	46.2	6.02	10.09	14,155	10.59	12,657	+ 60	......	— 708	+ 532	— 114
Ind	2	42.2	1.78	10.55	14,746	9.60	13,329	+ 347	+ 346	— 516	— 477	+ 234
Ind	4	44.8	6.73	9.60	14,089	6.17	13,220	— 16	......	— 550	+ 120	— 130
Ia	1	47.5	5.69	9.73	14,305	11.33	12,684	— 114	......	— 306	+ 680	— 94
Mo	2	47.3	4.85	10.68	14,202	7.37	13,156	— 5	......	— 164	+ 149	— 49
Mont	1	33.3	12.99	6.82	13,693	2.37	13,368	— 164	—1708	+ 231	+ 75	— 140
Mont	2	44.4	1.72	20.44	13,338	8.75	12,170*	+1293	......	+ 820	— 866	+ 565
Mont	3	43.7	2.00	15.87	13,162	6.34	12,324*	+ 13	......	+ 724	—1266	— 600
Mont	4	37.5	0.86	16.21	13,865	7.58	12,813	+ 456	—1155	+ 588	— 356	+ 486
Mont	6	32.6	2.88	16.14	12,438	8.09	11,432	— 45	—3042	—1318	—1674	—2583
N. Mex	4	42.8	0.78	14.00	13,939	11.70	12,309*	+ 120	— 28	+ 997	— 107	+ 25
N. Mex	5	46.8	2.38	15.69	13,322	7.87	12,008*	+ 94	......	+1046	— 699	— 122
Okla	1	45.9	5.93	10.62	13,667	7.74	12,609	— 133	......	— 856	— 233	— 197
Ore	3	48.1	1.65	......	14,618	11.88	12,882	+ 421	—3107	+ 27	+ 605	......
Utah	3	38.4	0.56	18.13	13,118	5.60	12,384	+ 723	—1782	+ 109	—1522	— 89
Utah	4	45.4	7.27	10.05	13,586	9.65	12,276	— 189	......	+1114	+ 35	— 676
Utah	5	44.0	7.10	14.18	13,081	11.47	11,374	— 103	......	+ 287	— 108	— 443
Wash	2	47.5	0.44	17.11	13,423	6.56	12,548	+ 255	......	+1411	—1134	+ 111

* Montana 2 and 3 and New Mexico 4 and 5 are classed as sub-bituminous in Bulletin 22 of the Bureau of Mines.

VIII. Sub-Bituminous and Lignite												
Ark	3	52.1	0.96	21.17	12,497	22.00	9,750	+ 496	......	+ 75	—1190	—1960 L
Cal	1	53.5	4.62	16.79	12,890	10.95	11,478	— 107	......	— 732	— 754	—1887 S
Colo	1	41.4	0.44	16.97	11,619	8.21	10,664	—1397	—1981	—1061	—2110	—1657 S
Colo	2	45.5	0.51	16.52	13,239	15.35	10,094	+ 223	......	— 668	—1378	— 254 S
Colo	3	41.1	0.39	18.00	12,746	8.68	11,638	— 33	—1854	— 87	—1563	— 476 S
Mont	7	69.0	1.86	23.47	11,900	15.55	10,143	+ 146	......	+1774	—1365	— 221 S
Mont	10	54.1	0.67	26.64	10,211	25.02	7,656	+ 162	......	—1656	—3806	—2805 S
N. Dak	1	49.8	1.16	......	11,398	13.93	9,801	......	......	— 599	—2044	 L
N. Dak	2	56.7	2.04	17.69	12,557	26.20	8,886	+ 297	......	+ 61	+ 658	— 528 L
N. Dak	3	45.9	0.86	22.67	12,101	11.66	10,885	+ 544	......	— 202	—1517	— 241 L
Ore	1	44.0	1.15	19.68	12,769	10.16	11,471	......	......	+ 183	—1579	— 43 S
Ore	2	47.0	5.52	......	11,493	7.05	10,684	......	......	—1203	—2473	...... S
S. Dak	1	40.0	0.68	......	12,098	15.77	10,189	......	—2662	—1123	—1267	 L
Tex	1	59.6	1.46	18.99	13,043	15.73	11,077	+ 341	......	+1729	—1801	+ 130 L
Tex	2	70.9	1.00	......	10,811	23.58	10,169	......	......	+2002	—1003	 L
Tex	3	45.3	1.61	18.66	12,890	11.02	11,578	+ 452	......	+ 382	—1908	— 117 L
Tex	4	49.6	0.90	20.54	12,452	11.82	11,036	+ 276	......	+ 428	—2366	— 251 L
Utah	7	46.6	4.88	22.14	11,264	15.35	9,535	— 111	......	—1115	—1670	— 730 B
Wash	4	54.6	0.53	22.06	12,226	17.21	10,122	+ 307	......	+ 422	+ 14	— 183 S
Wyo	1	27.8	1.09	10.94	12,956	9.56	11,573	— 177	—2704	—1489	— 127	—1002 S
Wyo	2	44.3	0.36	24.35	11,722	9.75	10,581	+ 715	......	— 706	—1353	— 427 S
Wyo	3	39.3	0.17	21.95	12,683	12.54	11,093	+ 847	—2217	— 544	—1177	+ 30 S
Wyo	4	59.9	1.18	23.41	11,194	24.09	8,496	+ 266	......	+ 996	— 918	— 448 S
Wyo	5	47.5	4.04	17.06	12,447	18.84	10,103	+ 6	......	— 222	— 317	— 622 S
Wyo	6	43.5	0.72	25.54	11,030	7.55	10,198	+ 521	......	—1327	—3286	— 906 B
Wyo	7	50.6	2.17	29.86	9,630	22.69	7,458	+ 492	......	—2317	—2263	—2383 S
Wyo	10	49.4	0.77	33.14	10,141	14.85	8,666	+1292	......	—1751	—3068	— 486 S
Not Classified												
R. I	1	6.6	0.05	5.59	13,120	1.26	12,955	— 749	—2170	—2173	—2037	—1410
R. I	2	6.3	0.09	3.27	14,002	0.52	13,930	— 207	—1208	—1138	—1237	—1536
Alaska	5	21.7	10.76	5.28	13,945	4.77	13,279	— 287	—1885	—1046	+ 297	— 313
Ark	4	21.0	1.43	6.44	14,945	1.77	14,722	......	— 895	— 13	+ 7	— 41
Idaho	1	50.9	4.77	......	16,457	16.42	13,757	......	......	+1607	+2972	......

L, Lignite; S, Sub-bituminous; B, Bituminous; Classification of the U. S. Bureau of Mines.

Wyoming 6, Sample taken 10 ft. from entrance, coal very much weathered; Wyoming 7, Surface exposure; Wyoming 10, Shallow prospect pit, coal badly weathered.

The Rhode Island coals are graphited and are not used as fuel. Alaska 5 and Arkansas 4 may be classed as semi-bituminous by their percentage of volatile matter, but they are higher in oxygen and in moisture, and lower in heating value than other semi-bituminous coals. The Idaho coal is apparently a cannel coal very high in moisture, but the ultimate analysis is lacking.

DISCUSSION

P. F. Walker. I believe that Mr. Kent's paper throws considerable light on the coal question, but am inclined to believe that the results are of more value negatively than positively, so far as the estimation of heating values from proximate analysis is concerned.

Very shortly after coming into the Western country, nine years ago, and beginning to use the lower grades of bituminous coal in Kansas and western Missouri, I found that the heat values per pound of combustible, as published by Mr. Kent and based on his study of Mahler's researches, did not apply. Not only did the coal in general fail to match up with Eastern coal, but marked differences within a comparatively limited area occurred. This was not so surprising when one considers that some of the coal measures now being worked in Kansas are situated, stratigraphically, 2000 ft. above others.

Many of us would like to see some method established by which heat values could be estimated with a fair degree of accuracy from the proximate analysis, thus avoiding the more exact and laborious methods of the ultimate analysis and the calorimetric test alike. It is not so important to know the exact position of a given coal in a classification established on chemical properties as to know its value in heat. Is there, then, any method by which the quick and reliable estimate may be made? And more specifically, does the study of government analyses here presented to us, go far in this direction?

Emphasis is laid in this paper on air dried coal, with especial reference to its moisture content and fixed carbon content. The entire question of moisture content of coal is a complex one. In the work of analysis by the United States Bureau of Mines, air drying of samples was carried out as a laboratory convenience. The sole purpose was to bring the coal to the condition of the surrounding atmosphere to prevent change of weight during handling and weighing. In the process, air was warmed and drawn through the dryer at from 10 to 15 deg. fahr. above room temperature. The heating lowered the humidity percentage, but in all cases the absolute degree of humidity was dependent upon the temporary conditions of the atmosphere. In the same laboratory, therefore, there might be marked differences in the extent of drying the coal at different seasons of the year as the humidity is changed far more in heating the air during the cold winter months. Also, more marked differences might occur among laboratories located in various parts of the country.

It will be observed that one set of values in Mr. Kent's table is based on moisture remaining in the coal after air drying, and the chart indicating relation of heating value to moisture in air dry coal shows that the quantities involved are of small magnitude. Differences due to varying atmospheric conditions or varying laboratory methods, or both, are thus thrown on a relatively small quantity, and the result is apparent. The variation in fixed carbon values because of such laboratory inaccuracies as these would not be so pronounced, but the wide fluctuation of values on the fixed carbon basis, as shown in another chart, is due to another well established cause. This cause is the same as that which makes the estimate by the earlier Mahler method inaccurate; namely, in the low grade bituminous coals, the volatile gases are made up of numerous hydro-carbon constituents, differing so widely in the amount of carbon which they carry from the fuel, that the solid or fixed carbon does not represent the real condition as to heat value in any such degree of regularity as is found in the case of the anthracite and other high grade coals.

A very brief analysis of results given in the final tables of the paper will show the extent of these variations. For the high grade bituminous coals, in the moisture formula column it is seen that the variations range from -447 to $+908$. This means that in an estimation of heat value the error ranges from 3 per cent high to 6½ per cent under. For the medium grade bituminous coals, the range is from -923 to $+967$, or from 6.4 per cent high to 7.3 per cent over. For both grades of coal, corresponding figures from the fixed carbon column show variations considerably greater than these even. A glance at the values in these two columns for the medium grade bituminous is sufficient to show the great magnitude of the variations between true values and these estimates.

The information presented in these tables and charts is most valuable, but I am forced to the conclusion that the way out for a simple and direct method of estimating heat values is not yet in sight. The direct calorimetric determination is a process, the labor and time for which are soon equalled by the labor and time spent in multiplying the steps in the proximate analysis and its result is to be trusted in far greater measure than that from the other can ever expect to be, especially when dealing with the lower grades of fuel. In my opinion, the most fruitful field for study in this connection is the volatile matter with its ever changing character with respect to carbon and hydrogen content.

A. G. Christie. I am inclined to agree with the opinion of Professor Walker that a proximate analysis is no reliable indication of the heating value of coal. In this connection I wish to refer to a bulletin recently published by the University of Wisconsin by Mr. O. C. Berry on the tar forming temperatures of American coals. The object of the investigation was originally in connection with gas producer work, but incidentally we found out a number of things about American coals that were embodied in that bulletin.

From investigations of the low grade coals which you get in the West, the variations in the character of the volatile matter become very prominent. It seems as though the volatile matter contained variables such as Professor Walker has stated in the carbon-hydrogen content. And also there seemed to be indications that in coals of the lignite and semi-lignite series, there were combinations of what one might call acetic and carbolic acid derivatives. Time was not available to go into an investigation of these combinations, but there did seem to be considerable quantities coming off where tar was expected. The tar from the Western coals was comparatively slight in amount and yet the volatile matter was extremely high. That would seem to indicate that there were combinations present which were not of high carbon-hydrogen ratios. The heating values of these coals were low. We found that a better indicator than any proximate analysis was shown by the ultimate analysis considering only the ratio of the carbon and hydrogen.

The Author. Referring to Mr. Christie's statement that "a proximate analysis is no reliable indication of the heating value of a coal," it would be strictly true if he added to it the words "when the volatile matter is more than 35 per cent of the combustible." When thus modified the statement would be in exact accordance with what is said in paragraph 8 of my paper, viz.: "The plotting shows that all the coals of the Appalachian field, cannel coals excepted, come close to the original curve drawn from Mahler's tests of European coals when the volatile matter in the combustible is 35 per cent or less. For coals higher in volatile matter and for Western coals generally, the heating value varies over a wide range and appears to have no relation to the volatile matter, but each district has a law of its own."

Undoubtedly, as Mr. Christie says, the character of the volatile matter in the Western coals differs widely. The chief difference is in the percentage of oxygen. For example, in seven Illinois coals the oxygen ranges from 22.3 to 29.0 per cent of the volatile matter; in six Ohio coals it is from 16.6 to 30.6 per cent; in four Oklahoma coals it is from 10.5 to 22.2 per cent, and in five Montana coals it is from 20.5 to 46.0 per cent. The precentage of oxygen might be taken as an indication of the heating value of these coals, but it is only a rough indication; for it appears that in some coals high in oxygen, part of the oxygen may be combined with carbon, instead of all being combined with hydrogen as it is assumed to be in Dulong's formula. The carbon-hydrogen ratio, for the same reason, can never be anything more than a rough indication of the heating value, for the variation in this ratio is a consequence of the variation in oxygen. If oxygen is high the carbon-hydrogen ratio must necessarily be low, as the hydrogen in all the high oxygen coals varies but little. In future studies of coal it is desirable that the carbon-hydrogen ratio be expressed as a percentage of C or H divided by C+H, for the reason given in the paper.

Professor Walker's statement that the results are of more value negatively than positively, as far as the estimation of heating value from proximate analysis is concerned, is correct for most of the coals mined West of the Mississippi River, and for all coals containing more than 35 per cent of volatile matter in the combustible; but there certainly is a relation between the proportion of volatile matter and the heating value in all the Eastern coals and also those of Oklahoma and Arkansas, when the volatile matter in the combustible is less than 35 per cent. It also appears that in the coals mined East of the Mississippi, as shown in the paper, there is a relation between the heating value and the moisture in the air-dried coal free from ash. In future studies of coals of particular districts, such as those of Indiana and Illinois, this relation should be investigated. Notwithstanding the probable variations in the recorded moisture, this relation appears due to the variation in humidity of the atmosphere in which the coals were dried, but in future researches it should not be difficult to obtain an atmosphere of standard humidity for drying purposes, by means of a chamber in which the moisture is controlled by a hygrostat at the same time that the temperature is controlled by a thermostat.

No. 1434

RAILROAD TRACK SCALE

By W. Wallace Boyd, Baltimore, Md.

Junior Member of the Society

The immense freight traffic of the railroads, with the necessity of interchanging cars in order that the merchandise which they contain may reach its destination without transfer, demands an accurate method of determining the weight of the loaded car as it stands upon the rails.

2 In order properly to weigh these loads, track scales of sufficient capacity and length must be supplied at the necessary points along the route; and above all, these scales must be of such construction as to put their continued accuracy beyond a doubt.

3 In these scales the following essential conditions must be observed:

a The foundations must be massive enough to resist successfully distortion or displacement due to repeated applications of the load.

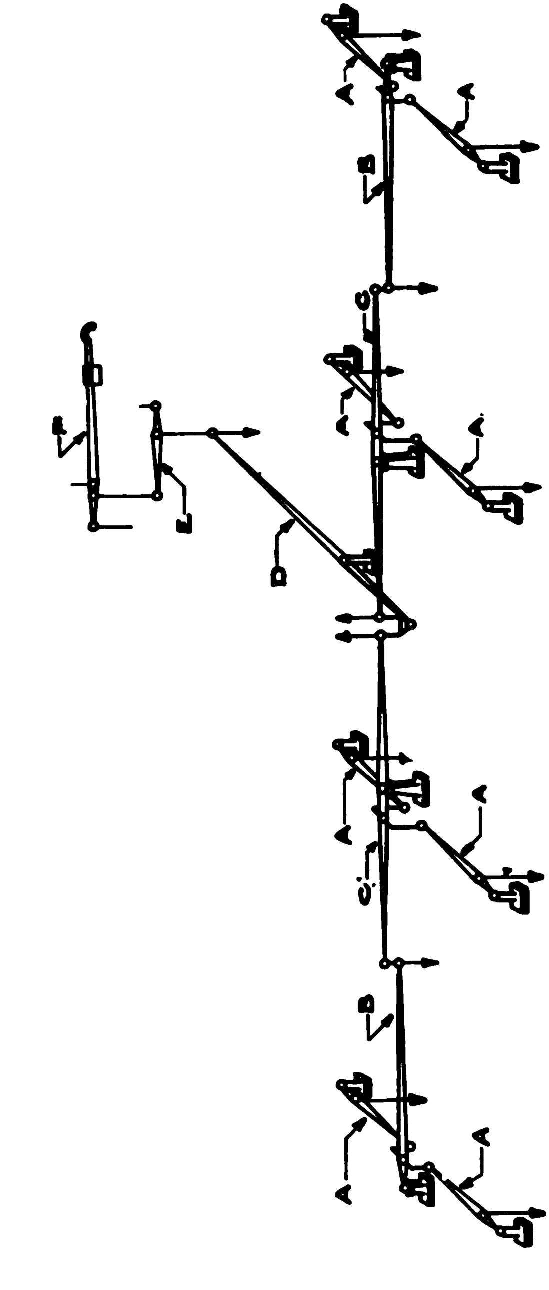
b Connections should be strong enough to resist the load imposed upon them even after considerable corrosion has occurred.

c Unnecessary friction must be eliminated since it produces sluggishness of action, insensitiveness to the smaller loads and inaccuracy in indicating the load.

d There must be a proper distribution of the metal in the levers to avoid undue deflection which may cause either quickness or slowness of action; or may cause inaccuracy through change in the length of the lever arms.

e All knife edges should be in the same plane and each a true edge, hard and sharp; if the edges are not in the same plane, the bearings have a tendency to slide, producing a pressure against the lever on the low side of the knife edge, causing friction and sluggishness of action.

Presented at the Spring Meeting, St. Paul-Minneapolis, June 1914, of The American Society of Mechanical Engineers.



THE ARROWS INDICATE THE DIRECTION OF THE LOAD

A— Main Lever
B— End Extension Lever
C— Middle Extension Lever
D— Fifth Lever
E— Shelf Lever
F— Beam

f There must be provision for draining the pit thoroughly and keeping it dry, to prevent corrosion as much as possible, as well as for inspection. Knife edges are subject to corrosion and this drainage and inspection must be provided in order to insure the continued accuracy of the scale.

4 In the design of a scale the maximum load per truck must be considered, otherwise the levers and connections will be too light and mischievous deflection with possible failure occur. At the present time the latest axle used in freight service has the 6-in. by 11-in. journal with a capacity of 50,000 lb., or a maximum load of 100,000 lb. upon one truck (four wheels).

5 Assuming a scale of four sections, of 150 tons total capacity, the usual allowance would be for a load of 37.5 tons at each section, plus a certain additional load due to the weight of the bridge and its dead load. On this basis, however, the levers and their connections would be too light, since with a load of 50 tons per truck moving across the platform, it is very evident that the stresses would mount higher than those for which allowance was made. By taking into consideration this maximum axle load, it is possible to have the main levers of all track scales made standard and with this standardization they become interchangeable and ready for immediate use.

6 The bridge may be built in one piece, or made in sections having a flexible connection, according to the length of the platform. For scales of large capacity and considerable platform length, it is advisable to design a bridge for the largest possible load that may come upon it, making it in sections, the joints of which come over the main bearings. This obviates the objectionable pounding upon the knife edges, which occurs with a continuous beam, due to deflection, and there are other advantages, such as ease of handling, etc.

7 To relieve the knife edges of some of the hammering, which they are sure to get when the moving wheels roll from the solidly laid track to the live rails on the weigh bridge, it is customary to carry the bridge girders somewhat beyond the end of the platform. The most satisfactory plan would be to prolong the girders for the end span so that the load would be applied at their middle points. This, however, would have the objection that the pit and the bridge would be too long, entailing unnecessary expense. On examining several designs, no standard proportions were observed, the length of the extension varying from less than a fourth the length of the end span down to nothing.

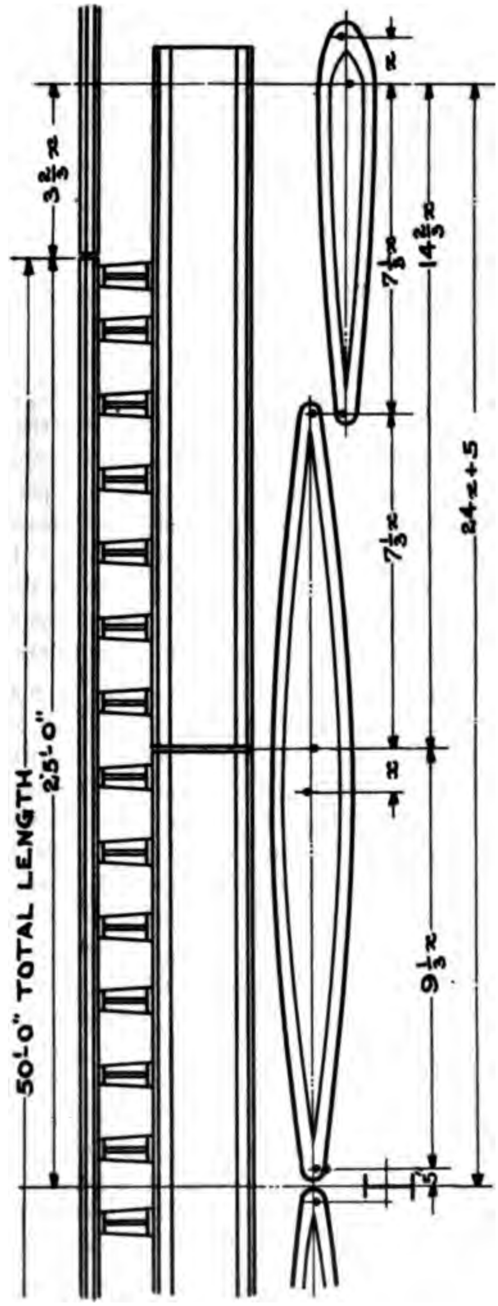


FIG. 2 DIAGRAM SHOWING DIMENSIONS OF PLATFORM, GIRDERS AND LEVERS

PROPORTIONS OF LEVERS

8 In Fig. 1 is shown a lever diagram and in Fig. 2 the platform arrangement and the proportions of the middle and end extension levers for a track scale. In this design it is assumed that the extension of the weigh bridge girders is ¼ of the length of the end spans.

9 Allowing 5 in. on each side of the transverse center line for the connections of the middle extension levers to the fifth lever, the necessary lengths of the weigh bridge girders, and the lengths of the end and middle extension levers may be found as follows, assuming the leverage ratios to be:

Main levers	3
Extension levers	8 1/3
Fifth lever	8
Shelf lever	5

This makes the leverage ratios at the several connection points as follows:

At fifth lever	25
At shelf lever	200
At butt of beam	1000

10 The lever lengths in Fig. 2 are expressed in terms of the short arms, x, of the levers, designated as "fulcrum" lengths. One-half the platform length, which is considered in connection with the levers shown, is 25 ft. = 300 in.

11 The length from the transverse center line of the scale to the load knife edge on the end extension lever is $24x + 5$ in. and the weigh bridge girder extension is one-fourth of the end span, or $\frac{11}{3}x$. Then

$$300 \text{ in.} + 3\ 2/3x = 24x + 5 \text{ in.}$$
$$x = 14\tfrac{5}{8} \text{ in. (approximately)}$$

which gives for the extension of the weigh bridge girders beyond the end of the platform

$$\frac{11}{3} \times \frac{117}{8} = 53\tfrac{5}{8} \text{ in., or 4 ft. } 5\tfrac{5}{8} \text{ in.}$$

The lengths of the levers will be

End extension, fulcrum 14⅝ in., total length 10 ft. 1⅞ in.

Middle extension, fulcrum 14⅝ in., total length 20 ft. 3¾ in.

12 The best condition for the application of the load to the main levers will be when the load knife edge is directly under the

center line of the rail. From center to center of rails is 4 ft. 11 i Allowing $5\frac{1}{2}$ in. on each side of the center line of the lever, for tl connections from the end of the main levers to the main, or loa knife edge on the extension levers, gives a lever 3 ft. long with fulcrum of 12 in., the main lever ratio being 3.

BEARINGS AND KNIFE EDGES

13 Both the knife edges and the bearings against which th rest should be of high-grade tool steel, annealed, hardened and groun Bearing surfaces must be generous and construction and materials the best, otherwise the rough treatment administered to scales, suc as the pounding due to the moving load and the tendency for tl knife edges to corrode, will lead to rapid deterioration. A load of 50C lb. per linear inch of knife edge may safely be allowed, but this shou not be exceeded.

14 The knife edges are of square, or flat, steel forged to a tap of not more than $\frac{1}{4}$ in. to one foot. If a smooth forging is mad very little, if any, finishing is required. After thoroughly annealir and hardening, the bearing edge is made true and keen by grindir and polishing, care being taken to have the faces of the bearing ed at an angle of not less than 90 deg. This edge must be straight i order to provide a full bearing along its length.

15 To insure a firm bearing in the levers, the knife edge sea are made in two ways. By skilful founding, the rough-forged kni edges are cast into the lever in their proper positions, and driven o for finishing, after the lever casting has cooled. This method is chea but it offers opportunity for misalignment. The preferable methc is to broach, or slot, the seats, thus assuring accurate spacing ar alignment, besides making the knife edges interchangeable. Tl knife edges should have sufficient metal backing to keep the un bearing stresses low and prevent bending.

16 The design of the bearings against which the knife edges re will differ according to the capacity of the scale. For the small capacities a direct and more or less non-adjustable bearing may l used; but where the capacity is large, a suspended, adjustable bearin is not only desirable, but necessary.

17 The bearings should be more or less self-aligning, vertic adjustment being provided by wedges over the main bearing, whic have screw adjustment. The wedges are held securely in position b bolts which are drawn down after adjustment has been made.

18 The present practice for the bearings is to use an insert of steel, usually set in the mold before the casting is poured, as in the case of the knife edges, although interchangeability and accuracy can be more readily attained by machining the recess for the seat. Hardening is readily accomplished by withdrawing the steel insert from the casting. A true surface is obtained by grinding and polishing the steel while it is in the casting, care being taken not to draw the temper in the operation.

19 In the track scale, the dimensions of which are given in this paper, the approximate load upon the main knife edge of the main lever is 64,000 lb., which requires a length of knife edge of ap-

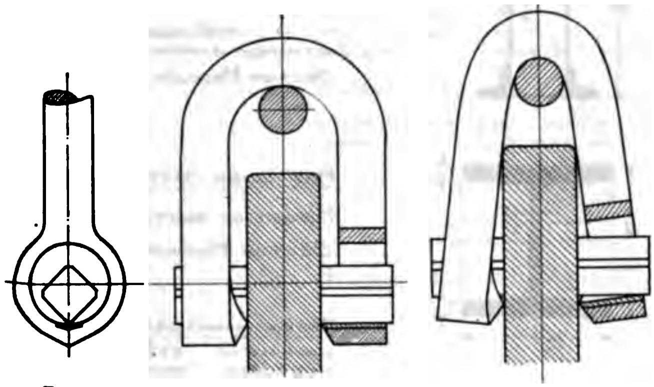


FIG. 3 FIG. 4

FIG. 3 KNIFE EDGE LOOP UNDER NORMAL CONDITIONS
FIG. 4 KNIFE EDGE LOOP UNDER ABNORMAL CONDITIONS

proximately 14 in. in order to keep the load below the specified 5000 lb. per linear inch. The butt knife edge will be 10 in. long, while the tip edge will be 5 in. long. The end extension lever will have the following knife edge lengths: butt 9 in., main 10 in., tip 1¼ in. The middle extension will be as follows: tip 1¼ in., main edge 5 in., bearing edge 9 in., and the tip nearest the fifth lever 2½ in. The fifth lever will be as follows: butt 5 in., main 5½ in., tip 1 in. The shelf lever knife edges need not be considered, because the theoretical lengths will not correspond to the finished article.

LINKS, LOOPS, SHACKLES, ETC.

20 All links, loops, shackles, and similar details should be designed stiff enough to prevent stretching, with consequent binding, which hinders ease of working. If the knife edge loops are not stiff

enough, the load has a tendency to straighten the arch, which t the load upon the knife edge at a point farthest from the su] the load being concentrated, produces excessive bending st either bending the knife edge or snapping it (Figs. 3 and 4). ' knife edges are not reinforced, this bending must be consider

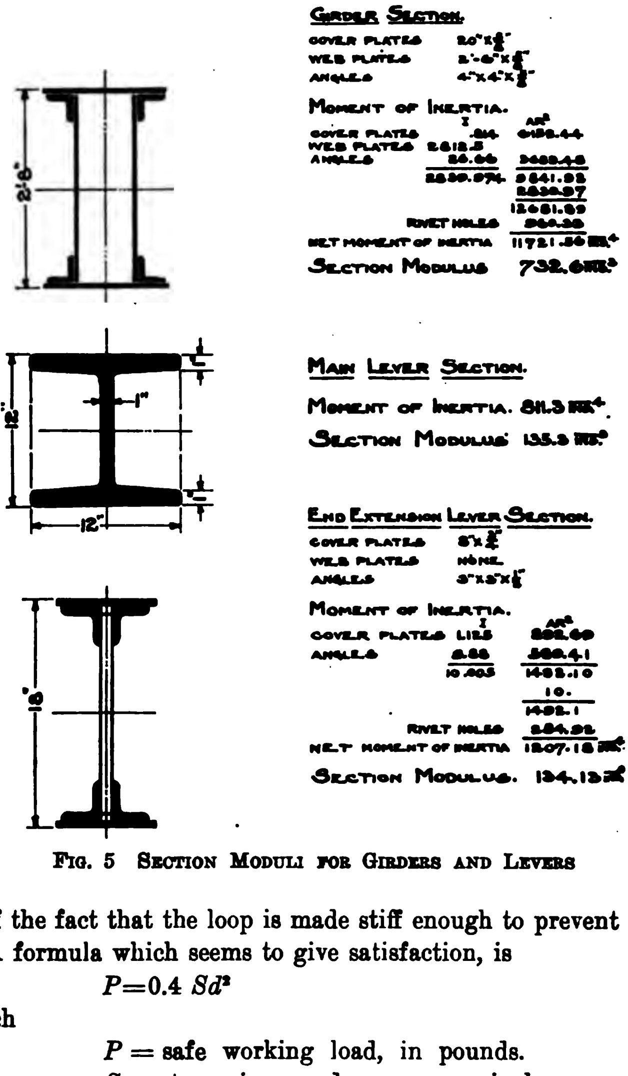


FIG. 5 SECTION MODULI FOR GIRDERS AND LEVERS

spite of the fact that the loop is made stiff enough to prevent st ing. A formula which seems to give satisfaction, is

$$P=0.4\ Sd^2$$

in which

P = safe working load, in pounds.
S = stress, in pounds per square inch.
d = diameter of iron, in inches.

It is advisable to use a good quality of wrought iron in preference to steel. Steel has a tendency to break without giving previous warning, while wrought iron will bend before breaking.

LEVER SECTIONS

21 The sections of the levers will next be investigated. It is necessary to consider stiffness more than strength. Too often a

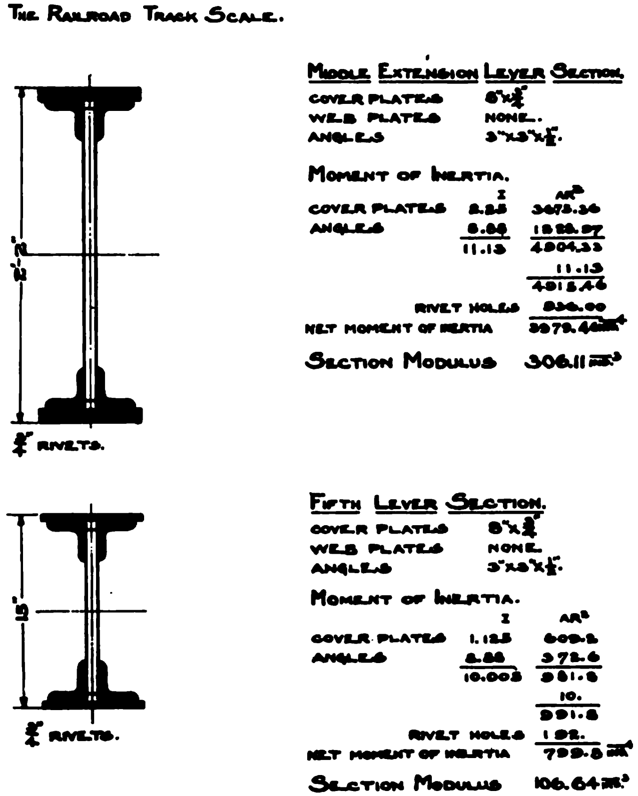


FIG. 6 SECTION MODULI FOR LEVERS

lever which is sufficiently strong from the standpoint of strength will deflect under load a noticeable amount, causing the ratio of the lever arms to change and giving inaccurate readings on the beam.

22 The main levers are to be steel castings, while the extension and fifth levers are to be made of structural shapes. The shelf lever may be either a forging or a casting. The beam is usually a casting,

although foreign manufacturers do not hesitate to make it from a forging. Since the levers are to be of steel, the allowable stress under repeated application of the load will be assumed to be 5000 lb. per square inch.

23 The maximum moment for the main lever will be about 600,000 lb.-in., requiring a section modulus of 120 (in.)^3. An I section 12 in. wide by 12 in. deep, having flanges and web 1 in. thick, will give a section modulus of about 135.3 (in.)^3, which is sufficient for all practical purposes. All knife edges are to be reinforced to prevent bending while under load. The depth of the lever will vary tapering from the point of maximum bending moment toward the tip and butt, and the width of the flanges will decrease toward each end. The thickness of the flanges and web will be uniform throughout.

24 The maximum bending moment for the end extension lever will be 643,500 lb.-in., which requires a section modulus of 128.7

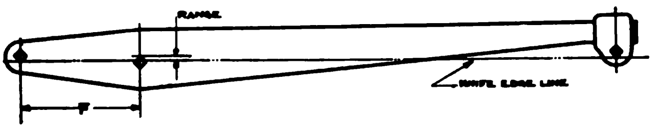


FIG. 7 RANGE IN LEVERS

(in.)^3. A latticed section made up of cover plates 8 in. by ¾ in. and 3-in. by 3-in. by ½-in. connection angles, gives a net section modulus of 134.13 (in.)^3, for a section 18 in. deep, due allowance having been made for $^{13}/_{16}$-in. rivet holes.

25 The maximum bending moment for the middle extension lever will be 1,452,500 lb.-in., which requires a section modulus of 290.5 (in.)^3. A section 26 in. deep, composed of 8-in. by ¾-in. cover plates and 3-in. by 3-in. by ½-in. angles will give a section modulus of 306.11 (in.)^3 net, deduction for $^{13}/_{16}$-in. rivet holes having been made.

26 The maximum bending moment for the fifth lever will be 456,000 lb.-in., which will require a section modulus of 91.2 (in.)^3. A section 15 in. deep, composed of 8-in. by ¾-in. cover plates and 3-in. by 3-in. by ½-in. angles, will give a section modulus of 106.64 (in.)^3, net, deduction having been made for $^{13}/_{16}$-in. rivet holes.

27 The maximum moment of the shelf lever will be 28,800 lb.-in., which will require a section modulus of 5.76 (in.)^3. A section

1 in. wide by 6 in. deep, will give a section modulus, gross, of 6 $(in.)^3$, or about 5.84 $(in.)^3$, when deduction for the knife edge hole has been made. This lever has a fulcrum of 12 in. and a length of 5 ft., its ratio being 5.

28 In all these computations, the dead load of the weigh bridge has been carried, a larger value than necessary having been chosen in order to be on the side of safety.

29 Range on each lever must be provided in order to compensate for unequal distribution of the metal about the knife edge line and any deflection that may occur. This range is accomplished by raising the main knife edge above a line through the tip and butt knife edges by an amount equal to 1/8 in. per foot of fulcrum (see Fig. 7).

30 The main lever main knife edge will be allowed a range of 1/8 in., as will also the extension levers, while the fifth lever will have a range of 3/16 in., the shelf lever will be given a range of 1/8 in., while the range on the beam is almost negligible, less than 1/16 in., yet it must be considered.

31 A resumé of levers will be useful (see Figs. 5 and 6):

Lever	M max.	Sec. Mod.	Section
Main..........	600,000	135.3	Cast steel I
End extension...	643,500	134.13	2–8 in. by 3/4 in. pl, 4–3 in. by 3 in. by 1/2 in. Ls—18 in. deep
Middle extension.	452,500	306.11	4–8 in. by 3/4 in. pl, 4–3 in. by 3 in. by 1/2 in. Ls—26 in. deep
Fifth..........	456,000	106.4	2–8 in. by 3/4 in. pl, 4–3 in. by 3 in. by 1/2 in. Ls—15 in. deep
Shelf..........	28,800	5.84	6 in. by 1 in. steel or W. I.
Beam..........	3,000	1.00	3 in. by 3/4 in. steel or W. I.

GIRDERS

32 The middle span of the weigh bridge will be subjected to a live load of 100,000 lb. passing over it; the end spans, particularly the one at entrance, will be subjected to impact, due to the moving load dropping from the dead rails to the live rails on the weigh bridge, or the wheel striking the end of the rail, due to a difference in level, or a gap, between rail ends. While a condition of unequal levels is not desirable, yet, wear, settlement, along with frequent repairs, cause inequalities in alignment.

33 As noted before, there will be an objectionable pounding upon the knife edges if a continuous girder is used, due to the deflection of the weigh bridge upon application of the load, so the bridge will be subdivided into three parts, the joints coming over the main bearing stands of the main levers; each girder will be made stiff enough to resist deflection due to the applied load.

34 The greatest bending comes upon the middle span; foı formity and quickness in assembling, the girder sections for end will be the same as for the middle span.

35 The girders should be designed for stiffness, so a permi deflection of 3/32 in. will be assumed. The deflection formula beam supported at the ends and loaded at the middle is

$$\epsilon=\frac{1}{48}\ \frac{PL^3}{EI}=0.02083\ \frac{PL^3}{EI}$$

$$I=0.02083\ \frac{PL^3}{E\epsilon}$$

36 Using a modulus of elasticity of 25,000,000 lb. per sq. ir limiting the deflection to 3/32 in., we have

$$I=0.02083\times\frac{50{,}000\times(283)^3}{25{,}000{,}000\times\frac{3}{32}}$$
$$=10{,}080\ (\text{in.})^4$$

37 It will be interesting to compare this result with what have been obtained if the fundamental formula for bending had used, with the stress due to suddenly applied loads.

38 From tests on the fatigue of steel under repeated loadir Wöhler and Spangenburg, and the later tests by Bauschinger a the Watertown Arsenal, the following formula may be used in fi the proper safety factor to be used for variable loading of an inde number of repetitions:

$$F_2=\left(2-\frac{P_2}{P_1}\right)F_1$$

in which

F_1 = safety factor under static loading.

F_2 = corresponding safety factor under a loading that repeatedly between the limits P_1 and P_2.

P_1 = greatest pressure in the most strained fiber of the ber due to the variable load, to be taken as plus if causing tension and minus (—) if causing pression.

P_2 = least pressure in the most strained fiber of the me due to the variable load, to be taken as plus (- causing tension, and minus (—) if causing pression.

This formula is applicable to the case of steadily applied loads as well as to the cases in which the load varies from O to P_1, and P_2 to P.

39 Since, for any given material, the working fiber stresses for the different conditions of variable loading are inversely proportional to the corresponding safety factors, it is apparent that the formula may be put in the following form:

$$f_2 = \frac{f_1}{2 - \frac{P_2}{P_1}}$$

in which f_1 = working fiber stress under static loading, in pounds per square inch.

f_2 = corresponding working fiber stress under a load that varies repeatedly between the limits P_1 and P_2, in pounds per square inch.

P_1 and P_2 have the same signification as noted before.

For the case where the load varies from O to P_1, the formula becomes

$$F_2 = \left(2 - \frac{O}{P_1}\right) F_1 = (2 - O)\ F_1 = 2\ F_1$$

or

$$f_2 = \frac{f_1}{2 - \frac{O}{P_1}} = \frac{f_1}{2}$$

which indicates, for a suddenly applied load, indefinitely repeated, that the safety factor should be twice that for static loads, under otherwise similar conditions.

40 The maximum bending moment for the end spans will be

$$\frac{50{,}000 \times 214.5}{4} = 2{,}681{,}250 \text{ lb.-in.}$$

The maximum bending moment for the middle span will be

$$\frac{50{,}000 \times 283}{4} = 3{,}537{,}500 \text{ lb.-in.}$$

The customary stress for bridges, subjected to live loads, is about 12,000 lb. per sq. in. The formula developed indicates that half this stress should be allowed; so, using a stress of 6000 lb. per. sq. in., we have a section modulus of

$$\frac{I}{c}=\frac{M}{S} = \frac{3{,}537{,}500}{6000}=589.6\ (\text{in.})^3$$

against a section modulus of 630 (in.)^3 (considering a section deep) derived by the flexure formula. Only too often, girders a signed without due regard to stiffness, or the effect of load denly applied, with very apparent deflection when loaded.

41 Using a section 32 in. deep, composed of two 20-in. by cover plates, two 30-in. by ⅝-in. web plates and four 4-in. by 4- ⅝-in. angles, and deducting for $^{13}/_{16}$-in. rivet holes, we have moment of inertia of 11,721.56 (in.)^4, which gives a section m of 732.6 (in.)^3, well within what is required.

42 To prevent buckling of the web, reinforcing angles are at intervals along the girder. Over the supports, sufficient must be used to carry the load, considering the angles as a cc Gordon's formula for columns with square bearings is:

$$P=\frac{a}{f}\left[\frac{50{,}000}{1+\frac{1}{36{,}000}\left(\frac{12\,L}{r}\right)^2}\right]$$

in which

P = load to be supported, in pounds.

a = sectional area of column, in square inches.

f = safety factor.

L = unsupported length of column, in feet.

r = least radius of gyration, in inches.

43 The load to be supported is 50,000 lb. plus about 20,C for the weigh bridge. Using two angles in each column, each can be assumed to carry a half of the imposed load, or 35,0 The formula then reduces to

$$35{,}000=\frac{a}{8}\left[\frac{50{,}000}{1+\frac{1}{36{,}000}\left(\frac{29\frac{1}{2}}{r}\right)^2}\right]$$

$$280{,}000=a\left[\frac{50{,}000}{\frac{r^2+0.024}{r^2}}\right]$$

$$28r^2 + 0.677 = 5ar^2$$

But

$$I = ar^2$$
$$I = 5.6r^2 + 0.135$$

44 Using a 4-in. by 4-in. by ⅝-in. angle with a moment of inertia of 6.66 $(\text{in.})^4$ the resulting radius of gyration is 1.067 (in.), while that from the table is 1.20 (in.). The area deducted for rivet holes will be more than made up by the 4-in. by ⅝-in. fillers which are necessary. Judicious spacing of 4-in. by 4-in. by ⅝-in. angles will go a long way toward stiffening the web and preventing it from buckling.

45 To prevent the girders from becoming displaced, and to hold them in proper alignment, each end of the middle section should be extended in such a way that the extension will telescope into the end of the end girders; and a tie plate should be riveted to the bottom plates of the girders, at the joint, in order to make a rigid connection horizontally and yet allow each girder to deflect, independently, vertically. In this way, freedom of movement for deflection is obtained, and the objectionable bending over the supports, which occurs in continuous beams, is eliminated. With each span deflecting with freedom, there will be no lifting from, or dropping upon, the knife edges, as the load passes from one span to the other.

THE BEAM

46 The beam is to be of the full capacity type, the main bar being graduated in thousands of pounds, and the fractional bar in hundreds of pounds, to a thousand, by tens. Assuming an index of graduation of 5 to the inch for the main bar, a run of 5 ft. will include a capacity of 300,000 lb., while an index of 10 to the inch for the fractional bar will give a run of 10 in.

47 With a fulcrum distance of 5 in. on the beam, the main poise will weigh

$$W = \frac{C\,F}{R\,M} = \frac{300{,}000 \times 5}{60 \times 1000} = 25 \text{ lb.}$$

and the fractional poise will weigh

$$W = \frac{1000 \times 5}{10 \times 1000} = \tfrac{1}{2} \text{ lb. or 8 oz.}$$

where

W = weight of poise in pounds or kilograms
C = capacity of scale in pounds or kilograms
F = fulcrum distance of beam, inches or centimeters
R = run of poise, inches or centimeters
M = ratio at butt of beam

48 If the beam is cocked, that is, flies all the way up or all th way down, and indicates a true balance only when the load indicate on the beam is exactly that on the platform there may be two faults either too much weight above the knife edge line, or too much range

49 Obviously, if there is too much metal above the knife edg line, the remedy lies in placing sufficient below to counteract it influence. In order to correct such troubles readily and avoid th useless addition of metal, it is usual to arrange the balance ball so tha it can be placed in a position to correct this fault. The difficulty, du to too much range, is eliminated by reducing the range until it ha been overcome. Slowness of action is very often caused by dull knif edges, unnecessary friction, too much metal below the knife edge line or no range; eliminate the cause and the effect produced will disappear

50 Since the beam has a fulcrum distance of 5 in., the total pul on the butt of the beam will amount to 600 lb., which gives maximum moment of 3000 lb.-in., requiring a section modulus o 0.6 $(\text{in.})^3$, which is satisfied by a section ¾ in. wide by 3 in. deep deduction having been made for the knife edge hole. The trig loo is placed at the tip of the beam and the precaution to have the trigge down whenever a load is entering upon the live rails will save th beam many hard jolts and prolong its accuracy.

51 More details of the beam will be useful. For rapidity o weighing the fractional poise will be mounted upon the main poise s that the latter will include the weight of the fractional poise, its beam and any other details that may be necessary.

52 The main beam will be notched for each thousand pounds and each notch accurately sealed, indexed and marked. The inde and marking should be cut quite deep, because the service which mos scales undergo is not of the best and seldom is much attention give to polishing and cleaning the beam or otherwise keeping it in orde The fractional beam will not be notched, due to inconvenience when quick weighing is desired.

53 The knife edges should be of square steel, the bearing edg being ground and polished to a true edge, which must be hard an sharp, clean at all times, to assure accurate and sensitive weighing

54 Projections upon the beam or poises are not desirable. Dir rapidly accumulates and destroys the accuracy of the scale. Likewise openings of any kind offer opportunity for dirt to accumulate o

weight to be surreptitiously extracted from the poise. In other words, anything that can be conscientiously done to promote accuracy in weighing must be done; it is preferable to leave no detail incomplete.

55 The beam stand must be built solid enough to withstand the shock of the suddenly-applied load. From the point of safety it is desirable to keep the beam as far as possible from the track, but too great a distance means a long lever, which is objectionable, due to the increased depth necessary to get the requisite strength and the consequent increase in weight. Cars average close to 10 ft. in width at the eaves; whether this width may be exceeded or not is due to clearance limitations on certain roads; at any rate, future expansion must be provided for. Allowing five feet between the side of the car and the building and about four feet from the outside of the wall to the reach rod from the tip of the fifth lever to the shelf lever, we have a fifth lever of 14 ft. 3 in. long, a ratio of 8 giving a fulcrum distance of 19 in. and a long arm of 12 ft. 8 in., this lever being of the first class.

PLATFORM, BRIDGE AND RAILS

56 A platform of such great size and weight as required for this scale should have ample clearance and be entirely free of any movement of the weigh bridge to prevent binding at any point due to the accumulation of dust and dirt. To provide proper clearance the pit will be made 10 ft. wide. To support the platform I-beams spaced at proper intervals will be used. The greatest load that can come upon one I-beam will be the load upon one axle and the maximum moment will be when the wheels just straddle the center line of the scale; this moment will be about 825,000 lb.-in., a 15-in. 42-lb. I-beam being sufficient.

57 To make the platform durable concrete should be used. With this construction repairs are infrequent and not very costly; a tight cover for the pit is assured.

58 The bridge, through its bearings, rests freely upon the main lever knife edges, there being no rigid connection between them. To prevent the bridge from sliding, a system of lateral and longitudinal checks is provided. These checks should be made as long as possible in order to prevent binding when the bridge deflects, while under load; the theory is, the longer the check, the more nearly the short path described approaches a straight line.

59 The load applied to the checks, is caused in several ways, any one of which may occur. The end of the live rail may be

some inches from the solidly laid dead rail, so that a blow is ministered to the end of the live rail as the wheels enter upoı Another condition is due to adhesion, or friction, between the wł and rails when the brakes are applied. Still another condil similar to the first, is a difference in the level of the live and ‹ rails, the worst blow coming when the live rail is above the ‹ rail. Probably, the worst situation is when the first two, or last occur at the same time. This will come about when three pair wheels are on the live rails, the fourth pair just entering, all brake and the last pair striking the ends of the live rails. The condit brought about by rail inequalities are indicated in Fig. 8.

60 The pressure, due to the friction between the wheels and r

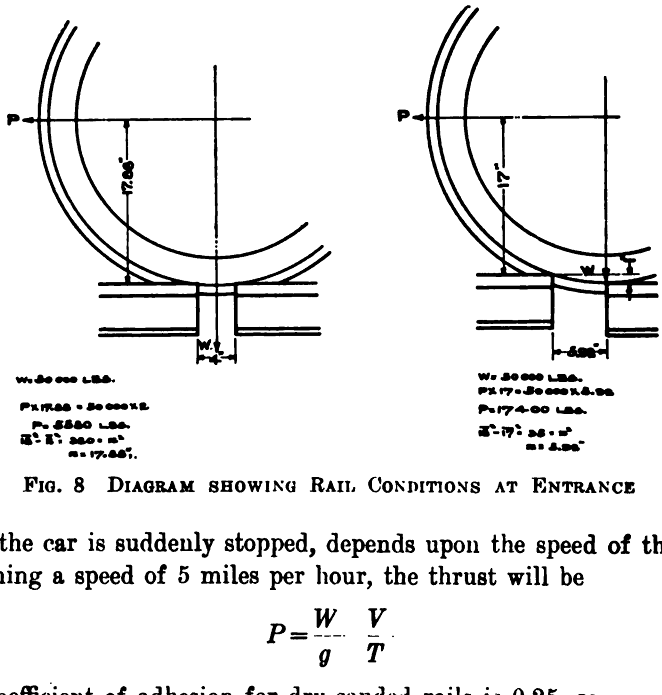


FIG. 8 DIAGRAM SHOWING RAIL CONDITIONS AT ENTRANCE

when the car is suddenly stopped, depends upon the speed of the Assuming a speed of 5 miles per hour, the thrust will be

$$P = \frac{W}{g} \frac{V}{T}$$

The coefficient of adhesion for dry sanded rails is 0.25, so

$$P = \frac{50{,}000 \times 0.25}{32} \times \frac{5 \times 5280}{60 \times 60} = 2865 \text{ lb.}$$

This value is for one pair of wheels; for three pairs, the value wil 8595 lb., which is the thrust delivered to two longitudinal checks, thrust of 4297 lb. to each one.

62 Assuming a gap of 4 in. between rail ends, and a 36-in. wheel, the force of the blow will be

$$P=\frac{2\times 50{,}000}{17.88}=5580 \text{ lb.}$$

delivered to the two longitudinal checks, or a thrust of 2790 lb. to each check. If there is a difference in level of 1 in., the blow would be very much aggravated, as is indicated below.

$$P=\frac{50{,}000\times 5.92}{17 \text{ in.}}=17{,}400 \text{ lb.}$$

delivered to both longitudinal checks, or 8700 lb. to each check.

63 The total highest thrust will be due to the sudden stopping of the car on the live rails and the wheel striking the end of the rail when the live rail is higher than the dead rail, which amounts to 13,000 lb. Using a stress of 7500 lb. per sq. in., a round bar $1\frac{1}{2}$-in. diameter will be sufficient. In order to provide adjustment, the check will be provided with a turnbuckle; accordingly, the end of the bar will be upset for a $1\frac{3}{4}$-in. thread.

64 The lateral checks serve to prevent side motion, so for the ake of uniformity, they will be made of the same stock as the longi-dinal checks. In order to prevent binding, the checks should fit the eck pins with freedom, and sufficient slack provided to allow, say, 16-in. movement; just enough to allow the checks to be free when ere is no load upon the scale.

65 The rails are carried upon stands which are fastened to the idge girders. These stands must be rigidly fastened to the girder d able to withstand much abuse, due to derailments. To hold the il firmly, suitable clamps must be used, which have not the bad bit of working loose in service.

66 A dead rail has not been considered, it being preferable to ovide a relief mechanism, or pass cars and locomotives around the ale on another track. Dead rails offer too much temptation to an gineer to use the live rails for shifting, etc., as is very often done.

67 The high axle loads of the locomotives now in use are often yond the capacity of the scale and such excessive loads must not be lowed to pass over the weigh bridge.

68 While the scale is designed to withstand considerable misuse ad much neglect, yet this provision does not mean that the abuse ay be continued with entire safety. The metal will fatigue,

eventually, and possible costly repairs result. When the design of track scale is considered, it must be borne in mind that stiffness construction, coupled with lightness of moving parts and absence friction, is to be desired.

69 Upon the sealer depends the accuracy and dependability the weights indicated. Inspection should be frequent and thorou in order to detect and repair any damage that may have occurr through age or abuse. It is always preferable to have sufficient for sight to prepare for an emergency and, if possible, prevent a brea down which may cause serious trouble.

70 Too much stress cannot be laid upon the honest and co scientious performance of the responsibility laid upon the weig master. The public no longer tolerates tampering with weights; th have demanded honesty and show their earnestness of purpose by tl many legal enactments and the frequent prosecution of offenders.

No. 1435

GEAR TESTING MACHINE

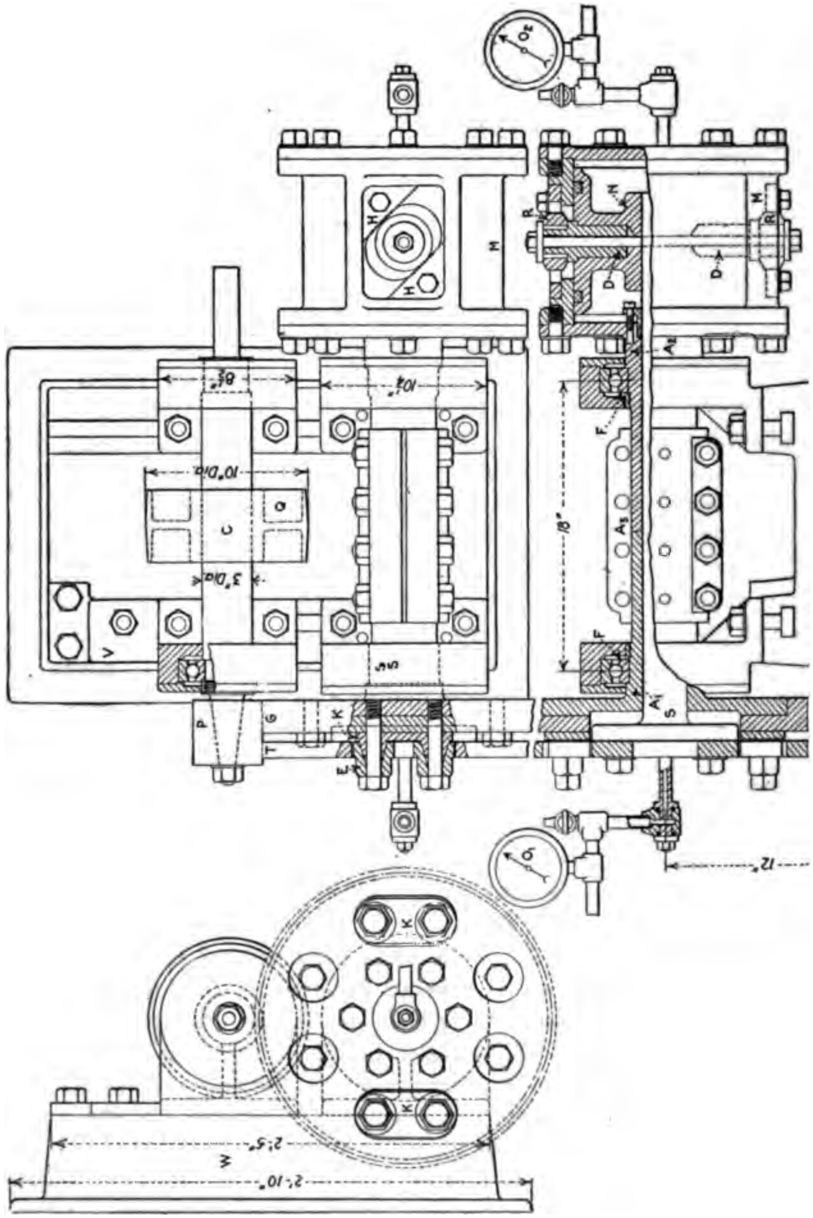
By Wilfred Lewis, Philadelphia, Pa.

Member of the Society

The gear testing machine, shown in Fig. 1, is the result of the writer's efforts to realize in concrete form an ideal machine for the purpose of continuing the experiments reported to the Society by Prof. Guido H. Marx at the Annual Meeting in 1912. The possibility of testing heavier gears at higher speeds with comparatively little power occurred at once to Mr. Ralph E. Flanders and to the writer, as pointed out in their discussions of the paper, but the problem remained to design a suitable machine which might also be used to supplement the experiments made by the Committee on Standards for Involute Gears to determine the friction losses and the running qualities of various types of gearing. After making a number of preliminary sketches, the writer was about to put them in the hands of a draftsman, when he had the good fortune to meet Prof. E. P. Lesley, one of Professor Marx's associates, who accepted the task of preparing the working drawing. The machine as it now appears is due in large measure to Professor Lesley's careful attention and skill in the perfection of every detail and the writer is pleased to acknowledge many helpful suggestions which have broadened the scope of the undertaking and made the design a practical possibility.

2 The machine proposed is based essentially upon the principle of the testing machine used by the Committee on Involute Gears, in which the teeth are put under a working load without consuming an excessive amount of power. The design, however, has been modified to facilitate changes in the working load and in the test gears employed. At the suggestion of Professor Lesley, it has been further modified to change not only the amount of the working load while running, but also to change its direction, thus producing the effect of reversing loads upon the teeth while running continuously in the same direction.

Presented at the Spring Meeting, St. Paul-Minneapolis, June 1914, of The American Society of Mechanical Engineers.



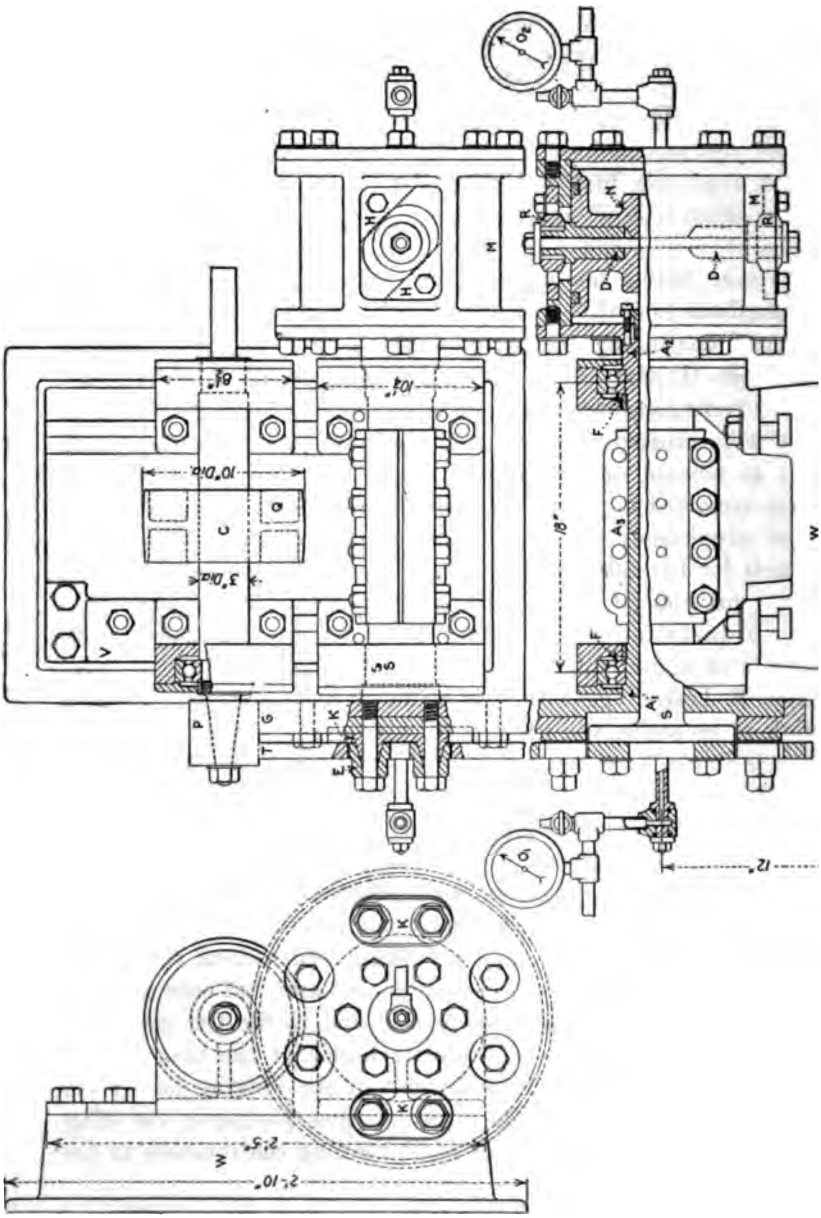
O_2
H
M
R
N
D
A_2
F
18"
A_3
10" Dia
C
Q
3" Dia
V
P
G
K
T
E
S
A_1
O_1
12"
W
2' 5"
2' 10"

3 The apparatus has a hollow shaft made in two parts, A_1 and A_2, united by a clamp A_3, also made in two parts to facilitate assembling. At one end of this hollow shaft is a flange to receive the steel gear ring *G*, which serves as a permanent part of the apparatus and is strong enough to resist the stresses due to testing.

4 Besides the hollow shaft *A*, there are two solid shafts *C* and *S* on which are mounted the gears or pinions to be tested. Shaft *S* passes through hollow shaft *A* and has a flanged end on which is mounted test gear *T*. Shaft *C*, parallel with shafts *A* and *S*, carries the wide-faced pinion *P*, which is in mesh with both the permanent gear ring *G* and test gear *T*.

5 Shafts A_2 and *S* are connected at their opposite ends by a novel device through which any desired amount of load in either direction can be applied to the teeth, whether at rest or while running in either direction. To accomplish this purpose, the hollow shaft A_2 is flanged to receive the pneumatic cylinder *M*, in which is the piston *N*, firmly secured to the shaft *S*. Pins *D D* are driven into the piston *N* through the openings in the cylinder *M* and upon the projecting ends of these pins rollers *R R* are mounted upon roller bearings. A bolt passing through the pins, piston and shaft secures the whole in place. These rollers *R R* engage helical segments *H H* let into the walls of the cylinder *M*. Air pressure can be applied to the piston *N* on either side to give a slight amount of end motion to the shaft *S* and so, through the action of the rollers upon the helical segments, a slight angular motion is produced between shafts *A* and *S*, resulting in a pressure between the teeth of the gears upon these shafts and the teeth of the pinion on shaft *C*. Pressure gages O_1 O_2 connecting with each side of the piston area are calibrated to record the resulting pressure on the gear teeth, taking account of the piston areas, the pitch of the helical cams and the diameter of the gear wheels.

6 Since but little power is required to drive the apparatus, the pinion *P* is simply clamped to the shaft *C*, by a nut on its tapered end. The shaft itself is made heavy for the sake of stiffness and a pulley *O*, between bearings, is attached for driving from a countershaft, or if preferred, a motor drive may be used in connection with the extended end. When the gear wheel *T* is to be tested, the intention is to run it in mesh with a steel pinion; and when the pinion *P* is to be tested, the intention is to make it of cast iron and



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cut down the width of face of the teeth engaging with *T*, by nickin down on either side.

7 When a tooth breaks in the wheel *T*, or in the pinion *P*, it i important, to avoid the complete destruction of the apparatus by th jamming of the remaining teeth on their ends, to maintain the wheel *G* and *T* in proper relation to each other, and for this purpose, th stops *K K*, with their adjustable eccentrics *E E*, are employed. Th block *K* is clamped to the wheel *G* through the intervening eccentri bushings *E E*. The intention is to keep one of the clamping bolt tight while the other is loosened and the eccentric adjusted to predetermined amount of clearance on either side, after which bot eccentrics are to be clamped. These stops do not come into actio unless a tooth is broken or deformed. Then they cause both gear *G* and *T*, to run together. By means of these stops it is also possible t study the effect of a predetermined irregularity in forming or spacin the teeth. For instance, an abnormally wide space or tooth can b simulated, when broken out or purposely cut away, by the positio of the stops and the pounding effect in running will be evident as th result of a certain measured irregularity.

8 The shafts *A* and *C* are mounted in ball bearings to reduc friction and as a matter of expediency the scale of the apparatus ha been determined by the bearings *F F* on the shaft *A*. These are o the largest commercial size and to make them available the shaft *A* was cut in two and united by the clamp A_3. The bearings for th hollow shaft are firmly bolted and doweled to a bed plate *W*, whil those for the pinion shaft are adjustable to the diameter of the pinio used, a distance piece *V* of proper width being used in every case t prevent movement under load.

9 It will be seen that the apparatus is capable of determinin to a nice degree of accuracy and at a very small expenditure for wea and tear and power, a number of unsettled problems of great practica importance. Jigs will be made for drilling the gears *G* and *T* afte cutting the teeth, so that the relative positions of the two wheels ma be accurately fixed. Friction is practically eliminated in the ball an roller bearings, and what remains must become inappreciable unde the well-known influence of vibration when running, except that du to air resistance and the friction in the teeth. With some accurat means for measuring the power consumed, both of these variable can be determined better than ever before. The apparatus in skilfu hands should therefore solve the mooted question of the effect o

speed on strength, and questions of durability, wear and noise can be studied at a small outlay in power and materials. It is possible that some slight modifications may finally be embodied to facilitate construction, but the machine as shown is believed to contain the elements needed for an exhaustive examination of the subject of gearing in all its phases and the writer hopes it will appeal to someone interested, who has the means to build it and time to experiment on the lines so well indicated by Professor Marx.

DISCUSSION

Elmer H. Neff. As I understand it this paper is simply a record of a design which has not yet been built. It would appear therefore that the real discussion of this machine will be brought out when it has been built and an attempt made to draw conclusions from experiments made with the machine. At that time more details will be apparent than a hasty examination reveals. We shall be able to judge somewhat of the statement in the last paragraph suggesting that vibration reduces the quantity of friction loss in the machine itself to a negligible quantity, leaving only the friction of the gears as they exist.

Henry Hess. Mr. Lewis has done a really extraordinary amount of self-sacrificing work in this line, for which he has earned chiefly criticism, largely interested criticism, but criticism nevertheless. There is probably no other one man who has given so much time and effort with absolutely no incentive of a financial reward of any kind and with no interest except a purely engineering one. It would be a very good thing if it were possible for the Society to make available surplus funds, which it has not at present, but which it may hope to have some day, for the prosecution of experiments with a machine such as this of Mr. Lewis' design. I do not mean to say necessarily this particular machine, but any machine which will realize the object underlying its design. I move that the Society suggest to the Council, the initiation of steps to render possible the carrying out of experiments of this character.

P. F. Walker. It may be of interest to some to know that in the engineering laboratory at the University of Kansas we have under way tests to determine the friction loss in gears. Our plans cover more than the gears, however, our first work having been on the universal joint as made for automobile transmission. On this latter portion of our work I had thought to comment here, since it will be some months before our work on gears will be brought to a point where any report may be made.

The point of greatest difficulty in the measurement of friction losses is in the measurement of power. Where the power transmitted is in fairly large amount and the friction loss small, and the power input and power output are measured in their full amounts, the small difference indicating friction loss is bound to absorb all errors. The error may be a small percentage of the power transmitted and still be so large in proportion to the loss being determined as to render results worthless.

For this reason, in the universal joint work we adopted the "load-back" method of testing. This consists in operating the joint between two electrical machines, the shafts being connected through the joint, one machine acting as motor and the other as generator while the first uses the current generated in the second. The only power supplied from outside is that required to make up the losses of machines and joint combined. The machine losses must, it is manifest, be determined separately, but a distinct advantage gained is the elimination of the large power readings. In any form of test the machine losses must be determined, thus introducing that detail in the work irrespective of other determinations.

We have spent three years on the universal joints and have reached the point where we are about ready to make the report. On the gears, only the preliminary runs have been made, but I have reason to believe that this work will progress much faster than the other.

A. G. Christie. It may be of interest to know that a number of the large state universities in the West have engineering experiment stations in connection with the institutions. Illinois, Wisconsin and Iowa, all have experimental stations in connection with their state university. These experimental stations are not tremendously wealthy, but they do have each year certain sums of money set aside for investigation work, and I believe that a great deal could be gained both by the stations and by the Society, if the latter would coöperate with these engineering experiment stations in carrying on research work. While I was at the University of Wisconsin we would have greatly welcomed such coöperation. In fact we did carry out some work suggested by the ventilating engineers. I believe the universities would welcome any suggestions coming from the Society.

THE AUTHOR. It is true, as Mr. Neff has stated, that the gear testing machine described in my paper has not yet been built. It is simply a design intended to meet the need of further light upon a number of questions pertaining to the use of gears. As suggested by Professor Walker, there are other ways of measuring the friction losses in gearing, and if good results can be obtained by electrical methods, it will be interesting to have such experiments for comparison.

There are, however, other features of this testing machine which do not appear to be so easily superseded by a motor-driven generator, and it is difficult to imagine how the load on the teeth can be varied and reversed with the same facility and measured with the same precision. Nor does it appear how the effects of irregularities in forming and spacing the teeth can be so carefully studied under different speeds and loads. Perhaps the same problems can be solved to advantage in other ways, and different methods of attack are certainly to be desired, but the direct mechanical method appeals to me as the most accurate and reliable. Friction can be practically eliminated by ball and roller bearings and if the little that remains is not further reduced to a negligible quantity by vibration, it is reassuring to know that the conclusions will not be seriously affected thereby. Vibration of a pattern on a molding machine certainly does eliminate most of the friction between that pattern and the sand, and it is well known that bolts and nuts work loose in machinery subject to vibration, unless special precautions are taken to secure them.

If the interest in the subject warrants the construction of a machine, as implied in the motion of Mr. Hess, by all means let us have the type of machine suggested subjected to the fullest and freest discussion. I have simply presented a design which appears to me to be complete and satisfactory, and I shall be glad to welcome other ways and means upon their merits.

with suitable pressure-ports in the inner and outer curved wall, b means of which the centrifugal action set up in deflecting the cour of the passing fluid is communicated to the registering apparatu The sketch (Fig. 1) will readily give an idea as to the applicabilit of the apparatus, and from Table 1 conclusions may be drawn a to its reliability, and as to its sensitiveness to errors due to di turbances in the flowing medium.

3 In suggesting a new method for measurement, it will of cour be necessary to bring out new formulæ applicable to it. The prii ciple on which the measurement of the flow of fluids is based, state in a way to assist the present purpose, is that when the velocity of fluid, as a whole or in part, is changed, a change in pressure accon panies the change in velocity and hence, when the areas carrying th fluid before and after the change are known, the original and fin velocities of the fluid can be determined from the change in th pressure that has been noted.

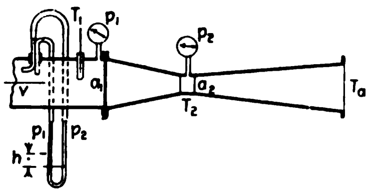

FIG. 2 KEY TO NOTATIONS

NOTATION

v and v_s = velocity in ft. per second
Q_m = volume, in cu. ft. per minute
W_m = weight, in lb. per minute
t = temperature, deg. fahr.
T = absolute temperature = $459.2+t$
T_0 = absolute temperature of 32 deg. fahr. = 491.2
T_1 = absolute temperature at entrance
T_2 = absolute temperature at throat
T_d = absolute temperature at delivery
P and p = absolute pressure, respectively in lb. per sq. ft. an in lb. per sq. in.

P_0 and p_0 = absolute pressure of the atmosphere, respectively = 2116.3 lb. and 14.7 lb.

P_1 and p_1 = absolute static pressure, or pressure at entrance per sq. ft. and per sq. in.

P_2 and p_2 = absolute dynamic pressure, or pressure at throat

p_d = absolute pressure at delivery

δ = density

δ_a = density of air

δ_{a_0} = density of air at 32 deg. fahr. and 14.7 lb. pressure

δ_1 = density at entrance

δ_2 = density at throat

δ_{s_t} = density of steam of the static pressure

δ_w = weight of water per cu. ft., at 32 deg. fahr. = 62.4 lb.

γ = specific density of gas with reference to air as unit

B = barometric pressure at 32 deg. fahr. and 14.7 lb.

B_1 = pressure in in., mercury

a_1 = area at entrance, in sq. in.

a_2 = area at throat, in sq. in.

n = ratio of specific heat of gas at a constant pressure to that at a constant volume = 1.405. From which. the exponents $\frac{1}{n} = 0.71$, $\frac{n-1}{n} = 0.29$ and $\frac{n}{n-1} = 3.47$

4 Let Fig. 3 represent an elementary part of a fluid flowing from the pressure p_1 toward the pressure p_2, and consider the elementary mass m of the fluid. When the flow is from a lower pressure to a higher the motion of m must become retarded and when the flow is from a higher pressure to a lower its motion must be accelerated. At a certain instant, while passing through ds, the velocity of m changes from v to $v-dv$, and the resistance acting on its area a is adp. When q is the resulting acceleration, we have

$$a \cdot dp = mq$$

Substituting

$$m = \frac{\delta}{g} a \cdot ds$$

and

$$q = \frac{v \cdot dv}{ds}$$

we obtain

$$\frac{dp}{\delta}=\frac{v \cdot dv}{g} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [1$$

5 This is, then, the general equation determining the parall flow of fluids, and from it should be derived all the formulæ pertaini properly to the pitot tube and to the venturi meter.

6 With respect to the density δ in the above equation, tl following assumptions may be made:

I That δ remains unchanged during the flow, as in the ca of water

II That δ changes at the rate an isothermal compression expansion would call for

III That it changes at the rate an adiabatic compression expansion would call for

7 *Case I. δ is constant.* Through integration of $\frac{dp}{\delta}=\frac{v \cdot d}{g}$ between the limits p_2 and p_1 and v_1 and v_2, there will be obtained tl following equations:

For retarded motion

$$\frac{v_1^2}{2g}-\frac{v_2^2}{2g}=\frac{P_2-P_1}{\delta} \quad \ldots\ldots\ldots\ldots\ldots\ldots [2$$

For accelerated motion

$$\frac{v_2^2}{2g}-\frac{v_1^2}{2g}=\frac{P_1-P_2}{\delta} \quad \ldots\ldots\ldots\ldots\ldots\ldots [2$$

8 *Case II. δ changes at the rate an isothermal compression expansion would call for.* Accordingly, $\frac{\delta}{\delta_1}=\frac{P}{P_1}$, or $\delta=\frac{P}{P_1}\delta_1$, whi substituted in the general equation [1] gives, by integration betwe the limits as before:

For compression

$$\frac{v_1^2}{2g}-\frac{v_2^2}{2g}=\frac{P_1}{\delta_1}\log_e\frac{P_2}{P_1} \quad \ldots\ldots\ldots\ldots\ldots\ldots [3$$

For expansion

$$\frac{v_2^2}{2g} - \frac{v_1^2}{2g} = \frac{P_1}{\delta_1} \log_e \frac{P_1}{P_2} \ldots\ldots\ldots\ldots\ldots\ldots [3b]$$

9 *Case III. δ changes at the rate adiabatic compression or expansion would call for.* Accordingly, $\frac{\delta}{\delta_1} = \left(\frac{P}{P_1}\right)^{\frac{1}{n}}$ or $\delta = \left(\frac{P}{P_1}\right)^{\frac{1}{n}} \delta_1$ which substituted in the general equation [1] gives by integration:

For compression

$$\frac{v_1^2}{2g} - \frac{v_2^2}{2g} = \frac{n}{n-1} \frac{P_1}{\delta_1} \left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} - 1\right] \ldots\ldots\ldots\ldots [4a]$$

For expansion

$$\frac{v_2^2}{2g} - \frac{v_1^2}{2g} = \frac{n}{n-1} \frac{P_1}{\delta_1} \left[1 - \left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}}\right] \ldots\ldots\ldots\ldots [4b]$$

10 From equations [2], [3] and [4], each derived under a specific assumption, there may be evolved many formulæ applicable under almost any condition where the flow measuring instruments are used.

11 Formulæ [2a] and [2b] apply more directly to the measurement of water or incompressible fluids, but for approximate results they may also be used for gases (at moderate speeds, say, up to 100 to 120 ft. per second without appreciable error).

FORMULÆ APPLICABLE TO THE PITOT TUBE

12 In the pitot tube the fluid (gas) is subjected to compression and the final velocity v_2 becomes zero, hence each of the general formulæ [2a], [3a] and [4a] can in this case be simplified by the elimination of the second term of the first member.

13 Formula [2a] may be written

$$v_s = \sqrt{2\, g\, H} \ldots\ldots\ldots\ldots\ldots\ldots\ldots [5]$$

when H is the difference between the dynamic and static pressure expressed in feet head of the measured gas.

14 This formula is made more serviceable through substitution.

We have

$$H = \frac{h_w}{12} \cdot \frac{\delta_w}{\delta_a \gamma}$$

Hence

$$v_s = \sqrt{\frac{2g}{12} \cdot \frac{\delta_w h_w}{\gamma\, \delta_a}} = 18.29 \sqrt{\frac{h_w}{\gamma\, \delta_a}} \quad \text{[6]}$$

when

h_w = head in in. of water
δ_w = density of water (62.4 lb. per cu. ft.)
δ_a = density of air of temperature and pressure of gas flowing
γ = specific density of gas with reference to air as unit. When applied to air γ becomes of course equal to 1.

This formula will be useful when δ_a, the density of air of the given temperature and pressure is known.

14 The volume of flow, in cu. ft. per minute, corresponding to the velocity expressed by equation [6], will be

$$Q_m = 60 \frac{a}{144} v_s$$

From this will be obtained

$$Q_m = 7.62\, a \sqrt{\frac{h_w}{\gamma\, \delta_a}} \quad \text{[6a]}$$

15 The weight flowing per minute corresponding to the velocity expressed by [6] will be

$$W_m = Q_m\, \delta_a\, \gamma$$

when δ_a is the density of the gas on which the volume Q is based. Hence, there will be obtained

$$W_m = 7.62\, a \sqrt{h_w\, \gamma\, \delta_a} \quad \text{[6b]}$$

16 Formula [3a] for the pitot tube will be written

$$v_s = \sqrt{2g.144 \frac{p_1}{\delta_1} \log_e \frac{p_2}{p_1}} \quad \text{[3c]}$$

or through substitution of $\frac{p_1}{\delta_1} = \frac{p_0}{\gamma\, \delta_{a_0}} \cdot \frac{T_1}{T_0}$

$$v_s = \sqrt{2g.144 \frac{14.7}{0.080728} \cdot \frac{1}{491.2}} \cdot \sqrt{\frac{T_1}{\gamma} \log_e \frac{p_2}{p_1}}$$

$$=58.58 \sqrt{\frac{T_1}{\gamma}} \log_e \frac{p_2}{p_1} \quad \text{[3d]}$$

This formula is based on the pressure p_1 and temperature T_1, and it requires that the pressure ratio $\frac{p_2}{p_1}$ be known.

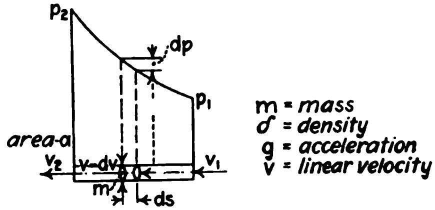

FIG. 3 VELOCITY AND PRESSURE DIAGRAM WITH RESPECT TO AN ELEMENTARY PART OF A FLUID

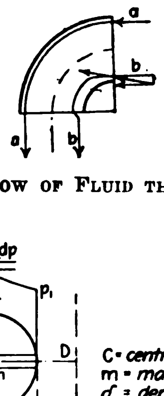

FIG. 4 COURSE OF FLOW OF FLUID THROUGH A FLOW BEND

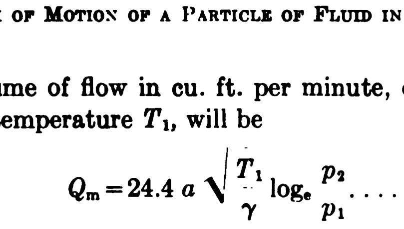

FIG. 5 DIAGRAM OF MOTION OF A PARTICLE OF FLUID IN THE FLOW BEND

17 The volume of flow in cu. ft. per minute, on a basis of the pressure p_1 and temperature T_1, will be

$$Q_m = 24.4\, a \sqrt{\frac{T_1}{\gamma}} \log_e \frac{p_2}{p_1} \quad \text{[7]}$$

and the flow in cu. ft. per minute on a basis of the delivery pressure p_d, will be

$$Q'_m = 24.4\,a\left(\frac{p_1}{p_d}\right)\sqrt{\frac{T_1}{\gamma}\log_e\frac{p_2}{p_1}} \qquad [8]$$

FORMULÆ RELATING TO THE FLOW BEND

18 When passing through the bend, the course of the outsid and inside stream lines of the fluid will be somewhat as illustrated b the lines *aa* and *bb* (Fig. 4). Assume the velocity in each stream lin to be proportional to its distance from the center of curvature, s that all particles of the fluid in a plane normal to the neutral axi move together, then the centrifugal action normal to the axis will b as illustrated in Fig. 5.

19 Here m is an elementary mass of the fluid, of a section area a normal to the diameter DD and of a length dx. In turnin the bend, the centrifugal force C acting on m will cause the pressu acting radially in front of it to be increased the amount dp, and th increase in pressure on the area a must at all instants balance th force C. Hence, we have

$$a \cdot dp = C = mxw^2$$

and since

$$m = \frac{\delta}{g}\, a \cdot dx$$

we get

$$\frac{dp}{\delta} = \frac{w^2}{g}\, x \cdot dx$$

20 As in the case of equation [1] for rectilinear motion, the sam three general assumptions may be made with regard to the density

21 *Case I. δ is constant.* Through integration of the gener equation

$$\frac{1}{\delta}\int_{p=p_1}^{p=p_2} dp = \frac{w^2}{g}\int_{x=r}^{x=R} x \cdot dx$$

there will be obtained

$$\frac{p_2 - p_1}{\delta} = \frac{w^2}{2g}\left(R^2 - r^2\right)$$

and as

$$h=\frac{p}{\delta}, \text{ or } \frac{p_2-p_1}{\delta}=h_2-h_1$$

therefore

$$\frac{w^2}{2g}(R^2-r^2)=h_2-h_1$$

22 Let V_m be the mean linear velocity, so that

$$V_m=w\frac{R+r}{2}, \text{ or } w^2=\frac{4\,V_m^2}{(R+r)^2}$$

Then through substitution

$$\frac{V_m^2}{2g}\times\frac{4\,(R^2-r^2)}{(R+r)^2}=h_2-h_1$$

or

$$\frac{V_m^2}{2g}=\frac{R+r}{4\,(R-r)}\,(h_2-h_1)$$

23 Finally call $R-r=D=$ the diameter, or width of the channel and $\rho=\frac{R+r}{2}=$ mean radius of the bend, then we get

$$\frac{V_m^2}{2g}=\frac{\rho}{2\,D}\,(h_2-h_1)\ldots\ldots\ldots\ldots\ldots\ldots[9]$$

which may be written

$$V_m=\sqrt{\frac{\rho}{2\,D}}\;\sqrt{2\,g\,H}\ldots\ldots\ldots\ldots\ldots\ldots[9a]$$

where H is the difference in the pressure at the outer and inner wall of the bend, in feet head of the fluid.

24 The corresponding formula for the pitot tube was

$$v=\sqrt{2\,g\,H}$$

Hence, the velocity measured by the bend will be $\sqrt{\frac{\rho}{2\,D}}$ of the velocity measured by the pitot tube for equal differential pressure. In other words, the differential pressure in the manometer tube will for the same velocity of the fluid be $\frac{2D}{\rho}$ of the pressure indicated by the pitot tube.

25 *Case II. δ changes as by isothermal compression.* Hence

$$\delta = \frac{P}{P_1}\delta_1$$

which substituted in the general equation gives

$$\frac{P_1}{\delta}\int_{p=p_1}^{p=p_2}\frac{dp}{p} = \frac{w^2}{g}\int_{x=r}^{x=R} x \cdot dx$$

and through integration and reduction

$$V_m = \sqrt{\frac{\rho}{2D}} \cdot \sqrt{2g.144\frac{p_1}{\delta_1}\log_e\frac{p_2}{p_1}} \ldots\ldots\ldots\ldots [10]$$

26 *Case III. δ changes as by adiabatic compression.* Accordingly,

$$\delta = \left(\frac{P}{P_1}\right)^{\frac{1}{n}}\delta_1$$

which substituted in the general equation gives through integration and reduction, as previously

$$V_m = \sqrt{\frac{\rho}{2D}}\ \sqrt{2g.144\ \frac{p_1}{\delta_1} \cdot \frac{n}{n-1}\left[\left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}} - 1\right]} \ldots\ldots [11]$$

Hence, the general formulæ for the bend are practically those of the pitot tube covering corresponding cases, with only the factor $\sqrt{\frac{\rho}{2D}}$ added, so that, strictly speaking, the use of the bend does not introduce any really new formulæ.

26 In order to determine what results could be obtained by the use of the flow-bend, investigations were made with the apparatus

illustrated in Fig. 6. The bend was of a sectional area of 1.24 sq. in. of a square section, and was attached in a $1\frac{1}{2}$-in. steam pipe line, with one throttling valve in front and one behind it, whereby the pressure and the velocity of the flowing steam could be regulated at

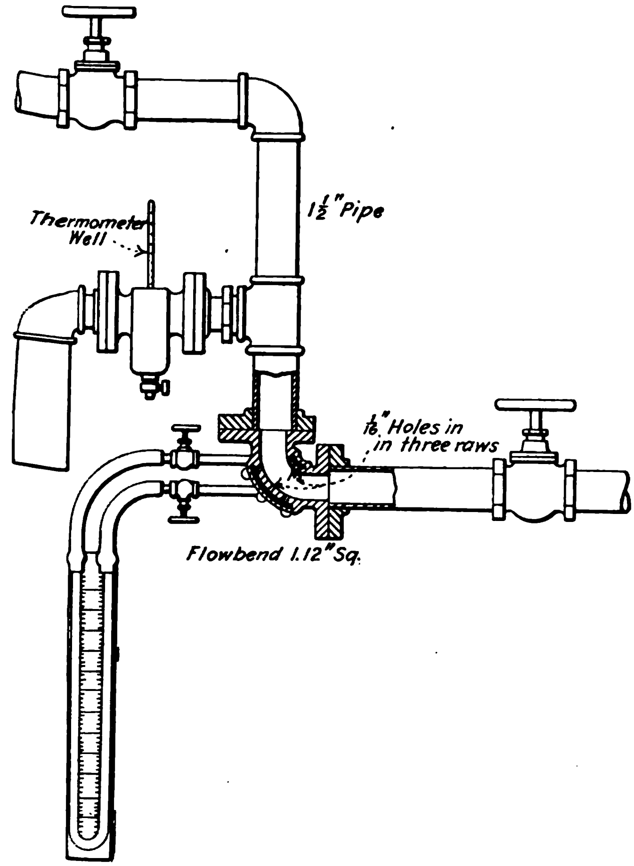

Fig. 6

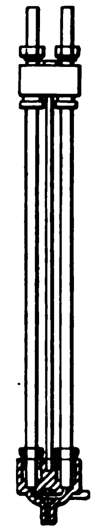

Fig. 7

FIG. 6 ARRANGEMENT FOR FLOW TEST
FIG. 7 MANOMETER WITH THROTTLING BYPASS

will. At the time of planning for the apparatus it was hardly expected that the abrupt change in area, from a cylindrical tube 1.6 in. in diameter to a square tube $1\frac{1}{8}$ in. on a side would be productive of the very best results. However, it was reasoned that as the centrifugal force is more or less independent of whirls in the body of the fluid, any irregularities in the flow would not have as an influence on the results as it would in the case of the pitot t in the venturi meter. It was also assumed that the great num pressure ports lengthwise of the bend would have a tende average up the possibly varying pressures throughout its l Besides, it was in part the object of the investigation to deter violent irregularities in the flow really would have any great inf on the readings; because on that circumstance would d largely, the final usefulness of the apparatus, as compared wit of those in general use.

27 The steam delivered through the apparatus was in the way condensed and weighed on a pair of platform scales, a quality of the steam was taken by means of a throttling calori The differential pressure readings were taken by means of a l manometer, employing for some of the tests a mercury colum generally for the lower speeds a column of water. Of the 34 pendent tests made, six were run during 30 minutes each, s during 20 minutes, and the rest during 15 minutes or therea

28 In working with steam, where any throttling of the p ports is hardly allowable, it is generally not very easy to re manometer heads, due to the unsteadiness of the column. present tests the manometer column was for certain pressu markably steady during long intervals, while for certain othe sures it was less steady, but no great difficulty in reading the sures was experienced. In working with steam the mano could be, however, improved by providing it with a throttli pass, as shown in Fig. 7.

29 The results of the tests are given in Table 1, and in are plotted the weight of steam per minute on a base-line which product of height of water-column, in inches, by the corrected d of the steam.

30 From the pitot tube formula [6b], the corresponding fo for the bend may be obtained, as explained, by adjoining th

tor $\sqrt{\frac{\rho}{2D}}$. Thus, for the present case

$$W_m = 7.62\ a \sqrt{\frac{\rho}{2D}}\ \sqrt{h_w\ \delta}$$

The average area through the bend was 1.24 sq. in., the fac-

TABLE 1 DATA OF TESTS OF A METERING FLOW BEND

No.	Steam Pressure Gage	Steam Pressure Absolute	Steam per min. lb. W_m	Density of Steam δ_o	Temp. Calorimeter t	Quality of Steam	Density corrected for moisture δ	$\frac{W_m}{\delta}$	V_s = Velocity Ft. pr. sec. $=1.94\frac{W_m}{\delta}$	Manom in. of water N_w	$\frac{N_w}{\delta}$	$N_w \times \delta$
1	46	60.5	9.04	0.14	245	0.988	0.142	63.6	123.4	10.42	73.4	1.48
2	44	58.5	8.65	0.1361	246	0.989	0.1376	63.0	122.2	10.64	77.3	1.46
3	45	59.5	8.08	0.1383	246	0.989	0.1398	58.0	112.2	9.6	68.5	1.34
4	30	44.5	8.13	0.1054	235	0.988	0.1065	76.3	148.1	12.14	114.5	1.29
5	20	34.5	8.30	0.083	216	0.985	0.0842	98.5	191.0	15.54	184.9	1.31
6	15	29.5	8.57	0.0716	218	0.999	0.0716	119.7	232	19.35	270.0	1.38
7	60	74.5	4.60	0.171	266	0.995	0.172	26.7	51.8	2.4	14.0	0.413
8	50	64.5	3.58	0.1493	262	0.996	0.1499	23.8	46.2	1.94	13.0	0.29
9	40	54.5	3.60	0.1274	258	0.999	0.1275	28.2	54.8	2.40	18.8	0.306
10	30	44.5	3.75	0.1054	252	0.999	0.1055	35.6	69.1	3.03	28.7	0.32
11	20	34.5	3.70	0.083	245	0.999	0.083	44.6	86.5	3.25	39.2	0.27
12	10	24.5	3.75	0.06	238	0.997	0.06	62.5	121.0	4.93	82.2	0.296
13	5	19.5	3.65	0.0486	226	dry	0.0486	75.1	146.0	5.22	108.0	0.254
14	2	16.5	3.65	0.0416	214	dry	0.0416	87.7	170.1	7.1	170.0	0.295
15	10	24.5	2.25	0.06	222	dry	0.06	37.5	72.8	1.55	25.8	0.093
16	5	19.5	1.70	0.0486	218	dry	0.0486	35.0	680	1.25	25.7	0.06
17	40	54.5	4.45	0.127	228	0.982	0.129	34.4	66.9	2.625	20.35	0.338
18	20	34.5	4.15	0.083	220	0.988	0.084	49.4	95.8	3.875	46.1	0.326
19	30	44.5	4.35	0.1054	214	0.980	0.1075	40.5	78.5	2.94	27.3	0.316
20	10	24.5	5.40	0.06	212	....	0.061	88.5	172.0	8.75	143.0	0.534
21	5	19.5	4.20	0.0486	212	....	0.0486	86.0	167.0	6.75	137.5	0.338
22	65	79.5	4.80	0.1818	224	0.978	0.187	25.6	50.0	2.25	12.1	0.422
23	60	74.5	4.0	0.171	224	0.973	0.176	22.7	44.0	2.06	11.7	0.365
24	50	64.5	4.33	0.1493	230	0.979	0.151	28.7	55.5	2.19	14.5	0.331
25	77	91.5	3.33	0.2076	230	0.972	0.2134	15.6	30.2	1.13	5.3	0.241
26	80	94.5	6.3	0.214	232	0.972	0.22	28.6	55.5	3.44	15.6	0.755
27	70	84.5	7.45	0.1926	228	0.974	0.1976	38.0	73.7	5.38	27.2	1.066
28	60	74.5	6.9	0.171	226	0.974	0.175	39.4	76.4	5.5	32.0	0.962
29	50	64.5	7.0	0.1493	222	0.974	0.1531	45.6	88.5	6.5	42.5	1.02
30	40	54.5	7.0	0.1274	212	0.974	0.1307	53.3	101.5	7.06	53.8	0.92
31	30	44.5	6.42	0.1054	212	0.976	0.1079	59.6	115.0	6.625	61.6	0.716
32	20	34.5	4.6	0.083	212	0.983	0.084	54.8	103.0	4.75	56.5	0.399
33	10	24.5	2.85	0.06	214	0.991	0.06	47.5	92.0	3.125	52.0	0.187
34	10	24.5	1.62	0.06	220	0.994	0.06	27.0	52.0	0.8	13.3	0.048

Bar. Pressure 29.6 in. Hg.

tor $\frac{\rho}{2D}=\frac{2}{3}$, or $\sqrt{\frac{\rho}{2D}}=0.8165$. Hence, for the bend used we have

$$W_m = 7.62 \times 1.24 \times 0.8165\sqrt{h_w \delta} = 7.716\sqrt{h_w \delta}$$

This formula is represented by the full-drawn curve of Fig. 8.

31 The approximate velocity formula, which applies c closely for steam of the moderate velocities of the present tests,

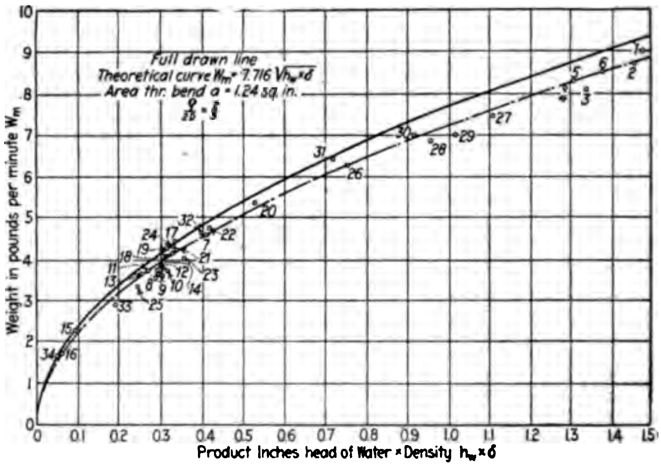

FIG. 8 CURVES OF WEIGHT PER MINUTE

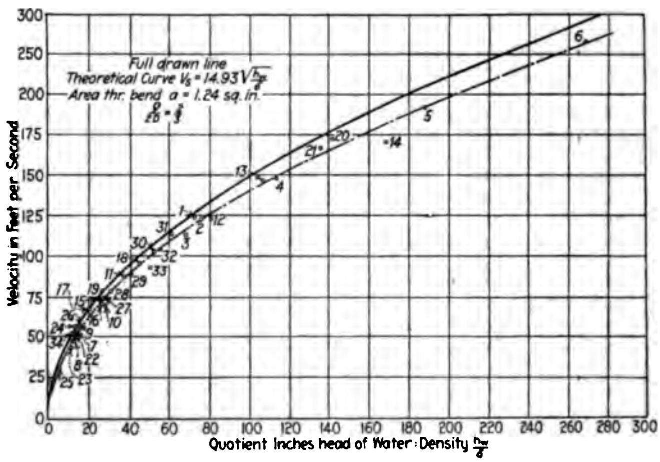

FIG. 9 VELOCITY CURVES

be written from formula [6] for the pitot tube, as

$$v_s = 0.8165 \times 18.29 \sqrt{\frac{h_w}{\delta}} = 14.93 \sqrt{\frac{h_w}{\delta}}$$

32 The curve representing this formula (the parabola) is shown in Fig. 9, and underneath are plotted, in feet per second, the velocities obtained in the 34 tests. The average velocity curve to suit the plotted points would be approximately as shown in the broken line, and it will be seen that the majority of the plotted points come as closely to their proper places as could reasonably be expected. It may be said that on the whole and under the circumstances, the results come surprisingly close to what the theory would have predicted; and it is judged that with reasonable care to eliminate as much as possible all disturbing influences with respect to the flow through it, the bend will in accuracy measure up well with the instruments in general use.

DISCUSSION

S. M. Woodward. This is an interesting matter and the instrument as explained seems to have given good practical results, but I doubt whether the correct theory of flow around the bend is as simple as the mathematics given in the paper would indicate. One of the fundamental assumptions made is that, in a fluid flowing around the bend, all the particles have the same angular velocity. It seems to me that it would be more rational to assume the same linear velocity. This would not affect the practical use of the apparatus but it would somewhat affect the calibration.

Flow around bends is a complicated matter. As motion around the bend begins and the pressure becomes less on the inner boundary of the curve, this change of pressure is accompanied by a corresponding change in velocity distribution through the cross-section. At first, the diminution of pressure produces an increase of velocity on the inner side of the bend, which is the opposite of the condition assumed in the paper.

The Author. I readily agree with Professor Woodward that the theory for flow through bends is, in its entirety, quite complicated; but in so far as it pertains simply to the centrifugal force coming to play it does not seem, necessarily, involved at all. The matter to which Mr. Woodward refers, I should perhaps have stated more fully, in order to be understood more readily.

The force acting on a given section of the fluid, and causing it to deviate its course is, successively, changing in direction as the fluid proceeds through the bend, but it always passes through the center of curvature of the bend. Its effect, therefore, upon the fluid, at : time throughout the sweep of the bend, will be a certain force thro the center of curvature, the centrifugal force, and a couple, which ter causes a whirl or eddy. But as far as the centrifugal force is c cerned the whirl is of no consequence whatever.

With this in view, the assumption with regard to the stream li of Fig. 3 had better be looked upon, of course, as referring to parti of the fluid of certain defined density, rather than strictly to sc mathematically defined material points. However, any way this r be looked upon, under the conditions of the problem the assumpt seems justified, and that it really is so the results verify.

With regard to the elementary section through the fluid, Fig which is the basis for the deduction of the formulae, there is no ne sity for considering it as being composed of exactly the same mate points for every section of the bend. That various particles may place each other from section to section does not affect the reasoni so long as they change position in a manner that will not affect centrifugal force.

The substance of the proposition may, perhaps, be stated sim thus: There is a certain mass passing through the bend, the cer of gravity of which is located, and of known velocity; there is then order to find the value of the centrifugal force, no need for know whether the mass revolves, or how it acts, so long as its center gravity follows a defined path.

Mr. Woodward's statement that the velocity of the fluid incre on the inner boundary of the bend as the pressure decreases, I can plain only on the ground that he refers to the velocity in the wh I have by "velocity" considered only that which causes the fluid progress through the bend.

No. 1437

POWER DEVELOPMENT AT THE HIGH DAM BETWEEN MINNEAPOLIS AND ST. PAUL

BY ADOLPH F. MEYER,[1] ST. PAUL, MINN.

Non-Member

The project for the improvement of the Mississippi River between Minneapolis and St. Paul had its inception in 1866. No definite action was taken, however, until 1894, when plans were developed for two locks and dams of about 13-ft. lift each, one at the site of the present High Dam, and another about three miles above the High Dam, near the Selby Avenue Bridge.

2 Work was commenced on the upper dam, known as dam No. 2. After about $750,000 had been spent, in the days when dry concrete was the order of the day and Portland cement was a luxury that could be advantageously diluted with ground sand, the proposition of utilizing the fall in the Mississippi River in this vicinity for power development received the attention of a special board of U. S. Army engineers, in 1907. This board reported that no power could be economically developed at the proposed 13-ft. dam No. 1, at the site of the present High Dam; that a small plant might be installed at dam No. 2; but that the probable saving estimated at $2000 per annum which would result from a 1300-h.p. development would not warrant the carrying out of the project.

3 This board predicted, however, that before many years had elapsed it would be economically desirable to build a high dam in the vicinity of the proposed Low Dam No. 1, which is the site of the present High Dam, where a head of probably 35 ft. might be secured, and a total of 15,000 to 20,000 h.p. developed.

4 The matter of power development was temporarily dropped until 1910 when a report was made by a second board of U. S. Army engineers favorable to the construction of the High Dam. The senti-

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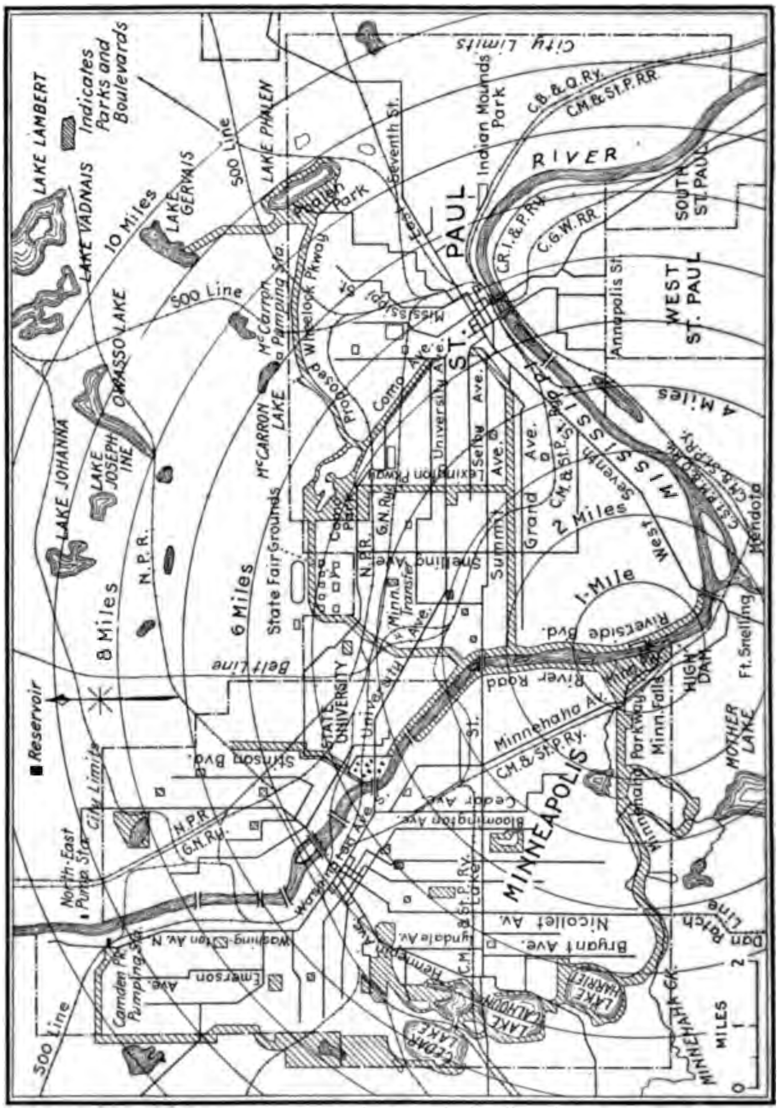
Presented at the Spring Meeting, St. Paul-Minneapolis 1914, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.


LAKE LAMBERT
Indicates Parks and Boulevards
LAKE VADNAIS
10 Miles
LAKE GERVAIS
LAKE PHALEN
500 Line
Phalen Park
City Limits
Indian Mounds Park
C.B.&Q.Ry.
C.M.&St.P.RR.
RIVER
SOUTH ST. PAUL
WEST ST. PAUL
PAUL
ST.
OWASSO LAKE
LAKE JOHANNA
LAKE JOSEPHINE
McCARRON LAKE
McCarron Pumping Sta.
8 Miles
6 Miles
N.P.R.
State Fair Grounds
Como Park
University Ave.
Selby Ave.
Grand Ave.
Summit Ave.
Snelling Ave.
2 Miles
1 Mile
4 Miles
MISSISSIPPI
Mendota
Ft. Snelling
HIGH DAM
MOTHER LAKE
Minn. Falls
Minnehaha Parkway
River Road
Riverside Bvd.
Belt Line
STATE UNIVERSITY
Reservoir
North-East Pump Sta.
City Limits
Stinson Bvd.
MINNEAPOLIS
Minnehaha Av.
C.M.&St.P.Ry.
Cedar Ave.
Bloomington Ave.
Nicollet Av.
Bryant Ave.
Lyndale Av.
Hennepin Ave.
Emerson Ave.
Washington Av. N.
Camden Pk. Pumping Sta.
LAKE CALHOUN
LAKE HARRIET
CEDAR LAKE
MINNEHAHA CR.
Dan Patch Line
500 Line
MILES
0 1 2

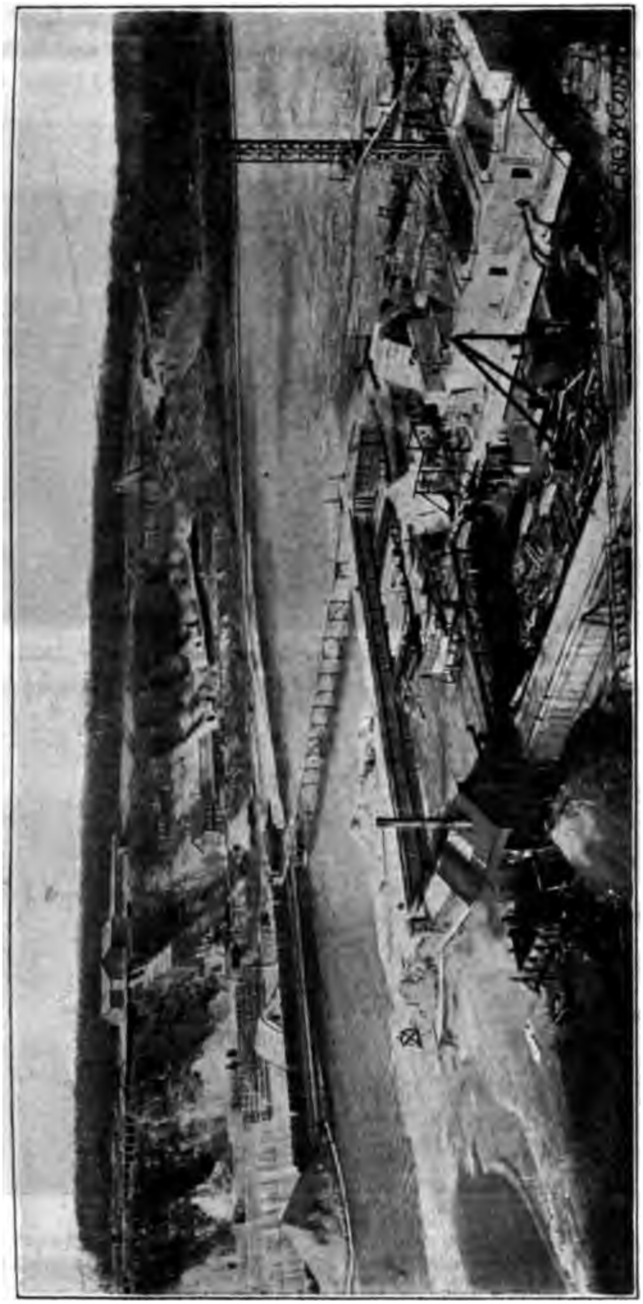


Fig. 1 Site of Dam No. 1, Known as High Dam, Across the Mississippi, Between Minneapolis and St. Paul

ment of the board as well as of the community was in favor of operation with the cities of Minneapolis and St. Paul and both ci passed resolutions pledging themselves to pay the additional cost

Fig. 2 Construction View of Power House, July 1913

Fig. 3 View of High Dam, January 1914

raising the projected navigation dam to a height of approxima thirty feet to permit the development of water power.

5 The Board of Engineers for Rivers and Harbors concurred in e recommendations of the Special Board and the Chief of Engi-

FIG. 4 VIEW OF HIGH DAM, MARCH 1914

FIG. 5 VIEW OF FOREBAY, FEBRUARY 1914

s recommended that negotiations be entered into whereby the icipalities of Minneapolis and St. Paul would become the lessees ny surplus power that might be created.

6 In the River and Harbor Act of 1910 Congress adopted modified project as recommended by the Chief of Engineers, with provision "That in the making of leases for water power a reason compensation shall be secured to the United States, and the rate fixed shall be subject to revision by Congress."

7 At the following session of the Legislature of Minnesot bill was passed permitting the formation of public corporations

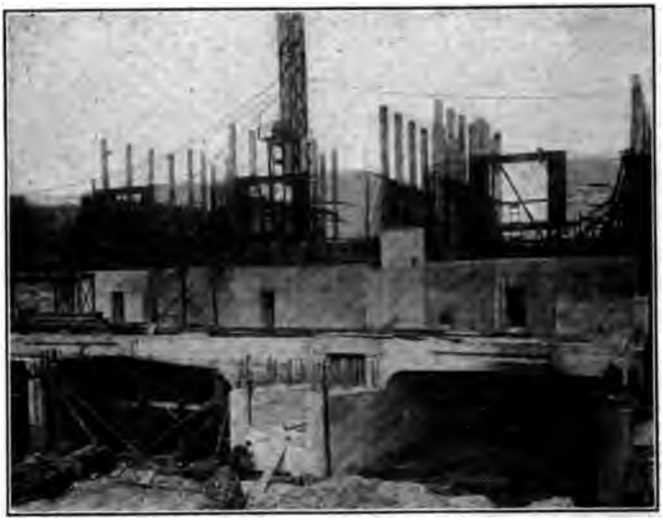


FIG. 6 CONSTRUCTION VIEW, FEBRUARY 1913, SHOWING TAIL RACE

the purpose of developing water power. Under this act there immediately incorporated the Municipal Electric Company, comp of the State University and the cities of Minneapolis and St. P

8 In 1913 a bill was introduced in Congress by Hon. F. Stevens, providing for a coöperative agreement with the citie Minneapolis and St. Paul and the State University, whereby, i becomes a law, the Municipal Electric Company may lease the av able water power upon the condition, among other things, that company pay not less than 3 per cent interest on the amount wl the government will have expended for the purpose of making water power available.

AVAILABLE POWER

9 The amount of water power which will become available through the construction of the High Dam can be ascertained with considerable accuracy, inasmuch as good physical data are available.

10 Estimates of stream flow have been made by the St. Anthony Falls Water Power Company and the Minneapolis Mill Company at

Fig. 7 Lock and Gate, April 1913

their plants in Minneapolis, covering a period of more than 20 years. In the more detailed analysis of available power which was made, however, the records kept by the U. S. Engineer office at St. Paul, during the eight years from 1905 to 1912 inclusive, have been used.

11 The diagram in Fig. 8 shows graphically the elevation of "tail water" and "head water" at the various rates of discharge. The head water curve gives elevations one foot below the maximum permissible elevation as computed, to which the water above the dam can

be raised without producing backwater at the lower power dar Minneapolis. The present dam is being constructed with its crest a elevation of 743.5 Cairo datum. The tail water curve gives the n

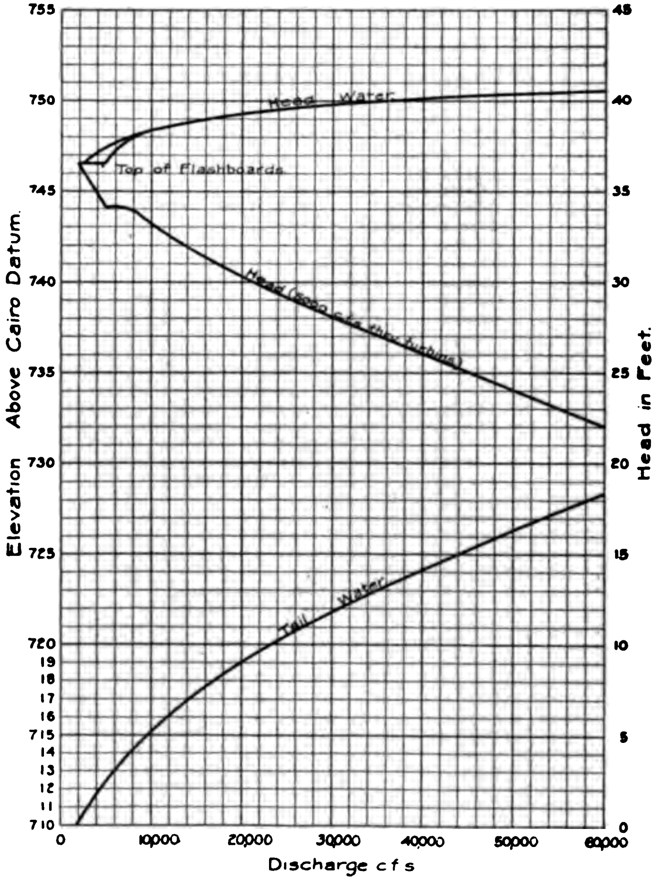


FIG. 8 ELEVATION OF TAIL WATER AND HEAD WATER AT VARIOUS RATI DISCHARGE

elevation of the water surface for various rates of discharge, b on the readings of the government gage at the site of the dam du the past eight years, taking into account the lowering of the tail w which will result from dredging a 6-ft. channel below the lock, backwater from the Minnesota River at flood stages, and backw from ice conditions in the winter.

12 The head curve gives the mean head which would be avai

on the assumption of three feet of flashboards on the dam at low water, and a turbine installation capable of using about 5000 cu. ft. per second. It will be noticed that the head varies from a maximum of 36½ ft. at low water to a minimum of 22 ft. during extreme flood conditions, such as might occur for a few days perhaps once in ten years. The normal head may be assumed as 34 ft. For perhaps twenty days a year on an average, or 5½ per cent of the time, the available head will be reduced during high water to less than 29 ft.

TABLE 1 MEAN MONTHLY DISCHARGE
1905-1913

	1905 c.f.s.	1906 c.f.s.	1907 c.f.s.	1908 c.f.s.	1909 c.f.s.	1910 c.f.s.	1911 c.f.s.	1912 c.f.s.	1913 c.f.s.
Jan.	3174	6667	6220	2390	3350	4198	1764	1840	2600
Feb	2745	6280	6250	2750	3300	4011	1799	1750	2200
Mar	5241	7320	11600	4550	4300	9470	2338	2140	2880
Apr	9775	24653	25099	8185	11721	8640	3404	7080	5125
May	21013	20227	13673	13300	11910	6280	4688	16080	7850
June	23749	29090	18681	32079	11950	4330	4762	7240	6015
July	31762	16525	8266	14364	6160	*3500	3719	5280	8950
Aug	15700	9185	7347	6992	8570	*3400	3400	5100	6255
Sept	12874	10965	7149	5100	6480	*3800	3588	5020	5990
Oct	11067	11378	7674	5980	5420	3210	4351	4840	....
Nov	9743	11301	7745	5070	5350	2690	2712	3840	....
Dec	8163	6980	3310	3800	5120	2010	2355	2890	....
Mean Annual	12920	13390	10250	8710	6965	4630	3240	5260	....

* Modified on basis of Anoka discharge.

13 *Water Available.* Table 1 gives the mean monthly stream flow at the dam site for the years 1905 to 1913 inclusive. It will be noticed that the mean monthly flow is below 2000 cu. ft. per second for four months in eight years. The minimum mean monthly flow is 1750 cu. ft. per second. In computing the minimum amount of power which would become available at the dam, an extreme minimum flow of 800 cu. ft. per second has been assumed. Such a flow, however, has in the past occurred for only a portion of a day during sudden periods of extremely cold weather. On such occasions the normal flow of 1500 to 2000 cu. ft. per second is usually re-established in two or three days. A minimum winter flow has been assumed as follows: 800 cu. ft. per second for one day; 1300 cu. ft. per second for three days; 1500 cu. ft. per second for five days; and 1750 cu. ft. per second for one month.

14 *Effect of Pondage.* The area of the pool above the dam the 740 contour has been determined by planimeter measurements recent government maps to be 22,500,000 sq. ft. Assuming the p to be full to the top of the flashboards at the approach of an extrem cold spell, the water surface would be lowered 4.2 ft. in order augment the supply from 800 cu. ft. per second for one day, and 13 cu. ft. per second for two additional days, to a mean of 1500 cu. per second. As the available head, in winter, would be at least 36 ft., the net head which would remain available after drawing dow the pool would still be 32.3 ft. By operating the steam pumps provide the municipal water supply for Minneapolis and St. Pa

TABLE 2 NUMBER OF DAYS PER YEAR CERTAIN AMOUNTS OF POWER WOU HAVE BEEN AVAILABLE
1905–1912

Year	1000 kw.	2000 kw.	3000 kw.	4000 kw.	5000 kw.	6000 kw.	7000 kw.	8000 kw.	9000 kw.	10000 kw.	10 k
1905	365	365	365	365	365	365	365	365	353	326	[illegible]
1906	365	365	365	365	365	365	365	365	365	342	[illegible]
1907	365	365	365	362	349	332	322	288	262	261	[illegible]
1908	366	366	366	366	366	363	349	303	270	227	[illegible]
1909	365	365	365	365	365	365	357	340	305	266	[illegible]
1910	365	365	365	363	290	262	215	133	113	104	
1911	365	365	365	362	307	244	202	142	90	45	
1912	366	366	366	363	329	273	256	241	228	203	1
Total	2922	2922	2922	2911	2736	2569	2429	2175	2085	1873	14
Mean	365	365	365	364	342	322	304	272	261	234	1
Per cent	100	100	100	99.8	93.7	88.2	83.4	74.5	71.5	64.3	
Mean deficiency (days)	.....	.....	.....	1	23	43	61	93	104	131	1

or by drawing upon the supply stored in the reservoirs, or both, station load can be sufficiently reduced to enable the pool to fill ag in two or three days.

15 *Power Available.* Table 2 gives the number of days year during which certain amounts of power in blocks of 1000 k would have been available for each year from 1905 to 1912 inclusi A flow of 1750 cu. ft. per second corresponds to about 4000 kw. the switchboard, assuming an overall efficiency of 75 per cent; 15 cu. ft. per second under 32.3-ft. head corresponds to about 3100 k This is the maximum amount of power which could be counted with positive certainty 24 hours of the day, and every day in t year.

ECONOMICAL SIZE OF INSTALLATION

16 The desirability of utilizing, for power development, water which is available for only a portion of the year, is dependent mainly upon the relative cost of producing power by steam plants and by water power plants.

17 If the cost of operating a given steam power plant a certain

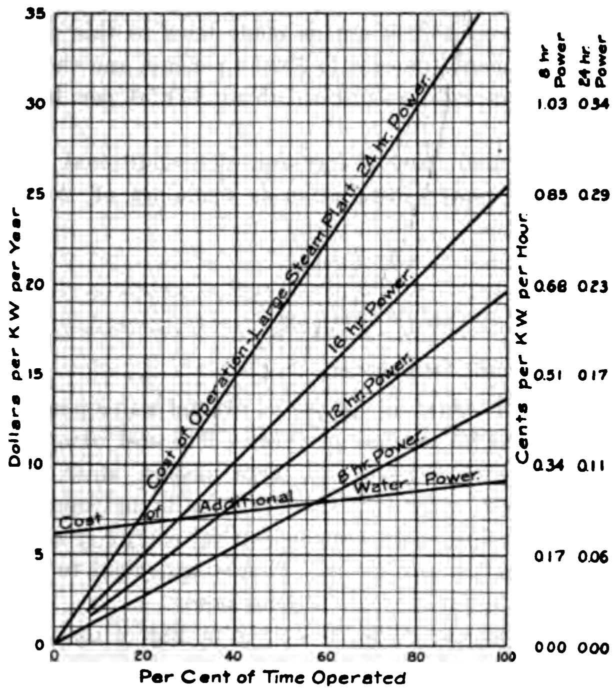


FIG. 9 COST OF OPERATING STEAM, AND FOR ADDITIONAL WATER POWER, FOR DIFFERENT TIME PERIODS

number of hours a day for the portion of the year during which additional water is available is greater than the fixed charge would be on the additional water power installation, plus the cost of operating this additional installation for that portion of the year, it would pay to develop such power.

18 The curves in Fig. 9 are based on the following assumptions: The Federal Government will have invested about $800,000 in a modification of the navigation project, to provide for the utilization of water power, consequently the fixed charges on this amount must

be borne by whichever size of installation is adopted. It will at onc be apparent that the larger the installation, the less the fixed charg per horsepower will be. This, of course, is true only within reason able limits, as the draft tubes have already been built, and hence th friction and other losses resulting from the discharge of larger quan tities of water by a larger turbine installation will lower the efficienc of the plant.

19 A detailed estimate of the total cost of an installation neces sary to develop about 15,200 h.p. is made later in this paper. Th government investment amounts to $52.50 per h.p. and the additiona cost of installation will amount to about $41.50 per h.p., or $6 per kw.

20 The estimated fixed charge for each additional kilowatt c capacity of water power installation is made up of the followin items:

4½ per cent interest on $60.00	$2.70
Sinking fund	0.40
Depreciation (or renewal fund)	3.00
Annual fixed charge	$6.10

21 The cost of operation for the additional water power instal tion is estimated at $3 per kw. per year. The cost of operation the steam plant is on the basis of large modern units. Plants 25,000 to 50,000-kw. capacity, using large units and operating on 50 per cent load factor, can produce electrical energy at an operati cost of about 0.45 cents per kw-hr. This is equivalent to a total co of about $28 per kw. per year for 12-hour power.

22 It would appear from the curves in Fig. 9 that the cost furnishing 8-hour power by a large steam plant would be the sar as the cost of furnishing such power by a hydroelectric plant, usi water available 58 per cent of the time. The cost of 12-hour stea power would just equal the cost of hydroelectric power produced fro water available 37 per cent of the time. As the ordinary commerci light and power loads have a load factor averaging between 35 and 5 per cent, it would appear desirable to install a plant capable of usin all the water which would, on an average, be available for at least 4 per cent of the time, provided the owner of the water power possesse a large steam plant.

23 If the Municipal Electric Company undertook to develop th power, however, it would either have to sell, in the open market, ar surplus power not required for public purposes, developed from wat

available for only a portion of the year, or else install a steam auxiliary. If it sold the excess power in the open market to consumers who were developing their own power by a large steam plant, it could not expect to receive more than about 75 per cent of what this power might be worth to said consumers.

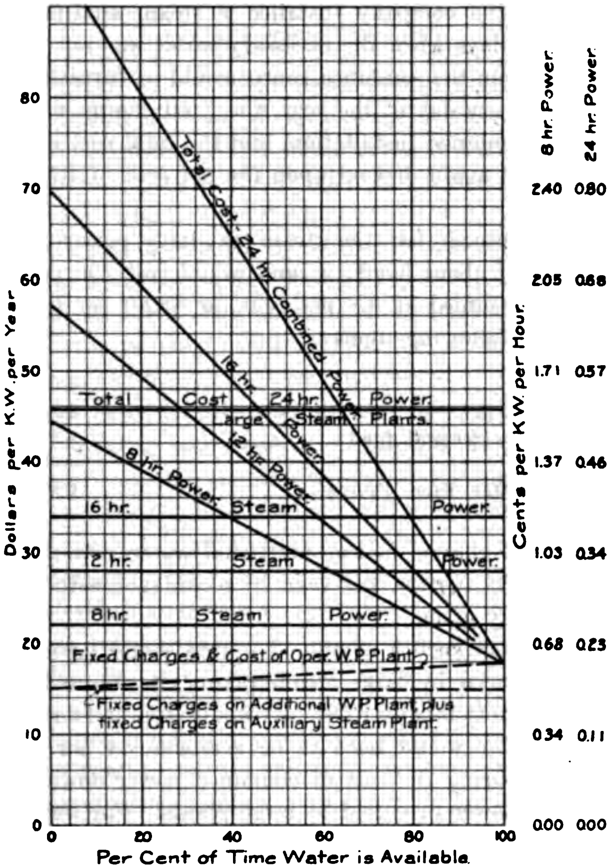


FIG. 10 COST OF COMBINED POWER FOR DIFFERENT PERIODS

24 On this basis, power developed from water available 50 per ent of the time might just find a market with consumers who were de-eloping 12-hour steam power. When available at all, such excess ower could be furnished at any time of the day, and for 24 hours if ecessary, but it would have to be either utilized or wasted, as the ater could not be stored. Ample notice, however, could be given onsumers.

25 On the above assumptions, it would appear advisabl install a plant of 10,500-kw. capacity, inasmuch as this amoun power would be available for at least 50 per cent of the time, accor to Table 2, smaller amounts being available, of course, for lo periods.

26 In case the company installed a steam auxiliary plan supply power on days when the necessary water was not availabl that the power from the combined source could be furnished any l of the day and every day of the year, the fixed charge would hav be paid on the combined installation, and the total cost of furnis such power would again depend upon the per cent of time the w was available.

27 It is assumed that the steam auxiliary power plant w have a capacity of about 5000 kw. and would cost $90 per kw. fixed charge is assumed as 9.8 per cent, or $8.80 per kw. per y composed of the following items:

Interest	4.5 per cent
Sinking fund	0.5 per cent
Depreciation (or renewal fund)	4.8 per cent
Total fixed charge	9.8 per cent

28 The fixed charge on the additional water power installa is assumed as $6.10 per kw. per year, in accordance with the deta estimate previously given.

29 Power from such a combined source would have to com with power produced by large steam plants, if not utilized by Municipal Electric Company itself. It would appear from the cu Fig. 10, that water would need to be available 84 per cent of time in order to bring the cost of combined power down to the of 8-hour steam power produced by large plants. For water avail 75 per cent of the time, the cost of combined power would just e the cost of 12-hour steam power, and for water available 70 per of the time, the cost would just equal 16-hour steam power. cost of 24-hour power developed by such a combined plant using w available less than 64 per cent of the time, would be greater than cost of 24-hour power developed by a large steam plant.

30 Considering the cost of connecting up, by pole line or cond to some large plant, and of the difference between cost and ma price of power, it is probable that the Municipal Electric Comp could not purchase even large blocks of peak power at less than

cents per kw-hr. for 12-hour power. On this basis it would just pay to install turbines capable of developing water power which would be available at least 50 per cent of the time, and to add a 5000-kw. steam auxiliary plant when the Municipal Electric Company's own demands for power warranted such installation.

INSTALLATION PROPOSED

31 The great reduction in head during high water makes it necessary to install a plant of very much greater turbine capacity than would be necessary under more uniform head conditions. At times of high water there is not only a reduction in the available head, but also a reduction in the amount of water which any given turbine installation is capable of utilizing. As the discharge from turbines varies with the square root of the head, any given turbine installation at the High Dam operated at a certain gate opening will be able to discharge only about eight-tenths as much water under flood conditions as under low water conditions.

32 On the basis of Holyoke test data, a preliminary study was made of the probable performance of turbines of the size which it will be necessary to install in order to develop the contemplated power, operating under the conditions which will obtain at the High Dam, i.e., under a head varying from 36.5 ft. at low water to 22 ft. at extreme flood stage. After this preliminary study had been made, it appeared desirable tentatively to recommend the installation of four units having a rated capacity at full gate under low water head of about 5000 h.p. per unit; either one or two runners to be used on each shaft and the turbines to be direct-connected to 3500-kva. generators. Even this installation, however, would be capable of developing only about 7000 kw. at extreme high water. Very good efficiencies would be secured under heads ranging from 32 to 36½ ft. when operating such turbines at from 65 per cent to 90 per cent gate opening. Four units would carry the normal station load of 10,500 kw. when operating at about 72 per cent gate opening and under a 34-ft. head. Such an installation would also be capable of developing 10,500 kw. during ordinary flood conditions, under a 29-ft. head, when all four units were operated at approximately full gate opening. Three units at full gate opening under low-water head, with only a small overload on the generators, depending on the power factor, would also be capable of developing 10,500 kw.

33 It is believed that the rather large installation would be fully

warranted by the conditions under which this plant would be requi to operate. While the full rated capacity of the plant at low wa and under full gate might be considered as 20,000 h.p., the nor capacity would really be only about 15,200 h.p., inasmuch as it wo be poor policy not to have a reserve unit under ordinary conditi of head, stream flow, and load.

PROBABLE COST OF DEVELOPING THE WATER POWER

34 The Federal Government has practically completed the mo fied project in accordance with the Act of Congress of 1910, and United States Engineer Office at St. Paul has estimated that total cost of the project, as modified for the development of wa power, including the construction of the power house substructi draft tubes, etc., will be $800,000 more than the cost of the origi project would have been.

35 In the Stevens bill now pending in Congress, it is provi that the Municipal Electric Company pay not less than 3 per c interest on the amount which the Government has invested for purpose of making the water power available. For an installat of 15,200 h.p., the Government investment amounts to about $52 per h.p.

36 *Additional Expenditure Required.* In order to complete power house and install the necessary machinery, an additional penditure of about $630,000 will be required. This includes inte during construction, insurance, engineering, supervision, and c tingencies, and $50,000 working capital or "emergency fund," quired by the laws of Minnesota under which the Municipal Elec Company is incorporated.

37 Adding the Government expenditure of $800,000 gives ! 430,000 as the investment cost of the plant. This amount is eq to about $94 per h.p. at the turbine shaft, and $136 per kw. at switchboard.

38 *Fixed Charges and Operating Cost.* The fixed charges on water power plant will be about as follows:

3 per cent interest on $800,000	$24,000	per an
4½ per cent interest on $630,000	28,400	per an
Sinking fund to pay off $630,000 in 50 years at 4 per cent	4,050	
Renewal of plant in 15 years at 4 per cent	31,460	
Maintenance	10,090	
Total fixed charges	$98,000	

39 Adding to the fixed charges the annual cost of operation and administration, including an allowance for the annual charge on the investment in transmission lines and substations not herein itemized, brings the total cost of developing power to about $150,000 to $175,000 per annum.

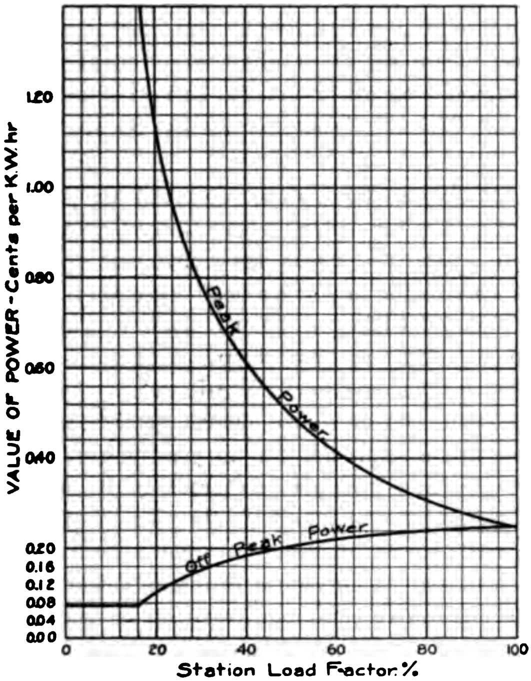


FIG. 11 RELATIVE VALUES OF PEAK AND OFF-PEAK POWER FOR DIFFERENT LOAD FACTORS

40 *Cost of Power per Kw-Hr.* According to Table 2, the mean annual deficiency of power up to 6000 kw. is 1,608,000 kw-hr. Assuming that the steam pumps would be operated to supply this deficiency, all power up to 6000 kw. may be considered as primary power as far as the Municipal Electric Company is concerned. The mean annual amount of such power which would have been available during the past 8 years is, on the basis of Table 2, 50,800,000 kw-hr. The total amount of power between 6000 kw. and 10,500 kw., which would have been available during the same time, is 27,900,000 kw-hr., or a total of 78,700,000 kw-hr. of available power per annum. This is equivalent to a mean of 9000 kw., and on this basis the cost of

developing 24-hour power would be a trifle less than two tenths of cent per kw-hr.

41 If we assume that the power which could not be furnishe at all times,—the "excess power"—is worth, on an average, one-thir as much as the "primary power," there would be an average o 60,100,000 kw-hr. of power available each year. This would mak the cost of developing power about a quarter of a cent per kw-h If a 5000-kw. steam auxiliary plant were installed so as to mak 10,500 kw. available at all times, the cost of developing this pow would be about 0.35 of a cent per kw-hr. on the basis of 24-hou power.

42 Fig. 11 shows the relative values, at the station, of "peak and "off-peak" power for different load factors, on the basis of a co of a quarter of a cent per kw-hr. for continuous power. If the lo factor of the station for any given load were very small, as, for e ample, in the neighborhood of 20 per cent off-peak power could sold at the mere additional cost of operating the water power pla This would be, in the case under consideration, less than one-ten of a cent per kw-hr. As the load factor became larger, the value off-peak power would approach that of peak power, equaling it wh the load factor became 100 per cent, and at all times possessing value about inversely proportionate to its effect in increasing the lo factor. The peak power, in order to yield a return equivalent to quarter of a cent per kw-hr. for continuous power, would be wor about one and one-fourth cents per kw-hr. at 20 per cent load fact taking into consideration the slightly lower cost of operation in t case of power furnished for only a small portion of the day, b without taking into consideration the compensating effect of pondag i.e., assuming that the available water must be either utilized wasted.

43 With a station load factor of 60 per cent, under the same a sumptions, the value of peak power at the station would be abo four-tenths of a cent per kw-hr, and off-peak power would be wor just about half this amount.

44 When the effect of pondage is taken into consideration, ho ever, the load factor is found to affect the cost of power considerab less than the value of that factor would make it appear. In Fig. 1 is shown a characteristic combined street lighting and miscellaneo light and power load, having a load factor of 40 per cent. Fig. 1 shows a mass curve of actual consumption of current and of mea

consumption, or equivalent in supply of water, from which can be scaled the quantity of power which must be furnished by stored water for various mean rates of stream flow. From this value, the area of the pond, and a mean head for each particular condition, the pool fluctuation for various rates of discharge, as shown in Fig. 13, was determined.

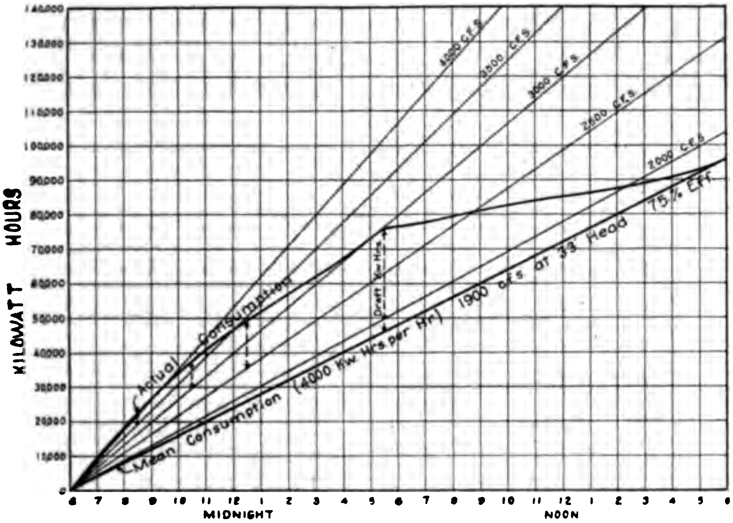
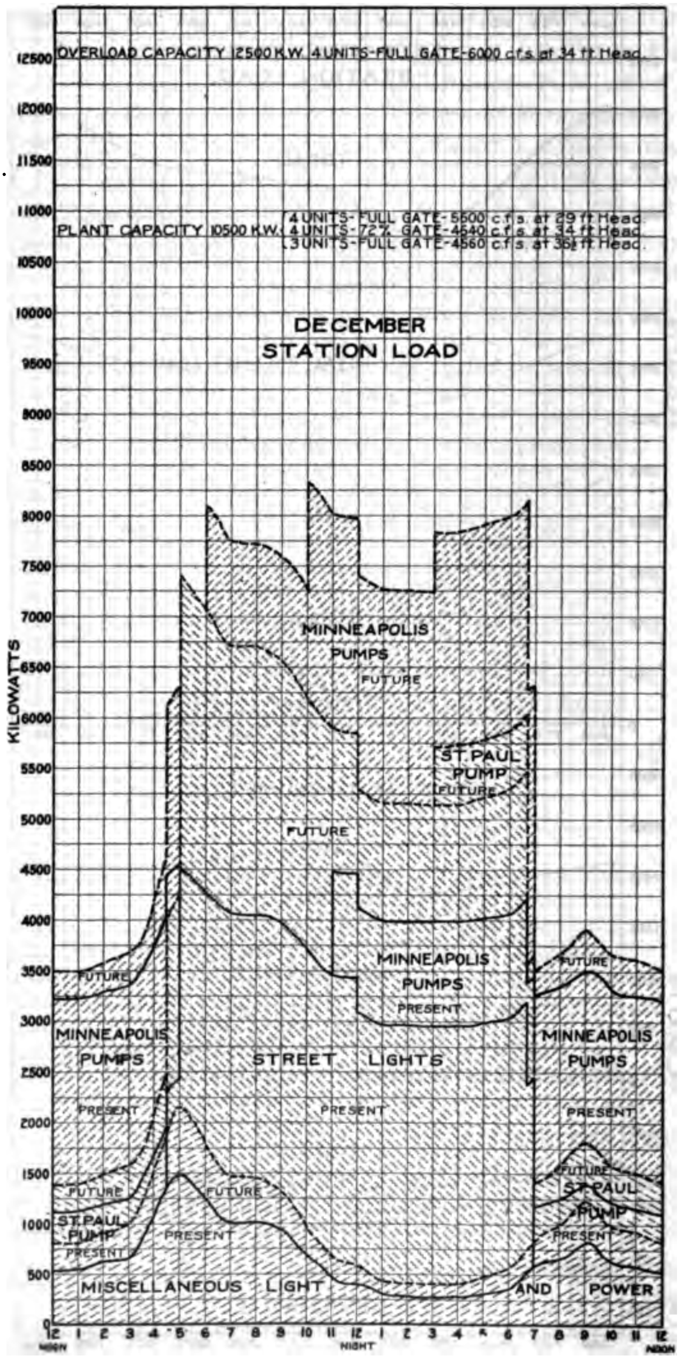


FIG. 12 MASS CURVE OF CONSUMPTION

45 The only effect of the load factor, then, in this case where the entire flow of the stream was being utilized through pondage, would be due to a reduction in available head from drawing down the pool, and from a rise in the tailwater at the time of high discharge, i.e., peak load. Instead of the 40 per cent load factor having increased the cost of power 2½ times, as indicated in Fig. 11, it has, in reality, increased the cost, under the conditions assumed, less than 10 per cent. Not until the amount of water continually available has increased to 4500 cu. ft. per sec., or peak load conditions, will the value of power be increased 2½ fold by a 40 per cent load factor.

UTILIZATION OF POWER

46 *Present Consumption.* Statistics were obtained, from all available sources, giving the amount of power at present consumed by the Federal Government, the State of Minnesota, and the cities



TYPICAL DECEMBER STATION LOAD FOR PUBLIC PURPOSES

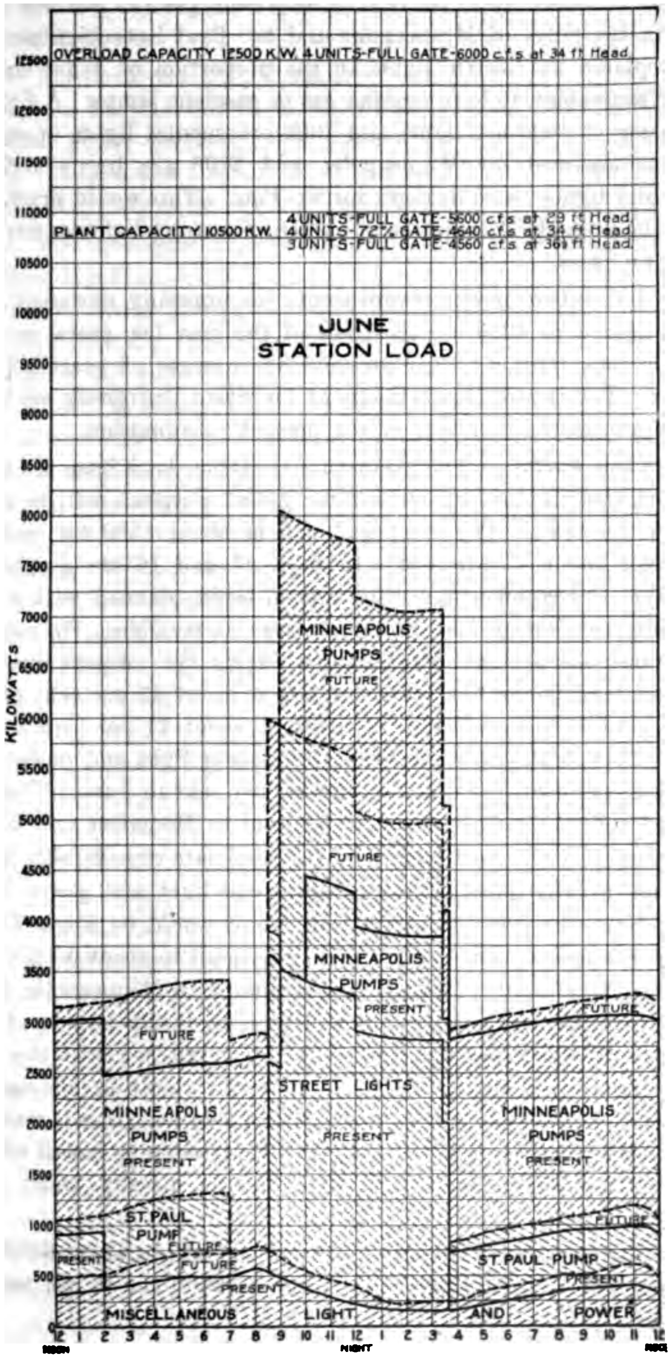


Fig. 16 Typical *June Station* Load for Public Purposes

have been increased by 25 per cent. The present gas and gasolene stree lamps in the cities of Minneapolis and St. Paul have been assume to be replaced by electric lights in the proportion of about one ar light or equivalent, to four existing gas or gasolene lamps. A lightin installation of 4000 arc lights and 1000 ornamental lights or equiva lent, was assumed for Minneapolis, and 2700 arc lights and 60(ornamental lights, or equivalent, for St. Paul. This would practicall double the present consumption of current for street lighting purpose in the two cities.

50 The future power requirements for pumping represent wha will be needed in 1920, on the basis of the past few years' increas in water consumption. It represents an increase of practically 5(per cent. The future requirements of the State University are base on an approximate doubling of the present consumption.

51 *Load Factors.* The mean annual station load from the abov estimated consumption of current for public purposes will be abou 5500 kw. by 1920. The peak load will be about 8500 kw. and th load factor about 65 per cent. In Figs. 15 and 16 are graphicall shown typical December and June station loads, planned with a view to keeping the station load factor as large as possible. By runnin the Minneapolis and St. Paul pumps during the off-peak hours, December load factor, for present loads, of about 87 per cent can b secured, and for future loads, a factor of about 74 per cent can b secured. The load factor for the miscellaneous light and power loa is about 44 per cent in December, and 60 per cent in June. That fo the street lighting load is about 56 per cent in December and 27 pe cent in June. These load factors on the whole are considerably bette than those usually obtained from commercial light and power loads During June, the present station load factor would be about 76 pe cent, but the future load factor would be reduced to about 60 per cen unless the installation of motor driven pumps in Minneapolis is in creased. The present installation will soon be insufficient to suppl the increased water consumption even if run 24 hours of the day This, of course, is uneconomical, as it would result in adding th Minneapolis pump load to the peak. Before this condition is reached however, Minneapolis no doubt will find it advisable to install an ad ditional motor-driven pump; in fact, this is already under con sideration.

52 The mean 1920 December station load will be about 6000 kw This would be secured from a discharge of 2600 cu. ft. per secon

under the low water head. The mean 1920 June station load will be about 5200 kw.

53 The total amount of electrical energy which will probably be required in December 1920, for street lighting and for miscellaneous light and power purposes, measured at the station, is about 93,000 kw-hr. This amount of electrical energy would be secured from a discharge of 1650 cu. ft. per second under the low water head.

54 *Use of Steam Pumps.* Through proper coöperation between the cities, the State University, and the Municipal Electric Company, the existing steam pumping plants of the two cities can be made to serve economically the dual purpose of emergency pumping equipment and small auxiliary power plant. So far as the reliability of a water supply is concerned, a combined steam and electric pumping plant is preferable to a plant dependent upon electrical power alone. So far as additional power required during periods of low water is concerned, the steam pumping plants constitute the very best small auxiliary. They can deliver water to the reservoirs at less operating cost than a 5000-h.p. steam plant, generating current which has to be transmitted and transformed, and then applied through a motor to centrifugal pumps, can possibly do. As the steam pumping plants are in existence, they serve as emergency pumping equipment and auxiliary power plant of about 2500 kw. capacity at the same time.

55 The reservoir storage at the Minneapolis filtration plant amounts to about 80,000,000 gal. By 1920 the daily water consumption in winter is not likely to exceed 40,000,000 gal. The Minneapolis steam pumps have a capacity of 30,000,000 gal. daily, so that in case the electrical pumps were temporarily disabled, or no current were available, the steam pumps, by running continually, would be able to furnish the additional water necessary to supply the city for 8 days. The St. Paul steam pumps have an aggregate capacity of about twice the present mean daily water consumption. A flow of 1750 cu. ft. per second is equivalent to about 98,000 kilowatt hours of power per day. Whenever, because of low water, the power output fell to this amount, it would be necessary to run the two Minneapolis steam pumps practically all day. Whenever the discharge fell to 2000 cu. ft. per second, it would be necessary to run these two Minneapolis pumps about 16 hours a day. It is probable that it would be necessary to run the steam pumps for at least a portion of the day, on an average 25 to 30 days a year, or 5 per cent to 8 per cent of the time. This is not entirely a disadvantage, however, as it would serve to insure the

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emergency steam pumping equipment of both cities being kep good operating condition.

56 On the basis of statistics obtained from the 1912 repor the Supervisor of Water Works, Minneapolis, the fuel and labor of operating the steam pumps has been computed to be equivaler a rate of practically one-half a cent per kw-hr. for the electric pu This is about half the cost of electric power developed by a s auxiliary steam plant.

57 As previously indicated, during extremely cold weather maximum available 24-hour power may occasionally fall to less 4000 kw. By utilizing the steam pumping plant for a few days year, and drawing on the available pondage, the maximum avail primary power can be raised from 3100 to about 6000 kw., and lower cost than could be done by a small steam power plant.

58 Even if, in the near future, there should be an extreme fl such as may occur for a day or two once in 15 or 20 years, the w power plant would still be able to carry a peak of about 7000 This is more than would be required for the street lights and mi laneous light and power uses. The steam pumps could again be for a few days to supply any deficiency.

59 *Surplus Power.* It is estimated that by 1920 the mean an rate of consumption of power for the purposes previously outlined be about 4520 kw., if the gas and gasolene lights are replaced electric lights as contemplated in this paper. This is equivalent mean annual station load of 5500 kw. The mean December sta load would be about 6000 kw., but in order to be able to meet Municipal Electric Company's own peak load at times of high w a very much larger installation would be required. In fact, an stallation rated at 10,500 kw. under normal head and with one s unit would furnish only very little more than the peak load w will probably have to be carried during the spring months by 1

60 Assuming, then, that the Municipal Electric Company in near future would want to reserve for its own uses, as previously lined, 6000 kw., there would still remain about 4500 kw. of e power. The mean annual amount of available power will be a 9000 kw. With an installation as contemplated in this pape would be possible to carry a peak load for several hours of 12,500 under normal head, and for one hour a peak of about 13,500 kw. asmuch as the Municipal Electric Company's peak would be a 8500 kw. by 1920, it is apparent that 4000 or 5000 kw. of excess po

when available at all, could be carried over the peak. This, undoubtedly, would make the excess power of considerably greater value than if it were necessary to sell it all as off-peak power.

61 The installation contemplated in this paper would assure a reserve unit for use in case one of the other three units was temporarily disabled. This unit could also be put into service whenever, at times of ordinary high water, such as may occur for about a month each year, the head is reduced to a point where the three units would no longer be able to carry the load. It would also serve to make available, as peak power, the excess power, whenever such power could be furnished at all. Until the demands of the community, for power for public purposes, enable the Municipal Electric company to utilize all of the available power, the surplus should be disposed of in such manner as would be of the greatest benefit to the public.

PROBABLE BENEFITS

62 The writer has made detailed estimates of the savings to the community that would result from the operation of the proposed hydroelectric plant, and places it conservatively at about $200,000 per annum by a few years after the Municipal Electric Company has begun operations.

DISCUSSION

At the time of the Spring Meeting high water in the Mississippi made it impossible for those in attendance to inspect the construction work of the High Dam. In presenting his paper, therefore, the author showed slides of the dam and power house in various stages of completion, which gave a clear idea of the work in progress. He concluded with comments on the high stage of the river and the amount of power that would be available at different levels, referring to the effect of the Government reservoirs at the headquarters of the river, which comprise the largest reservoir system for stream regulation in the world.

As a result of these remarks most of the discussion which followed centered about the effect of the reservoirs, both in relation to the use of the river for navigation purposes and the development of the power project at the High Dam. This subject is one of great magnitude and the short time available at the meeting permitted only fragmentary discussion quite inadequate to the problem.

No. 1438

THE HANDLING OF COAL AT THE HEAD OF THE GREAT LAKES

By G. H. Hutchinson,[1] St. Paul, Minn.

Non-Member

1 An industry of such importance as the handling of coal on the Great Lakes is of interest from an historical as well as a mechanical view point, so that it has seemed well to trace briefly the growth of the traffic and to give step by step the gradual development of the mechanical coal handling devices from the simple beginning to the present elaborate installations.

2 The natural waterway formed by the Great Lakes, extending for 1000 miles from Buffalo to the head of the lakes, not only affords cheap transportation, but facilitates the handling of enormous tonnage with greater dispatch and with less confusion and congestion than would be possible by rail. The transportation annually of many million tons of iron ore, copper and coal, of large quantities of manufactured goods, and immense grain crops from tributary territory has resulted in the building up of several natural centers of distribution of considerable magnitude. Among these in order of tonnage are the twin ports of Duluth-Superior, Buffalo, Chicago, and Milwaukee (Fig. 1), together with a large number of other ports of importance on the lower and upper lakes. The Great Lakes not only facilitate the distribution to consumers of the products of the mines, the soil and the factory, but make possible the bringing together, at a minimum cost for transportation, of millions of tons of iron ore and coal, a factor of importance in the cheap production of steel.

3 The Duluth-Superior harbor at the head of the lakes is not only the natural distributing point for the Northwest, but the harbor itself is unsurpassed, considering the essential features of safety, size of harbor, length of shore-line, and the large easily improved area available for dockage.

[1] Chief Engineer, North Western Fuel Company.

Presented at the Spring Meeting, St. Paul-Minneapolis, 1914, of The American Society of Mechanical Engineers.

4 The shipment of coal to the Northwest by way of the (Lakes began as far back as 1855, when about 1414 tons p: through the Soo Canal. Little, if any, of this was taken to Dı and Superior, as the bulk of it went to the copper country in Mich It remained for E. N. Saunders, for many years president of the N Western Fuel Company, to conceive the idea that coal could be e and cheaply carried by way of the Great Lakes through the S this northwest territory, so much in need of good fuel at reasoı prices. In 1871, he brought up the first cargo of commercial ever unloaded in Duluth, and his total shipments during that were about 3000 tons. This enterprise was conducted by Saunders personally for a period of about four years, during w time he had no dock and the coal was unloaded for him, either b railroad company or by B. S. Russell, a dealer in Duluth. The

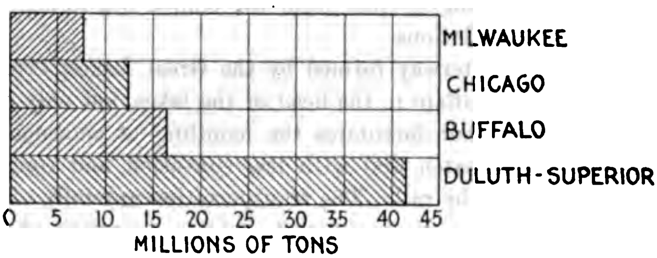


FIG. 1 DIAGRAM SHOWING TONNAGE HANDLED AT TWIN PORTS OF DU SUPERIOR, BUFFALO, CHICAGO AND MILWAUKEE

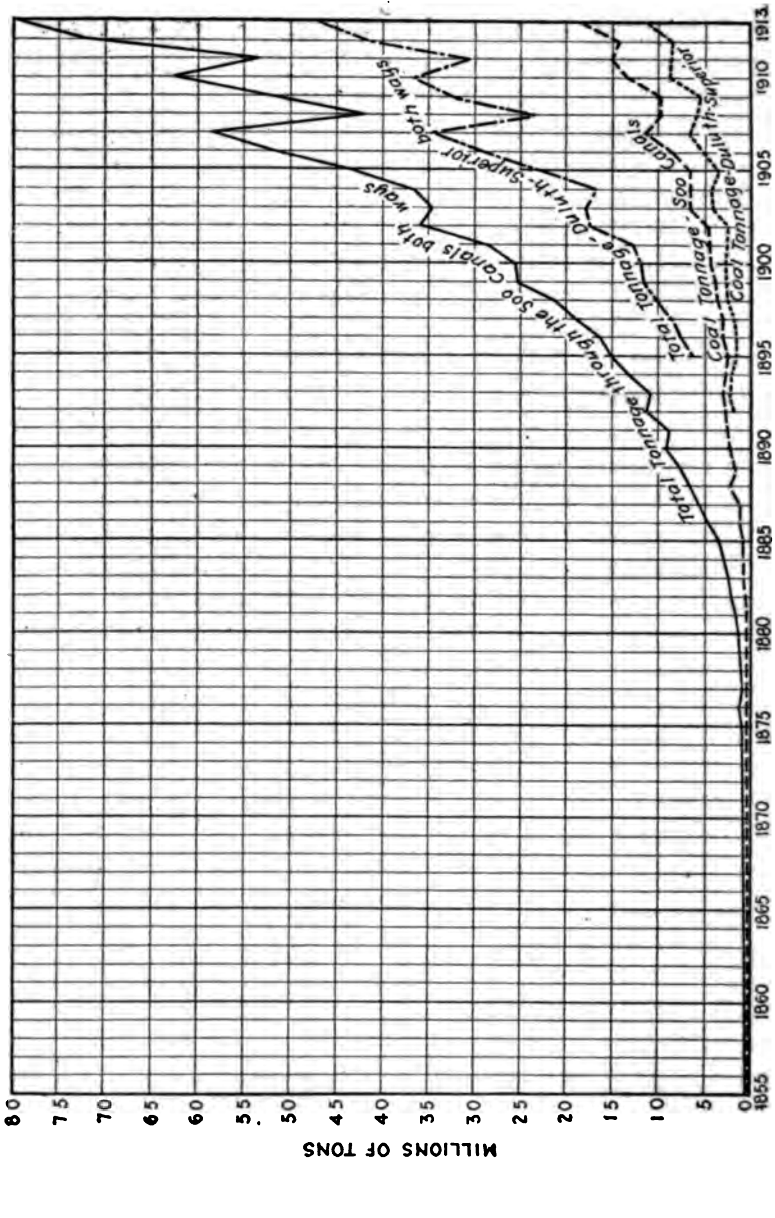
was not stocked, but was reshipped direct by rail. The coal bus having grown to somewhat large proportions, the leading coal de in St. Paul and Minneapolis formed an association in 1875 to h coal at Duluth, which in 1877 was organized as the North We Fuel Company. J. J. Hill was the first president and E. N. Sau was the general superintendent. The same year, a dock was se at Duluth and equipped for handling coal.

5 The increase in tonnage of coal distributed through the N west is perhaps the best index of the growth of this section o country, as coal is used almost exclusively for fuel for domestic power purposes in the cities, and for locomotive firing, and is al general use throughout the farming districts. To a limited e Eastern coal shipped by lakes is distributed as far west as the P coast. The growth of the coal traffic, which has been very

within the past few years, will be further augmented by the general growth of the Northwest, the demands made by the mills of the Minnesota steel plant now nearing completion, and by industries which will be established near the steel plant with a view to the fabrication of its output. The demand for coal will be further increased by the decreasing available supply of wood for fuel.

6 The kinds of coal transported by water for distribution through the Northwest comprise the various grades of bituminous and anthracite and the several intermediate grades of coal from Pennsylvania, West Virginia, Ohio, Maryland and Kentucky; the bituminous coal from Illinois and Iowa and other states being distributed by rail. Briquets for both power and domestic purposes are also being manufactured in considerable quantities at Superior from anthracite dust and Pocahontas smokeless screenings.

7 The marked increase in the coal trade and of lake and rail traffic of all kinds, as shown in the diagram in Fig. 2, has called for radical development in the means for lake and rail transportation, and in the harbor and other terminal facilities, and the writer believes that the statement is justified that this demand is being met in an adequate manner. As in other lines of activity, the increased volume of business and the development of facilities are mutually dependent, each making the other necessary and possible. In considering the extensive and highly developed equipment of today required by the large tonnage handled, we should not lose sight of the fact that the primitive methods and equipment may have been as well adapted, all features considered, to the primitive conditions and to handling the tonnage of the early days, as the modern methods and equipment are suited to the present conditions and demands. The dispatch which is required in handling large tonnage, is the chief element justifying as well as demanding present day equipment and facilities, for when ultimate economy is considered, the gain is apparent rather than real, as the cost of actually handling coal is but a small percentage of the total cost, including initial investment, maintenance and other overhead charges. This development of facilities has not been restricted to any individual feature, but has been general and applies to methods of mining, preparation of coal at mines, transportation to lake ports, loading to vessels, water transportation, and the unloading and other handling operations at the receiving docks.


Total Tonnage through the Soo Canals both ways
Total Tonnage - Duluth-Superior - both ways
Coal Tonnage - Soo Canals
Coal Tonnage - Duluth-Superior
1855
1860
1865
1870
1875
1880
1885
1890
1895
1900
1905
1910
1913
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
MILLIONS OF TONS

DEVELOPMENT OF TRAFFIC ON THE GREAT LAKES

8 The degree in which lake vessels have responded to the demand of increasing traffic becomes evident when we consider that 40 years ago the lake craft was made up largely of wooden schooners of

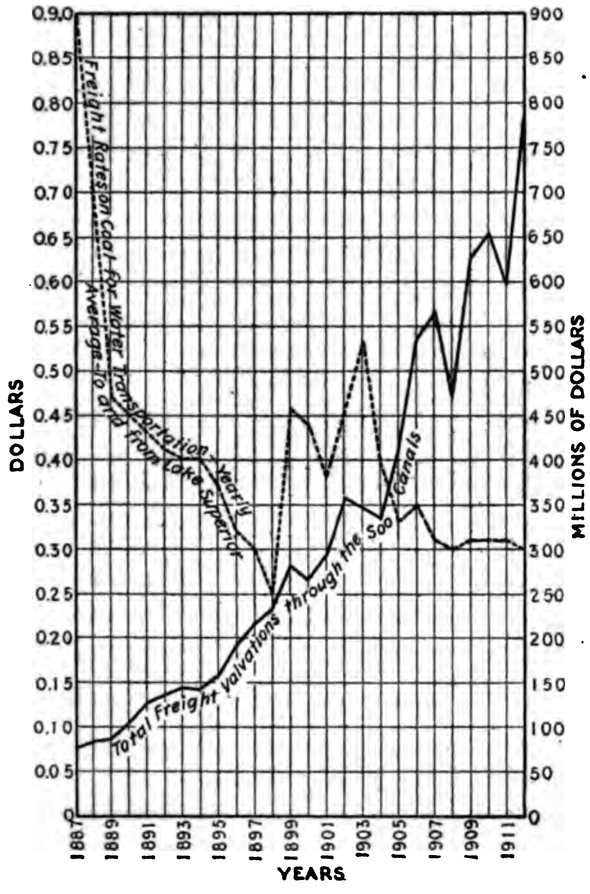


FIG. 3 DIAGRAM SHOWING ESTIMATED ANNUAL VALUATIONS OF FREIGHT PASSING THE SOO FROM 1887 TO 1912

300 tons to 700 tons burden, at which time the total annual tonnage passing through the Soo canal was less than 900,000 tons. In 1912, out of a total of 853 freight carriers, there were 127 vessels between 500 ft. and 600 ft. long, having carrying capacity of from 9000 to 11,000 tons; and 12 vessels over 600 ft. long, having a carrying

capacity of between 11,000 tons and 14,000 tons. The total tonnage passing the Soo canal in 1913 was nearly 80,000,000 tons. Fig. 3 shows the estimated annual valuation of freight passing the Soo from 1887 to 1912, showing an increase of slightly more than 1000 per cent during 25 years. The coal passing through the Soo canals in 1855 was 10 per cent of the total tonnage for that year; in 1912 the percentage was 20.6 per cent.

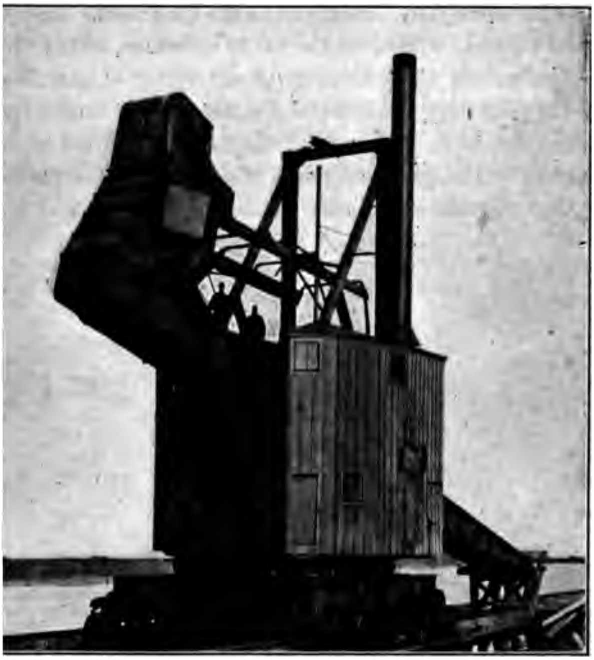
9 The gradual reduction of freight rates for water transportation of coal to Lake Superior for 25 years is also shown in Fig. 3, from which it will be noted that the rate in 1912 was 30 cents per short ton, or only one-third of that in 1887.

10 Forty years ago, it was necessary to guarantee return cargo for a boat before chartering it for a trip to the head of the lakes. At the present time, however, the eastbound shipments from Lake Superior are about three and one-fourth times as large as the westbound shipments, with the result that many boats engaged in the iron ore trade return light on the westbound trip.

11 The increasing tonnage of coal handled from mines to lake and seaboard ports has, in conjunction with the iron ore traffic from the lower lake ports to furnaces, led to the introduction of railroad cars of large capacity, with corresponding development of track and motive power, until today there are several hundred 90-ton cars in service on at least one road, transporting coal to seaboard, which is from six to twelve times the size of coal cars of 40 years ago, and provision is now being made at the docks for handling still larger cars.

TRANSFER OF COAL FOR LAKE SHIPMENT

12 The transfer of coal at the lower lake ports is ordinarily made direct from cars to boats without stocking. Prior to 1892, coal was loaded to boats from railroad cars either by wheelbarrow or by simple derricks equipped with small tubs, into which coal was dumped or shoveled, depending upon the kind of cars. In about 1892, however, the first successful car dumper (Fig. 4) was built at Ashtabula on Lake Erie for dumping the entire contents of gondola cars into vessels at a single operation. This was an end dumper designed by G. H. Hulett and built by the McMyler Manufacturing Company; it tilted the car endwise, requiring special gondola cars with end doors for discharging the contents of the car into the boat. After the installation of a second similar end dumper at Fairport in 1893, there followed in rapid succession several types of side car dumpers, known respec-



r End Car Dumper, designed by G. H. Hulett, installed at Ashtabula, Ohio, in 1893

ett Car Dumper, installed on Buffalo, Rochester and Pittsburgh Dock about 1898 tively as the McMyler, Long, Brown, Thornburg and Hulett dumpers or tipples, which, as the term indicates, tilted the cars si wise and permitted the handling of all types of gondola cars, charging the coal over the sides of the cars into a concentrating ap or hopper, Figs. 5, 6, 7, 8 and 9. So far as specified above, the p cess of handling the coal was much the same for the various side dumpers, but for the remainder of the process, in which the coa

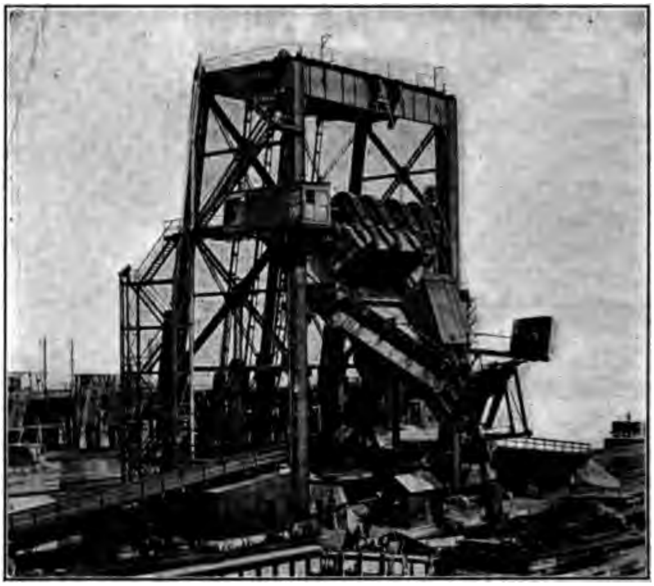


Fig. 6 McMyler Car Dumper, Philadelphia, Pa.

transferred from the concentrating apron or hopper to the hold the vessel, there are three methods:

a That in use on the earlier dumpers in which the coal v discharged from the hopper direct to the hold of the b through simple short chutes

b That in use on several of the dumpers, built between 18 and 1900, in which the coal was discharged from the co centrating hopper into two or more bottom dump sk of sufficient aggregate capacity to hold the contents o car, these skips being then carried over the boat on ra or on overhead track and lowered into the hatch bef dumping, with a view to keep-down the breakage *c* That in use on all, or nearly all, the dumpers built within the past 15 years, and on a few earlier ones, in which the flow of the coal is measurably controlled within articulated, entirely enclosed, telescopic chutes or spouts, which are extended to the bottom of the boat for starting the pile of coal in the hold, and gradually raised as the pile

G. 7 THORNBURG CAR DUMPER, BUILT BY WEBSTER, CAMP AND LANE, 1896, AND INSTALLED AT SANDUSKY, OHIO

is built up, thus largely avoiding free fall of the coal, in order to reduce breakage.

13 The number of car dumpers in service is increasing rapidly, nd at present there is in progress the installation of several large car dumpers designed for handling forty 100-ton cars per hour. In all

the car dumpers, except a few of the very earliest ones, every pre
tion has been taken to avoid breakage of coal.

FIG. 8 HULETT TRAVERSING CAR DUMPER, BUILT BY WELLMAN-SEAVER-MO COMPANY FOR STOCKING IRON ORE AT PITTSBURGH STEEL COMPANY'S PLANT, MONESSEN, PA.

DOCKS FOR RECEIVING, STOCKING AND RESHIPPING COAL

14 At the receiving ports, in addition to the unloading of from vessels and loading to cars for reshipment by rail, provisio made for the stocking, during the season of navigation of about se

months, of several million tons of coal to serve as reserve stock for supplying the heavy winter demands, and also to be drawn upon for the filling of such orders, during the season of navigation, as cannot be reshipped direct from boats without docking. The docks for receiving, stocking and reshipping of coal are built out from the shore and vary in width from about 400 ft. to about a quarter of a mile,

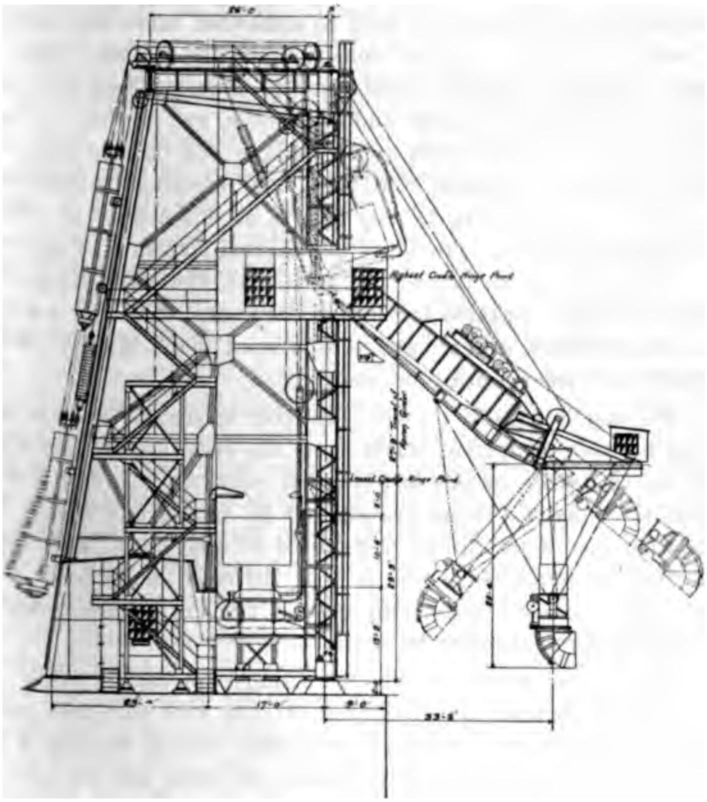


FIG. 9 McMYLER CAR DUMPER BUILT IN 1913 FOR PITTSBURGH AND CONNEAUT DOCK COMPANY

and in length from about 1000 ft. to three-quarters of a mile. Ordinarily these docks are served by a single slip along one side, although a few of the wider docks, which are equipped for unloading on both sides, have two vessel slips for discharging cargo. The depth of water in these slips should be as much as 21 ft., and some slips have been dredged to a depth of 26 ft., or more below U. S. mean low water datum. The slips are of various widths from about 60 ft. or up to about 200 ft., in the wider slips provision having been for the passing of two of the widest vessels under tow. The st areas are surrounded on the water sides by timber cribs, exte from somewhat below the bottom of the slip to dock level elevation of approximately 6 ft. above mean low water; or by bination cribs, in which the lower timber part is capped with crete, which extends from dock level to somewhat below the su of the water. In both types of construction, the timber crib ordinarily sand filled and additional stability is provided by the ing of piles in front of the front and back walls, and further in instances by anchoring the cribs to piles driven well back in the area. The dock area is usually filled with sand deposited by hyd dredge, which gives very satisfactory results, as this method of insures against settlement, providing the original bottom is of su nature. This district is favored in having an abundant supp river and lake sand suitable for filling purposes. The coal st area is covered either with a hard or soft wood plank floor, 2 3 in. thick, or is paved with concrete.

15 The machine tracks on which the coal hoists and coal b and other movable equipment travel along the dock, are ordina pile and heavy timber, or pile and concrete construction. For on which the heavier bridges travel, 100 lb. high-grade steel laid in either one or two lines are required at each truck, and the pile and concrete construction is used, the rails should be c directly either on continuous longitudinal timber stringers, wood cross ties for cushioning the rails.

16 The proper provision for the storage of loaded car empties, and the loading and weighing of cars, with sufficient tional trackage to supply dispatch in switching service, requires two or three to five miles of railroad track per dock, and the p serving of these tracks requires extensive belt-line facilities.

DEVELOPMENT OF EQUIPMENT FOR UNLOADING, STOCKING RELOADING FOR RAIL SHIPMENT

17 Prior to 1876, the equipment for unloading coal from v comprised a tub formed of a half oil barrel, which a horse, tra along the dock, hoisted by means of ropes passing around defl sheaves located on the dock near the water front, and thence snatch blocks suspended on fore and aft ropes spanning the di

between masts on the vessel, permitting the shifting of the tubs along the suspension rope from hatch to hatch. In unloading by this method, the boats, which were of 300 tons to 700 tons capacity, were required to lay up about a week. After hoisting, the coal was dumped into wheelbarrows and transferred to stock pile on the dock, for which purpose wheeling planks were provided, extending from a point over the boat to the rear side of the dock, which at this time had a width of about 50 ft. to 75 ft. These wheeling planks were carried on wooden supports or "horses," of sufficient height to clear the vessel rail, which, at the beginning of unloading, would be about 3 ft. to 5 ft. above the dock. From time to time, as the boat rose in being unloaded, it was necessary to interrupt the taking out of coal while the wheeling gang blocked up the several bents supporting the wheeling plank on the dock to suit the new height of boat. Delays incident to this work occupied about 50 per cent of the total unloading time. This first process is shown on Fig. 10.

18 In 1876 there was made at Duluth the first improvement which largely avoided this delay, permitting practically continuous work in the actual discharging of the cargo. As a consequence of this first improvement, which resulted in greatly increasing dispatch in unloading, the lake freight rate was cut about 75 cents per ton, amounting to about 250 per cent of the present lake rate. While this change was of a very simple nature, it represents a greater saving per ton than any subsequent improvement, and in fact is one of the few developments which has resulted in marked increase in dispatch with actual reduction in cost of equipment and operation.

19 This revised method of unloading is shown on Figs. 11 and 12, from which it will be noted that similar but simplified equipment was used, and that the improvement resulted principally from the method of supporting the wheeling plank and of stocking the coal. The wheeling plank was placed at a fixed height of about 10 ft. above the dock, and was carried on adjustable horses placed on the deck of the boat and on a horse located on the front of the dock. As the boat rose, the wheeling plank was maintained at a constant height above the dock level by shifting the cross beams, which carried the wheeling plank on the horses, located on the vessel deck, to successively lower supports on these horses; this operation was readily performed, and without appreciable delay to unloading operations.

20 Another feature which reduced the time and simplified the operation was the method of building the stock pile, which, in the

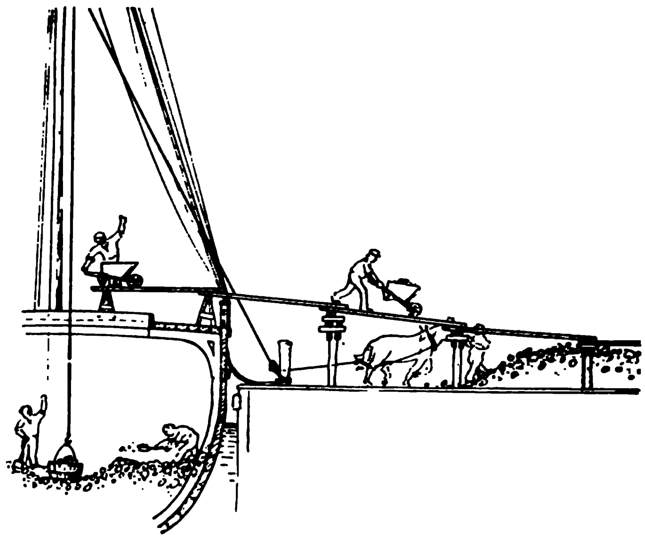


FIG. 10 PRIMITIVE METHOD OF UNLOADING COAL, IN GENERAL USE OVER LAKES PRIOR TO 1876

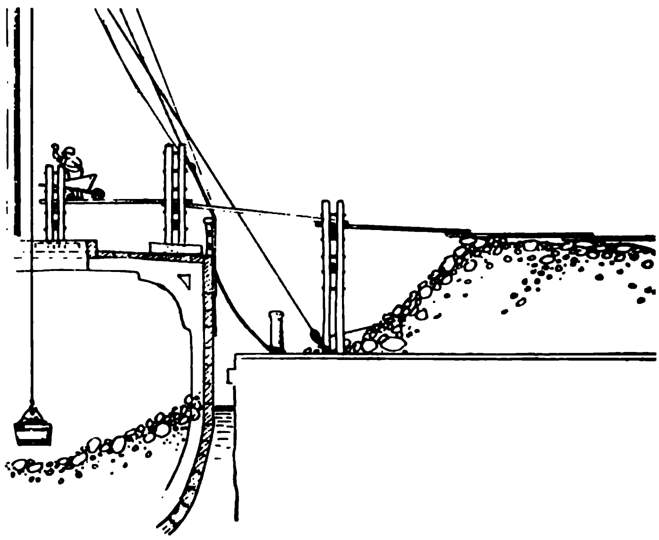


FIG. 11 FIRST IMPROVED METHOD USED IN 1876, IN GENERAL USE THE LAKES

Fig. 12 Early Method of Unloading Coal and Iron Ore by Hand Shovelling and Wheelbarrow

improved method, required the wheeling plank to extend only to th crest of the 10 ft. pile at the front of the dock, from which point th pile was extended at full height to the rear of the dock, and serve as support for the wheeling plank, thus reducing the number (horses required. In the original method, the wheeling plank extende the full width of the dock from the start, and the coal pile was bui up as the boat rose. The writer is advised by the dock superintende who first used this improved method at the head of the lakes, th both the original method referred to and this improved method wei in general use over the lakes at the times mentioned.

21 A simple form of derrick was in use in Chicago in 1877 f the purpose of hoisting coal from boats. About 1878 or 1879, special type of derrick was introduced on the North Western Fu Company's Duluth Dock No. 1, six of which were spaced along tl dock front about 66 ft. apart and arranged for operation in pairs, being possible to operate only one pair on a boat at a time. Tl tubs on the two derricks were hoisted simultaneously by mea of a small hoisting engine. These derricks were similar to those sti in use on some of the older docks at Duluth and Superior, and we equipped with half-ton Stuebner self-righting tubs of the same gener type as the tubs now in use. Tracks were provided along a long tudinal unloading platform about 20 ft. above dock level with tur outs to tracks on transverse timber run-ways, on which dump ca were operated by hand, making it possible to stock the coal to a dept of about 20 ft. on any part of the dock, irrespective of the position (the boat. This gave as great flexibility in the distribution of coal i stocking as is afforded by that type of present day plant in whic bulk is broken at dock front and in which separate hoisting, long tudinal transferring and stocking units are employed. This princip of flexibility was recognized in this first steam-operated plant, a though it remained for later installations to perfect the structur and mechanical details.

22 About 1881 or 1882, a third and marked improvement w made by the introduction of a main lineshaft running the full lengt of the dock and equipped with an individual hoist for each derric which permitted the independent operation of each derrick.

23 In 1883, a Cleveland concern installed for the Ohio Centr Barge & Coal Company on its dock in Duluth, now Pittsburgh Do No. 1, eight wooden bridges of 150 ft. span, arranged four alon each side of the dock and patterned after similar bridges in Clev

land. These bridges were built in pairs, with boiler and two hoisting engines located on the double pier, from which point a rope trolley, equipped with 1-ton tub, was operated on each span. They were equipped with hinged aprons extending over the boat when in service and raised for clearing vessels when not in use. Coal was stocked 28 ft. high. The bridges were moved along the dock by hand power. These were the first coal-handling bridges at the head of the lakes.

24 Further improvement was introduced in about 1885 or 1886 in the spacing of the derricks to suit the hatch spacing on the boats, which was now becoming more uniform, making possible the working of every second hatch simultaneously without shifting the boat. About this time, also, cables were installed on the level stocking runways for pulling dump cars in both directions by power, after having been pushed from the unloading platform to the runways by hand.

25 Prior to the installation of the first reloading runway in about 1885, reloading to cars for rail shipment was done by wheelbarrow. From 1885 to 1888 or 1889, these reloading runways were equipped with trolleys carrying self-righting tubs. The first shovel bucket, which was made by Mr. Dole of Cleveland, was put into service at the head of the lakes on the Pennsylvania and Ohio dock, at present known as the Boston Dock of the St. Paul & Western Coal Company.

26 In 1887, nine portable, steam, timber, Hunt hoists, each equipped with ¾-ton tub and a cable railway stocking system, were put into operation on the Lehigh Coal & Coke Company's dock in Superior on St. Louis Bay, which is the North Western Fuel Company's present Dock No. 2. The hoists were located on an elevated platform at the dock front, along which they traveled from hatch to hatch in unloading vessels. These hoists were placed opposite the runways on which it was desired to stock the coal. Side dump cars carried the coal back to the stock pile by gravity, at the same time raising counterweights which returned the empty cars to the hoists for reloading. As these cars had no longitudinal movement along the dock, it was necessary to stock the coal opposite the point where it was unloaded, making in this respect a less flexible system than that last mentioned, in which derricks served by stocking cars traveling longitudinally on the unloading platform and transversely on runways were used.

27 In 1888, the Brown Hoisting Machinery Company installed for the Pioneer Fuel Company four steel bridge tramways on their

dock on Rice's Point, Duluth, now operated by the Clarkson Co & Dock Company. These bridges, which are still in use, have a spa of 188 ft., a rear 80 ft. cantilever extension, and a hinged apron 34 f in length for lowering over the boat. Each bridge is carried on a til ing shear leg located at the front near the apron hinge. The tw outer bridges are carried on single piers, and the two inner bridg on a double pier at the rear, spanning two railroad tracks. A boil and four steam hoisting engines are installed on the double pier f operating the four bridges, each of which is equipped with a ro trolley carrying a 1-ton tub. The bridges are propelled on machi tracks along the dock, in part by steam and in part by hand powe The bridges are inclined with a rising grade toward the back of t dock, and are pivoted at the piers to permit skewing horizontally suit hatch spacing.

28 In 1890, three similar Brown bridge tramways were erect on the Silver Creek Coal & Dock Company's dock, Superior, which w later taken over by the Philadelphia & Reading Coal & Iron Compan and now operated by the Great Lakes Coal & Dock Company. I 1893, three Brown bridges of the same type were erected on t Pennsylvania & Ohio Fuel Company's dock at Duluth, which lat came into the hands of the Boston Coal & Wharf Company. In 18 a single additional bridge was installed on this dock, this last brid being one of the latest installations, if not the last one, where tu were used exclusively, or before the introduction of clamshells.

29 In 1893, the McMyler Manufacturing Company install several steel bridges of 180 ft. span with 100 ft. cantilever, on t dock of the Youghiogheny & Lehigh Coal Company, Superior, o which tubs were at first used but later replaced by 1-¾ ton clam This dock is now known as the Pittsburgh Dock No. 3, and is ope ated by the Reiss Coal Company. The Mead Company, in about 189 installed on this dock an automatic car and cable railway system.

30 In 1896, the McMyler Manufacturing Company installed se eral stationary timber steam hoists, fitted with steel booms a equipped with rope trolley carrying clamshell grab bucket, on the do of the Lehigh Valley Coal Sales Company at Superior.

31 In about 1899, four steel suspension cable tramways, ope ated by Lidgerwood hoisting engines, were installed on the Lehig Coal & Coke Company's dock, Superior, which had already been pa tially equipped with the movable Hunt hoists previously mentione At the time these hoists were built, or possibly a little later, the

were equipped with Dole single rope clamshell buckets of about 1-ton capacity, which required hand tripping. In 1902, a fifth tramway, equipped with grab bucket, was installed by the Mead Company. Steam was furnished by main steam line from a central boiler plant at the inner end of the dock. In unloading, coal was discharged into the hopper on the front pier, and stocked by means of bottom dump skips. Reclaiming was done by shovel buckets.

32 From 1886 to 1890 inclusive, the Dodge system of anthracite storage[1] was developed in the installation of several plants in the

FIG. 13 DODGE COVERED ANTHRACITE STORAGE PLANT, LEHIGH VALLEY COAL SALES COMPANY, SUPERIOR, WIS.

East, and in 1894 a 110,000-ton covered anthracite plant of this type, comprising two units of 55,000 tons each, was installed for the Lehigh Valley Coal Sales Company at Superior, shown in Fig. 13.

FIRST ELECTRIC COAL HANDLING PLANT

33 In 1901, the Brown Hoisting Machinery Company started for the North Western Fuel Company the construction of the first electric coal handling plant ever installed. This plant consists of four hoisting towers with 1½-ton clamshell grab buckets, later replaced by 2-ton grab buckets; three transfer cars; three stocking and reclaiming bridges, each having 155 ft. 2 in. spans and 42 ft. 9 in. rear cantilever, giving overall length of 508 ft. 3 in., and each

[1] Described in a paper on Hoisting and Conveying Machinery by Geo. E. Titcomb, Trans. Vol. 30, p. 123.

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equipped with one stocking man trolley, carrying a 7-ton self-right tub, and one man trolley for reclaiming, carrying a 4-ton sh bucket. The hoisting motors on the towers are controlled by dr type controllers and magnetic switches. Two continuous lines timber bins are provided, one near the front end of the dock im diately in the rear of the hoisting towers, on which the transfer travel, and one at the rear of the dock forming support for the bridge tracks.

34 Coal is unloaded from the boat by means of the clamshell, deposited in a 15-ton hopper in the tower. The stocking trolley w its 7-ton tub is brought by the transfer car to place opposite the to

FIG. 14 BROWN HOIST TOWERS ON NORTH WESTERN FUEL COMPANY'S D No. 1, SUPERIOR, IN 1902. FIRST ELECTRIC DOCK

bin, from which it receives the coal. The transfer car then runs bridge, with which it registers, permitting the stocking trolley to liver coal to stock pile. The function of the transfer car is to flexibility of operation in unloading, stocking, reclaiming and di reshipment by rail, thus permitting the stocking of coal when desired on the dock, irrespective of the location of the vessel hoisting towers, and equal flexibility in loading out.

35 Later, a fourth bridge was added with reclaiming trol Direct current is furnished this equipment from a central generat system located on the dock. To relieve the generators of the h

peaks, incident principally to accelerating in hoisting and traveling, a storage battery, having momentary output of 2040 amphercs, later increased to 2720 ampheres, was installed. The rated capacity of this plant was the unloading of a 5000 ton boat in ten hours. In actual performance, however, this has at times been considerably exceeded. The construction and equipment of this dock is important, as it was the first electrically operated dock in the world; the first on which coal handling man trolleys were used; and the first coal dock on which all the operations were performed by power, making possible a new record for speed and capacity (Figs. 14, 15, 29 and 30).

36 In 1902, three Brown bridge tramways were installed for the Eastern Railway Company of Minnesota, and later taken over by the Jones & Adams Company. This dock is now known as Pittsburgh Dock No. 6, and operated by the Island Creek Coal Sales Company. These bridges were equipped with rope trolleys carrying 1¼-ton clamshell grab buckets, and were operated by steam.

RECENT INSTALLATIONS

37 In 1905, the Mead Company installed, for the M. A. Hanna Coal Company on their Superior Dock, a plant comprising three steam traveling unloading hoists, which are mounted on a longitudinal unloading platform, each equipped with a 2-ton clamshell; two 262 ft. span traversing bridges for stocking and reclaiming bituminous coal, and Mead automatic cars and cable railway for stocking both bituminous and anthracite coal. In stocking bituminous coal, the automatic cars run along tracks carried on transverse stationary elevated runways, leading to the longitudinal tracks on the bridges, giving flexibility in stocking operations. In stocking anthracite, the course of the car is confined to the elevated stationary runways.

38 A similar installation was made by the Mead Company about the same time on the Northern Coal & Dock Company's dock, Superior.

39 The Zenith Furnace Company's dock, Duluth, is equipped with four Mead unloading towers handling 2-ton clams, one Mead bridge and Mead automatic car and cable railway system.

40 In 1906 and 1907, the Duluth and Iron Range Railroad Company's coal dock at Two Harbors was equipped with a Mead plant comprising three steam hoisting towers handling 2-ton clams and mounted for traveling on a 40-ft. high steel trestle; an electric 4-ton

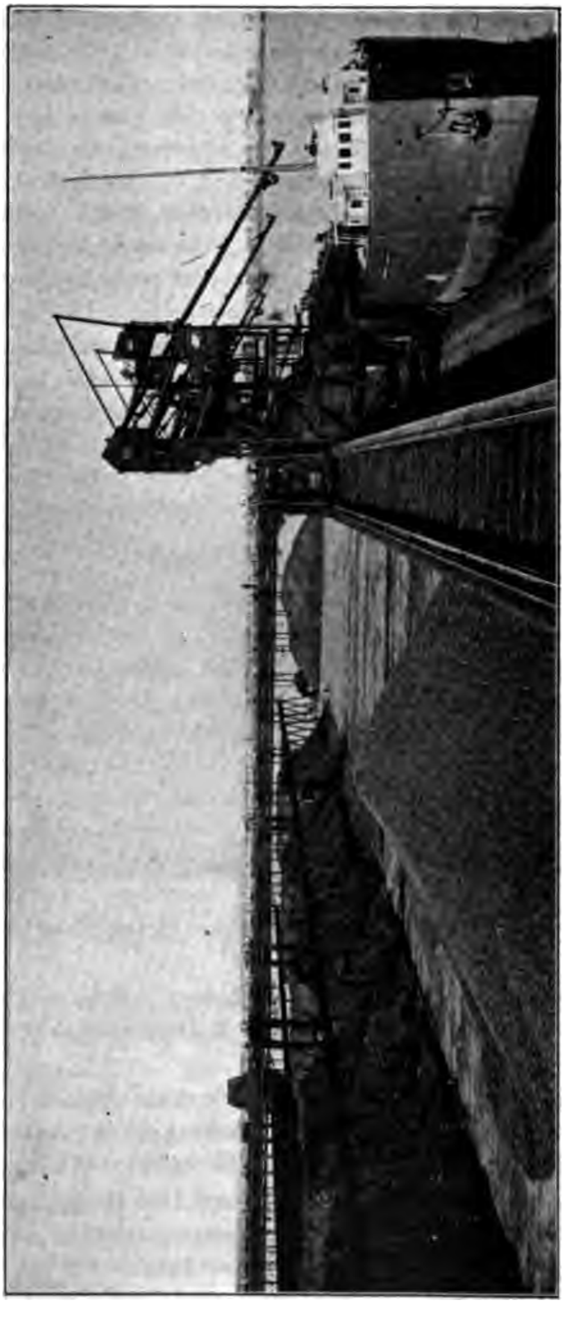

FIG. 15 BROWN HOIST TOWERS, BRIDGES AND TRANSFER CARS ON NORTH WESTERN FUEL COMPANY'S DOCK NO. 1. FIRST ELECTRIC DOCK

Fig. 16 Mead Hoist Towers, Automatic Cars, Cable Railway and Bridges, Milwaukee Western Fuel Company's Washington Street Dock, Milwaukee, Wis.

automatic car and cable railway system; and an electrically opera stocking and reclaiming bridge handling a 2-ton shovel bucket. T dock has a storage area about 275 ft. wide by 900 ft. long, an nominal storage capacity of about 150,000 tons. Owing to local c ditions the dock does not directly face the slip, which requires hoisting towers to operate at some distance from the storage a giving conditions to which the portable hoist and cable railv system is peculiarly adapted.

41 A recent Mead installation of same general type but differ in detail, made on the Washington Street dock of the Milwau Western Fuel Company at Milwaukee, and equipped with screen plant in bridge in place of the fixed loading bins, is shown in Fig.

42 The stocking of coal by means of a belt conveyor on a bri is a method used by the Robins Conveying Belt Company. In plant of this type coal is stocked on the dock at the rate of 600 t per hour, the conveyor having a traveling tripper for distributing coal, which it receives from a second belt conveyor, which in turn ceives the coal from a system of conveyors at the unloading tow Reclaiming is done by a clamshell bucket at the rate of 300 t per hour.

43 In 1906, a 200,000-ton covered anthracite storage plant stocking coal 60 ft. high was installed on Section 2 of the Nc Western Fuel Company's Superior Dock No. 1. Coal is unloaded two Heyl & Patterson electric hoists, equipped with 3-ton clamsh and stocked and reclaimed by means of Dodge reversing, elect driven, ribbon bottom, flight conveyors of 250 and 300 tons ho capacity. In stocking, coal is discharged from the top run of c veyors into storage building or 3000-ton shipping pocket, and claimed by the bottom run of these conveyors, working in tun beneath the coal pile. Breakage of coal is avoided, when starting pile in stocking, by lowering the coal through Humphrey self lov ing chutes, Fig. 17. After building the pile to full height at a si point, the ribbon bottom of the conveyor is drawn in, or extended the crest of the pile advances. The coal is loaded for reshipmen the single 3000-ton shipping pocket. This plant is shown in Fig.

44 In 1907 or 1908, the Wellman-Seaver-Morgan Company stalled two Hulett bridges of 176-ft. span with 130-ft. cantilever, equipped with 2-ton grab buckets, on the Boston dock of the St. P & Western Coal Company. These bridges are steam-operated and

provided with separate hoists and trolley engines, and controlled by two operators.

45 One of the larger electric bituminous coal handling bridge installations, on which the rope trolley is used, was made on the Berwind Fuel Company's Dock in Superior in 1907. Fig. 19. This is one of the later trolley installations prior to the general introduction of the large man-trolley bridge. These bridges are 506 ft. long with 295 ft. span, equipped with 3-ton clamshells, and are supplemented

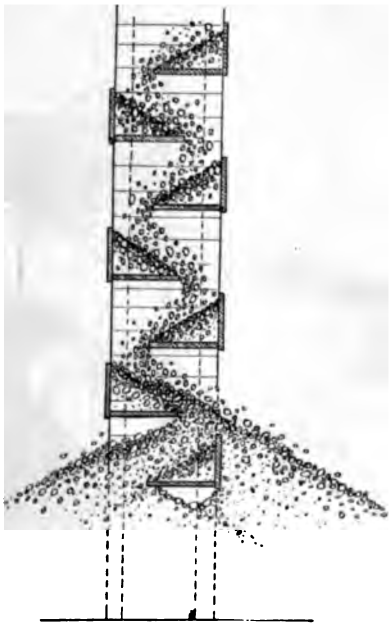

FIG. 17 HUMPHREY SHELF LOWERING CHUTE

by revolving locomotive cranes and movable screenings tower. All motions of bridge and bucket are controlled by one operator from either of two fixed control stations. All equipment on this dock is electrically operated by means of 400-volt, three-phase, alternating current.

46 Fig. 20 shows the Duluth, Missabe & Northern coal dock at Duluth, which is 604 ft. wide by 2000 ft. long. On one half of this dock was installed in 1907 a Mead plant, comprising three portable hoists equipped with 2-ton clams, 4-ton automatic car and cable railway system, and a stocking and reclaiming bridge with 2-ton shovel

bucket. Provision has now been made for similarly equipping other half of the dock, using 4-ton clams, in place of the 2-ton cl on two additional hoists.

ELECTRICALLY-OPERATED MAN-TROLLEY COAL BRIDGE

47 The first electrically operated man-trolley coal bridge which the unloading, stocking, repreparing, reclaiming and loa

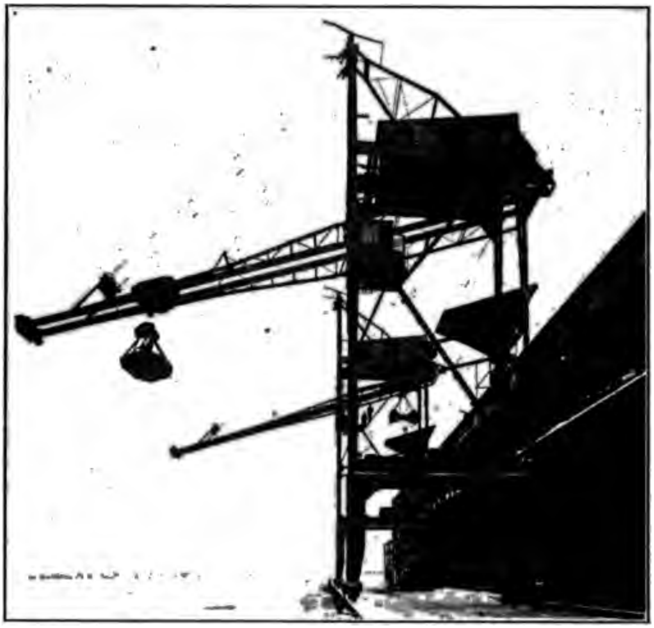

FIG. 18 HEYL AND PATTERSON ANTHRACITE HOISTS AND DODGE STOC CONVEYER, INSTALLED ON NORTH WESTERN FUEL COMPANY'S SUPERI DOCK NO. 1, 1906

out were accomplished by a single unit, was installed by Heyl & terson on the North Western Fuel Company's Superior Dock N in 1909. This bridge has a span of 363 ft. 4 in. and is 455 ft. 6 long overall, with screening and loading-out plant mounted on shear, and run of pile loading plant on the pier. The man-tro was equipped with 5-ton Heyl and Patterson clam for unloading reclaiming bituminous coal, this being the largest clam thus far stalled at the head of the lakes. One man controls the operatio

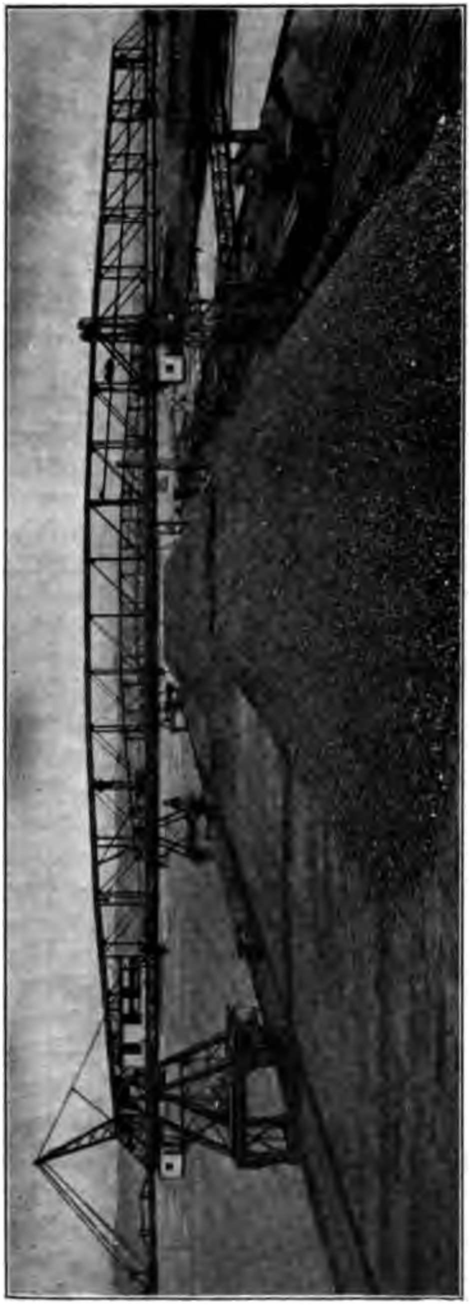

FIG. 19 DODGE COAL HANDLING BRIDGES AND AUXILIARY EQUIPMENT, BERWIND FUEL CO., SUPERIOR, WIS.

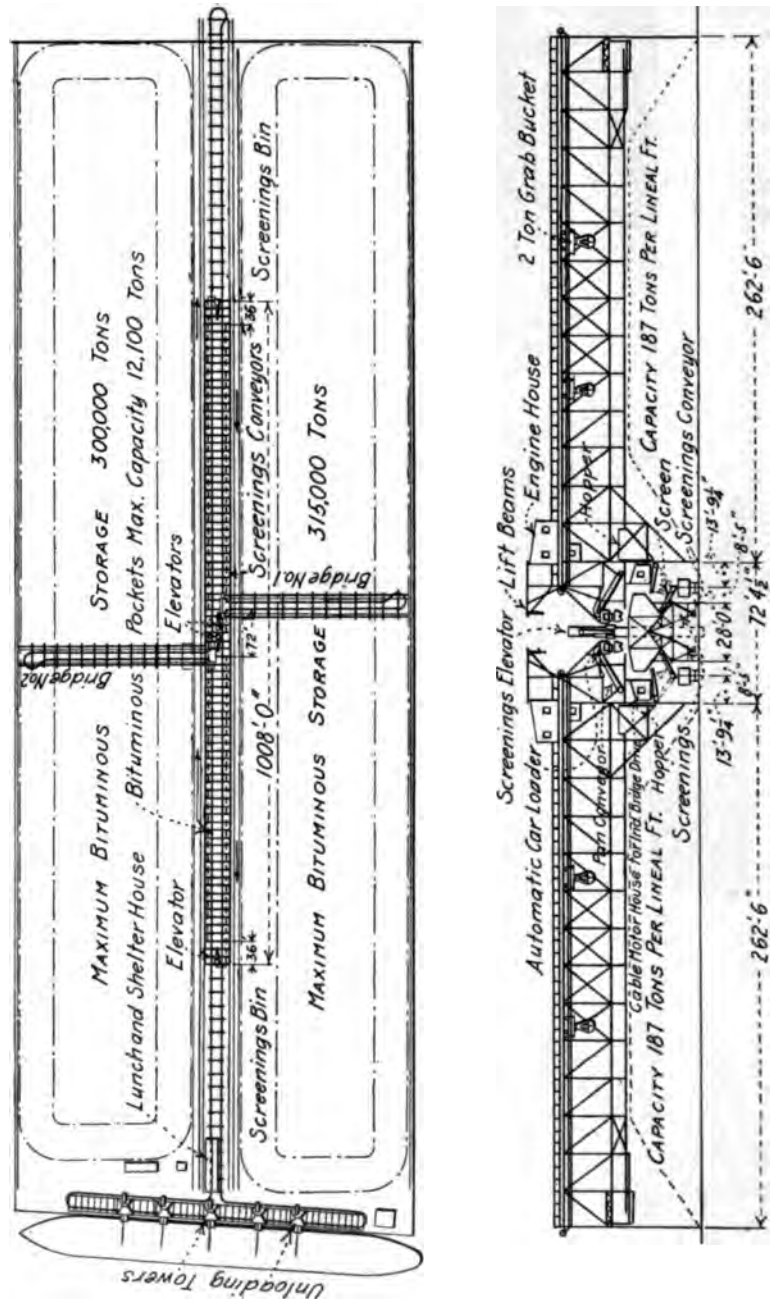

Fig. 20 Mead Hoists, Automatic Cars, Cable Railway System and Stocking and Reclaiming Bridges, Duluth, Missabe and Northern Railway Company's Dock, Duluth, Minn.

the trolley in unloading, stocking and reclaiming and bridge traversing. This bridge is operated by three-phase, 25-cycle, 440-volt, alternating current, stepped down from 13,200 volts by main transformer located on the bridge. This is the first traveling bridge to take current from high-tension trolley feeder line along the dock by means of collector shoes. The man-trolley is equipped with two-hoist motors and two-rack motors, operated by master controllers and magnetic switches. The friction clutches and brakes are operated by compressed air. Dynamic braking is provided for racking and lowering, for which direct current is supplied by a small motor generator set delivering direct current at 40 volts.

48 Beginning with 1909, there was an unusual development of docks and equipment, and within the next few years, ten bridges, similar to the ones just described, were installed in Superior and Duluth, as follows; two on the Carnegie Fuel Company's Dock No. 1, Superior; two on the Philadelphia & Reading Coal & Iron Company's Dock No. 2 in Superior; two on the Island Creek Coal & Sales Company's dock in West Duluth; two on the North Western Fuel Company's Dock No. 2, Superior; one on the North Western Fuel Company's Dock No. 1, Superior, and one on the Reiss Coal Company's dock—Pittsburgh Dock No. 3—in Superior. With the last bridge installed on the North Western Fuel Company's Dock No. 2 in 1912, the screening plant, which was somewhat more elaborate, was mounted on separate trucks and attached to the bridge for traveling, Fig. 21. A 6-ton clamshell was provided for this bridge, and the 5-ton clams on the other two bridges on this dock were also replaced by the 6-ton clams. In order largely to eliminate hand shoveling in cleaning up boats after the unloading clam had picked up the coal within reach, a specially-designed, 4-ton clean-up clam was developed. This clean-up clam is described in more detail in a later paragraph.

49 In 1910, in conjunction with two of the bituminous bridges above mentioned, there was installed on the Philadelphia & Reading Dock at Superior, an electric, covered anthracite plant, comprising two stationary unloading hoists equipped with rope trolleys carrying 5-ton clamshells, a double storage building of steel construction 350 ft. by 500 ft., a mechanical screening plant for repreparation of the coal, and a shipping pocket for reloading at a single point (Fig. 22).

In 1910, an extension 144 ft. by 480 ft. was made to the North Western Fuel Company's Superior Dock No. 1 anthracite storage

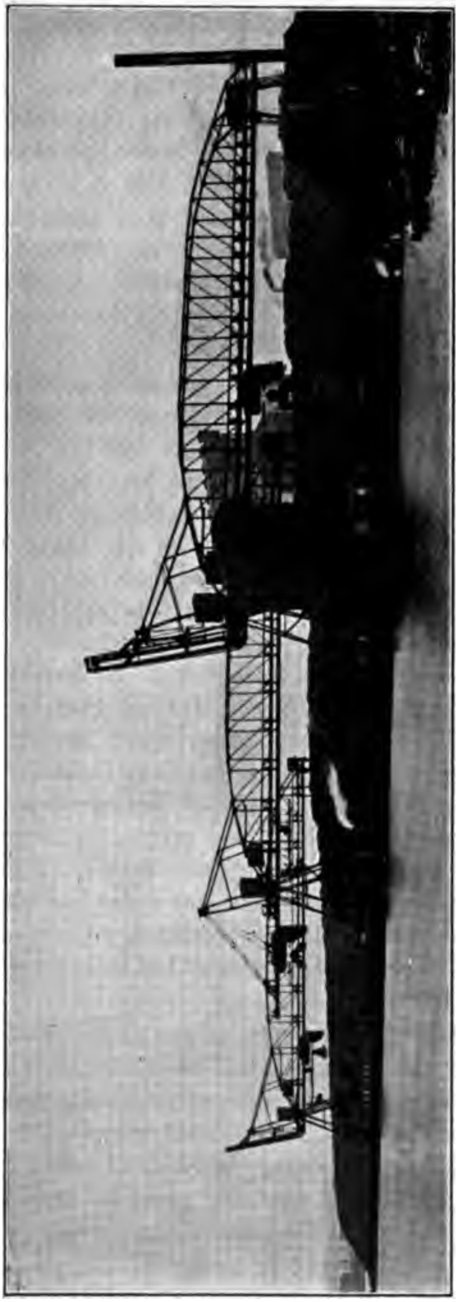

FIG. 21 THREE HEYL AND PATTERSON BRIDGES ON NORTH WESTERN FUEL COMPANY'S DOCK NO. 2, SUPERIOR, WIS.

FIG. 22 HEYL AND PATTERSON BITUMINOUS AND ANTHRACITE PLANT, PHILADELPHIA AND READING COAL AND IRON COMPANY'S DOCK, SUPERIOR, WIS.

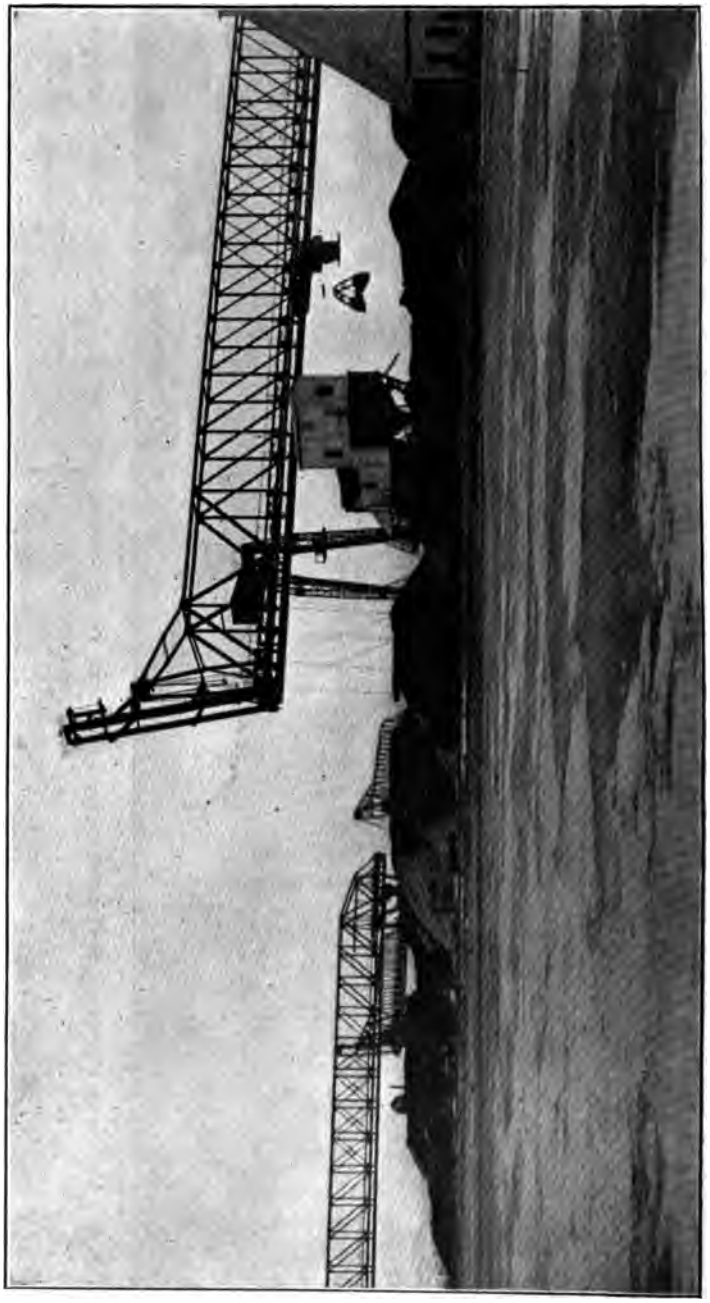

FIG. 23a MEAD ANTHRACITE AND BITUMINOUS PLANTS, INSTALLED ON CARNEGIE DOCK NO. 2, DULUTH, IN 1912

FIG. 23*b* OTHER HALF OF PLANTS SHOWN IN FIG. 23*a*

plant, in the form of a steel storage building equipped with a 3-tc man-trolley, which carries a 5½-ton skip for stocking and a 3-tc clamshell for reclaiming, with necessary additional elevators ar conveyors to supplement the original conveyor system, for transferrir coal to and from the building. This gives a total anthracite stora capacity of about 265,000 tons on this dock.

50 Fig. 23 *a* and *b* show an electrical installation on the Ca negie No. 2 Dock, Duluth, comprising two Mead bitumino bridges of 382 ft. span, and anthracite plant consisting of two traver ing unloading hoists equipped with clams, and a steel storage sh 280 ft. by 404 ft. equipped with rope trolleys, operating on six ru ways.

51 An unusual arrangement of bridges was installed in 1911 (the Pittsburgh Coal Company's Dock No. 7 by the Brown Hoisting M chinery Company (Figs. 24*a* and *b*). This installation comprises thr two-span bridges on the front of the dock and two single-span bridg at the rear, the spans having a uniform length of 242 ft. Each of tl two-span bridges and one of the single-span bridges is equipped with man-trolley carrying a 5½-ton grab bucket. The single-span bridg may be operated separately, or may be registered with any of the tw span bridges, thus forming continuous runways 726 ft. long acro the dock; or including cantilevers and apron the overall length 839 ft. Other interesting features of this installation are the swive ing trolley and the screening plant. The swiveling man-trolley, pr vided with turntable to facilitate cleaning up the hold of boats, further described in a later paragraph. A very complete screenin plant, of new design and large capacity, is located in the rear pier one of the single-span bridges, Fig. 25. This is furnished with bir shaking and revolving screens, and the necessary elevators and co veyors for the preparation of lump coal and the separation of t degradation into nut, stove and screenings, with provision for loadir box and gondola cars or returning to stock pile on the dock, as desire Last year, a similar installation with longer span bridges was ma on the Pittsburgh Coal Company's Dock No. 5 in Superior.

52 The coal handling plant installed last year on the Canadi Pacific Railway Company's Fort William Dock by the Wellma Seaver-Morgan Company, consists of two automatic unloade equipped with 8-ton scoops, a man trolley bridge carrying a 9-t grab bucket, and a transfer car system with trestle and bins to gi flexibility to the plant. Transfer cars are of 35-ton capacity, and a

FIG. 24a BROWN HOIST BRIDGES ON PITTSBURGH COAL COMPANY'S DOCK NO. 7, DULUTH, MINN.

FIG. 24b OTHER HALF OF BRIDGES SHOWN IN FIG. 24a

l with recording scales accurately weighing all the coal they The plant has a capacity for unloading a 10,000-ton boat in ;. Thirty loading pockets are provided from which cars are y means of a double-ended Christy box-car loader, giving a ;e loading out capacity. Fig. 26 shows a good general view of ıt.

PARISON OF ELECTRICALLY OPERATED PLANTS 1902-1913

Fhe tendency towards a few large units in the development of dling equipment within the past few years is shown in the

BROWN SCREENING PLANT ON PITTSBURGH COAL COMPANY'S DOCK No. 7, DULUTH, MINN.

ıon of the electrically operated plant installed on Section 1 of th Western Fuel Company's Dock No. 1 in 1901, and the coal handling bridge installed in 1913 on Section 3 of the :k, these being the first and latest electrically operated plants at the head of the lakes. The plant first mentioned has, as ly described, four hoisting towers and four bridges with ssary transfer cars, having rated capacity for unloading a

FIG. 26 HULETT AUTOMATIC UNLOADERS, TRANSFER CARS, AND STOCKING AND RECLAIMING BRIDGE ON CANADIAN PACIFIC DOCK, FORT WILLIAM

5000 ton boat in 10 hours, and serving a dock about 560 ft. by 1100 ft. on which bituminous coal is stocked 30 ft. high. The second installation referred to, on Section 3 of this dock, consists of one Heyl & Patterson bridge having a single span of 551 ft. and being 712½ ft. long overall, on which is operated a man-trolley equipped with a 12-ton clamshell for unloading, stocking and reclaiming, and 6-ton clean-up clam. This bridge serves a section of the dock about 610 ft. by 750 ft. and stocks bituminous coal to a height of 50 ft. Coal is reloaded to cars at both ends of the bridge and rescreened, when

Fig. 27 Loading Plant and Trucks at Shear End of North Western Fuel Company's Bridge No. 5, Dock No. 1, Superior, Wis.

desired, at the pier end. Provision has also been made in the construction of the bridge for the future installation of a more elaborate detached screening plant for repreparation of coal. There is required on this bridge for its operation one man-trolley operator and one oiler. This bridge has a rated capacity for unloading and stocking coal on dock from a 10,000-ton boat in 20 hours, accomplishing, with a single unit and with only two men on the bridge, as much as four unloading hoists with a total of eleven units accomplished with about

FIG. 28 NORTH WESTERN FUEL COMPANY'S DOCK No. 1, SUPERIOR, SHOWING ANTHRACITE SECTION AND LARGEST COAL HANDLING BRIDGE INSTALLED TO DATE

e men on the equipment in the first mentioned installa-
27 and 28).

incidental advantage of bridges long enough to span the ı of dock is the elimination of intermediate runways or m the stocking area, which in the short span bridges re- ırage space and obstruct the operations of stocking and

the present time two installations are being made, one ı No. 3 Dock at Superior, which is being equipped with tterson bridge, and the other on the Missabe and Northern

VN 7-TON STOCKING TUB ON NORTH WESTERN FUEL COMPANY'S SUPERIOR DOCK NO. 1

luth, comprising Mead hoists and cable railway system as previously mentioned.

METHODS OF HANDLING AT RECEIVING DOCKS

le it is evident, from a consideration of the several types iefly described above, that there are several methods of : coal at the receiving docks, it is true that these methods ıelves under two general heads, as follows:

at in which the bulk of coal is broken at the dock front ›y temporarily storing the coal in a receiving hopper, lo- ›ated, in the hoists, for later discharging to independent ınits for transferring to stock pile

at in which coal is delivered direct to stock pile in a ıingle operation without breaking bulk.

57 Under case *a*, where bulk is broken at the dock front, the unloading is done by fixed or traversing hoists or unloaders used only for this operation, while the stocking is done by equipment ordinarily acting independently of the hoists. This stocking equipment is of various types, and the method employed for stocking is again divided into two general classes:

1 That in which no provision is made for longitudinal transfer of the coal, necessitating its being stocked directly back of the unloading tower, so that boat must be placed opposite the area on which coal is to be stocked.

FIG. 30 BROWN 4-TON SHOVEL BUCKET ON NORTH WESTERN FUEL COMPANY'S SUPERIOR DOCK NO. 1

2 That by which provision is made for longitudinal as well as transverse movement of the coal in transferring to stock pile, giving perfect flexibility in stocking and enabling the coal to be stocked on any part of the dock desired, regardless of the position of the boats and hoists.

58 Method *a*-1 obtained in a few of the earlier plants but has now been largely, if not entirely, displaced by the method designated as *a*-2.

59 Method *a*-2 is used in

Plants equipped with transfer cars and stocking bridges

Installations of dump car systems operated either by hand or by cable on bridges or stationary runways

Systems of longitudinal and transverse conveyors

Longitudinal conveyors in conjunction with trolleys, or conveyors operating on transverse runways, or bridges

60 Method *b* comprises

One or more units designated as coal handling bridges on each of which a single trolley is used for the various operations of unloading, stocking, reclaiming and delivering to bins for reshipment by rail

Traversing hoists registering with stationary runways, or combined units made up of fixed hoists in line with stationary transverse runways

31 FIRST RECLAIMING CLAM AT THE HEAD OF THE LAKES, DESIGNED BY FRED BARROWS. FIRST USED AT THE OHIO COAL COMPANY'S DOCK IN 1888 OR 1889

Trolleys employed in stocking ordinarily equipped either with automatic dumping tubs, which are self-righting, or with drop bottom skips.

61 The reclaiming of coal for reshipment by rail is done by ious methods dependent in part upon the method employed in :king. Where the stocking is done by means of trolleys, automatic ; or belt conveyors, operating on bridges or runways, the reclaim-

ing is largely done by trolleys equipped either with shovel buckets clamshelled grab buckets, which have practically superseded shovel to tubs. Where coal is stocked by flight conveyors, the over and un type is used, the reclaiming being done on the lower run of convey which are enclosed in concrete or timber tunnels, running und neath the coal piles.

CLAMSHELL GRAB BUCKETS

62 On practically all unloading equipment in which the str tural and mechanical parts are of sufficient strength to permit, cl

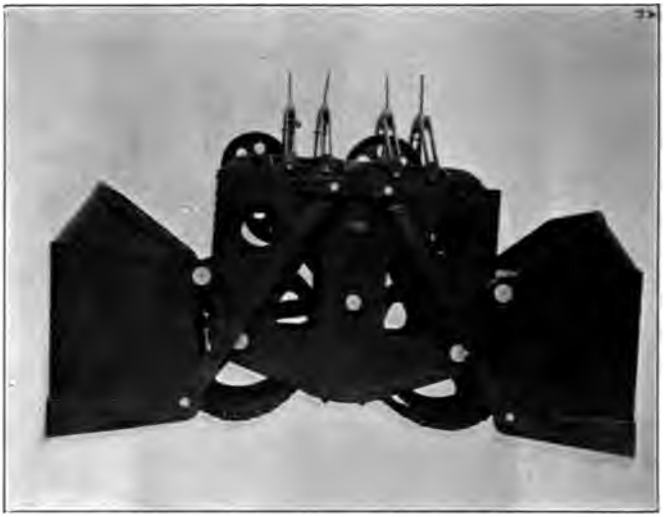

FIG. 32 HULETT 7½-TON CLAMSHELL GRAB BUCKET

shell grab buckets have superseded the tubs formerly in comn use. The clamshell designated as the two-rope type is ordina used on larger installations, while the single rope type is someti used in replacing tubs on old hoists, and on some new installati where simplicity of the hoisting mechanism or light weight on trolley is desired.

63 The first clamshell used at the head of the lakes was vented by Fred Barrows in about 1888 or 1889, and manufactu under patents of Mr. Barrows and D. B. Smith, both of the O Coal Company, which patents were later purchased by the No Western Fuel Company. This clam was used for reclaiming o

A clam of this type, still in service on the North Western Fuel Company's Duluth dock, is shown on Fig. 31.

64 The first unloading grab bucket put into service at the head of the lakes, was the Newell & Ladd clamshell bucket and was installed on the Duluth dock of the Ohio Coal Company in 1895. The first clam of this type was made by the John A. Meade Manufacturing Company in 1883, and the clams were used to a limited extent in the

FIG. 33 HEYL AND PATTERSON MAN TROLLEY AND 12-TON UNLOADING CLAMSHELL ON NORTH WESTERN FUEL COMPANY'S NO. 5 BRIDGE

East. This was one of the first, if not the first, clam to come into general use.

65 Clamshell grab buckets of several types and makes now in use, are shown on Figs. 32 and 33.

66 The process of breaking down or the removal of the free coal from the hatches of the vessels at the present time is done by means of clamshell grab buckets, which open crosswise of the boat, and are of such width as to have sufficient clearance in entering the hatch. Formerly, the coal out of ready reach of the unloading clams was either trimmed to the hatch by hand shoveling for picking up by the clams, or hand shoveled to tubs, and, in some instances, to the clam itself in cleaning up the boat. As this process, however, necessitated

considerable intermittent high-priced labor, various methods have bee devised for cleaning up the boat by mechanical means.

67 The first equipment, of which the writer has knowledge, i which the cleaning up of the vessels by mechanical means was pr vided for, was the Hulett automatic unloader designed by G. I Hulett, the first installation of which was made at the iron ore docl of the Pittsburgh & Conneaut Dock Company of Conneaut, Ohio, i 1898. In these unloaders, the clamshell, which is of large capacit was rotated after entering the hatch so as to extend lengthwise the boat, enabling it to reach the ore tributary to each hatch. The machines had an unloading capacity far in excess of any equipme previously installed, and have been extensively used in the unloadi of iron ore at the lower lake ports.

68 Following the development of the unloader above mentione clamshells came into general use in the unloading of both ore a coal, and several devices were tried out with varying degrees of succe for scraping or trimming the ore and coal from the wings to withi reach of the clamshell, with view to avoiding hand trimming a hand shoveling to tubs in cleaning up the vessels.

69 In the Brown swiveling trolley developed for this purpo a turntable is provided, which rotates the clam in the hold of t boat, and is used on the recent installations of the Brown equipme on the Nos. 5 and 7 docks of the Pittsburgh Coal Company at S perior and Duluth, to which reference has previously been made.

70 The Heyl & Patterson clean-up clam is built of dimensio to permit its entering the hatch closed and to open below deck lengt wise of the boat, with a reach of twenty-four feet, covering the enti space center to center of the hatches on each side of the hatch bei worked, thus requiring the clean-up clam to be worked only in alte nate hatches for boats having hatches spaced twelve foot centers. Th clean-up clam, first installed on the North Western Fuel Company Superior Dock No. 2, has been applied in a considerable number later installations of both larger and smaller capacity, and in each ca is so proportioned as to give the same total lifted load on the trolle as for the unloading bucket (Figs. 34 and 35).

71 The Mead Company has since produced a clean-up clam less reach and dead weight, with capacity for proportionately great coal load.

72 For the trimmings of anthracite coal within a storage buildi in stocking and reclaiming, and for the transferring of bitumi

FIG. 34 HEYL AND PATTERSON 4-TON CLEAN-UP CLAM, INSTALLED ON NORTH WESTERN FUEL COMPANY'S DOCK NO. 2, IN 1912

FIG. 35 HEYL AND PATTERSON 6-TON CLEAN-UP CLAM, 13 FT. 6 IN. WIDE, WITH 24-FT. REACH, INSTALLED ON NORTH WESTERN FUEL COMPANY'S NO. 5 BRIDGE, DOCK NO. 1, SUPERIOR, WIS.

screenings to and from stock piles, steel scrapers, sometimes desi nated as flying scrapers, were introduced in about 1890. The scrapers are ordinarily worked by means of ropes, for pulling the in opposite directions.

SCREENING

73 Coal is screened before shipment from the mine and all a thracite and all bituminous coal, with the exception of railroad co which is used largely for locomotive firing, is reprepared before r shipment from the dock, care being taken to make the coal of ea grade uniform. It is also carefully inspected upon its arrival by vess while being unloaded and during the process of repreparation; ea car load is also inspected while being loaded for rail shipment.

74 Various types of screens are used, choice of type being ma to suit kind of coal, the tonnage handled at a single point, and t particular part of the process for which the screen is to be use When coal is to be loaded out through various openings in long co tinuous lines of bins, where the tonnage loaded out over each scre is comparatively small, single stationary lip screens are used wi good results. This type of screen is also considerably used in t rescreening of the degradation made in the first screening proce For anthracite coal, the screens used are either wire mesh or perf rated plate; and for bituminous coal, they are of the bar type. A tomatic baffles or retarders are occasionally used for controlling t flow over lip screens, but possibly one of the most effective devic is a flight conveyor of light open construction running over the scre surface at a predetermined speed. This controls the velocity ov the screen and insures uniform discharge to the car.

75 Where, however, large tonnage is to be loaded at centr shipping pockets, either mechanical screens or a large bank of l screens are used. Mechanical screens are of two general types, r volving screens and shaking screens. Revolving screens are provid with one full length inner jacket and one or more concentric short outer jackets, and shaking screens are made up either with a sing bed or in tiers of two or more beds for the proper separation a distribution of the coal.

RELOADING FOR RAIL SHIPMENT

76 Three general methods are used in reloading coal to cars f rail shipment:

a That in which coal is loaded out through a long continuo line of bins, with loading chutes or lip screens at frequent intervals permitting the loading of several cars simultaneously. Bituminous coal, under this method of loading, was formerly trimmed in the cars by hand, while the anthracite was, and to some extent still is, trimmed in the cars by the use of telescopic chutes attached to forked aprons at the outer end of the screens. Box-car loaders are now used for both kinds of coal

b That in which the coal is loaded out through central shipping pockets, which is made possible by tilting box-car loaders having capacity of from ten to twelve cars per hour or from 3000 to 4000 tons per 10-hr. day

c That in which the coal is loaded out through bins mounted on traversing coal handling bridges or through detached movable screening plants, the coal being trimmed in the car either by portable box-car loaders traveling along the dock or by box-car loaders mounted on the bridge or screening plant.

77 As a great deal of the coal is now shipped in box-cars, and loading these cars by hand is both slow and expensive, a number of mechanical loaders have at various times been put on the market. The first box-car loader[1] of which we have record is that invented by Richard Ramsey, of Illinois, in 1885. This was manufactured by the Ottumwa Box Car Loader Company and the Litchfield Foundry & Machine Company. Two years later William Ramsey, of Iowa, invented a loader which was also manufactured by the Ottumwa Company. In 1894, F. W. Bond invented the third loader, which was built by the Litchfield Foundry & Machine Company. The coal was so badly broken and the cars so badly damaged by these loaders, that their manufacture was soon discontinued.

78 In 1897, the first really successful loader was manufactured by the Ottumwa Box Car Loader Company, their first loader built two years previously being a failure. In 1898, the first Christy loader, invented by J. M. Christy, was installed in Des Moines. The following year, the first Victor loader, invented by D. A. Chappell, President of the Victor Fuel Company, Denver, was installed.

79 In 1900, the Smith gravity loader, invented by S. Kedzie

[1]Data relative to early history of box car loaders are taken from a paper read by Wm. L. Affelder, Supt., Mosgrove Coal Co., before the Central Mining Institute of Western Pennsylvania, December 1904.

Smith, Civil Engineer in Billings, Mont., was installed for the Nor western Improvement Company, Roslyn, Wash. This is manuf tured by the Dodge Coal Storage Company and the Ottumwa B Car Loader Company.

80 In 1902, the Ottumwa Box Car Loader Company develop at the request of the North Western Fuel Company, and installed their Superior Dock No. 1, the first portable box car loader. T was a steam loader, equipped with engine and boiler. The followi year, the same company, also at the request of the North West Fuel Company, developed the first electric loader, which was install on the same dock. Since that time, a large number of electric porta loaders of this make have been installed at the head of the lakes. the Ottumwa loader, the coal is trimmed in the cars by means of reciprocating cradle and pusher traveling therein the full length the cradle, Fig. 36.

81 During the same period, a large number of Christy portal electric loaders have also been installed on the docks in Duluth a Superior. The distinctive feature in this loader is the use of a st lagged conveyor for trimming coal in the car, the speed of the co veyor being under control to suit conditions of loading, Fig. 37.

82 In 1906, a Smith tilting box car loader was installed on t North Western Fuel Company's Dock No. 1 by the Dodge Coal St age Company, with rated capacity for handling 100 cars or 3000 to of anthracite coal in ten hours. This loader tilts the car endwise the cradle, which permits the flow of coal alternately to each end the car by gravity. After the two ends are loaded the car is broug to level position and the middle of the car filled without hand tri ming. This type of loader permits the loading of a large tonnage a single central point, and is used for handling both anthracite a bituminous coal. Smith loaders have since been installed on t Philadelphia & Reading dock in Superior and the Carnegie No. dock in Duluth, Fig. 38.

83 For the purpose of handling bituminous screenings, the was installed on the North Western Fuel Company's No. 1 dock 1909 a Fairmont centrifugal loader, manufactured by the Fairmo Mining Machinery Company, of Fairmont, W. Va. In this load the coal is received by a cylinder, from which it is discharged blades attached to a rotating head.

84 Two other types of loaders have recently been developed Milwaukee, one of which, the Manierre loader, is adapted for handli

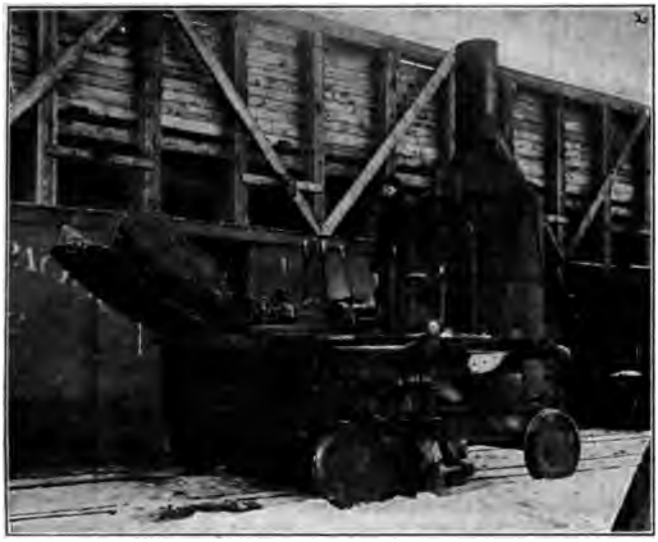

Fig. 36 Ottumwa Steam Box Car Loader, installed on North Western Fuel Company's Dock No. 1, in 1902. First Portable Loader ever Built

Fig. 37 Christy Box Car Loader Company's Electric Swiveling Conveyor Loader, installed on North Western Fuel Company's Dock No. 1, Superior, 1913

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FIG. 36 OTTUMWA STEAM BOX CAR LOADER, INSTALLED ON NORTH WESTERN FUEL COMPANY'S DOCK NO. 1, IN 1902. FIRST PORTABLE LOADER EVER BUILT

FIG. 37 CHRISTY BOX CAR LOADER COMPANY'S ELECTRIC SWIVELING CONVEYOR LOADER, INSTALLED ON NORTH WESTERN FUEL COMPANY'S DOCK NO. 1, SUPERIOR, 1913

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FIG. 37 CHRISTY BOX CAR LOADER COMPANY'S ELECTRIC SWIVELING CONVEYOR LOADER, INSTALLED ON NORTH WESTERN FUEL COMPANY'S DOCK NO. 1, SUPERIOR, 1913

FIG. 38 SMITH TILTING BOX CAR LOADER, BUILT BY THE DODGE C
STORAGE COMPANY

FIG. 39 MANIERRE CONVEYOR LOADER, MOUNTED ON BRIDGE PIER, CARN
COAL COMPANY'S DOCK NO. 2, DULUTH, MINN.

both bituminous and anthracite coal. The Hanna Coal Company installed two of these loaders in 1912 for handling anthracite. Since then, three loaders of this type have been installed on the bridge piers on the Pittsburgh Nos. 5 and 7 docks for handling bituminous coal, and a fourth loader for anthracite has been installed on No. 7 dock. This is a stationary type of loader, located on the same side of the car as the loading bin, as shown by Fig. 39. The distinctive feature of this loader is the swinging supporting arm, to the outer end of which the conveyor is pivoted. This permits conveyor being extended alternately into the opposite ends of the car, allowing low conveyor speed in unloading.

85 In 1911, the other type of stationary anthracite conveyor loader was designed by John Ecks, Chief Engineer of the Milwaukee-Western Fuel Company, and was installed on one of the docks of this company, for loading anthracite coal to box cars on two tracks between which it is located. The distinctive feature of this loader is the reciprocating motion of the belt conveyor, permitting it to travel toward the end of the car for reducing throw of the coal to the minimum, thus permitting low conveyor speed.

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87 With the exception of a few of the earlier steam loaders, the portable loaders thus far installed have been electrically operated. At the present time, however, a Christy "Superior" type loader is under construction for the North Western Fuel Company's Superior Dock No. 2, in which a gasoline engine will furnish power for the travel of the loader along the dock.

88 Portable loaders serve not only for loading coal, but also for the switching and spotting of loaded and empty cars.

89 To expedite loading operations, the spotting and local switching of cars, when not done by the portable loaders, is usually done at the receiving docks by one of the several types of rope haulage or carpuller systems. Gravity tracks are also frequently used where conditions make it desirable. At the car dumpers at the lower lake ports, it is customary to run the cars down grade from the storage tracks onto a kick-back track, after which they are run onto the cradle of the car dumper by means of a small car attached to a haulage rope, variously designated as a ground hog, mule or pig.

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less of the distance through which the coal is lowered. Where it is desired to lower and also convey the coal horizontally by gravity, step chutes built on similar principle are employed to advantage.

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Fig. 40 Specialty Engineering Company's Wagon Loader, Nor' Western Fuel Company's Yard No. 1, St. Paul, 1914

Fig. 41 McMyler Mechanical Plant for Retail Yard, Cleveland A Pittsburgh Coal Company's Retail Yard, Cleveland, Ohio

automatic safety devices can be introduced for safeguarding operations of hoisting and lowering of bucket, and traversing of man-trolleys and bridges. Dynamic braking is also a valuable feature in man-trolley operation, where the loads are heavy and high speed is attained. Probably the greatest disadvantage in the use of electricity in place of steam is the absence of steam for heating purposes, as while the use of electric heaters is feasible, the cost is excessive. In hoisting operations, current fluctuations are excessive, owing to peaks incident to accelerating and to intermittent operation of the individual units. When conditions warrant, provision is made for equalizing the load on the generating plant by the installation of motor-generator flywheel set or storage battery.

97 The handling of coal in retail yards is another important branch of industry. The most of these yards simply have covered sheds, into which coal is unloaded from cars and from which coal is loaded into wagons and auto trucks by hand shoveling. Where the volume of business warrants, however, elevator and conveyor installations for unloading and stocking coal in sheds and bins are coming into more general use, and electric portable wagon loaders, shown on Fig. 40 for taking coal from storage pile at ground level and loading to delivery trucks are being more generally used. An increasing number of plants are being installed for mechanically performing all the operations at retail yards of large capacity, with 3- to 5-ton auto trucks for long hauls, Fig. 41.

98 The non-occurrence of high grade coals in this section of the country, and the high cost of delivery by rail incident to long haul, make of vital importance careful consideration of the subject of cheap lake transportation, and the development of mechanical equipment which will at low cost, and with dispatch, load, unload, and deliver to the consumer the large and rapidly increasing tonnage of coal required for distribution throughout the northwest.

99 The writer wishes to acknowledge the courtesy extended in furnishing information for this article by the management of the various coal companies and by the manufacturers of the equipment herein described.

No. 1439

MINNEAPOLIS FLOUR MILLING

By Chas. A. Lang, Minneapolis, Minn.

Junior Member of the Society

In the popular mind, the word flour is as intimately associated with the name Minneapolis as steel is with Pittsburgh. The first manufacturing enterprise in Minneapolis was a government grist mill built in 1823 by Colonel Snelling from whom Fort Snelling derives its name. He sent, under Lieutenant McCabe, a detachment of fifteen soldiers to the west bank of the Falls of St. Anthony and on the site of the present mill "D" of the Northwestern Consolidated Milling Company, the first mill was built. It was a crude affair about 20 ft. square, built of logs and containing one pair of mill stones. The power was derived from a log flume from the crest of the Falls, discharging into a flutter wheel at the mill.

2 From such a beginning has the present milling industry and its allied interests grown. The potential possibilities of the Northwestern territories for the production of wheat was, at that time, undreamed of. The water power was evident and gave the first incentive for the building of grist mills and lumber mills at Minneapolis. The supply of wheat in that time was the most serious handicap. The fitness of the soil in the immediate vicinity for raising wheat was not known. The soldiers at the time of building the first mill tried their hands at raising wheat and as very light crops resulted, they were soon discouraged and gave it up. This first mill ceased grinding wheat about four years after being built.

3 This seemed to be the end of flour milling, for nothing was heard of the government mill until about 1849 when the town of St. Anthony was established on the east side of the Falls. The first court ever held in Hennepin County convened in the old mill in 1849. The mill was apparently the only place available at that time for court sittings. It is a far cry from a grist mill to a court of law, and serves to show how close was the connection of the flour mill with the early

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Smith, Civil Engineer in Billings, Mont., was installed for the Northwestern Improvement Company, Roslyn, Wash. This is manufactured by the Dodge Coal Storage Company and the Ottumwa Box Car Loader Company.

80 In 1902, the Ottumwa Box Car Loader Company developed at the request of the North Western Fuel Company, and installed on their Superior Dock No. 1, the first portable box car loader. This was a steam loader, equipped with engine and boiler. The following year, the same company, also at the request of the North Western Fuel Company, developed the first electric loader, which was installed on the same dock. Since that time, a large number of electric portable loaders of this make have been installed at the head of the lakes. In the Ottumwa loader, the coal is trimmed in the cars by means of a reciprocating cradle and pusher traveling therein the full length of the cradle, Fig. 36.

81 During the same period, a large number of Christy portable electric loaders have also been installed on the docks in Duluth and Superior. The distinctive feature in this loader is the use of a steel lagged conveyor for trimming coal in the car, the speed of the conveyor being under control to suit conditions of loading, Fig. 37.

82 In 1906, a Smith tilting box car loader was installed on the North Western Fuel Company's Dock No. 1 by the Dodge Coal Storage Company, with rated capacity for handling 100 cars or 3000 tons of anthracite coal in ten hours. This loader tilts the car endwise on the cradle, which permits the flow of coal alternately to each end of the car by gravity. After the two ends are loaded the car is brought to level position and the middle of the car filled without hand trimming. This type of loader permits the loading of a large tonnage at a single central point, and is used for handling both anthracite and bituminous coal. Smith loaders have since been installed on the Philadelphia & Reading dock in Superior and the Carnegie No. 2 dock in Duluth, Fig. 38.

83 For the purpose of handling bituminous screenings, there was installed on the North Western Fuel Company's No. 1 dock in 1909 a Fairmont centrifugal loader, manufactured by the Fairmont Mining Machinery Company, of Fairmont, W. Va. In this loader the coal is received by a cylinder, from which it is discharged by blades attached to a rotating head.

84 Two other types of loaders have recently been developed in Milwaukee, one of which, the Manierre loader, is adapted for handling

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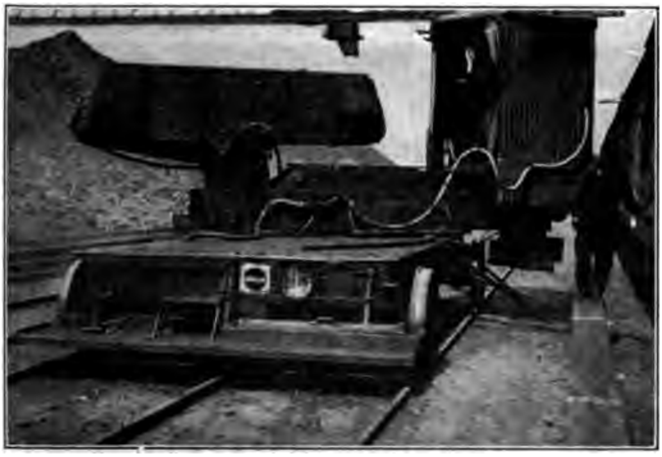

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both bituminous and anthracite coal. The Hanna Coal Company installed two of these loaders in 1912 for handling anthracite. Since then, three loaders of this type have been installed on the bridge piers on the Pittsburgh Nos. 5 and 7 docks for handling bituminous coal, and a fourth loader for anthracite has been installed on No. 7 dock. This is a stationary type of loader, located on the same side of the car as the loading bin, as shown by Fig. 39. The distinctive feature of this loader is the swinging supporting arm, to the outer end of which the conveyor is pivoted. This permits conveyor being extended alternately into the opposite ends of the car, allowing low conveyor speed in unloading.

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FIG. 40 SPECIALTY ENGINEERING COMPANY'S WAGON LOADER, NORTH WESTERN FUEL COMPANY'S YARD NO. 1, ST. PAUL, 1914

FIG. 41 MCMYLER MECHANICAL PLANT FOR RETAIL YARD, CLEVELAND AND PITTSBURGH COAL COMPANY'S RETAIL YARD, CLEVELAND, OHIO

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FIG. 40 SPECIALTY ENGINEERING COMPANY'S WAGON LOADER, NORTH WESTERN FUEL COMPANY'S YARD NO. 1, ST. PAUL, 1914

FIG. 41 MCMYLER MECHANICAL PLANT FOR RETAI[illegible]LEVELAN[illegible] PITTSBURGH COAL COMPANY'S RETAIL YAR[illegible]D, O[illegible]

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MINNEAPOLIS FLOUR MILLING

By Chas. A. Lang, Minneapolis, Minn.

Junior Member of the Society

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FIG. 41 MCMYLER MECHANICAL PLANT FOR RETAIL YARD, CLEVELAND AND PITTSBURGH COAL COMPANY'S RETAIL YARD, CLEVELAND, OHIO

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Smith, Civil Engineer in Billings, Mont., was installed for the Northwestern Improvement Company, Roslyn, Wash. This is manufactured by the Dodge Coal Storage Company and the Ottumwa Box Car Loader Company.

80 In 1902, the Ottumwa Box Car Loader Company developed, at the request of the North Western Fuel Company, and installed on their Superior Dock No. 1, the first portable box car loader. This was a steam loader, equipped with engine and boiler. The following year, the same company, also at the request of the North Western Fuel Company, developed the first electric loader, which was installed on the same dock. Since that time, a large number of electric portable loaders of this make have been installed at the head of the lakes. In the Ottumwa loader, the coal is trimmed in the cars by means of a reciprocating cradle and pusher traveling therein the full length of the cradle, Fig. 36.

81 During the same period, a large number of Christy portable electric loaders have also been installed on the docks in Duluth and Superior. The distinctive feature in this loader is the use of a steel lagged conveyor for trimming coal in the car, the speed of the conveyor being under control to suit conditions of loading, Fig. 37.

82 In 1906, a Smith tilting box car loader was installed on the North Western Fuel Company's Dock No. 1 by the Dodge Coal Storage Company, with rated capacity for handling 100 cars or 3000 tons of anthracite coal in ten hours. This loader tilts the car endwise on the cradle, which permits the flow of coal alternately to each end of the car by gravity. After the two ends are loaded the car is brought to level position and the middle of the car filled without hand trimming. This type of loader permits the loading of a large tonnage at a single central point, and is used for handling both anthracite and bituminous coal. Smith loaders have since been installed on the Philadelphia & Reading dock in Superior and the Carnegie No. 2 dock in Duluth, Fig. 38.

83 For the purpose of handling bituminous screenings, there was installed on the North Western Fuel Company's No. 1 dock in 1909 a Fairmont centrifugal loader, manufactured by the Fairmont Mining Machinery Company, of Fairmont, W. Va. In this loader the coal is received by a cylinder, from which it is discharged by blades attached to a rotating head.

84 Two other types of loaders have recently been developed in Milwaukee, one of which, the Manierre loader, is adapted for handling

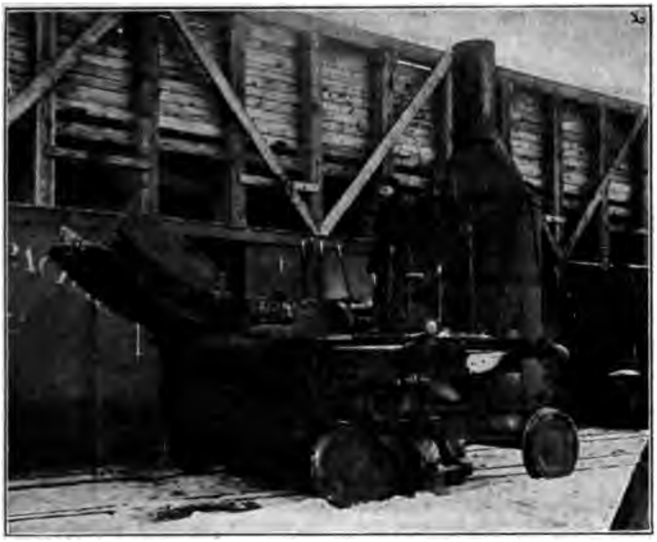

FIG. 36 OTTUMWA STEAM BOX CAR LOADER, INSTALLED ON NORTH WESTERN FUEL COMPANY'S DOCK NO. 1, IN 1902. FIRST PORTABLE LOADER EVER BUILT

FIG. 37 CHRISTY BOX CAR LOADER COMPANY'S ELECTRIC SWIVELING CONVEYOR LOADER, INSTALLED ON NORTH WESTERN FUEL COMPANY'S DOCK NO. 1, SUPERIOR, 1913

FIG. 38 SMITH TILTING BOX CAR LOADER, BUILT BY THE DODGE COAL STORAGE COMPANY

FIG. 39 MANIERRE CONVEYOR LOADER, MOUNTED ON BRIDGE PIER, CARNEGIE COAL COMPANY'S DOCK NO. 2, DULUTH, MINN.

:h bituminous and anthracite coal. The Hanna Coal Company in-lled two of these loaders in 1912 for handling anthracite. Since n, three loaders of this type have been installed on the bridge rs on the Pittsburgh Nos. 5 and 7 docks for handling bituminous l, and a fourth loader for anthracite has been installed on No. 7 :k. This is a stationary type of loader, located on the same side the car as the loading bin, as shown by Fig. 39. The distinctive ture of this loader is the swinging supporting arm, to the outer l of which the conveyor is pivoted. This permits conveyor being .euded alternately into the opposite ends of the car, allowing low iveyor speed in unloading.

85 In 1911, the other type of stationary anthracite conveyor .der was designed by John Ecks, Chief Engineer of the Milwaukee-estern Fuel Company, and was installed on one of the docks of this mpany, for loading anthracite coal to box cars on two tracks be-een which it is located. The distinctive feature of this loader is e reciprocating motion of the belt conveyor, permitting it to travel ward the end of the car for reducing throw of the coal to the min-ium, thus permitting low conveyor speed.

86 The following year, one of these loaders was installed for ding anthracite coal at the North Western Fuel Company's Su-rior Dock No. 1.

87 With the exception of a few of the earlier steam loaders, the rtable loaders thus far installed have been electrically operated. At e present time, however, a Christy "Superior" type loader is under nstruction for the North Western Fuel Company's Superior Dock). 2, in which a gasoline engine will furnish power for the travel of loader along the dock.

88 Portable loaders serve not only for loading coal, but also for switching and spotting of loaded and empty cars.

89 To expedite loading operations, the spotting and local tching of cars, when not done by the portable loaders, is usually ie at the receiving docks by one of the several types of rope haul- or carpuller systems. Gravity tracks are also frequently used ere conditions make it desirable. At the car dumpers at the lower e ports, it is customary to run the cars down grade from the rage tracks onto a kick-back track, after which they are run onto cradle of the car dumper by means of a small car attached to a ulage rope, variously designated as a ground hog, mule or pig.

90 Cars are weighed before and after loading on railroad scales

of from 100 to 150 tons capacity. Both the overhead and pit types of scales are used and are ordinarily provided with dead rail. Automatic scales are used to a limited extent, and where this type of scale is not in use, the scales are of recording or registering beam type, which enables the weighmaster to retain a ticket for each car, with the net and gross weights stamped thereon, corresponding to the position of the poise, thus avoiding the possibility of error in writing the weights. The weighing in Minnesota and Wisconsin is done by the Western Railway Weighing Association. Every precaution is taken to insure accuracy in weighing and the scales are given frequent attention and are regularly inspected by the dock companies. Periodically, inspection and tests are made by the state scale inspectors, for which purpose a special test car is used. The scales at the retail yards for weighing coal delivered by auto trucks and wagons are given the same attention. Both the track and wagon scales are balanced frequently during the day, while in service. Smithing coal, which is sacked for shipment in comparatively small quantities, is weighed on wheelbarrow scales during the process of sacking, prior to taking total weight on wagon or track scales.

91 Conveyor weighers, by which the weight of the coal being handled by belt conveyor is obtained automatically by electrical device, have been in use for several years to a limited extent by purchasers of coal and other bulk material, and also for check weighing, but have not thus far been used on the coal docks at the receiving ports for determining shipping weights.

CONDITIONS RELATING TO THE HANDLING OF COAL

92 In the handling and storage of coal, numerous precautions are necessary in order to avoid undue breakage or degradation. It is necessary to break bulk as few times as possible in handling the coal from the time it leaves the boat until it is loaded to cars for reshipment by rail. With the same end in view, it is also necessary to limit the free fall of the coal and the velocity of the flow as much as practicable. In compliance with above conditions, coal handled by clams or other buckets should be lowered to pile or bin before being discharged. An ideal device for lowering anthracite and other small sized coal vertically, where the drop would be large, is the Humphrey type of shelf lowering chute, which consists of a vertical shaft, in which the shelves, placed alternately on opposite sides, are so arranged that the coal flows over itself at a uniform moderate velocity, regard-

less of the distance through which the coal is lowered. Where it is desired to lower and also convey the coal horizontally by gravity, step chutes built on similar principle are employed to advantage.

93 The deterioration of bituminous coal in storage is slight, and recent experiments show it to be less than it is commonly supposed to be. Anthracite coal is not subject to any appreciable deterioration even though stored out of doors, but to supply the demand for bright coal it is housed in buildings for protection from the weather.

94 The liability of bituminous coal, especially screenings and some grades of run of pile, to spontaneous combustion, has made it necessary to limit the height of pile to suit the available rehandling facilities, as the first step in handling a coal fire is to get direct access to the fire by rehandling the hundreds, and frequently thousands, of tons of coal within the inverted cone tributary to the small area at the bottom of the pile, where the fire starts. It is sometimes also necessary to isolate the burning area to prevent the fire spreading. After the fire is uncovered, it can be extinguished by the use of water and the rehandling of the smoldering or burning coal. The application of water, however, to the top of the original coal pile is ordinarily useless and frequently increases the fire. While the liability to spontaneous combustion cannot be entirely eliminated, a clean dock surface and the absence of combustible foreign matter within the coal pile, and, after the coal is in storage, careful watching and prompt rehandling upon the first indication of heating, reduce the liability to a minimum.

95 Another essential condition, which is being complied with in an increasing degree, is the safeguarding of employees by the provision of sanitary conditions and the application of safety appliances to the dock equipment. For the removal of coal dust from enclosures where it is produced in unusual quantities, dust exhaust fans are being introduced for the benefit of employes and to facilitate operations.

96 The use of electric power in place of steam, which was common until twelve or thirteen years ago, has several very marked advantages. Electric power can easily be distributed, with comparatively small loss, to various remote centers on movable equipment. Branch lines can readily be cut out when not in service, and there is slight loss from leakage in feeders whether the motors are in operation or idle. Other advantages are the control of motors by means of magnetic switches and master controllers, and the ease with which

FIG. 40 SPECIALTY ENGINEERING COMPANY'S WAGON LOADER, NORTH WESTERN FUEL COMPANY'S YARD NO. 1, ST. PAUL, 1914

FIG. 41 MCMYLER MECHANICAL PLANT FOR RETAIL YARD, CLEVELAND AND PITTSBURGH COAL COMPANY'S RETAIL YARD, CLEVELAND, OHIO

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history of the settlements which were to form the future city of Minneapolis. The west side of the river at the Falls was still a government reservation. Upon this ground now stands what is known as the milling district and is the center of the flour manufacturing industry in Minneapolis.

4 The history of the various mills as they were developed from the time of the old government mill is too long a story to go into at

FIG. 1 ROLL FLOOR

this time, covering as it does, a period of some 80 years. This history in itself covers practically every development and invention that gave rise to the present system of American milling. It is not a record of success in every venture, for mills were destroyed by flood and fire and rebuilt in continuously increasing size and completeness. Some men made fortunes and others failed. With them all there was the belief that Minneapolis would be a great milling center. Transportation facilities were crude and uncertain; the difficulties of getting the grain to their mills and their product to the markets of the world made many give up the field. Mills were dismantled, built and rebuilt to take advantage of some newly invented system of milling, and money was spent by some with a lavish hand to improve the quality of their product over that of their competitors. It became a question of the survival of the fittest. One mill would receive a shipment of machinery and try to hide the fact from the other mills. The mill would be closely guarded while this new machinery was installed and operated. It would be but a short time before one of the employees would go to some other mill and the secret become common property. There is no doubt but that this keen rivalry between the various mills in raising the standard of the product of all the mills, gave Minneapolis its standing to the point where Minneapolis Patent Flour is the standard by which all are judged..

5 The great mill explosion of May 2, 1878, which destroyed the Washburn "A," Pettit, Galaxy, Humboldt, Diamond and Zenith Mills, threatened to bring Minneapolis milling to a sudden end. Instead of that, the industry was many times strengthened by new and better mills erected on the site of the ruins. In the new mills, the mistakes of the past were corrected and the possibility of a second dust explosion greatly lessened by the use of air suction systems for removing the dust as it was created in the machines and before it could fill the air of the mill. This great explosion occurred in the Washburn "A" and was so violent that it is said that hardly one stone was left on top of another. The walls of the surrounding mills were wrecked so that the fire, which followed, quickly completed their ruin. A second fire occurred in 1881, which destroyed the Pillsbury "B," Excelsior, Empire and Minneapolis Mills, the latter exploding as a result of the fire. The rebuilding of these mills marked the passing of the old milling district.

6 From that time up to the present, the operations have been more in the increasing of capacity and the improving of milling systems than in the building of new plants. The larger companies have improved their grain handling facilities by the building of large terminal elevators in connection with their mills. This grain storage assures a uniform supply of the various grades of wheat and puts it in the proper condition for delivery to the mill. The building of these elevators as well as the increase of capacity of the mills, called for increased power. To meet this condition large central steam power stations have been built and hydraulic turbines of increased power and efficiency installed, so that in the present milling district is seen some of the most modern and up to date power apparatus that the market affords. As an example, at the present writing, there is being

installed by two milling companies, two pairs of 42-in. hydraulic turbines of 1800-h.p. capacity, to have in their settings a guaranteed efficiency of 87 per cent. All of the larger mills have their water power supplemented by steam power or electric motors driven from the central steam stations. Where formerly each mill had its individual steam plant for relay, most of these have been abandoned in favor of the electric drive from central stations. The consolidation of

FIG. 2 PURIFIER FLOOR

the various mills into the present three large companies made it possible for each to centralize its power.

7 The present capacity of the Minneapolis mills is 84,000 bbl. of flour every 24 hours. There are 23 mills, which makes the average capacity 3600 bbl. per mill. The largest mill in the world, the Pillsbury "A," has a record of having made 16,125 bbl. in one day, although its capacity is rated at about 11,000 bbl. The mills vary in size from this to experimental mills of a few hundred barrels capacity. Flour mills run 24 hours a day, sometimes for many weeks without stopping. The usual running time is from Monday morning to the following Sunday morning.

THE MINNEAPOLIS WATER POWER

8 The Falls of the St. Anthony have played so prominent a part in the development of milling in Minneapolis, that they deserve special mention. The present developed power is approximately 60,000 h.p. under an average fall of 47 ft. This power, with the exception of 12,000 h.p. in the Hennepin Island station used by the Street Railway Company, is practically all taken by the flour mills. The races from the mills and this island station discharge into the pond of what is called the Lower Dam. This gives another fall of 18 ft. and is used entirely in a second plant where 10,000 h.p. is generated for use of the Street Railway Company. The Hennepin Island Station is an excess plant and is run only when the demands of all other users of power are satisfied.

9 The unit of measurement is the mill power defined as 30 cu. ft. per second under a fall of 22 ft., or approximately 75 h.p. gross. The mill powers are numbered from 1 to 48, there being in many cases several having the same number. Under conditions of limited water supply such as occur in the winter months, the mill powers are cut off in the inverse order of their priority number. That is, Series No. 48 would be taken off first and so on down until a balance was reached between the available supply and the amount used. It is under such conditions that the steam relays have to be used. Early in the history of the mills, these mill powers were owned or leased by the various mill owners in proportion to the power they used, and the water power company was something in the nature of a coöperative organization. The rental of the early powers was but nominal, which gave so little for dividends that free powers were given instead. These free powers and also the leased powers are perpetual and non-assessable. As the value of the power began to be appreciated, the rental increased when new leases were made to where $1000 per year was charged for Series No. 48.

10 In the water power development of the main falls, there is nothing that could rightly be called a dam. Underlying both sides of the river and the falls, is a limestone ledge which is about 12 ft. thick on the downstream edge and which tapers in thickness as it extends up stream to where it stops some 1200 ft. above the Falls. In fact, it is like a shingle with its thin edge lying up stream. The downstream edge of the ledge is in the form of a great hollow square or horseshoe whose sides extend down stream. At the upper end of

the hollow square in the center, is the spillway. This is an apron which protects the face of the ledge and slopes from the top of the ledge to the pool below. Starting from either end of the apron, extending up stream and built on top of the ledge in an elongated U shape, is a dam which gives a depth of water of 14 ft. above the ledge, forming the mill pond, from which the water is taken in canals to the mills. The water spills over this dam on to the ledge and down

FIG. 3 SIFTER FLOOR

over the apron. From ends of the apron and forming a continuation of the dam, are walls built on top of and following the edges of the ledge downstream. These walls form the river side of the main head races to the mills, one on either side of the river. The mills on the river side of the head race have their front walls built on the wall of the canal and their back walls extending down to tail race level, making them some three stories higher in the back than in the front. These mills take their water supply through penstocks and the waterwheels discharge directly into the main tail race. The mills on the other side of the head race take their water through canals from the head race into open flume waterwheel settings. These wheels discharge through holes cut through the ledge. From these wheel pits nels are cut under the ledge to the main tail race. The formation ›w the ledge is a tightly compressed white sand which just misses ıg sandstone, and it is through this that the tail races are cut. ıt of these races are lined with concrete or brick up to the ledge, ledge making the roof.

11 The water power development in its present state was not :hed without as many serious mishaps as befell the mills in their ution. The earlier retaining walls and canals were timber and structures and there were many wash-outs, even carrying entire .s away. In 1870 the most severe wash-out occurred. Through a ık on the east side, almost the entire river ran under the ledge. and ›oked as if the Minneapolis water power were a thing of the past. ras then that the federal authorities were called upon for help. gress appropriated over half a million dollars and with this a dike :ut-off wall was built across the river under the ledge.

12 In the early days there was no attempt made to maintain a form head of water by limiting the amount each mill could use. en the water was low it was just a grand scramble to see who ıld get enough to keep their mill running. Stories are told of ', when there would be but two or three feet of water in the canal, crew in one mill would build dikes of sand bags and boards to ·rt the water into their wheel pit. Then the crew from the mill w them would try to tear out the dike so they could get the water, a fight would ensue with material damage to the heads of the y having the smallest number of picks and shovels. The power he east side of the river was controlled by the St. Anthony Falls er Power Company, and on the west side by the Minneapolis Mill pany. While these two companies still exist, they are now under ıame management.

THE MILLING PROCESS

2 Probably the oldest known mechanical process is the reduction ·eds or grain to meal. The prehistoric man may have had a loom weaving his cloth, but he did not leave one for us to see. He did : us the hollowed out boulder to testify to the fact that he ground wild seeds that they might be made more suitable as food for an beings. He discovered the fact that his digestive apparatus not effective in penetrating the outer protective coating of the ; so that the meat within might be assimilated and give him ıgth. His mental processes may have been as crude as his time, they were concerned chiefly in getting food and clothing—mostly

Fig. 4 Milling District from West

food—and he seems to have solved the problem for many following generations.

13 For centuries the mortar and pestle were the mills for the grinding of grain. It is still used in the less civilized countries. Then ame the stones which were too large to be easily used by hand and rere turned by animal or man power in treadmill style with a long weep attached to the upper stone. The French Buhr stone of the resent day is the same idea except that the upper stone is driven by vertical shaft which passes down through the hole or eye of the ›wer or stationary stone. This type of mill is not entirely obsolete ut is used in some of the present day mills for finishing certain of ıe purified streams or middlings.

14 In 1839 came the next step when cast-iron rollers began to e used in Budapest. The first successful machine used there was the ulzberger cast-iron roller machine. About this same time the Hunarian millers began to use the gradual reduction process which came › be known as the Hungarian process. The term Hungarian process misused when it is given to cover the use of chilled iron rolls, and ach is often the case. This process can be carried out on Buhr stones s well as on rolls.

15 The next improvement was the purifier which was developed Minneapolis, and is distinctively an American contribution to illing, although some attempts had been made in France to use such machine. The purifier is a machine which in simple terms can be escribed as a reciprocating sieve over which passes certain of the reams of mill stock and through which is drawn a current of air hich removes the dust that would cause discoloration in the finished our.

16 The old-time method of making flour was to reduce the wheat rry in one grinding operation to as nearly the fineness of the finished roduct as was possible. That part of the bran or husk which was ot at the same time reduced to an equal fineness to the flour, was moved by sifting. The flour obtained by such a process was inferior color, containing as it did a large percentage of finely ground bran nd dust from the crease in the wheat berry.

17 The Hungarian, or gradual reduction process, is the system which the wheat passes through numerous grinding operations in eries before its final reduction to flour. The first grinding operation, r first break, as it is called, lays the berry open. The next or second reak, cuts off some of the inside of the berry left exposed by the first

break. The third break takes off some more, and so on to the fifth and final break where nothing but the bran is left in its familiar flattened condition. The pieces of the inside of the berry cut off by the break rolls, are called middlings and are what are finally reduced to flour. The middlings are passed over the purifiers and the dust caused by the grinding is removed. Dust cannot be removed from flour, and therein lies the advantage of the gradual reduction process in producing clean, white flour. The term cut is used in describing the action of the break rolls, as these rolls have knife-like corrugations on their surfaces, and actually do cut rather than grind.

18 The color of finished flour, aside from its being free from impurities, is obtained by granulation. A piece of glass reduced to powder is pure white. This is because the light which it reflects is broken up by the facets of the minute particles. So it is with flour. The inside of the hard spring wheat berry is an opaque, flint-like substance, slightly yellow in color. When reduced to the fineness of flour, the more granular or sharp the particles, the whiter the color.

19 The wheat from the different sections of the country tributary to any mill is by no means the same in characteristics or quality. Again the wheat grown on a certain piece of land this year, will in its milling value or strength, be very different from that grown last year, even though the same seed be used. The quality of the wheat is a variable but the quality of the flour must be a constant. The color of the flour must be the same this year as it was last year; the gluten must be of a certain percentage and quality, and its ability to absorb water must not vary. The modern mill has a well-equipped laboratory, and it is here that the various kinds of wheat are tested as to their value for making flour. A large part of the available supply of wheat may be inferior in color or low in gluten. A stronger wheat must be found to blend with it, that the product may be uniform.

20 The various kinds of wheat are delivered to the mill elevator loaded in bulk in box cars. These cars may come from the large terminal grain storage elevators or directly from the small farmers' elevators that are scattered along the lines of railroads that tap the wheat producing country. The wheat is taken out of the car by power shovels and drops through a grating into a receiving hopper. From here it is elevated to the top floor of the elevator and discharged into a garner which is large enough to hold the contents of the largest car, or about 2,000 bu. The garner opens into the hopper of the receiving scale, and the car load is weighed in one draft. The wheat then falls

into what is called a receiving separator which is a machine having a number of reciprocating sieves of perforated metal. This removes the coarse refuse such as pieces of wood, coal, iron ore, straw joints and even an occasional Ingersoll watch. It is then ready for storage and drops on conveyor belts which discharge directly into the storage bins. This wheat having been inspected and graded before unloading is carded to go to bin No. 20, for instance. Bin No. 20 contains wheat of the same grade or of the same value for milling purposes. The advantage of a large mill elevator lies in this ability to take care of many kinds of wheat and store them in quantities that insure a uniform mixture.

21 In the basement under the storage bins is a conveyor belt having spouts leading to it from the bins. By means of graduated slides in these spouts, a predetermined percentage of wheat from any bin may be drawn on to the conveyor. A number of bins may be drawn upon in this manner to get a wheat mixture that is right for milling. The mixing conveyor discharges into an elevator which takes the wheat again to the top of the elevator where it passes through another weighing process on its way to the bins in the mill proper.

22 This wheat is still far from being in condition for grinding. Every bushel contains from one to two pounds of foreign seeds, such as oats, cockle, mustard, grass, flax, etc. These are removed by passing over numerous sieves in the milling separators. These seeds, after the removal of the mustard, are pulverized and sold as stock food or ground screeings.

23 The next step is the cleaning process. There are two different methods in use, the wet and the dry. In the wet process the wheat, together with a stream of water, passes into a washing machine, or "whizzer." This machine has a rapidly revolving cylinder which violently agitates the wheat in the flowing water. As the wheat passes further along in the machine, the water, together with the impurities, is thrown off by the centrifugal force, partially drying the grain at the same time. The wheat has to be dried further by dropping through large cylinders having baffles to retard the flow, while hot, dry air is blown upward through the cylinder, thus completing the drying. The dry process cleans the wheat by dry scouring many times in series. The scouring machines used have cylinders made up of chilled iron plates having very narrow openings or vents. Inside of the cylinders are rapidly revolving paddles or beaters that keep throwing the wheat against the cylinder. At the same time a strong current

of air is drawn out through the vents in the cylinder, which removes the dust and material that is scoured off the wheat. Each machine gives nine separate scourings and four or five machines are used in series. This scouring is so complete that the outer coating of the bran and the "beard" of the wheat is removed, yet the berry is not broken or bruised, but emerges in a smooth, polished condition.

24 After having had so much air drawn through the wheat, the shell or bran has become dried out and is so brittle that if put over rolls

FIG. 5 MILLING DISTRICT AND FALLS FROM EAST

in this condition, this bran would pulverize and become impossible of separation from the flour. To correct this, the wheat is dampened, after which it is allowed to stand for a number of hours in a bin, that the moisture may penetrate the bran. After coming from the bin, the stream of wheat is passed through live steam which still further toughens the bran by driving the moisture in. This is called the tempering process.

25 The tempered wheat is now ready for grinding and flows directly to the first break rolls where the berry is opened up. The stock then passes to the scalping process, which is the separation of what flour and middlings are made by the first grinding from the bran, which has practically all of the inside of the wheat berry adhering to it. The scalping is done on revolving cylinders of wire

cloth called reels, or on large gyrating sifters having a number of flat sieves of wire cloth. As small an amount of flour is made on the first break as possible, as this flour, containing as it does some of the dust from the crease in the wheat berry, which cannot be removed by any washing or scouring process, is inferior in color and must be diverted to the lower grade products. This applies to practically all of the flour made on the break rolls.

26 The first break stock after scalping passes to the second break rolls. It is on these rolls that a large amount of middlings are made. This stock is treated to remove the middlings and flour in the same manner as that from the first break, after which it passes to the third break. The process is continued to the fourth and fifth breaks when all of the inside of the berry has been removed from the bran. The bran then goes to a machine called a bran duster which removes what flour has adhered to it. The bran duster is somewhat on the same principle as the wheat scourer, except that soft brushes are used instead of paddles or beaters, and the cylinder against which the bran is brushed, is of wire screen. This finishes the bran so far as the milling process is concerned and it is ready to pack out.

27 The middlings made by the break rolls vary in size from that of a coarse quartz sand to a fineness that is hardly different from that of finished flour. These middlings are graded or sifted into six different sizes, so that each resulting stream contains granular particles of practically the same size. This sifting is done through wire or silk gauze having very accurately spaced meshes. These streams of graded middlings then pass to purifiers where strong air currents are drawn upward through them as they pass over the sieves, the meshes of which are of a spacing that does not permit of the granular particles falling through. The coarser middlings then pass to reducing rolls having finer teeth or corrugations than the break rolls, these corrugations being still finer for the smaller sized middlings. The action of the reducing rolls is still a cutting action, it being the idea to make finer middlings of coarser, and not to make flour in the process. From these rolls the grading and purifying process, followed by further roll reduction, is continued until all the streams of middlings have been reduced to very nearly the fineness of flour.

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FIG. 3 SIFTER FLOOR

over the apron. From ends of the apron and forming a continuation of the dam, are walls built on top of and following the edges of the ledge downstream. These walls form the river side of the main head races to the mills, one on either side of the river. The mills on the river side of the head race have their front walls built on the wall of the canal and their back walls extending down to tail race level, making them some three stories higher in the back than in the front. These mills take their water supply through penstocks and the waterwheels discharge directly into the main tail race. The mills on the other side of the head race take their water through canals from the head race into open flume waterwheel settings. These wheels discharge through holes cut through the ledge. From these wheel pits tunnels are cut under the ledge to the main tail race. The formation below the ledge is a tightly compressed white sand which just misses being sandstone, and it is through this that the tail races are cut. Most of these races are lined with concrete or brick up to the ledge, the ledge making the roof.

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12 In the early days there was no attempt made to maintain a uniform head of water by limiting the amount each mill could use. When the water was low it was just a grand scramble to see who would get enough to keep their mill running. Stories are told of how, when there would be but two or three feet of water in the canal, the crew in one mill would build dikes of sand bags and boards to divert the water into their wheel pit. Then the crew from the mill below them would try to tear out the dike so they could get the water, and a fight would ensue with material damage to the heads of the party having the smallest number of picks and shovels. The power on the east side of the river was controlled by the St. Anthony Falls Water Power Company, and on the west side by the Minneapolis Mill Company. While these two companies still exist, they are now under the same management.

THE MILLING PROCESS

12 Probably the oldest known mechanical process is the reduction of seeds or grain to meal. The prehistoric man may have had a loom for weaving his cloth, but he did not leave one for us to see. He did leave us the hollowed out boulder to testify to the fact that he ground his wild seeds that they might be made more suitable as food for human beings. He discovered the fact that his digestive apparatus was not effective in penetrating the outer protective coating of the seeds so that the meat within might be assimilated and give him strength. His mental processes may have been as crude as his time, but they were concerned chiefly in getting food and clothing—mostly

FIG. 4 MILLING DISTRICT FROM WEST

food—and he seems to have solved the problem for many following generations.

13 For centuries the mortar and pestle were the mills for the grinding of grain. It is still used in the less civilized countries. Then came the stones which were too large to be easily used by hand and were turned by animal or man power in treadmill style with a long weep attached to the upper stone. The French Buhr stone of the present day is the same idea except that the upper stone is driven by vertical shaft which passes down through the hole or eye of the lower or stationary stone. This type of mill is not entirely obsolete ut is used in some of the present day mills for finishing certain of the purified streams or middlings.

14 In 1839 came the next step when cast-iron rollers began to e used in Budapest. The first successful machine used there was the ulzberger cast-iron roller machine. About this same time the Hungarian millers began to use the gradual reduction process which came to be known as the Hungarian process. The term Hungarian process is misused when it is given to cover the use of chilled iron rolls, and uch is often the case. This process can be carried out on Buhr stones as well as on rolls.

15 The next improvement was the purifier which was developed n Minneapolis, and is distinctively an American contribution to milling, although some attempts had been made in France to use such machine. The purifier is a machine which in simple terms can be described as a reciprocating sieve over which passes certain of the treams of mill stock and through which is drawn a current of air which removes the dust that would cause discoloration in the finished flour.

16 The old-time method of making flour was to reduce the wheat berry in one grinding operation to as nearly the fineness of the finished product as was possible. That part of the bran or husk which was not at the same time reduced to an equal fineness to the flour, was removed by sifting. The flour obtained by such a process was inferior n color, containing as it did a large percentage of finely ground bran nd dust from the crease in the wheat berry.

17 The Hungarian, or gradual reduction process, is the system n which the wheat passes through numerous grinding operations in eries before its final reduction to flour. The first grinding operation, r first break, as it is called, lays the berry open. The next or second reak, cuts off some of the inside of the berry left exposed by the first

break. The third break takes off some more, and so on to the fifth and final break where nothing but the bran is left in its familiar flattened condition. The pieces of the inside of the berry cut off by the break rolls, are called middlings and are what are finally reduced to flour. The middlings are passed over the purifiers and the dust caused by the grinding is removed. Dust cannot be removed from flour, and therein lies the advantage of the gradual reduction process in producing clean, white flour. The term cut is used in describing the action of the break rolls, as these rolls have knife-like corrugations on their surfaces, and actually do cut rather than grind.

18 The color of finished flour, aside from its being free from impurities, is obtained by granulation. A piece of glass reduced to powder is pure white. This is because the light which it reflects is broken up by the facets of the minute particles. So it is with flour. The inside of the hard spring wheat berry is an opaque, flint-like substance, slightly yellow in color. When reduced to the fineness of flour, the more granular or sharp the particles, the whiter the color.

19 The wheat from the different sections of the country tributary to any mill is by no means the same in characteristics or quality. Again the wheat grown on a certain piece of land this year, will in its milling value or strength, be very different from that grown last year, even though the same seed be used. The quality of the wheat is a variable but the quality of the flour must be a constant. The color of the flour must be the same this year as it was last year; the gluten must be of a certain percentage and quality, and its ability to absorb water must not vary. The modern mill has a well-equipped laboratory, and it is here that the various kinds of wheat are tested as to their value for making flour. A large part of the available supply of wheat may be inferior in color or low in gluten. A stronger wheat must be found to blend with it, that the product may be uniform.

20 The various kinds of wheat are delivered to the mill elevator loaded in bulk in box cars. These cars may come from the large terminal grain storage elevators or directly from the small farmers' elevators that are scattered along the lines of railroads that tap the wheat producing country. The wheat is taken out of the car by power shovels and drops through a grating into a receiving hopper. From here it is elevated to the top floor of the elevator and discharged into a garner which is large enough to hold the contents of the largest car, or about 2,000 bu. The garner opens into the hopper of the receiving scale, and the car load is weighed in one draft. The wheat then falls

into what is called a receiving separator which is a machine having a number of reciprocating sieves of perforated metal. This removes the coarse refuse such as pieces of wood, coal, iron ore, straw joints and even an occasional Ingersoll watch. It is then ready for storage and drops on conveyor belts which discharge directly into the storage bins. This wheat having been inspected and graded before unloading is carded to go to bin No. 20, for instance. Bin No. 20 contains wheat of the same grade or of the same value for milling purposes. The advantage of a large mill elevator lies in this ability to take care of many kinds of wheat and store them in quantities that insure a uniform mixture.

21 In the basement under the storage bins is a conveyor belt having spouts leading to it from the bins. By means of graduated slides in these spouts, a predetermined percentage of wheat from any bin may be drawn on to the conveyor. A number of bins may be drawn upon in this manner to get a wheat mixture that is right for milling. The mixing conveyor discharges into an elevator which takes the wheat again to the top of the elevator where it passes through another weighing process on its way to the bins in the mill proper.

22 This wheat is still far from being in condition for grinding. Every bushel contains from one to two pounds of foreign seeds, such as oats, cockle, mustard, grass, flax, etc. These are removed by passing over numerous sieves in the milling separators. These seeds, after the removal of the mustard, are pulverized and sold as stock food or ground screeings.

23 The next step is the cleaning process. There are two different methods in use, the wet and the dry. In the wet process the wheat, together with a stream of water, passes into a washing machine, or "whizzer." This machine has a rapidly revolving cylinder which violently agitates the wheat in the flowing water. As the wheat passes further along in the machine, the water, together with the impurities, is thrown off by the centrifugal force, partially drying the grain at the same time. The wheat has to be dried further by dropping through large cylinders having baffles to retard the flow, while hot, dry air is blown upward through the cylinder, thus completing the drying. The dry process cleans the wheat by dry scouring many times in series. The scouring machines used have cylinders made up of chilled iron plates having very narrow openings or vents. Inside of the cylinders are rapidly revolving paddles or beaters that keep throwing the wheat against the cylinder. At the same time a strong current

of air is drawn out through the vents in the cylinder, which removes the dust and material that is scoured off the wheat. Each machine gives nine separate scourings and four or five machines are used in series. This scouring is so complete that the outer coating of the bran and the "beard" of the wheat is removed, yet the berry is not broken or bruised, but emerges in a smooth, polished condition.

24 After having had so much air drawn through the wheat, the shell or bran has become dried out and is so brittle that if put over rolls

FIG. 5 MILLING DISTRICT AND FALLS FROM EAST

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the granulation process and instead of flattening or rounding up the particles, the flour obtained is sharp and granular. Not all of the middlings are reduced by the first passage through the smooth rolls to the proper fineness for flour, so the stream must pass again to a reel where the finished flour sifts through the silk cloth covering and the middlings that are separated out are sent again to the smooth rolls for reduction. This process is continued until all the stock is dressed or sifted to flour. From wheat to flour there are about 21 reductions in the process.

29 The second grade of flour made in the process is called "bakers" or first clear. This is composed of the cleaner flour from the break rolls and part of the flour made in the reduction of the middlings, including that taken out of the middlings by the air purifying process. This flour is not as white as the First Patent and while high in its percentage of gluten, this gluten does not have the expansive power of that in the Patent Flour. The expansion of the gluten is what makes large, firm loaves of bread, while its quality determines the lightness of the loaf and to a certain extent, its color.

30 The next lower grade of flour is the Second Clear, and is made up of all the rest of the by-product flour that is "clear" of fine particles of bran. Every machine in a mill, roller mills, bolters, purifiers, reels and elevators, has an air suction connected to it. This suction system yields a large part of the lower grade by-product flour.

31 The next product is known as "Red Dog" and consists of that part of the flour which contains very small particles of bran that cannot be separated from it. It is the dividing line in the mill products, being a mixture of flour and bran.

32 Then comes the "Shorts" which consists of finely divided particles of bran. While it is the idea in milling to keep the bran intact, there are many small particles broken off in the process. The ones that are large enough to be sifted out, go to shorts.

33 A great many adjustments in milling machinery are provided for. Slides and valves in the spouting enable various streams of mill stocks to be combined or divided at will, or switched from one machine to another. There is a continual changing of the flow of a mill that the flour may be uniform. On a damp, rainy day, the flour absorbs moisture and does not bolt or sift through the silk cloths as freely as on a clear, dry day. At least once an hour, the flour is tested by wetting a sample and comparing with a standard sample which is of unvarying quality. The wetting emphasizes any tendency

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NEW HAVEN, NOVEMBER 18

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THE ANNUAL MEETING

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... Building, New York, ...
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... the latter alone extending thro...
... papers were read, besides
... Tuesday evening, and 15 sessi...
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... meeting, under the supervision of
... Committee on Meetings of the Society
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... Van Winkle, Chairman. The chief soc...
... evening at the Hotel Astor, where the ann...
... a dinner dance. More than 300 cov...
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... courses. There was dancing between cour...
... of the dinner. This dinner dance was
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... it might be made a permanent feature
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... present an opportunity to meet a large numb...
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PROGRAM

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Reception by the Society to the President, President-elect, ladies, members, and guests.

Wednesday Morning, December 2

Business Meeting

Report of the Council and Standing Committees. Amendment to the Constitution. Progress Report of the Boiler Specifications Committee.

Professional Session

Floor Surfaces in Fireproof Buildings, Sanford E. Thompson.

(Contributed by the Sub-Committee on Industrial Building.)
Discussed by R. F. Tucker, L. C. Wason, G. S. Walker, W. S. Timmis, G. P. Hemstreet.

Reinforced-Concrete Factory Buildings, F. W. Dean.

(Contributed by the Sub-Committee on Textiles.)
Discussed by G. C. Stone, J. P. H. Perry, W. F. Ballinger.

Wednesday Afternoon

Professional Session

Measuring Efficiency, H. L. Gantt.

Discussed by H. E. Harris, F. J. Miller, H. K. Hathaway, H. H. Suplee, W. A. Polakov, F. A. Waldron.

Standardization in the Factory, C. B. Auel.

(Contributed by the Sub-Committee on Machine Shop Practice.)
Discussed by H. B. Lange, L. D. Burlingame.

Operation of Grinding Wheels in Machine Grinding, George I. Alden.

Discussed by C. H. Norton, M. D. Hersey.

Friction Losses in the Universal Joint, P. F. Walker and W. J. Malcolmson.

Discussed by C. W. Spicer, F. H. Sibley, R. R. Potter.

Railroad Session (Simultaneous)

Steam Locomotives of Today: Report of the Sub-Committee on Railroads.

Discussed by F. F. Gaines, F. J. Cole, C. D. Young, J. T. Anthony, H. B. MacFarland, C. E. Chambers, G. L. Bourne, C. J. Mellin, H. H. Vaughan, J. P. Neff, G. W. Rink, W. E. Woodard, H. V. Wille, Clement F. Street, E. A. Averill, J. E. Muhlfeld, G. R. Henderson, J. B. Ennis.

Wednesday Afternoon

Reception and Thé Dansant given by the Ladies Committee in th[illegible] of the Society.

THE ANNUAL MEETING

The thirty-fifth Annual Meeting of the Society, held Decemb 1-4, 1914, in the Engineering Societies Building, New York, w notable for its unusually large number of professional papers a technical sessions, and for the discussion of the preliminary repo of the Boiler Code Committee, the latter alone extending throu six sessions. In all a total of 27 papers were read, besides t address of President Hartness on Tuesday evening, and 15 sessio were held, including those on the Boiler Code, there being som times three simultaneous sessions under way, and on Thursday aft noon four were in progress at the same time. The papers cover a wide range of subjects and were effective in drawing a lar audience. The attendance at the meeting was the largest in t history of the Society, the total registration being 1367, of which 8 were members.

The social features of the meeting, under the supervision of t House Committee and the Committee on Meetings of the Society New York, were attractive and well attended. The usual presidenti reception was held in the Society rooms on Tuesday evening with large attendance, and on Wednesday afternoon the rooms were t scene of a successful reception and thé dansant given by the Ladi Committee, Mrs. Edward Van Winkle, Chairman. The chief soci event came on Thursday evening at the Hotel Astor, where the annu reunion took the form of a dinner dance. More than 300 cove were laid in the grand ball room, the guests progressing from tal to table for the various courses. There was dancing between cours as well as at the conclusion of the dinner. This dinner dance was innovation which apparently was very pleasant to every one and ma expressed the hope that it might be made a permanent feature the Annual Meetings. Unlike the usual dinner or formal receptic it gave every person present an opportunity to meet a large numb of others and the event promoted sociability to the greatest possil degree. Another delightful occasion was the luncheon tendered the ladies of the Society on Thursday in the Orangerie of the Ho Astor by Mrs. Harrington Emerson, which was attended by about 12

The presentation of the John Fritz Medal on Wednesday evenin together with the interesting addresses given by Dr. James Dougl Honorary Member and Past-President of the American Institute Mining Engineers, and Dr. S. W. Stratton, director of the Bure of Standards at Washington, proved to be another interesting featu

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of air is drawn out through the vents in the cylinder, which removes the dust and material that is scoured off the wheat. Each machine gives nine separate scourings and four or five machines are used in series. This scouring is so complete that the outer coating of the bran and the "beard" of the wheat is removed, yet the berry is not broken or bruised, but emerges in a smooth, polished condition.

24 After having had so much air drawn through the wheat, the shell or bran has become dried out and is so brittle that if put over rolls

FIG. 5 MILLING DISTRICT AND FALLS FROM EAST

in this condition, this bran would pulverize and become impossible of separation from the flour. To correct this, the wheat is dampened, after which it is allowed to stand for a number of hours in a bin, that the moisture may penetrate the bran. After coming from the bin, the stream of wheat is passed through live steam which still further toughens the bran by driving the moisture in. This is called the tempering process.

25 The tempered wheat is now ready for grinding and flows directly to the first break rolls where the berry is opened up. The stock then passes to the scalping process, which is the separation of what flour and middlings are made by the first grinding from the bran, which has practically all of the inside of the wheat berry adhering to it. The scalping is done on revolving cylinders of wire

cloth called reels, or on large gyrating sifters having a number of flat sieves of wire cloth. As small an amount of flour is made on the first break as possible, as this flour, containing as it does some of the dust from the crease in the wheat berry, which cannot be removed by any washing or scouring process, is inferior in color and must be diverted to the lower grade products. This applies to practically all of the flour made on the break rolls.

26 The first break stock after scalping passes to the second break rolls. It is on these rolls that a large amount of middlings are made. This stock is treated to remove the middlings and flour in the same manner as that from the first break, after which it passes to the third break. The process is continued to the fourth and fifth breaks when all of the inside of the berry has been removed from the bran. The bran then goes to a machine called a bran duster which removes what flour has adhered to it. The bran duster is somewhat on the same principle as the wheat scourer, except that soft brushes are used instead of paddles or beaters, and the cylinder against which the bran is brushed, is of wire screen. This finishes the bran so far as the milling process is concerned and it is ready to pack out.

27 The middlings made by the break rolls vary in size from that of a coarse quartz sand to a fineness that is hardly different from that of finished flour. These middlings are graded or sifted into six different sizes, so that each resulting stream contains granular particles of practically the same size. This sifting is done through wire or silk gauze having very accurately spaced meshes. These streams of graded middlings then pass to purifiers where strong air currents are drawn upward through them as they pass over the sieves, the meshes of which are of a spacing that does not permit of the granular particles falling through. The coarser middlings then pass to reducing rolls having finer teeth or corrugations than the break rolls, these corrugations being still finer for the smaller sized middlings. The action of the reducing rolls is still a cutting action, it being the idea to make finer middlings of coarser, and not to make flour in the process. From these rolls the grading and purifying process, followed by further roll reduction, is continued until all the streams of middlings have been reduced to very nearly the fineness of flour.

28 The final reduction of middlings to flour is on smooth rolls where the action is more truly a grinding one. The stock passing to these rolls is so very fine grained that this action extends still further

the granulation process and instead of flattening or rounding up t particles, the flour obtained is sharp and granular. Not all of t middlings are reduced by the first passage through the smooth r to the proper fineness for flour, so the stream must pass again t reel where the finished flour sifts through the silk cloth covering a the middlings that are separated out are sent again to the smooth r for reduction. This process is continued until all the stock is dres or sifted to flour. From wheat to flour there are about 21 reducti in the process.

29 The second grade of flour made in the process is cal "bakers" or first clear. This is composed of the cleaner flour fr the break rolls and part of the flour made in the reduction of middlings, including that taken out of the middlings by the purifying process. This flour is not as white as the First Patent a while high in its percentage of gluten, this gluten does not have expansive power of that in the Patent Flour. The expansion of gluten is what makes large, firm loaves of bread, while its qual determines the lightness of the loaf and to a certain extent, its col

30 The next lower grade of flour is the Second Clear, and made up of all the rest of the by-product flour that is "clear" of f particles of bran. Every machine in a mill, roller mills, bolt purifiers, reels and elevators, has an air suction connected to it. T suction system yields a large part of the lower grade by-product flo

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Address: Practical versus Theoretical Ideals in Motor Truck Installation, by Ellis L. Howland, automobile editor of the Journal of Commerce of New York.

SAN FRANCISCO, DECEMBER 8

Paper: A Rational Method for the Treatment of Boiler Feedwater, by A. H. Babcock, consulting electrical engineer, Southern Pacific Company.

BOSTON, DECEMBER 9

Paper: Technology of Paper Making, by Mr. Nunez.

In connection with the meeting, the engineering alumni of nine colleges held reunions on Friday evening, following the practice of last year.

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Reception by the Society to the President, President-elect, ladies, members, and guests.

Wednesday Morning, December 2

BUSINESS MEETING

Report of the Council and Standing Committees. Amendment to the Constitution. Progress Report of the Boiler Specifications Committee.

PROFESSIONAL SESSION

FLOOR SURFACES IN FIREPROOF BUILDINGS, Sanford E. Thompson.

(Contributed by the Sub-Committee on Industrial Building.)
Discussed by R. F. Tucker, L. C. Wason, G. S. Walker, W. S. Timmis, G. P. Hemstreet.

REINFORCED-CONCRETE FACTORY BUILDINGS, F. W. Dean.

(Contributed by the Sub-Committee on Textiles.)
Discussed by G. C. Stone, J. P. H. Perry, W. F. Ballinger.

Wednesday Afternoon

PROFESSIONAL SESSION

MEASURING EFFICIENCY, H. L. Gantt.

Discussed by H. E. Harris, F. J. Miller, H. K. Hathaway, H. H. Suplee, W. A. Polakov, F. A. Waldron.

STANDARDIZATION IN THE FACTORY, C. B. Auel.

(Contributed by the Sub-Committee on Machine Shop Practice.)
Discussed by H. B. Lange, L. D. Burlingame.

OPERATION OF GRINDING WHEELS IN MACHINE GRINDING, George I. Alden.

Discussed by C. H. Norton, M. D. Hersey.

FRICTION LOSSES IN THE UNIVERSAL JOINT, P. F. Walker and W. J. Malcolmson.

Discussed by C. W. Spicer, F. H. Sibley, R. R. Potter.

RAILROAD SESSION (SIMULTANEOUS)

STEAM LOCOMOTIVES OF TODAY: Report of the Sub-Committee on Railroads.

Discussed by F. F. Gaines, F. J. Cole, C. D. Young, J. T. Anthony, H. B. MacFarland, C. E. Chambers, G. L. Bourne, C. J. Mellin, H. H. Vaughan, J. P. Neff, G. W. Rink, W. E. Woodard, H. V. Wille, Clement F. Street, E. A. Averill, J. E. Muhlfeld, G. R. Henderson, J. B. Ennis.

Wednesday Afternoon

Reception and Thé Dansant given by the Ladies Committee in the rooms of the Society.

THE ANNUAL MEETING

The thirty-fifth Annual Meeting of the Society, l
1-4, 1914, in the Engineering Societies Building, N
notable for its unusually large number of profession
technical sessions, and for the discussion of the preli
of the Boiler Code Committee, the latter alone exte
six sessions. In all a total of 27 papers were rea
address of President Hartness on Tuesday evening, a
were held, including those on the Boiler Code, ther
times three simultaneous sessions under way, and on T
noon four were in progress at the same time. The
a wide range of subjects and were effective in dr
audience. The attendance at the meeting was the
history of the Society, the total registration being 1367
were members.

The social features of the meeting, under the sup
House Committee and the Committee on Meetings of
New York, were attractive and well attended. The us
reception was held in the Society rooms on Tuesday
large attendance, and on Wednesday afternoon the r
scene of a successful reception and thé dansant given
Committee, Mrs. Edward Van Winkle, Chairman. T
event came on Thursday evening at the Hotel Astor, wh
reunion took the form of a dinner dance. More th
were laid in the grand ball room, the guests progressi
to table for the various courses. There was dancing b
as well as at the conclusion of the dinner. This dinne
innovation which apparently was very pleasant to every
expressed the hope that it might be made a perman
the Annual Meetings. Unlike the usual dinner or for
it gave every person present an opportunity to meet a
of others and the event promoted sociability to the gr
degree. Another delightful occasion was the lunche
the ladies of the Society on Thursday in the Orangeri
Astor by Mrs. Harrington Emerson, which was attended

The presentation of the John Fritz Medal on Wedn
together with the interesting addresses given by Dr. J
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Mining Engineers, and Dr. S. W. Stratton, director
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l Thé Dansant given by the Ladies Committee in the rooms

35 In the average mill, the distribution of power to the various classes of machinery is as follows:

	Per Cent
Wheat cleaning	35
Smooth rolls	25
Break and middling rolls	14
Bolting, purifying, etc.	26
	100

This includes the transmission and friction losses including that of the machines themselves.

36 Flour mills, in general, are driven as a unit from a single source of power. The process from start to finish is a continuous one, and the various streams must not be stopped. If troubles occur through breakage of machinery the entire mill must shut down, else the choking up of spouting and machines would cause more delay than the accident itself. There are a few mills having group drive by motors where the roll floor is driven by one motor, the bolting machinery by another, etc. With such a drive, remote push button control is necessary to stop and start all motors at the same instant to prevent choking. Aside from this an interlocking system on the trip and no voltage release coils should be used, so that if one motor were cut out by an overload or no voltage, all the motors would be released at the same time. The advantage of such a system over unit control is doubtful. The grain-machinery in the storage elevator and the flour packing machinery is very often used with individual drive.

37 A flour mill offers almost ideal conditions for cheap production of power. The load is uniform and steady, so that the load factor is practically unity.

38 The writer is indebted to the Northwestern Miller for facts relating to the history of milling in Minneapolis.

No. 1440

MEETINGS SEPTEMBER-DECEMBER

MEETINGS IN LOCAL CENTERS

SAN FRANCISCO, SEPTEMBER 10

Quarterly meeting. Lecture: The Large Spaulding Dam of the Drum Hydroelectric Installation, by John A. Britton.

CINCINNATI, SEPTEMBER 17

Address: Electrical Wires and Cables, by Charles R. Sturdevant, American Steel & Wire Company, Worcester, Mass.

ATLANTA, SEPTEMBER 19

Second annual barbecue of the affiliated technical societies of the City of Atlanta. Addresses by A. M. Schoen, Paul H. Norcross, T. P. Branch, J. T. Brogden, Gabriel R. Solomon, Frederick Kloepper, H. P. Wood, R. D. Kneale, and Dan Cary.

PHILADELPHIA, OCTOBER 8

Joint meeting with The Franklin Institute. Paper: Recent Developments in Cast Iron Manufacture, by J. E. Johnson, Jr.

BOSTON, OCTOBER 14

Subject: Means and Methods of Measuring the Flow of Fluids in their Application to Industrial and Engineering Problems, with papers by Frederick N. Connet, E. L. Brown, and D. R. Yarnall.

CINCINNATI, OCTOBER 15

Joint meeting with the Engineers Club. Address: Testing of the Motor Vehicle, by Frederick R. Hutton.

NEW YORK, OCTOBER 21

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Organization meeting. Paper: Local Transportation, by G A. Damon, Dean of Throop College of Technology.

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The social features of the meeting, under the supervision of th House Committee and the Committee on Meetings of the Society i New York, were attractive and well attended. The usual presidentia reception was held in the Society rooms on Tuesday evening with large attendance, and on Wednesday afternoon the rooms were th scene of a successful reception and thé dansant given by the Ladies Committee, Mrs. Edward Van Winkle, Chairman. The chief socia event came on Thursday evening at the Hotel Astor, where the annua reunion took the form of a dinner dance. More than 300 cover were laid in the grand ball room, the guests progressing from tabl to table for the various courses. There was dancing between course as well as at the conclusion of the dinner. This dinner dance was a innovation which apparently was very pleasant to every one and man expressed the hope that it might be made a permanent feature o the Annual Meetings. Unlike the usual dinner or formal reception it gave every person present an opportunity to meet a large numbe of others and the event promoted sociability to the greatest possibl degree. Another delightful occasion was the luncheon tendered t the ladies of the Society on Thursday in the Orangerie of the Hote Astor by Mrs. Harrington Emerson, which was attended by about 125

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Wednesday Evening

Award of the John Fritz Medal to Prof. John E. Sweet, Honorary Member and Past-President of the Society. Addresses by Dr. James Douglas, Honorary Member and Past-President of the American Institute of Mining Engineers, and Dr. S. W. Stratton, Director of the Bureau of Standards.

Thursday, December 3

ALL-DAY SESSION ON PUBLIC SERVICE

Opening Remarks, Hon. John Purroy Mitchel, Mayor of the City of New York.

THE FUTURE OF THE POLICE ARM FROM AN ENGINEERING STANDPOINT, Henry Bruère.

Discussed by R. P. Bolton, C. J. Driscoll, Alex. C. Humphreys.

SOME FACTORS IN MUNICIPAL ENGINEERING, Morris Llewellyn Cooke.

Discussed by Alex. C. Humphreys, C. E. Merriam, R. P. Bolton, H. S. Person, Chas. Day, Carl Schwartz, Alex. Dow, N. D. Baker, R. B. Wolf, F. W. Taylor, C. W. Baker, R. S. Woodward.

THE NEW CHARTER FOR ST. LOUIS, Edward Flad.

THE ENGINEER AND PUBLICITY, C. E. Drayer.

Discussed by A. J. Himes, H. McDonald, C. W. Baker, E. H. Whitlock, C. W. Rice.

SNOW REMOVAL: A Report of the Committee on Resolutions of the Snow Removal Conference held in Philadelphia, April 16 and 17, 1914.

Discussed by J. T. Fetherston, E. D. Very, W. Goldsmith, F. Kingsley, Martin Schreiber.

THE HANDLING OF SEWAGE SLUDGE, George S. Webster.

Discussed by C. W. Hendrick, W. L. D'Olier.

TRAINING FOR CITY EMPLOYES IN THE MUNICIPAL COLLEGES OF GERMANY, Clyde Lyndon King.

Discussed by J. F. Young, J. A. Fairlie, H. S. Gilbertson, S. E. Thompson.

A STUDY OF CLEANING FILTER SANDS WITH NO OPPORTUNITY FOR BONUS PAYMENTS, Sanford E. Thompson.

Discussed by C. E. Davis.

THE DESIGN AND OPERATION OF THE CLEVELAND MUNICIPAL ELECTRIC LIGHT PLANT, Frederick W. Ballard.

Discussed by R. L. Brunet, J. R. Cravath, W. C. Allen, Alex. Dow, E. W. Bemis, R. P. Bolton, C. F. Lacombe.

Thursday Afternoon

Luncheon at the Hotel Astor given for the ladies of the Society by Mrs. Harrington Emerson.

PROFESSIONAL SESSION

FACTORS IN HARDENING TOOL STEEL, John A. Mathews and Howard J. Stagg, Jr.

(Contributed by the Sub-Committee on Iron and Steel.)
Discussed by H. M. Howe, J. J. Ralph, Bradley Stoughton, O. R. Cary, J. A. Brashear.

STANDARDIZATION OF CHILLED IRON CRANE WHEELS, F. K. Vial.

(Contributed by the Sub-Committee on Hoisting and Conveying.)
Discussed by A. L. Williston, W. A. Bennett, W. L. Stork, Augustus Smith.

THE MECHANICAL ELIMINATION OF SEAMS IN STEEL PRODUCTS, NOTABLY STEEL RAILS, R. W. Hunt.

Discussed by H. C. Hibbard, J. D. Howard, M. H. Wickhorst, P. H. Dudley.

TOPICAL DISCUSSION ON ALLOY STEELS, John A. Mathews, A. S. Kinsey.

CEMENT SESSION (SIMULTANEOUS)

ELECTRIC DRIVE FOR ECONOMIC OPERATION AND DEVELOPMENT OF CEMENT MILLS, J. Benton Porter.

STUDENT BRANCH CONFERENCE

Conference of the Honorary Chairmen of the Student Branches with the Committee on Student Branches.

Thursday Evening

Dinner dance in the Hotel Astor.

Friday Morning, December 4

PROFESSIONAL SESSION

A RATE-FLOW METER, H. C. Hayes.

Discussed by F. zur Nedden, A. R. Dodge, Carl Smerling.

LABORATORY FOR TESTING AND INVESTIGATING LIQUID FLOW METERS OF LARGE CAPACITY, W. S. Giele.

Discussed by H. E. Ehlers, Geo. H. Gibson, J. H. Norris.

A NEW VOLUME REGULATOR FOR AIR COMPRESSORS, Ragnar Wikander.

Discussed by W. L. Saunders, Jas. Tribe, John Glass, Paul Diserens, Joseph Esherick, Frank Richards.

PHYSICAL LAWS OF METHANE GAS, P. F. Walker.

Discussed by Carl Smerling.

THE CLINKERING OF COAL, Lionel S. Marks.

Discussed by F. C. Hubley, O. W. Palmenberg, O. P. Hood, E. B. Ricketts, P. F. Walker, Roger DeWolf.

DAMAGES FOR LOSS OF WATER POWER, F. W. Dean.

Discussed by Jay M. Witham.

No. 1441

THE HUMAN ELEMENT THE KEY TO ECONOMIC PROBLEMS

PRESIDENTIAL ADDRESS 1914

By James Hartness, Springfield, Vt.

President of the Society

Again the Annual Convention brings us together. We are here not only to harmonize our efforts in carrying forward the objects of this Society but to enjoy the personal contact that in the past has been so rich in inspiration to better and more useful endeavor.

At all these reunions, with the joy of greeting there is mingled an element of sadness. It is with deepest regret we think of our loss by death of a number of our members, each of whom is sorely missed by a group of friends here today. Among the missing are engineers who have played a most conspicuous part in carrying forward the unprecedented advance of this age of mechanism, but whether world famous or known only within a relatively smaller circle, all are deeply mourned by those who knew them. So great have been the attainments of some of these that it is impossible to make adequate reference to their achievements at the present time; nevertheless, when we remember that among their number were George Westinghouse, Honorary Member and Past President; Sir William White, Honorary Member; Dr. Rudolph Diesel, Honorary Member; and Dr. Alfred Noble, Honorary Member of the Institution of Civil Engineers of Great Britain, Manager of this Society and Past President of the American Society of Civil Engineers, we realize that in addition to the loss of sterling friends the world has lost some of the greatest engineers it has ever known.

In their lives was evidenced not only rare ability as scientists and engineers of a most usefully constructive type, but real bigness of heart with its resulting knowledge of men which is the sign of the truly noble. By contemplation of their lives we may learn the great

Presented at the Annual Meeting, December 1914, of The American Society of Mechanical Engineers.

lesson that the human element is of supreme importance. These men were successful in great constructive achievements, not merely because they possessed brains of unusual power and were untiring workers in the field of science and mechanism, but because of their clearer understanding of their fellow workers. They knew the inner man as well as the physical man and their work was carried forward with that knowledge.

This knowledge of the inner man is of greatest value in our own attempt to cope with the problems of today and I shall try to suggest a way to use it most effectively. I have chosen for my subject "The Human Element as the Key to Economic Problems" and shall begin by presenting some phases of present conditions and then shall suggest a simple method for plotting the best course for each man, and finally I hope to show that the best course for the individual will indicate the best one for society in general.

In giving the subject the individualistic treatment we are forced to certain conclusions that seem to warrant a different general attitude towards specialization and large organizations, and it leads to certain definite conclusions regarding monopolies and their relation to industrial supremacy.

It is needless to remind this audience that the engineer is first of all a director of men. His knowledge of mechanism has made it possible for him to design machinery; but since machinery is always for the human being, it must fit man's needs. It must be designed with a full recognition of man's characteristics. The successful engineer has always been a human engineer. Of course this is true of men in all other callings, the title of lawyer or engineer merely indicating that in addition to a knowledge of man, one has acquired a knowledge of law or mechanism.

The engineer's knowledge of mechanism is a truly important part. It is this special knowledge that enables him to know what to do and how it should be done, but it does not comprise the whole of his knowledge. It is very ineffective if it is not accompanied with the fullest possible conception of man. In fact, his measure of success is directly proportioned to the extent of his knowledge of man. Without this the engineer is a tool and not an intelligent worker; an animated cyclopedia, perhaps, for the convenient use of men who do things. But with a knowledge of men he becomes a most potent force.

It is therefore necessary that the engineer study the human factor as well as the science of mechanism if he is to direct men successfully.

He must know the human being not only as an animated physical structure, but he must know the personality of that man. He must know his likes and dislikes and what constitutes and forms his controlling motives.

The degree in which he can estimate what man will do under a certain stimulus determines the degree of his ability as director of men. The engineer must possess as much of this knowledge as it is possible to grasp and he must use this knowledge to carry forward the world's progress.

All our interests demand that we make the best use of our minds and our energies. The great need of this is forced in upon us whenever we realize that along with the evolution of the mind there has been a much greater increase in the intricacy of our problems. Even the world of mechanism has become too complicated for one mind to grasp. One brain cannot grasp all the elements and still retain a comprehensive view. Our scientific and technical libraries in which are stored the knowledge of so many contributors contain more than it is possible for any one human being more than partially to comprehend. There is so much to learn about each of thousands of subjects that the capacity of the human brain seems small indeed. An entire lifetime can be devoted to one subject in acquiring merely a knowledge of what has already been prepared by others, and this of course, leaves no time to make one's own contribution to this knowledge.

With such an accumulation available, an engineer finds himself embarrassed to know just how to use his mental energies. He soon realizes that it is impossible to assimilate all that is prepared, and he is forced to conserve his brain force by switching off some of the myriad of things that would otherwise be impressed on his mind. If he does not do this consciously the mind itself automatically does it for him, but unfortunately the automatic process is not always the best one. It tends to notice the near events to the exclusion of other happenings of greater significance and therefore it does not build up the most desirable complex.

THE SELECTIVE PROCESS

We know that the human mind is naturally selective; that it picks its own food as it goes through life. We know that no two men carry away with them the same group of impressions, and that this is true of men having had practically the same home environment, the same heritage, the same education, and the same general experience. Each one receives impressions of the kind which his mind by its nature has selected. The character of this selection determines the habitual conduct of the man. It determines his characteristics and the degree of his success. It is the process by which he may acquire the most useful knowledge for existence in the world as it is today and unfortunately it is also the process by which the mind may be fully loaded with a valueless conglomeration of knowledge. Under the best control the selective character not only assimilates the most desirable kind of knowledge, but it also protects the mind from the myriad of impressions that would otherwise abscure the group of ideas most essential.

We know that it is possible to improve the character of this selective process by diverting undesirable impressions and accepting those that are of a beneficial type, and that by such control we can conserve our energies and fit ourselves, not only for coping with routine problems, but for taking those steps that make for the greatest advancement.

The process is something more than merely dividing all knowledge into two classes, one to be received and one rejected. It is a plan that allows knowledge to be absorbed with varying intensities. Some elements must be deeply impressed and kept in mind. Others should be permitted to make only a slight impression, and so on, from the center of the picture on which the eye is focussed to the complete background and all that goes into the full scope of receiving impressions.

This process of selecting rationally the knowledge which we permit to make an impression is the real key to our development. It determines our characteristics, and it determines the degree of our success. In fact the degree with which we rationally determine the character of knowledge that we will permit to make the deepest impressions may be said to be the measure of our minds. The man who with clear thinking determines the character of this selectiveness may be said to be the highest type of intellectual man.

We have many evidences that the mind may take in everything within our range of senses, and that all this may be recorded in some way. But this need not disturb us in our aim to store up in deepest impressions the kind of knowledge most useful to us in carrying forward the kind of work we as individuals must consider, for if we keep our brains occupied by useful thoughts, the other impressions will be kept harmlessly submerged.

The vastness of knowledge that is available in our libraries or may be acquired by observation should force us to recognize that the engineer of today and the future must more and more protect his mind against unnecessary impressions and reserve it for those impressions most needed in his own field of work.

The existing conditions force on us the necessity, not only of selecting the kind of knowledge most useful in our fields, but also our need of simpler standards of measure and of means by which we may use the general results obtained by other engineers and avoid the bewildering effect of scrutinizing the vast detail.

Our study of the work of others must be more or less superficial, however, for it must not submerge our own ideas. We should always keep in mind the size of our mental capital, for our success in a large measure depends on the proportion of this capital expended in acquisition of a knowledge of what has been done, to the balance reserved for our own contribution.

HABIT

The industrial world is truly complicated at the present time. But, after all, we find that the short-cut to the solution of its problems is by the way of getting at the nature and needs of the individual. In this way we will better understand the laws governing groups of men. This study, combined with the aim of enhancing human welfare, always leads to clarifying the whole subject and gives one a few cardinal doctrines by which the greater problems may be determined.

One of the striking facts brought out by this study of the nature of the individual is that man is a creature of habit to such an extent that there is always a great factor of inertia to be encountered in all our plans for changing his mental attitude or plan of action. He tends to follow habit grooves. He has been started on his scheme of life by imitating others so that he carries along the habits of the race. Not that he is wholly like the bird that builds its nest today with but slight change from the nest built ages ago, but that there is enough of that characteristic left in him to make it the real problem for us today.

We may boast of our ability to progress, but in our moments of serious contemplation we come to the conclusion that it is very difficult for us to change either our course or our speed.

If we think of this inertia as habit it will aid us in realizing its important influence. Let us remember that habit is not necessarily the enemy of the race. On the contrary, when rightly managed it is man's best friend, for by habit the mind and body act automatically without a constant drain of mental energy. Realizing this characteristic of habit, we clear away all that group of impressions which associate the word "habit" with the so-called group of bad habits, and we get a new meaning that extends its associations with an entirely different group of ideas.

The study of this human characteristic clearly shows that habit is more beneficial than otherwise, and that it should be neither dreaded nor maligned. Our best plans for advancement call for no conflict with habit; we can build up a progressive habit, and by this slow but most powerful agency may make pleasurable the road that has been hard to travel.

In all our dealings with ourselves and others we should recognize that friend habit has an imperial control of all affairs. He is truly a powerful king who becomes our most effective ally when we shape our plans for a campaign of betterment in keeping with the laws of his domain.

THE EFFECT OF HABIT ON THE INDIVIDUAL

Let us for a moment consider the effect of habit upon the individual, remembering that our whole aim is to find some simple solution of the problems before us in the management of engineering and other undertakings in which there are large groups of men, for if we find its effect on the individual we shall surely find the key to its effect on small and large groups of men. In fact, it will furnish us a formula for the solution of some of the mightiest problems that confront us as engineers and citizens. It will also give us a standard of measure by which we can rightly appraise many of the elements that so harass the minds of welfare workers, labor leaders, business men and statesmen.

This may seen a most pretentious claim for King Habit, but let us now consider his characteristics and analyze his powers. First of all he directs us to continue along in our customary channels, deviating from our course only under the influence of environment and inner purpose. He never orders us abruptly to face about and go in the opposite direction or instantly to increase or reduce our speed. He always allows time for us gradually to become inclined to obey his laws. He generally allows time for the inner motive to become favorable to the change. He urges us to go as we please by the most natural routes. If for some reason we have a tendency toward the habit of progress, he aids us and he also coöperates with us if we are disposed toward retrogression. He encourages and strengthens our thought processes as well as our actions. He builds up habits of receiving and ignoring suggestions, and habits of varying the effect of impressions.

Since all of us are more or less susceptible to suggestion and are ready and anxious to take in everything that is favorable to our advancement and comfort, it is possible gradually to change a habit of stagnation for one of progress. And since there is this opportunity to progress while living in a domain of comfort reigned over by King Habit, we should not look upon this submission to him as adverse to our best interests. On the contrary, we should recognize that by laying our plans for progress in keeping with the laws of his realm, we shall not only attain to our best development but we shall reach that stage by the easiest method.

Skill, dexterity and facility in performance of work are due to acquired habit; but habit is more than a mode by which we do easily what we do often; it is also a disposition and an aptitude for work. It brings an involuntary tendency to continue and with it an ease and reliability of performance.

The mental habits are special qualities that have been acquired by the process of repetition. The successful man in commerce, engineering, finance or any other field of mental work is the one who has acquired the habit of thought of special value in his own particular field.

We have much evidence to show that a mere repetition of either the thought or action, even if distasteful at first, will in the end establish a habit. This actually transforms the worker and converts the work that has been drudgery into a pleasurable occupation, for in addition to its being the most natural mode of action and consequently one that is the easiest to practice, it establishes a disposition to continue. Furthermore, the effort and act of conquering an aversion to a given work facilitates further conquests of the same character, so that we actually acquire a habit of establishing desirable habits of mind and body.

The great need of this contest is clearly apparent to one having a dislike for the only kind of work at which he can obtain a livelihood. There is no intention to underestimate the real battle that must be waged within oneself to dislodge inborn traits or those acquired from early environment. The purpose is to show the easiest way and to make it clear that continued practice will win, not only in dislodging a dislike but in establishing a satisfaction in the work and in some instances an absorbing liking for it. Since success is in proportion to this degree of liking for the work, it becomes of greatest importance that this course of habit building should be chosen.

THE VALUE OF REPETITION AND SPECIALIZATION

Since repetition forms habit, it is absolutely essential to success in this world today. A shiftless wandering of mind or body should not be tolerated. We should not become mental tramps. While repetition work has been condemned by many, it is not in itself degrading. On the contrary it is the best means for progress.

It certainly brings the work within the capacity of the greatest number of men and by repetition of operations each man becomes most efficient at his particular work. It is only necessary to carry into effect the most complete subdivision in all the various mental and physical tasks to get the great results that accrue from repetition of processes.

In order to give each man's energy the most efficient use, there is required a most complete subdivision of work so that each operation, mental or physical, may become by repetition the most natural. This division and classification of tasks facilitates the upbuilding of habit action and at the same time it simplifies the work of each one and this results in putting the work in reach of men of more ordinary talents.

There is no more clearly demonstrated fact in this world than that specialization is the method by which human energies are most efficiently used. The reason for this is found in the study of man. It is obscured and submerged the instant we complicate the problem with the myriad theories, policies and fads that have been built up on the study of the group without reference to the individual.

We know that by specialization each man has a chance to use his energies most efficiently. There is nothing more harmful to the thinker or the worker than to force him to become a tramp either in the mental or the physical sense. Men should be permitted to work in the way that is most pleasurable and by which they can create the greatest value with a given effort.

This law of human economics is also one of industrial economics. It is one of those laws that we have too often disregarded. We have endless examples of its infallibility, and yet in the face of them we frequently try to go contrary to it.

The result to be obtained by specialization is not merely to create more value, which in turn gives a thirst for still more value, but to improve the condition of the people as a whole through the betterment of the individual's condition. Any plan that contributes to this desirable end will be favored by every friend of man.

LARGE ORGANIZATIONS ESSENTIAL

We all know that as a general principle there is no hope of a small organization competing either with the Ford motor or the Waltham watch companies. To the superficial observer the advantage of the Ford plant might be attributed to mere size which it may have obtained by chance, but the automobile plant that makes one model of machine and specializes in that gains a tremendous advantage over all others, just as the individual specialist has the advantage over the jack-of-all-trades.

Large organizations are essential to the happier condition of each mortal for in them may most easily be brought about that most complete subdivision of work which makes specialization possible and the consequent most effective employment of human energies.

Whether it is agreeable or otherwise the inexorable law remains that large organizations best conform to this process of life. All this points in one direction. It clearly indicates that the ultimate supremacy in each of the industries will be attained by those that specialize in the highest degree, and thus in turn that the largest organizations, other things being equal, will have an enormous advantage, and furthermore that industrial supremacy will go to the state or nation that fosters such organizations. We know that in other countries large organizations are being built up and the scheme of specialization has been carried to a point which in some instances excels our American practices.

All this leads to the conclusion that the engineer has a great work to do in making clear to the public that certain large units are essential to success if this country is to compete with other countries and if the energies of labor are to be most efficiently employed. Let us hope that at no very distant day this fundamental law will be recognized.

Size is an element of the greatest importance. It is advantageous in various directions, as in the purchasing of material, but the real advantage, and the one which is beneficial to all concerned, is that the various men in the organization have been compelled to confine their attention and efforts to a restricted range of work. The workers have become most efficient because they have not been mismanaged, because they have not had to do a variety of kinds of work in a day, a week, a year, and because the various executives and administrators of the affairs of the organization have themselves so divided the work that each one has concentrated his attention to a limited range. With a given capacity of brain and energy, each one of these individuals becomes the ablest producer of value in his line of work.

One of the obscuring conditions in connection with large and small organizations is the fact that many large organizations are poorly managed. Their large size gives them some advantage over competitors and may carry them along with very inefficient officials. For this and other reasons we have seen the small organization grow in size and prosperity, notwithstanding the competition of one which at the beginning was very much larger.

It goes without saying that small organizations may most successfully compete with large organizations when there is a great difference in the type of management favorable to the smaller organization; but this fact should not lead to the conclusion that wagons may be competitively manufactured in the roadside blacksmith shops, while we have the magnificent monuments to industry in our great wagon building plants.

In certain lines of industry at the present time, especially in those where invention is making rapid changes in the character of product, it is still possible for new organizations to get under way, starting as the plants in the vegetable kingdom start with the small beginning. But in those industries in which the conditions of product and market remain more stable, there is little or no opportunity to organize new companies successfully, particularly if success is only considered success when the company attains a paying condition within a few years after its organization.

The significance of this fact must be apparent to us, for it means that, other things being equal, the large organization, whether in America or elsewhere, becomes an invincible monopoly. And does this not suggest that a time may come when we as Americans, for the sake of the men if not for the nation, will give up our antagonism to monopolies?

A large specializing plant has a monopoly of a part of the automobile business, yet it may be one of the achievements of American industry and good management, and one that is universally and rightly looked upon as a great benefit both to the worker and the purchaser. Let us imagine, however, that the establishment of a similar company in some other branch of the industry necessitated the combination of a number of smaller plants, in order to compete with other companies, which in turn would ultimately lead to closing down some of the inefficient plants in order to get the best results. This new organization might run contrary to some of our existing laws as recently interpreted and yet it might not differ essentially from another company that is received by every student of such matters as one beneficial to all concerned.

REFORMS SHOULD BE INTELLIGENTLY CONDUCTED

The reform movement against trusts has accomplished some good results but it has also been very injurious to the industrial life of this country, for this good work has been done by men who have not known the supreme value of industrial coördination of effort, established at great expense of energy and after years of labor on the part of workers and executives. This synchronous action of many workers is what constitutes the life blood of the industries. It represents the highest type of coöperation. Notwithstanding its great power for effective effort, it is something that may be destroyed by a word. Its destruction is not the destruction of something having a material value only; it is a vital thing. It is something that can neither be weighed on the scales nor measured with a yard stick. To certain types of investigators it is not known and yet it may be destroyed or weakened by a disorganizer without his intention or knowledge. He may feel that nothing has been destroyed as long as the buildings and machinery are still in good condition. To him the mere matter of manning the plant can be easily accomplished. This may seem an extravagant statement, but it is better to let it stand as it is than to take the alternative, namely, that this disorganization is done with full knowledge of the great loss entailed by the worker, and the general public.

Destroying organized work when the purpose is to correct a harmful mode of transacting its commercial or financial business is a serious blunder that has caused suffering and great loss to the very people it was intended to benefit, and many of these people are still calling for more such work.

The antagonism to the trust should be centered against the corrupt practices and not against the organization, for that involves the worker's interests.

The high character and noble purpose of many of those in the industry-obstructing camp should make us all more tolerant of their blunders and we should try to get these same earnest workers to see that in the life of the individual they can get a clue to the best plan o betterment of the public in general. With the individual's interes at heart they will be very careful as they plan the improve ment of industrial conditions; their plan will be one that do not attempt abrupt reforms, one that takes into account inertia, on that enlists the men who know, one that changes every normal bein into a promoter of best activity, and one that does not interfere wit the actual constructive work that is going forward. Destroying th latter in trying to correct certain business methods is on a par wit burning down the barn to kill the rats.

Our government should be equal to correcting irregular busine practices. It wishes to benefit the people, but it seems to be lackin in that completer knowledge of industrial conditions and life that i essential to a successful coping with this important matter. It is fc the engineer who knows the conditions essential to efficient organiza tion to point out how we may reform business methods without the injury of the public involved in the interruption of industry. If w are to be constructive instead of destructive members of society we wi build upon what we have with due regard for the inertia of the huma being. We will not disorganize and disturb the creative work in ou attempt to correct the business administration.

If we consider the welfare of the individual inside and outside c these large organizations and let that be the measure, we will ceas much of this destructive campaign.

THE LARGE ORGANIZATION AND THE COMMON GOOD

If we bear in mind that the greatest good to the greatest numbe can come only from plans that take into consideration each huma being, his desire, or at least need for the best work for which he i endowed, it will change our attitude towards the larger units and th combinations of smaller units.

This will lead to a general recognition of the fallacy of the theor that the interests of the people can be served by the destruction of th large organization. This may seen tantamount to endorsing th unfair and inhuman business methods that have been employed b some large organizations, but it is not an endorsement of such busi ness. On the contrary, it only calls for the most altruistic policy The facts that some of these organizations have been built up by unfai methods, and that much harm has been done to both the workers with in the organization and to the general users of the product, shoul not obscure the fact that due to economic laws there is an inevitable trend towards the large units, and that in these units the individual is most favorably conditioned. We must remember too, that the final contest in the world will be fought out by the large units and that ultimately there will be a monopoly established somewhere in each branch of industry.

Of course we can keep monopolies out of our country, but we cannot keep them off the face of the globe. Until this recent horror of European war our friends and cousins in other countries were coming forward in such matters in a thrilling manner. The war has undoubtedly given each country engaged in it a serious set-back industrially, and it may give this country a little more time in which to allow the fact to take hold of the public mind that we must not try to change natural law by legislative action. If the best interests of individual worker in office or workshop and the best interests of manufacturer or consumer are conserved by permitting the growth of the large units it would seem that the American people should be the first to see the truth and profit by it.

With this great war so full of horror and heroism, so freighted with anguish to millions of hearts, so full of incidents that show at once the nobleness and blindness of man, it is difficult to center our thoughts on the more potent forces that affect the destiny of nations. Industry has built up the nations that are so powerful in war, and let us hope that the time will come when the constructive forces of industrial contests will replace the destructive power both of war and the industry disorganizers.

The industrial conquest is a peaceful conquest. It is one beneficial to the victors, beneficial in a way that other conquests seldom can be. It means merely that an industry of a given kind will be located in a given country, and human beings flock to that industry. With the greater facilities of travel men are drawn to the centers in which their energies can find most efficient use; because at such places there is the greatest possibility of their receiving the largest remuneration.

If we are great according to the breadth of our altruism, then we are truly great if we can consider this question independently of political boundaries. At the present time, however, our innermost feelings prompt us to think first of our homes, and to build up and protect the organization with which we are connected. After this we combine for the general good of those having common interests. We reach out, moving from the home circle again to the city, to the state, to our own nation, and those nations which, by frequent intercourse, we are in most friendly touch, and finally to all peoples.

If we are ready for the broadest altruism, this question of which country is to obtain the industrial supremacy should not greatly affect our attitude. On the other hand, if we wish to push forward our own nation in a friendly spirit of contest let us keep in mind the real essentials of the game, and let us not deceive ourselves into thinking that we can win with small units against others having the larger units.

Even if these questions of national supremacy are put aside, have we any justification for the stultifying misuse of human energies? Is it not better to realize that through subdivision of work into a proper range of mental and physical tasks we bring about that condition in which it is possible to give each man the work for which he is best fitted and in which he can create the greatest value with his energies? Surely we all know the inestimable blessings of a congenial occupation. We all know that it is one of the best things we can give to our fellow man, and one of our greatest crimes is to withhold it. The engineer who sees these conditions should not hesitate to make the facts known to those outside of the engineering profession. We have a great obligation to our fellow creatures right here, and our attitude on this subject will greatly affect their welfare.

MAINTENANCE OF INTEREST IN INDUSTRIAL ORGANIZATIONS

In an industrial organization there is an opportunity for the executive to influence the degree and the maintenance of interest of each worker. Failure on the part of executives to show an appreciation of the efforts of the workers tends to destroy the interest. On the other hand an expression of an appreciation of the services rendered tends to increase the length of time in which the worker holds his interest.

We know that the dollar is too often looked upon as the only real measure of recognition of value of services rendered, but this general view should not obscure the fundamental fact that it is not the dollar for the dollar's sake, even when the dollar seems to be the only stimulus, but that the most important and the most potent stimulus is one that satisfies man's longing for an appreciative recognition of the value of his services. With such stimulus he works in his best mood and has a real interest in the work.

A loss of interest may be brought about by anything that takes away due recognition for services; therefore, in any ideal organization there should be some system by which earnest efforts are recognized by someone who can in a beneficial way express an appreciation. This will not only create and maintain the interest of each individual in the work for which he is fitted, but it will lead perhaps to something more than a passive campaign against all those agencies which tend towards discontent.

But in work in which there is little or no opportunity for the acquisition of a keen interest, there is frequently a chance to improve conditions and soften the hardship of monotony by the introduction of some system by which the worker may know that his efforts are appreciated. Piece work system, Halsey premium plan, Gantt bonus method, the Taylor system, and various other dollar rewards, in a measure fill this need, but the more we study the human mind the more we see that the real pay that each man craves is a recognition and an appreciation and even with the dollar as a standard, in the final analysis we find that it is sought because it bears evidence of recognition of value of service. Although men generally strive for recognition, we know that many men pass through the world working valiantly and effectively with no one person to pay them in the real coin of appreciative esteem. A manager must see to it that his men are not underpaid in this coin. Scrimping here involves more than can be offset by dollars.

This, then, is one of those standards of measure which is to be used in determining our attitude and action. If we are to direct well we must get at the essential elements that control ourselves and others. These elements we find deeply hidden within us. This is all within the bounds of orthodox psychology, thoroughly demonstrated by rigorous laboratory experiments.

The study of the inner motive has long since passed into the most respected group of sciences, but the engineer has left it to the preacher, the teacher, and the psychologist, when there is none that can make a better use of it than the engineer himself who knows mechanism and the great needs of industrial life.

We should employ every means to aid us in managing not only our own selves, but all those whom we direct. This becomes the rule of success of human activity, both in its application to the individual and to large groups as represented in industries, in states, and in countries. Wherever these elements or units are in competition, success goes to the unit which takes advantage of this knowledge of the inner motives, and it is the study of the human being that presents to us the facts from which we can most accurately determine what is for the best interest of the man and society in general.

Is it not possible that we may live to see the day when labor organizations and manufacturers, and last but not least, the ultimate user,—the general public, shall demand that the work be done by methods under which each worker is most favorably conditioned and by which the greatest value is produced by a given effort?

THE IDEAL ORGANIZATION

In keeping with this general idea an outline in an ideal industrial organization might be formulated as follows:

It should have a capital equal to or as large as any competing organization. If possible it should have a small harmonious board of directors with an able leader. But if the directors merely represent the monied interests without special knowledge of the industry, then it would be sufficient if they were capable of appointing an able staff of officers, the chief executive of which should combine a knowledge of the technical and business side of the industry with the fullest possible conception of the human element. He should stand firmly for the cardinal principles of industrial economics as based on the human characteristics. Each officer should possess some special knowledge essential to the organization, so that the combined staff would have a general knowledge of all the various branches.

The chief executive should make it known that long continuity in service of each man in office would be given the first place in the scheme of management, and this should not only include the officers but it should be the key to the management of the entire organization.

The period of years of service of each man in the organization in a given task or in a given office should compare favorably with that in a competing organization.

It should be the aim of the executives to fill each position throughout the entire organization with someone who considers that position the best place in the world for him. Each officer and each workman should have a live interest in his part of the work. Each one should by specialization become the most efficient in his particular work. The interest of the officer or worker should be maintained by some fitting stimulus, and each one should be protected so far as possible from influences calculated to induce discontent.

Each man should be treated in a respectful manner. Needless direction or heartless correction by an overbearing executive should not be permitted. Criticism or reprimand should not be uttered in the presence of others, for the best control of the organization comes from contact with the better side of man, and that side is not reached by one who rides rough-shod over man's self-respect.

Personal dignity and self-respect is an important characteristic in everyone. It is not the exclusive quality of those whose self-respect is very apparent, nor is it limited to those whose natural conduct and bearing indicate their high regard of the esteem of others. It is to be found in the entire human family and he who fails to see it, even in an apparently careless person, is blind to a very important part of the human spectrum.

This ideal organization should keep in touch with the better side throughout the entire organization regardless of its size. Not that the chief executive can come into personal contact with every man, but that every man must be appreciated by some other man in the organization so that this connection of interest pervades the entire organization. It travels from chief executive through the various officers to each man till it reaches and stimulates the newest recruit, so that there is in each man a feeling of personal connection with the organization.

The newest recruit, for instance, should early find a personal touch between himself and his foreman, and should know that the foreman in turn is connected by the same powerful influence through those immediately over him to the controlling spirit of the organization.

THE VALUE OF A HUMAN REPORT

As these truths become known will it not be possible to formulate general rules of management of industrial organizations that will be of great value to both the investor and the promoter? With such rules the investor could see to what extent an organization conforms to success standards. There would be in addition to the regular treasurer's report a human report. The human report would begin with a description of the directors and go through the entire organization. This report would contain a statement regarding the elements of harmony of organization; of length of service of manager and workers; the frequency of change of methods or article manufactured; intelligence of executives in the management of men; the degree of contentment of each member; the extent to which each man in the organization approaches the best position for which he is endowed and how nearly he obtains the best remuneration for which he is qualified;

the extent to which the management recognizes the inertia of habi of both mind and body; the degree in which the various men in th organization approximate the condition of highest efficiency; the ex tent to which the management goes in expression of appreciation; th degree of its knowledge of the most important characteristics of ma as indicated by his inner motives and desires and the condition of h mind as he goes to his home at night. No mention is made here the conditions of buildings from point of sanitation and comfort, f such conditions are now closely scanned; but mention has been ma of a few of those other conditions that must some day be measur just as we now measure power and other less vital things.

All of these elements should be carefully appraised and the avera should be the rating of the company. The investor who considers th human rating with the treasurer's statement will seldom make mistake in estimating the true worth of an industrial organizatio

May we not hope that tabulations of these various elements tak from a variety of industries will lead to establishing a standard th will be a guide to both the manager and the investor?

Surely the investor should look with distrust upon a manageme that is always changing officers, changing men, changing mode changing methods without regard to the inertia of habit and t human element which is the life blood of every organization. I would also look with doubt on any scheme of management that allo the careless employment and discharge of men without due regard the loss involved by such changes, for the perpetual changing of m is equivalent to the change of character of work in its handicap to i dustrial efficiency.

A REVIEW OF THE SITUATION

We have pointed out that this world of mechanism has become intricate and complex that the whole thing has gone beyond the bra capacity of the individual, that each one must be contended to compr hend only a small part, that the relation between the individua brain capacity and the knowledge possessed by the race as a who shows the great need of selecting the character and limiting t amount of material that is taken into our minds, and that only this way can we hope to accomplish the best results.

We have also indicated that the mind receives impressions fro all directions and becomes peculiarly selective, sometimes witho volition, and that this may result in an undesirable trend in our pe sonality and ability; that the best use of our mental energies makes it desirable that we keep in mind those things we have learned regarding directive psychology; that the engineer should devote a part of his time to the care and study of his own thinking machine instead of devoting it all to the machine created by that thinking machine, and that with proper regard to this point we shall make fewer mistakes due to overloading the mind with data to the exclusion of thoughts of an initiative character; that the engineer must study not only his own mind, but also the minds of the men whom he is directing, in order to make due allowance for the personal equation of both the transmitting and receiving mechanism.

Following this we have indicated that man is a creature of habit to an extent that renders this characteristic a most dominant one; that the most efficient use of the mind and body of each mortal demands a scheme of life that permits each one to take advantage of this great fact, and that all people having the welfare of the human family at heart must lend their energies to the maintenance of all those conditions most favorable to this end.

Furthermore we have shown that the dominance of habit and all that it implies will account for success and failure of various schemes of management and that it shows clearly the great economic waste due to abrupt change.

It may have been necessary in the past to accomplish reforms by abrupt revolutions. It may be necessary in the future to resort to sudden changes, but let us hope that the engineers will use their energies to make it clear that due regard should be given to the element of human momentum, so that the public in general will know the real cost of abrupt change in methods of work or business, that all such change imposes a heavy tax on those least able to bear it, that the benefit or harm done is not in proportion to our good intention but as our action conforms to man's real needs and nature's laws; with this knowledge possessed by the public we shall progress in ways that do not involve the calamity that comes from sudden change.

This plan which fits the individual's characteristics, although it recognizes and endorses large organizations and even hints at the clearly inevitable coming of monopolies (notwithstanding our position on the seashore with brooms trying to keep back the flood tide) is still the best plan for the individual.

Every desired reform can be effected without a destructive policy. When we break up an organization of men we destroy something just as real as if we burned down a warehouse filled with grain. Anythi that tends to interfere with continuity of service, anything that ter to break up the order of work, is a cruel blow at humanity with wi spread effects.

Is it too much to hope that a recognition of the importance continuity of service under wholesome conditions will change t present order of things, in which men are ruthlessly shifted fr plant to plant, and from work to work within a plant, and at casional intervals of business depression they are told that there is work. They are not told at the same time that they and their famil will have no expenses during the period of idleness. They are mer told that their income will be cut off for an indefinite period.

May we not hope that even in this age of complexity of soc structure and intricacy of the world of mechanism that transcends t weighing power of the human mind, we have in the human eleme the real measure by which we may truly determine our best line action.

Is not the engineer with his knoweldge of mechanism, supp mented by his knowledge of the inner as well as the physical m destined to play an increasingly important part in bringing forwa this human element as the controlling factor in determining t major policies of management of our lives, our industries, our natio

And is it too much to hope that the good sympathetic touch l tween man and man in the different walks of life may be establis by those who act in accordance with this knowledge of hum characteristics?

Let us as engineers and men, with our appreciation of the supre importance of the inner man, so direct our work and so preach t gospel of human welfare that we shall hasten the approach of the ti when all men shall have the joy of a congenial work; when people w combine to demand the kind of management of our industries a nation that shall be in keeping with the beneficent laws of habit tion; when specialization will be recognized as the best policy for concerned and when organizations favorable to such modes sh receive constructive aid instead of the obstructive and destructive tion that is now being exerted by some of our ablest citizens; wh constructive work will be the only kind that will meet with pub favor; and when the energies of all our albest men will be directed in useful channels,—channels in which they will receive the joy th comes with pleasurable duties and fuller credit than can ever be corded those who, even under stimulus of public favor, are on the wrong side; when each one may feel the satisfaction of having achieved the most with his mind and energies and may have the full recognition and appreciation of his fellow men. And last, but not least, may we not hope that each may receive the best possible remuneration to the end that he and his family may have the largest possible share in the good things that make for comfortable and happy homes?

No. 1442

FLOOR SURFACES IN FIREPROOF BUILDINGS

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In fireproof construction, whether it be office building, factory, or institution, the question of the type of floor surface to select and the method of construction to adopt is a most important one. The constant tread and shuffling of feet cause a friction that it is difficult to withstand without serious wear.

2 From the construction standpoint, in a non-combustible structure a cement surface is in keeping with the rest of the building and is naturally the first considered. In many instances the cement concrete or granolithic floor has proved extremely satisfactory, while in others, because of the use of improper constituents, of inexpert construction, or of its selection for places to which it is not adapted, it has proved a disappointment. As a matter of fact, no one type of floor surface is adapted to all conditions, while for any type that is properly selected, the choosing of the materials and the manner of the construction will govern to a large extent the durability of the surface.

3 It is the purpose of this paper to discuss briefly the different kinds of floor surfaces, and to compare their various qualities, their cost, and their adaptability to specific conditions. This is followed by a more detailed treatment of the methods of constructing the concrete or granolithic surface which have produced satisfactory results.

4 An engineer in consulting practice is called upon frequently not only to design and construct but to investigate defective construction and also to make special tests for the determination of the best methods to employ in a particular case. In this paper are embraced not only the results of experience in floor construction and repairs, especially as they relate to granolithic surfaces, but also the

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conclusions derived from special tests and investigations made in connection with services as consultant on the superstructure of the New Technology buildings in Cambridge.

5 Embodied in the paper is much of the material forming a report to the Stone & Webster Engineering Corporation, engineers and builders of New Technology. The matter covered, then, will include:

Discussion of selection of type of floor surface
Relative costs of various floor surfaces
Characteristics of floor surfaces
Tests and investigations of granolithic construction
Recommendations for granolithic construction

SELECTION OF TYPE OF FLOOR

6 The selection of the type of floor is dependent on the character of the structure, the nature of the wear, and the architectural appearance. Every building must be considered by itself. Suggestions for the type of surface to select are covered in the following pages. As a preliminary guide, the material suitable for different conditions may be given as:

Basements: Granolithic finish with trowelled surface made with approved materials and workmanship.

Factory Floors: Granolithic finish with trowelled surface; hardwood.

Machine Shops: Granolithic finish with trowelled surface; hardwood on substantial base.

Ground Floors for Heavy Manufacturing: Wood block; granolithic.

Warehouses: Granolithic with trowelled surface; asphalt composition; hardwood.

Offices: Hardwood; linoleum on concrete; magnesium composition.

Corridors and Halls for institutions and office buildings: Terrazzo; granolithic finish with ground surface.

Entrance Pavilions: Terazzo; mosaic; tile; natural stone.

Class Rooms, Lecture Rooms, and Drawing Rooms: Linoleum on concrete; granolithic with ground surface; hardwood; magnesium composition.

Laboratories: Granolithic with trowelled surface; magnesium composition; tile; hardwood.

Lavatories: Terrazzo; granolithic finish with ground surface; tile.

The above selections are given in the order in which choice might be made for the average building or room of each class.

APPROXIMATE COST OF VARIOUS FLOOR SURFACES

7 In giving approximate costs of floors it is recognized that the condition of the market both in labor and materials and the quality

of the materials selected, affects the unit price to a very large degree: also the location, size and shape of the rooms to be finished.

8 The following prices are based on estimates of cost in place. For the materials like hardwood that are laid after the partitions are placed, the prices apply more particularly to a building such as a college or other institution divided into offices and rooms of various sizes. Each price is assumed to include total cost of the labor and material, exclusive of the structure itself. It is assumed that the base upon which the floor is laid is either structural concrete or some similar material.

	Cost per sq. ft.
Granolithic:	
If laid at same time as base, with trowelled surface	$0.05
If laid at same time as base, with ground surface	0.08
If laid after completion of base, and trowelled	0.07
If laid after completion of base, and ground	0.10
Linoleum:	
Battleship linoleum including $0.03 per sq. ft. for placing and trowelling a ¾-in. layer of mortar immediately after base concrete is laid, linoleum being figured at $1.30 per sq. yd., cemented in place	0.18
Hardwood:	
Maple or birch, single thickness, including $0.01 for leveling off base concrete and including stringers with cinders between, with rough 1-in. floor underneath	0.22
Maple or birch, single thickness, including $0.01 for leveling off base concrete and including stringers with cinders between	0.18
Maple or birch, single thickness, including $0.01 for leveling off base concrete and including stringers with cinders between, with rough 2-in. floor underneath	0.25
These prices are based on good quality of hard wood at about $45 per 1000 ft. B. M.	
Terrazzo:	
With small stone ⅛ in. to ½ in. including $0.01 for leveling the base concrete	0.19
With large stone ⅝ in. to 1 in. including $0.01 for leveling the base concrete	0.24
For areas of 50,000 sq. ft. or more, deduct 10 per cent from these figures.	
Base 6 in. high	0.36–0.50 per lin. ft.
Marble Mosaic:	
Grouted and ground	0.50–0.60
Magnesium Composition:	
For large areas, say 100,000 sq. ft., including $0.01 for leveling base concrete	0.20
For small areas, say 25,000 sq. ft., including $0.01 for leveling base concrete	0.24

Asphalt Flooring:	
Including $0.01 for leveling base concrete	0.15–0.17
Asphalt Mastic:	
For areas 100,000 sq. ft. or more including $0.01 for leveling base concrete	0.15–0.16
In chemical laboratories	0.17–0.18
6-in. sanitary base,	0.25 per lin. ft.
Tile:	
Quarry tile	0.35–0.40
Fancy pattern tile	0.50
Cork Tile:	
Moravian tile, fancy pattern	0.75–1.25

CHARACTERISTICS OF FLOOR SURFACES

9 *Granolithic Trowelled.* As ordinarily laid in buildings, granolithic or concrete surfaces are subject to dusting and under heavy traffic, such as trucking, are liable to serious wear. On the other hand, experience with first-class construction and tests of actual floors shows that it is possible, by proper selection of the aggregates and expert workmanship, to reduce the dusting to an insignificant amount and to produce a surface hard enough to stand even severe wear.

10 For factory floors, notwithstanding many cases of inferior construction, the use of granolithic is largely increasing. It is becoming recognized that the durability of granolithic is in a very large measure dependent upon the sand or other aggregates used in the construction and the methods of laying it.

11 The chief objection to concrete or granolithic surfaces for offices, drafting rooms, class rooms, and certain laboratories, is that it is dull in appearance, hard on the feet for men standing all day, tends to break tools dropped upon it, and is not adapted to attaching seats and other furniture readily, especially where they have to be shifted occasionally. In certain colleges, however, concrete surfaces are used widely and highly recommended. At Bowdoin and at the University of Wisconsin it is considered satisfactory for all purposes. At the University of Missouri the newer buildings are all being built with granolithic surfaces. In some colleges granolithic is being satisfactorily used for corridors. Most of the colleges favor granolithic for chemical, mining, and mechanical laboratories. The Leland Stanford, Jr., University states that in the mechanical and engineering laboratories the men complain of hardness and coldness, requiring wood platforms in many places. In this university, how-

ever, granolithic has been used in the chemical laboratories for 15 years with excellent satisfaction. It should be noted, further, that in the mechanical and engineering laboratories the floor rests directly on the ground, while in the chemical laboratory there is a warm room or basement underneath.

12 The life of a well laid granolithic surface under foot traffic is practically permanent. Tests of various materials and methods are discussed elsewhere in this paper, and specifications are given in appendices for durable granolithic surfaces.

13 *Granolithic with Ground Surface.* Experimental surfaces, together with laboratory tests made as a check, show that a pleasing surface, approaching terrazzo in appearance and fully as durable under foot traffic, can be obtained by placing granolithic with scarcely any trowelling, and then grinding the surface just enough to expose the grains of sand and stone. The grains which show are finer than in terrazzo and darker colored. The appearance, however, is pleasing. Removal of the scum takes away the monotony of the plain gray cement surface, since this is relieved by the various colors of the sand and stone. A glossy effect can be produced if desired by the grinding which permits of easy cleaning and gives a surface suitable even for a lavatory at much less cost than tile or terrazzo. Still further to give variety to the appearance, tile can be placed in patterns or as a border.

14 The University of Missouri, which refers to the dust from granolithic floors, believes that this difficulty would be solved by grinding the surface instead of trowelling. Specifications giving the method of laying the concrete granolithic and grinding it are presented at the end of this paper. From observations of the time required for grinding the surfaces and allowing amply for delays, the extra cost for grinding is estimated not to exceed 3c. per square foot of surface area.

15 *Linoleum.* The hardness and noise characteristic of granolithic finish are overcome by covering the surface with Battleship linoleum. In the few colleges where this has been adopted they are very enthusiastic over the results. In other places, such as offices, the same type of construction meets with a great deal of favor. At the University of Chicago cork carpets are used, which answer a similar purpose.

16 Linoleum is laid on a concrete surface, which need not be brought to a fine finish and therefore can be completed at the time

the base concrete is laid and at a low cost. Any marring of tl surface or sudden rains will not affect its use for the linoleum finis

17 The linoleum should be stuck firmly to the granolitl surface and preferably a cove base should be run around the roo and sills provided at entrances so that the surface of the granolitl will be flush. In this way the edges are prevented from frayin The life of first-class quality Battleship linoleum, if edges are n frayed, is probably from 15 to 30 years, depending upon the amou of travel. These ages are estimated from records of linoleum nc in use.

18 Linoleum, after allowing for the better finish required on tl concrete, costs substantially the same as a single floor of birch maple, but it is noiseless, more uniform in appearance, and requir less labor for maintenance in good condition. Its superiority wood is indicated by the fact that wood floors are frequently cover with linoleum.

19 *Hardwood Floors.* Floors of maple, birch, beech, oak, long leafed Southern pine are used most largely for offices, classroom or lecture rooms, and in many of the older colleges for laboratori and halls. A wood surface, however, is not usually consider entirely satisfactory either in general appearance or in wearii qualities. If one passes from a corridor with a granolithic, terraz or tile floor, into a room or auditorium having a wood floor, there is marked effect of inferiority and cheapness. There is just as mu danger of poor materials and workmanship with wood as with oth kinds of floors. Unless the greatest care is taken in selection materials and workmanship, they are liable to shrink or swell ar sometimes to squeak under foot. If at all hollow underneath, the are more noisy than a concrete surface. The floors of the Ne Grand Central office buildings are an example of this.

20 For corridors, wood is being largely superseded by granolithi terrazzo, or tile. For laboratories other materials are being sul stituted for wood in most of the newer structures, although wood occasionally preferred, especially for physical laboratories and f laboratories where men stand for long periods. The linoleum o concrete will overcome practically all the objections that are mac to wood floors, with a cost substantially the same.

21 There are various methods of laying hardwood floors. F classrooms a single thickness of maple or birch nailed to sleepe with cinder concrete between should be satisfactory. Another typ of construction is to use patented metal screeds embedded in th

base concrete, and nail the floor boards to splines in the screeds. For rooms subjected to heavy traffic, 2-in. or 2½-in. plank may be placed underneath the hardwood floor.

22 Of all the different materials, oak is the most expensive and the finest in appearance at the beginning, but under heavy traffic is more liable to splinter than the finer grained woods. Georgia pine, if of best quality, makes a durable floor, and is preferable to the finer grained woods in wet places, as it does not swell and warp so badly. It is less durable, however, and therefore not recommended for the greatest permanence in rooms such as class and lecture rooms. Maple, birch, and beech, all make good floor material. These are usually laid in strips ⅞-in. thick by 2¼-in. wide. The quality varies largely, ranging in cost from $32 per 1000 to $75 per 1000.

23 *Terrazzo.* Terrazzo is made by spreading upon the base concrete a mixture of neat cement and marble chips and grinding the surface to a depth sufficient to cut into stones and expose them on their largest diameters. Marble, sometimes white and sometimes colored, is used, and since no sand is employed the particles may be of fairly uniform size. The joints between the particles being of neat cement are hard and even more durable than the pieces of the marble themselves. Large pieces of marble, from ¾-in. to 1-in. in diameter, give a more distinctive floor but cost more than a floor of the smaller stones, from ⅛-in. to ½-in. in diameter, because the large stones require much more grinding to get down to the large diameters of the particles. There is more tendency to crack than in a good granolithic properly bonded to the base, but if laid with the best workmanship, this cracking is reduced to a minimum.

24 Terrazzo is largely used, especially in the newer office buildings and in institutions, for corridors and halls. It also is satisfactory for lavatories, although more expensive than granolithic. It appears from our investigation that for both of these uses concrete with a ground surface can be substituted at less cost and with satisfactory results.

25 In certain cases objection—which applies also to any hard material like granolithic or tile—is raised to terrazzo because of the noise, and even corridors are covered with linoleum or similar material.

26 *Marble Mosaic.* Mosaic consists of small squares of marble laid on the cement bed, something like terrazzo. Surfaces are

ground enough to make all pieces true and level. The pric mosaic is too high to be considered for large areas and in n cases the pieces of marble pull out from the surface. Mosa suitable in certain cases for an ornamental border which is subject to wear.

27 *Magnesium Composition.* When laid with great composition is a satisfactory and durable material. Floors 6 years old have been examined and show satisfactory wear. work must be done by a responsible firm with a suitable guara bond, because even with the greatest care the work is occasio imperfect. The imperfections, however, are apt to show withi first year of service. Composition is more resilient than granoli so that there are less complaints of hardness. It is nearly, but quite, as noisy. Furniture can be screwed directly to the position.

28 Composition has not yet been used to a great exte colleges. The floors of Cooper Union in New York City are ma them covered with this material and the results have been factory. It is suitable for certain laboratories, such as physical biological.

29 *Asphalt Composition.* Asphalt composition is suitabl certain places where no heavy tools or machines are liable to into the soft surface. It is resilient and easy to walk and stand u The color is not pleasing, being a dead black. In a few col it has been used satisfactorily for chemical laboratories. At Har for example, asphalt mastic on top of wood has been in satisfa use for many years. Johns Hopkins considered this materia their new chemical laboratories but abandoned it because o viscous properties, substituting granolithic finish, which has pr satisfactory.

30 *Tiles.* Tile of various colors is an excellent materia corridors, lavatories, and even for laboratories, but is too expe to use except where required for architectural treatment. T are various types and qualities of tile, ranging from quarry ti cork and rubber tile. All of them, however, are expensive.

31 *Wood Block.* Wood block may be suitable in certain for a basement floor having severe usage. In the Universit Cincinnati wood block is used in the mechanical and electrical te laboratories and appears to be satisfactory.

TESTS AND INVESTIGATIONS OF GRANOLITHIC FLOORS

32 The material used most largely for floor surfaces in factory construction and also to a considerable extent in other structures is what is termed a granolithic surface. This, as generally understood, is a layer of mortar or concrete from ½-in. to 2-in. thick, usually about 1 in. on top of the concrete slab and bonded to it. Although granolithic or concrete floors are so widely employed, neither the materials nor the methods of construction are standardized and scarcely two contractors or engineers adopt the same methods. Moreover, the materials available in a given locality largely affect the choice.

33 In order to compare the materials, that is, the aggregates, available for new Technology, and to determine the best proportions and methods of laying these materials, a series of sample surfaces were laid at the factory of the Simplex Wire & Cable Company, in Cambridge. Also, comparative tests were made with similar materials in other locations. A few preliminary laboratory tests were carried through, and certain tests to determine the best method of bonding a new granolithic surface to a hardened concrete base. As a result of these experiments, the following recommendations are made for the granolithic finish of floors for which this material is to be used. The conclusions apply also to structures in general.

34 *Materials.* The various aggregates used in the tests include three kinds of sand mixed as mortars in different proportions, and combinations of these sands with samples of different granites and traps. One or two sections were also laid with a patented compound.

35 Careful examination and comparisons of the various sections of slab with reference to hardness and appearance led to the selection of Plum Island sand, which should be specified to have not more than 10 per cent of its grains pass a sieve having 50 meshes to the linear inch, and not more than 2 per cent pass a sieve having 100 meshes to the linear inch; and crushed granite of a size which has passed the ¾-in. screen in a crusher plant and been caught on the 3/16-in. screen.

36 As a result of this selection, a slab of considerable area was laid at a later date at the Simplex factory with the selected materials and proportions, and in a position where it would receive rather hard usage. The Simplex Company have recently advised us that they consider this slab the best piece of granolithic that has been laid in the factory.

37 *Proportions.* Different proportions of the materials were employed in the various sample sections, each of which was about 2 ft. wide by 3 ft. long. The principal proportions tested were 1:2 with sand alone; 1:1½ with sand alone; 1:1:1¼ with sand and fine crushed stone; 1:1:1½ with the same materials, and 1:¾:1¼. As a result the proportions selected as best are one part cement to ¾ parts Plum Island sand to 1¼ parts crushed granite.

38 *Method of Laying Granolithic.* Instead of using a soft, flowing mixture, the best results were obtained by using a fairly stiff mixture, stiff enough to be rammed in place by a square-faced rammer, which would bring the mortar readily to the surface. In this way the surface skin is thinner, there is less liability to dust, and the body of the concrete, which is of a better quality than with a wetter mix, is reached with comparatively little wear, so that the dusting does not continue.

39 *Treatment of Surfaces.* Dusting is temporarily overcome by paint, but this is always unsatisfactory because it wears off under ordinary travel, and if the concrete is not of the best quality it then begins to dust. With the adoption of the specifications in the Appendix no surface material should be needed.

40 *Grinding Surfaces of Granolithic.* Objections to granolithic finish are dusting of the surface, the dead gray color, and the liability of local defects. Experiments show that these can be overcome by grinding the surfaces with a carborundum machine. This method was followed on a section of slab at the Simplex Wire & Cable Company.

41 The general plan adopted is similar to that used with terrazzo finish. Instead, however, of grinding off a considerable thickness and thus entailing a large expense per square foot, only a very thin layer is taken off so as to show the grains of sand and the pieces of coarser aggregate.

42 With this treatment, the surface is of a varied texture, and shows the various colored grains, and permits of different effects by using aggregates of different colors. While the effect is not so conspicuous as the terrazzo, the surface is of a quieter tone, and should be satisfactory for ordinary corridors and halls. The grinding renders the surface more glossy and denser, so that it is possible to use this treatment with good results in a lavatory or other place where frequent washing and cleaning is required. To produce a more ornamental effect, borders or patterns of tile may be placed in the concrete.

43 *Bond of Granolithic to Base Concrete.* A perfect bond between the granolithic and the base concrete is obtained most easily by placing the granolithic before the base concrete has reached its set. Surfaces thus laid are liable to injury from the workmen who have to go upon them before they have hardened thoroughly, and occasionally an unexpected shower will roughen the surface in such a way that it is very difficult to repair. To determine the best method of bonding, one which would give thorough assurance of perfect adhesion, tests were made and then tried out in the field on a large concrete building.

44 Laboratory tests were made on bonding new mortar to an old concrete surface, using various methods of treatment of surface, including acid treatment, roughening, and no surface treatment whatever. As bonding material, neat cement was used in different conditions of plasticity, also certain patented compounds. As a result of these tests and experience in the field, a roughened surface of the old concrete, with neat cement paste brushed in, is recommended as an effective method to produce a positive bond.

45 Specifications for bonding are given in the Appendix. It was shown in the tests that with a proper neat cement bond on a roughened surface the break under tension was frequently through the concrete rather than at the joint.

46 *Preparing Concrete Base for other Surface Materials.* If some other material than granolithic is used for the wearing surface, the base concrete must be left in a condition satisfactory for placing the surface. For most materials, such as hardwood finish, composition, asphalt, and similar treatments, the surface of the base must be brought more nearly level than where granolithic is used. This can be accomplished by very careful screeding of the surface, trowelling of rough places, and filling holes made by footprints before the concrete has hardened. An allowance of 1 cent per sq. ft. is made in the cost estimates for this extra treatment.

47 For linoleum, a real granolithic is not required, but the surface must be level and true. This should be accomplished by spreading a thin layer of mortar before the base concrete is set, but this need not be of the very best quality of granolithic unless with the object of using portions of the floor without linoleum. This thickness of the mortar may be ½ in. to ¾ in. This should be trowelled at the proper periods, but with less care than for a granolithic that is to be used as wearing surface. Some form of cove base around the walls is advantageous to use with the linoleum.

APPENDIX

SPECIFICATIONS FOR LAYING GRANOLITHIC FINISH ON SET CONCRETE

48 Specifications for laying granolithic finish on set concrete are as follows:

a Roughen surface of base concrete at the age of about 24 hours, so as to remove most of surface scum.

b If surfaces have not been thus roughened, pick with a bushhammer to remove a part but not all of the surface skin.

c Spread dilute muriatic acid about one part acid to four parts water over the surface, allow to stand for a few minutes, then soak thoroughly with water, and wash off the surface.

d Sweep off the excess water on the surface of the concrete and spread on a coating about ⅛ in. thick of neat cement paste, and broom it well into the concrete. (Do not use dry cement for this.)

e Mix the granolithic in proportions 1 part cement to ¾ parts coarse sand, like Plum Island, to 1¼ part crushed granite screened through a ¾-in. screen and caught on 3/16-in. dust jacket.

f Make the consistency of granolithic rather stiff so that the mortar will just flush to the surface.

g Have the screeds laid parallel and level so that the granolithic can be spread even with straight-edge. Run over the screeds. See that plenty of material is being pushed ahead of the straight-edge at all times so as to avoid pockets in the surface.

h Ram granolithic with light square-faced tamper.

i Float granolithic surface as soon as it begins to stiffen.

j Trowel granolithic surface hard as soon as the proper stage has been reached. (If surface is to be ground do not give surface this final trowelling.)

k Cover the surfaces of the granolithic about 24 hours after laying, with wet burlap or similar material which will hold water. Wet material each day, and oftener if necessary, for a period of 14 days.

GENERAL REQUIREMENT

49 Never lay concrete finish in cold weather unless a uniform temperature can be maintained by artificial heat, as the cold prevents the surface of the granolithic from hardening satisfactorily. In laying floors where water is to be used, care should be exercised to provide the required slope for cleaning and drainage. This is especially necessary in such places as chemical laboratories.

GRINDING GRANOLITHIC SURFACES

50 Specifications for granolithic grinding surfaces are as follows:

a Lay the granolithic as described in Appendix No. 1, but omit the final trowelling.

b Rub the granolithic surface by hand with carborundum block at the age of about 24 hours after placing. Rub lightly and take off only the top scum of the cement and remove any surface irregularities.

c Grind the surfaces with a floor polishing machine at the age of about 7 days (time varies with weather and temperature). Use about 60–80 grit with water and do not use any sand unless it is found necessary. This grinding should take off the top film of the surface and cut into the sand grains enough to expose them and to leave the surface smooth but not shiny.

d Rub wet cement paste into any pinholes.

DISCUSSION

In presenting the paper THE AUTHOR stated that good granolithic floors were being built which would stand very severe traffic and dust only to a very small degree. The five principal requirements are, materials, proportions, bonding, methods of laying, and treatment of surface. Use coarse material with the cement, avoiding fine sand or stone with fine particles because this rises to the surface in trowelling. Use a comparatively dry mix that will require a slight tamping. There are certain compounds on the market that will prevent dusting, but if the right materials and workmanship are employed, so little dusting will occur that it will not be objectionable for ordinary uses.

For durability it is best to lay the floor surface along with the base concrete. This is often impracticable and tests have proven that a good bond can be obtained on old concrete with the proper treatment. Special attention is called to the specifications given at the close of the paper and to the note with reference to laying granolithic in cold weather.

ROSS F. TUCKER[1] (written). So much difficulty exists in securing a good wearing surface for granolithic that hardwood is preferred for all purposes, particularly where operatives have to be on their feet.

L. C. WASON[2] (written). In regard to costs, my figures for granolithic construction would in each case be 2 cents less than those quoted by the author. For hardwood floors, there is a difference of 3¾ cents per sq. ft. between 2 in. face by 1⅛ in. thick and 3½ in. face by ⅞ in. thick, in both cases the material costing

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[2] Pres. and Engr., Aberthaw Constr. Co., 8 Beacon St., Boston, Mass.

the same per thousand. Magnesium composition is also laid at a third less than quoted.

Lameness and fatigue, which factory operatives thought were caused by the hardness of granolithic floors, are due to the fact that such floors are better conductors of heat. This has been overcome where floors are cold by wearing heavy shoes.

Nalecod, another material composed of asbestos, portland cement and sand, is giving better results than screed for wood floors.

For a granolithic floor no particles should be used smaller than those passing a No. 30 sieve, and hard rock which will withstand abrasion should be used, without any sand, the proportion being one to two. In bonding to old surfaces, a thin top i.e., ¾ in. or 1 in., is more likely to come loose than a thicker one.

Commenting on paragraph 48, a multiple pick is cheaper and requires a less experienced workman than a bush hammer.

Dilute muriatic acid is unsafe unless the concrete is dense, otherwise it is likely to soften it.

The mixture should not be limited to granite, as traps and gravel give good results. A stiff mortar gives best results, although a different consistency should be used, depending on whether the base is fully set.

G. S. Walker. There is almost certain to be trouble with granolithic if the base is allowed to set and an attempt afterward made to bond the surface to it. This is due to the shrinkage rate being different. They should always be laid together.

Walter S. Timmis. There is a very serious defect in wood floors in fireproof buildings, that of springiness. This was more apparent in the earlier buildings where floors were laid directly on the arches but even in recent buildings it occurs, owing to lack of care in bringing the cinder fill to the top of the screed. Dry rotting of screed also often takes place, especially when the floor is laid before the cement is dry. On granolithic floors, the difficulty in getting a smooth surface and no dusting is due to the trowelling not being done at the psychological moment.

G. P. Hemstreet (written). I desire to call attention to another form of asphalt floor for fireproof buildings, streets, piers, warehouses, etc., used for many years, viz., asphalt blocks composed of hard crushed stone and about 7 per cent asphaltic cement formed under hydraulic pressure of various sizes and forms. These are laid in cement mortar with joints grouted. The surface is smooth, resilient, non-slipping, dustless, sanitary and not easily marred. This material can be taken up whenever desired and readily replaced. The cost is $1.50 to $2.50 per square yard.

The Author, in closing, recognizes the force of Mr. Wason's requirement that the aggregates should be practically free from grains finer than a No. 30 sieve. Unless a sand consisting of very coarse grains, like Plum Island sand, is available, he agrees that it is proper to use an aggregate with no sand but with particles graded from ¾ inch down to, say, a No. 30 sieve.

Regarding Mr. Walker's criticism on bonding new granolithic surfaces to old concrete, the best answer is that it has been done with good results by the methods described.

No. 1443

REINFORCED-CONCRETE FACTORY BUILDINGS

By F. W. Dean, Boston, Mass.

Member of the Society

The reinforced-concrete type of factory building is in considerable favor at the present time and is likely to be increasingly so. It has some very important qualities, the chief of which is probably that it is fireproof, for it is generally agreed that it gives the maximum resistance to fire. Independent of considerations of merit, it is being pushed by many specialists in its construction or design, both in general and in detail. In fact it is difficult to keep informed of the various methods of reinforcing both beams and slabs.

2 In addition to its resistance to fire, there are other merits to this type of construction, among which may be mentioned the somewhat greater window area than that which is practicable in a regular mill construction building, the light color of the ceilings with consequent good lighting, (although wood ceilings are often painted white), and its adaptability to heavy floor loads without requiring narrow bays.

3 There are two general types of concrete floor construction in use, one having beams and the other smooth ceilings, the latter being usually known as mushroom construction although there are other designs. The beam system is advisable in most factory buildings, especially if there are to be lineshafts with pulleys of much size. The beams enable short hangers to be used while giving room for the pulleys and belts. For textile mills and some kinds of machine shops the beam construction is, in the writer's opinion, to be preferred, while in storehouses and perhaps in machine shops with small tools, and especially if motor driven, the smooth ceiling is best. Both systems permit equally good lighting as the light enters parallel to the beams. The strains in the mushroom system of reinforcement are more uncertain than in the beam system and are

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empirical. In practice, however, no inconvenience or risk co from this.

4 When the beam system is used a building can be built up whole, being wholly encased in forms, or it can be built by the] some or unit system in which columns and beams are cast separ and erected somewhat as wood beams are. By this means claimed that a concrete building can be built more cheaply rapidly than by the other system. It seems as if this may be t as no doubt less lumber is used, and all forms are built, an pouring done, on the ground where both can be done most veniently.

5 A claim for the reinforced concrete building is made machinery can be run faster than in a mill construction buil on account of reduced vibration. This seems improbable as t is no evidence, so far as I know, that vibration is increased in p tice, by an increase of speed. In fact it might be reduced. T there is less vibration in general in reinforced-concrete buildings in the other type, is, of course, true, but whether it permits a gre increase of speed is another question. Speed limits are cause other things than the rigidity of buildings, such as the limitat of the machines themselves, personal skill, and accompan processes.

6 An inconvenience of reinforced-concrete buildings is the l size of columns required, and this is so great that it is hardly pr cable in some cases to use them, and in many cases steel colu have been used covered with cement. In textile mills large colu cannot be tolerated.

7 Floors are always a source of trouble if of concrete. S floors cannot be uniformly dense or hard and they therefore w unevenly, especially if trucking is done. In fact trucking integrates them and they become rough and full of cavities. effort to prevent this by using coarse crushed granite in rather cement has been made, but this cannot be made uniform. T are also special materials for incorporation into concrete which quite effective in preventing wear, but which are so expensive they must be used sparingly. They are probably becoming expensive, as their manufacture is becoming widespread.

8 A disadvantage of concrete buildings is that many th in connection with placing machinery, wires and pipes req working out in advance. Errors are in this way introduced and t correction is slow and expensive. Many of these things do

require working out at all with regular mill construction. Moreover some have to be worked out in forms for concrete construction, which have no counterpart in regular mill construction, such as sockets for supporting sprinkler and other pipes, inserts for wires, and built-in angles for supporting shafting hangers, or inserts which can be used for supporting angles for this purpose. Similarly, inserts must be built in for bolts for securing machinery, or the concrete floor must be drilled for expansion bolts, unless wood floors are used over the concrete. All add to the cost of drafting and to construction and make delay in both cases. In case machinery requires moving, the work is again troublesome.

9 In chocolate factories dust rises from concrete floors which affects the flavor of the goods and renders a wood top floor necessary. This is indicative of a dust pervaded atmosphere and may affect operations in other factories.

10 It is often asserted that operatives do not like to stand on concrete floors, because, probably, they are cold. This has in some cases been a reason for using a wood top floor.

11 Concerning methods of putting down such a floor, the writer is of the opinion that it is best to simply lay planks 2½ in. to 3 in. thick on the concrete, and nail the regular top floor to them. The mass of the planks is sufficient to give all desired stability, and the nailing of the top floor makes one mass of the whole. When such floors are washed water settles in the cracks and will cause the planks to rot. They should therefore be kyanized or otherwise treated to prevent rot. For certain factories in which food products are made, kyanizing is better than some of the other treatments, because lumber so treated is odorless.

12 Concrete buildings unless finished on the outside in some manner to obliterate the marks of the forms are very unsightly, but if properly treated are very handsome. There is no limit to the ornamentation and beauty that can be given to them. There are two different treatments that are commonly given to the outside surfaces of such buildings: one is tooling, usually with a pneumatic tool; and the other is washing with a marble, cement, or other wash which obliterates to some extent the form marks, and makes the color more uniform. Some chiseling may be necessary before this is done, and stoning down with sand and water make the result still better.

13 While concrete buildings are fireproof, it should not be supposed that they do not need sprinklers and other fire protection, as the contents are as inflammable as in any building. Some people

of construction, the result of his comparisons is rather pessimistic from the reinforced concrete point of view.

In favor of reinforced-concrete for factory buildings, three points of prime importance should be emphasized: (*a*) resistance to fire, (*b*) percentage of window area, (*c*) spacing of columns.

We wonder that his reference to the Salem fire did not include the *other* storehouse at the Naumkeag Mills, the one of reinforced concrete, which came through the fire with its wired glass windows buckled and melted but with its frame uninjured and its inflammable contents unharmed. It stood squarely across the path of the fire and its walls were literally bathed in the flames from a building only 4 or 5 ft. from it.

The author fails to mention one important factor in connection with inside conflagrations, and that is the waterproofing of floors. In regular mill construction, with wood floors laid on wood or steel framing, it is necessary so to construct these floors that the opening of a sprinkler will not deluge all stories below; and this involves not only watertight flooring, but watertight connections between floor and wall and floor and columns. The reinforced-concrete floor, without additional precaution or expense, is in itself sufficiently waterproof.

No practical construction of a four-story factory building with brick bearing walls can give a clear window opening of more than 85 per cent of the gross wall area between sill and ceiling in each story. Yet 85 per cent of window opening is not an uncommon figure in reinforced-concrete construction, and frequently this percentage is exceeded.

The author mentions briefly the adaptability of reinforced concrete to a combination of heavy floor load and long span construction. This is a feature which deserves to be amplified. Regular mill construction is cheaper than reinforced-concrete for the floor loads and the column spacing *best adapted to mill construction;* at the same time, the mill construction is *not* fireproof.

If we materially increase the floor load or the column spacing, steel framing must be substituted for the timber, and this greatly increases the cost and at the same time the fire risk, because steel framing will succumb to the heat from a hot fire of short duration which would only char the timber framing. Increasing the load or the column spacing for reinforced-concrete floors increases the cost of the construction, but the ratio for this is less than the corresponding ratio for mill construction. Furthermore, the concrete construction includes its own fireproofing at no additional cost. The nearest approach of mill construction to the floor loads and column spacing best adapted to reinforced-concrete construction is obtained by laying "slow burning" wood floors on fireproofed steel beams and girders supported on fireproofed steel or cast-iron columns; and the cost of this combination will exceed the cost of the equivalent reinforced-concrete construction.

As to the two types of reinforced-concrete floor in most general use, each has advantages making it especially adaptable to certain conditions. Among these may be mentioned the stiffness and rigidity of the building with beams or beams and girders and the saving in head room and story height by the use of the flat or paneled ceiling. One or the other may be preferable for the attachment of overhead machinery, according to the needs of each particular instance; but where a flat ceiling is desirable for attaching machinery, it is obvious that regular mill construction can offer nothing comparable to reinforced-concrete.

In mill construction, whether it be framed with wood or steel beams, attachment of machinery to the beams frequently involves a sacrifice in the strength of the framing. With concrete the presence or the absence of inserts has no effect upon the strength of the floor. With wood or steel beams, later connections for machinery must often be made at the expense of the strength of the framing; and with steel beams, these connections involve considerable expense; while with reinforced-concrete construction if such a provision seems to be warranted an initial expenditure of about 2/3 of one cent per sq. ft. of ceiling area for a liberal placing of inserts will make the building perfectly elastic for the entire rearrangement of any ordinary kind of overhead machinery.

The author mentions only two types of floor finish, and these but briefly, concrete surface (granolithic) and wood top floor on plank. Certainly we should make mention of such common finishes as plain trowelled cement, wood top floor on screeds in cinder concrete, wood block on end, terrazzo, linoleum, and tile; each of these has its advantages peculiar to itself; nor is the floor finish in a building of reinforced-concrete construction limited to the materials here named. In connection with the author's reference to the necessity of wood top floor in chocolate factories, the writer some time ago visited a factory of one of the finest brands of candy in New England and found the floors nearly all with granolithic finish, the exception being where terrazzo was used.

Concrete buildings are frequently though unnecessarily unsightly, and this is due to a variety of causes of which the chief, perhaps, are thoughtlessness in design and carelessness in building forms. Engineers and others are in the habit of considering a completed reinforced-concrete building as a "monolith" whether its members are cast in place or precast and built as units. They overlook the fact that the "monolithic" building is actually cast a piece at a time, with construction or time-joints between the separate pourings. The wall of a reinforced-concrete building is in reality a masonry wall with gigantic blocks of artificial stone laid one upon another and dowelled or otherwise fastened together. If the importance of the building or its location does not warrant any special care in the construction of forms or location of joints, neither does it warrant any dissatisfaction with or criticism of the hideousness which frequently results; that is if "a dollar saved is a dollar earned."

Briefly, where a firepoof factory building is to be built, reinforced concrete stands preëminent in the choice of materials; for high percentage of window area, it has no rival unless we consider the use of steel wall columns, and there the element of cost comes into play. For wide column spacings the cost will not be greatly different whether reinforced-concrete or exposed steel beams are used, and if the steel beams and the columns are to be protected, the advantage in cost will nearly always be in favor of the reinforced concrete. A reinforced-concrete factory building in nearly every case can be built in less time than the same building with wood or steel framing, giving an advantage which may more than offset any difference in total cost to build. Anchorage for machinery is not such a bugbear if laid out on broad lines rather than for special cases; and the choice of floor finish is a problem in itself, regardless of what materials are used in the frame of the building. We are heartily in agreement with the author when he says that there is no limit to the ornamentation and beauty that can be given to a reinforced-concrete building, except that we would modify the statement and say that the only reasonable limit is the amount of the expenditure which is justified for that purpose

J. P. H. PERRY[1] (written). The paper is interesting to me chiefly because it so aptly phrases the opinion frequently expressed by the mill engineers and architects of New England. The engineers and architects controlling textile construction have until the last year or so been extremely conservative in permitting their clients to adopt reinforced-concrete construction.

To those who are thoroughly familiar with reinforced-concrete

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many of the objections raised in Mr. Dean's paper seem exaggerated. For example, the speaker knows of a number of plants, notably printing houses or paper goods concerns and machine shops, where (the owners are on record in writing) they have been able to get a greater efficiency out of their machinery in reinforced-concrete buildings than they ever could in the best mill construction.

This greater efficiency is due to two things: (*a*) the fact that there is less vibration by a considerable degree, and (*b*) that machinery or shafting once set up or lined up remains permanently true.

In the Robert Gair Company plant, Brooklyn, are 1,300,000 sq. ft. of concrete floors, most of it used for manufacturing paper goods; in one building alone a saving of $5000 annually is reported by the owners in machinery upkeep and maintenance compared with a similar equipment in a first-class mill construction building in their old plant.

Objection is also raised to the large size of concrete columns. In my experience covering the construction of over 300 industrial buildings, largely for factory purposes, there have been not over 8 or 10 jobs where steel columns have had to be used. These buildings have run from one to 17 stories.

The expense of fireproofed steel columns, if regarded as a capital investment and interest charges thereon equated against the value of the extra floor space occupied by concrete columns, has usually been found to be unnecessarily high, and it is only where clearances are of maximum importance that an owner will pay the extra cost for the steel columns.

Today experienced contractors are able to build economical octo-spiral columns of the Hoadley type which approximate a circular column and thus get away from any waste space occupied by a square concrete column; also the psychological effect on the owner looking across a loft is far better. The objection to the size of concrete columns is almost wholly one of appearance.

To claim that concrete floors cannot be uniformly dense or hard and they therefore wear unevenly, is in the speaker's judgment a little severe on this type of construction.

In the Bush Terminal there are probably 6,000,000 sq. ft. of granolithic floors. These buildings are built for rental purposes and if concrete floors were as bad as the paper indicates, the renting of these lofts would be a difficult problem; whereas, the reverse is the case.

It is true that there has been some very bad concrete floor work done and that severe trucking will cut this kind of work and sometimes damage even a good floor.

The various floor-hardening compounds and preparations on the market help to improve the quality of concrete floors, but in many ways, unless a substance such as wax can be driven into concrete floors by some process of impregnation, these treatments do very little to improve the quality of what is regarded as a first-class job.

Mr. Dean raises the most common objection or prejudice to concrete industrial buildings, viz., the making of changes or cutting of holes or openings. Concerning this, it is only necessary to state that the majority of progressive industrial institutions today are using reinforced-concrete buildings for manufacturing purposes.

At a very slight expense, usually not exceeding 1/4 of 1 per cent of the cost of the building, it is possible to provide sockets or to leave openings through beams and girders in sufficient quantity to give an absolutely elastic means of attaching any equipment.

Perhaps the most efficient method of handling this problem on large operations is that used in the Robert Gair Company plant mentioned. With a small portable pneumatic drill run by an electrically-driven compressor the owners are able to tap holes in any part of the concrete building at a very small expense and they report that they get about the same results, as far as time and costs are concerned in attaching equipment in this manner, as they used to get in their mill construction buildings.

Mr. Dean cites particularly the case of chocolate factories requiring wood top floors. Chocolate factories used by three nationally-known concerns have the usual granolithic top floor throughout. These buildings have been used for an average length of three years and the owners have had no complaints. It is the speaker's belief that the majority of chocolate factories throughout the United States are using reinforced-concrete buildings mostly with granolithic floors with complete satisfaction.

Mr. Dean seems to feel that it is essential to remove board marks in order to get a reasonably satisfactory exterior appearance on a concrete building. Such has not been found to be the case in New York practice. In fact, without a considerable expense, it is impossible to remove these markings. There are only three ways to do it as far as the speaker knows: one is to tool the concrete; the second is to stucco it; the third is to veneer the building with brick or tile. The appearance of a concrete building very largely depends on the proportion of the structure and the simplicity of the ornamental detail, plus some wash or paint treatment to bring the structure to a uniform color. A certain amount of pointing of imperfections in the concrete is generally necessary. Aside from this, concrete can be left as it comes from the forms, and if the critic will appreciate the fact that the building is of concrete and will try to consider concrete as concrete and not as brick, or some more conventional material, his opinion will be more favorable.

In a great many cases it is found desirable to use brick curtain walls to break up the color scheme and obtain a result perhaps a little more pleasing than some people will grant is possible with an all concrete exterior. Brick curtain walls 12 in. thick cost about the same as 8 in. concrete, sometimes a fraction more. If a veneer is used over columns and lintels the expense runs up considerably, depending on the character of the brick, i.e., whether it is common brick or face brick, or whether an ornamental tile is used.

The writer has found that it is not usually satisfactory to attempt sand blasting concrete surfaces, nor are as good results obtained with a pneumatic tool as with a hand-operating cold chisel. This for the reason that the hardness of the concrete is not uniform and that sand blasting will pick out soft spots or eat into the mortar in preference to the aggregate and thus produce an uneven surface.

Mr. Dean apparently overlooks the most remarkable lesson taught by the Salem fire, viz., the four-story concrete storehouse of the Naumkeag Steam Cotton Company which was in the center of a whirlpool of flame under conflagration temperature for nearly three hours and, aside from damage to wire glass windows, came through unscorched. Not a sprinkler head went off in this building and the inflammable contents were in no way damaged.

The circular brick storehouse, which Mr. Dean refers to, was originally a gasometer and had no openings in the walls. The roof was cone-shaped and covered with a recently-laid asbestos roofing. There was an ordinary wood and plain glass skylight at the peak of this roof. This was undamaged by the fire, thus showing that the storehouse was probably protected by one of the recognized phenomena of conflagrations, viz., the collection of cold air in spots. Certainly had the temperatures been severe or the flames been in active play over this brick storehouse, the wooden skylight would have gone.

The rest of the Naumkeag plant consisted of what was recognized by the Factory Mutual Fire Insurance Companies as one of their best risks, viz., a supposedly properly protected first-class brick and heavy mill construction group of buildings. They all were destroyed and the brick walls in many cases collapsed.

It is only necessary to point to fires in mill construction buildings, where sprinkler lines have been cut in two by the early blaze and the rest of the plant entirely destroyed as a result thereof, to appreciate the fallability of relying on timber, regardless of how well it was protected theoretically, to stand up under a severe fire. Concrete buildings can be gutted of contents from basement to roof and the building, aside from windows, is ready for new contents as soon as it is cool.

Reference is made to what has been called elsewhere the "terrible permanence of concrete." Had the writer of the paper acquainted himself with the removal of the Munsey Building in Baltimore or with similar jobs elsewhere, he would have appreciated that the problem of removing concrete buildings has been worked out in an exceedingly economical and efficient manner.

Mr. Dean's reference to comparative costs of mill construction and economically designed concrete buildings does not agree with the speaker's experience on this point. Many competitions in the Metropolitan Territory with mill construction have shown an average increase if concrete is used of from 8 to 15 per cent, depending on the floor loads required and on the size of the job. For the same column spacing, concrete is usually about as cheap as mill construction.

Regarding German practice, most of the concerns with German home offices with which the writer has done business point proudly to the fact that the home plants are built of reinforced-concrete.

As to the old question of adhesion of concrete to reinforcing bars, it has been demonstrated to the satisfaction of most engineers who have made a thorough study of reinforced-concrete design and construction that, with deformed bars at least, the stresses assumed in design will be distributed and obtained in actual work. The bond between concrete and reinforcing bars is essentially a mechanical one, as some tests in a middle western university laboratory brought out. By taking a commercial smooth bar and milling same to a shafting smoothness, it was found that the bond between the concrete and the shafting was materially reduced.

The writer feels that the author has been unfair to the recognized merits of properly designed and executed reinforced-concrete construction for industrial purposes. In view of the tremendous fire loss in this country, it seems unwarranted to recommend non-fireproof or slow-burning construction, wherever the owner can possibly afford a fireproof proposition. Protection to employes alone is ordinarily worth the extra expenditure. This is particularly true in view of the increased difficulty in securing high-class heavy timber such as mill construction requires. The recent articles in the Engineering News on dry rot should make every advocate of mill construction consider carefully the satisfactory erection of this type of building.

W. F. BALLINGER. Regarding comparative costs, some buildings we have designed, and on which we have obtained prices both ways, have shown a difference as low as six cents per sq. ft. of floor surface between an entire reinforced-concrete building with cement floors and one of slow burning construction, i.e., brick walls, planking and timber with maple floors. In certain circumstances where supply of material is at hand and where railroad sidings exist reinforced-concrete is less expensive. In the majority of cases, insurance and upkeep considered, reinforced-concrete is usually more economical.

Reinforced-concrete permits a smaller number of posts and larger spans which is a great advantage irrespective of the size of posts or columns. Posts or columns are usually larger in reinforced-concrete because 750 lb. per sq. in. in compression is allowed on yellow pine posts and most building laws allow only 500 lb. per sq. in. on reinforced-concrete columns. If the reinforced column is built of a spiral type, a higher unit stress is allowable, so that the post need not necessarily be any larger than the yellow pine. Where they would otherwise be too large for high buildings the size can be reduced by the construction of steel column cores. It is practicable to build a span as long as 60 ft. This has been done at an actual saving over steel fire-proofed, and in one case was even cheaper than having the steel structure unprotected.

It is known that machinery will vibrate less in a reinforced-concrete building, and this has actually resulted in saving of electric current due to the machinery running more true.

THE AUTHOR said in closing that one object in writing the paper is to create discussion, and that he was appreciative of the contributions which so well accomplished this.

No. 1444

MEASURING EFFICIENCY

By H. L. Gantt, New York City

Member of the Society

The widespread interest in the subject of management which has grown up within the last few years, has, I believe, a deeper significance than is at first realized.

2 The readiness with which employers of labor have been willing to seek advice from almost anybody calling himself an "efficiency engineer" is hard to understand on any theory except that many employers realize that they are not operating their plants as well as they should be operated; and the fact that so many so-called "efficiency engineers" with but little experience or training have been able to accomplish results apparently well worth while, seems to bear out the theory that the art of management as practiced by many employers is still in a very crude state.

3 To be sure, many "efficiency engineers" have become discredited and gone out of business, but others have entered the field, and apparently the number in active practice is greater today than ever before. It would be impossible for such a large body of men to find employment unless at least a fair number of them were doing some good. Certainly the continual call for efficiency has made many employers study their problems in a way they have never done before.

4 To the engineer the word "efficiency" has a definite meaning, which may be expressed approximately as the ratio of the useful result produced to the effort utilized in producing it. To the public in general it means simply doing things better.

5 It is very unfortunate that the term "efficiency engineer" was ever invented, for every engineer is engaged in the work of promoting efficiency, and it seems presumptuous for any class of engineers to arrogate to themselves a title which implies that they are preëminently promoters of efficiency. A more correct appellation would be "management" or "industrial" engineers.

Presented at the Annual Meeting, December 1914, of The American Society of Mechanical Engineers.

6 Waiving the subject of name, however, it is certainly a fact that the agitation of the subjects of management and efficiency during the past few years has caused many employers to study their management problems very much more closely than heretofore, with the result that there has undoubtedly been a marked improvement in the efficiency with which industrial operations as a whole are being conducted.

7 So far so good. But in spite of this increase in efficiency, the greatest of our industrial problems, the relation between the employer and the employee, seems but little nearer solution. While there has been a distinct improvement in isolated cases, these cases are few compared with the total number, many of which show no improvement whatever.

8 It is safe to say then, that the promotion of efficiency is not alone sufficient to serve the needs of a nation that aspires to be a leader in industrialism. As a matter of fact one of the most efficiently run plants I have ever seen promises, unless my theories are all wrong, to widen the gap between employer and employee. The solution lies deeper, and before we can make any real progress toward it, we must revise some of our fundamental conceptions.

9 With the growth of competition within the last 20 years the necessity for some knowledge of costs became evident, and the manufacturer turned to the accountant for a system of finding costs.

10 The present system of railroad accounting had been developed, and certain ratios accepted as measures of efficiency of operation; notably among them the ratio of operating expense to total income.

11 Being accustomed to having the managerial efficiency of railroads expressed by a simple ratio, the financier demanded a similar simple measure of the efficiency for an industrial plant. The cost accountant promptly gave him what he called the ratio of "non-productive" to "productive" labor, which he said should be low for good management. By "non-productive" labor he meant salaries of all kinds, and all other labor that could not be charged directly to an order, including miscellaneous labor such as watchmen, sweepers, truckmen, etc. By "productive" labor was meant simply that labor which could be charged directly to an order.

12 While the ratio of operating expense to total income may be a fair measure of efficiency in a transportation company, the ratio of "non-productive" to "productive" labor is not only not a fair meas-

ure of the efficiency of operation in a manufacturing plant, but is often exactly the reverse.

13 To my mind the widespread use of this ratio as a measure of efficiency, has been more effective in producing inefficiency than any other single factor, except the oft-repeated statement that you must have low wages if you would have low costs. Until these two fallacies are absolutely discredited, we cannot expect a solution of our most serious problems.

14 Of these two fallacies, the second, namely, that you cannot have high wages and low costs, seems to be yielding gradually to the overwhelming mass of evidence against it. So many cases are now on record where the industrial engineer has increased output, raised wages, and at the same time lowered costs, that only those who are too conservative to investigate are still holding on to the old theory. Better still, many employers have shown the courage of their convictions by adopting a scheme of management for the increase of output and the reduction of costs, which they are perfectly well aware will make a decided increase in wages. With evidence of this kind at hand, it is safe to say that this fallacy will before long be entirely discredited. On the other hand it must be fully understood that something more than a simple increase in wages is necessary to increase output, and if nothing is done but to increase wages we are sure to get higher costs.

15 The other fallacy, that the ratio of "non-productive" to "productive" labor is a gage of efficiency, is so firmly rooted, however, that it is hardly to be expected that it will yield in the near future.

16 In considering this subject I wish to call attention first to the terms "productive" and "non-productive" labor, which seem to me to be misleading. If any expense is "non-productive," namely, does not contribute to the end for which the factory was established, it should be eliminated. The salaries of the officers, foremen, janitors, truckmen, and laborers, as well as the money paid for taxes, insurance, or interest are necessary to the operation of the factory and therefore productive. They are, however, not chargeable usually to any specific order, but must be distributed over all the work done according to some definite rule. I prefer to call all such expenses that have to be distributed "indirect" expenses, and those that are chargeable to specific orders "direct" expenses. The ratio which we have in mind is thus more correctly described as that of "indirect"

to "direct" labor. This, however, is a matter of names and does no affect the fact that to base any conclusions as to the efficiency wit which a factory is run on this ratio is misleading, and to attempt t use it as the gage in operating a factory may be, and often i productive of inefficiency rather than efficiency.

17 This fact can best be made clear by a series of examples. In factory where this ratio was used as a guide the following incider occurred:

18 A foreman had ten men on a job, which he said could t done by eight if he could have a boy to supply them with work. H said, however, that if he made the change, the boy's wages woul be called "non-productive" labor and his ratio would go up, with th result that he would be criticized, so he did not make it.

19 In the U. S. Navy an energetic officer studied the loadin of ammunition and very much reduced the direct labor employe but, being unable to reduce the indirect labor in the same propo tion, the above ratio went up. He came in for very severe criticisn notwithstanding the fact that his total labor had been decidedl reduced.

20 I might give numerous examples of this kind, including or where 2 men took the place of 16, and a daily direct wage of $8 too the place of $48, with but little increase of the corresponding in direct expense. The result of this and other changes was that th ratio for that shop became over double its former value, with marked reduction in the total cost. Needless to say, that the rati theory in that plant is not regarded with the same reverence that once was. In plants where such results have been accomplishe those who have been accustomed to worshipping this ratio, at on demand another idol in place of the one that has been so badl discredited.

21 Inasmuch, however, as the efficiency of the operation of factory is made up of the efficiency of a great many independe operations, and is really indicated only by the cost of the variou articles produced, there has not yet been found any easy way of in dicating the efficiency without first getting the cost of the individu articles. Hence there is no readily available idol that can be sul stituted for the discredited one. Having been accustomed to an ido however, both the accountant and the financier demand one, and a loathe to give up the idol they have so long worshipped no matt how badly shattered it may be. When, however, a reliable cost sy

tem has been installed, this idol becomes so badly discredited that even its most devoted high priests are obliged to abandon it.

22 In speaking of the cost systems, we must discriminate between cost systems and expense systems. Before we can get correct costs we must have a correct knowledge in detail of all the expenses of a plant, and some idea of how to combine these to get costs.

23 In discussing this subject, I wish to avoid the controversy as to the proper method of distribution of indirect labor and indirect expense and to confine myself to the problem of how to get a true knowledge of the various items of labor and expense, both direct and indirect. This subject seems to have been given but scant consideration by the average accountant, who has usually assumed this to be easy and devoted his energies to working out elaborate theories as to what should be done with the various items of expense. Inasmuch as I find that the information which the office gets of what the shop has done is, as a rule, not very reliable, I feel that it is far more important to get this information correct than to get up elaborate schemes for using it.

24 Everybody is agreed that all expense of material or labor that can be readily charged to an order should be so charged, but whether the indirect labor and expense should be charged in proportion to direct labor or machine hours, and how other items of rent, taxes, insurance, etc., should be distributed, are questions which it seems to me should be largely determined in each case on its merits. I have never yet seen any general scheme that seemed to suit all cases.

25 We shall therefore confine ourselves to the consideration of what the essential elements of a reliable cost system are, and how to get an exact knowledge of them. These elements are a knowledge each day of

(*a*) what was done the day before
(*b*) who did it, and
(*c*) what was paid for it

It is necessary to check these items daily, for it is impossible to check them accurately after the lapse of any appreciable time.

26 It is comparatively easy to get a set of returns purporting to give the above information, but the real difficulty comes in knowing whether these returns are correct or not. The only sure way of knowing whether these returns are correct or not is to know beforehand

(a) what should be done the next day
(b) who should do it, and
(c) what should be paid for it

27 When we have arrived at a condition under which we car plan our work in advance on these lines, we have the basis of a rea system of management, in which we can promptly check what ha been done with what should have been done, and know with certaint each day how we stand.

28 It is not my intention to go into details as to how this car be done, as the subject is too big for a paper of this character. How ever, as the criticism will be at once raised that the clerical worl needed would be so great as to make it out of the question, in repl I may say that even in the most poorly run business, some attempt either consciously or unconsciously, is made to control work on thes lines. Moreover, we generally find that the more nearly the abov ideal is approached, the more successful the plant is, and all wil admit the desirability of such a system if it can be established with out excessive clerical work.

29 When it is realized that the installation of such a systen seldom results in an increase of output of less than 25 per cent, an often as much as 100 per cent, it is easy to see that the additiona clerical work cuts but little figure. As a matter of fact *the clerica work needed to operate the best systems of this type is decidedly les than that needed to operate any of the standard cost systems put i by chartered accountants.*

30 It must be borne in mind, however, that during the proces of installing the new system and training the employees to operat under it, the old system must be continued; and not until eacl function performed by the old has been taken over by the new ca we drop the old entirely.

31 During the process of installation, therefore, we must t a large extent operate two systems. This necessarily runs up th ratio of "non-productive" to "productive" expenses, and the ac countant lifts up his hands in horror at the expense the new sys tem is running them into. If at the same time the new system i successful in reducing the "productive" labor, the ratio is still highe and the "showing" is still worse, even though the total cost is less I therefore repeat that the first step to be taken before introducin a modern system of management is to eliminate the ratio of "non productive" to "productive" labor as a measure of efficiency.

32 The elimination of this ratio as a measure, and the establishment of the fact that total cost is the only reliable guide, will do much to pave the way for an improved system of management. How is this to be accomplished?

33 The first step is to revise our ideas as to the functions of a cost system. In the past the principal function of a cost system, besides indicating a limiting selling price, has been to enable those in financial control to criticize those operating the factory. These criticisms are usually from one to three months late, and are so general in their character as to afford, as a rule, no guide whatever by which the superintendent can be governed. Such a system is too often most highly prized for its worst defect, namely, that it enables those in financial authority to criticize without taking any responsibility whatever for showing how to do better.

34 If, instead of making the function just described the prime one, we raise to equality with it, a function which requires the system to furnish promptly, day by day if necessary, exact information of what has been done and what the expenditure has been, we shall find that its most valuable function becomes, not finding costs, but furnishing the superintendent with information which helps him to reduce costs.

35 In other words, before we can expect to get any great benefits from the newer managerial ideas, we must readjust our ideas of the functions of the cost accountant, *who must become the servant of the operating executive as well as of the financial executive.*

36 As long as the cost accountant is simply a critic, he may be called "non-productive," but when he furnished the superintendent with prompt information which enables him to reduce costs he becomes "productive." Prompt detail information of what is being done each day, furnished in such manner as to be readily compared with what has been done, and what can be done, is the best method of measuring efficiency.

DISCUSSION

HARRY E. HARRIS (written). That which interests those who are financially responsible for an undertaking is the actual monetary return for the amount invested. This cannot be measured by any arbitrary rule of accounting or by a comparison of the earnings of the wage worker, nor can it be judged by the individual costs of separate operations without a due consideration of all overhead or non-productive factors entering into such cost, as it is possible to sh by cost records a very high increase of efficiency and still oper under an increasing loss.

Efficiency, taken in the sense of manufacturing at a low dir labor cost, is not always synonymous with economy and therefore is always expedient.

In almost every, if not all, manufacturing establishments there many opportunities for reaping a much greater return by inve ment made in improvement.

However, what the manufacturer needs is not a radical overthr of existing conditions under the ineffectual supervision of an inco petent or the fanatical enthusiasm of an extremist, but a careful lection of such conditions as may be changed to bring in a bet return, and the avoidance of change in those conditions, whi may be technically inefficient, but whose alteration would net no pro

Systems, methods, cost records, rate plans, etc., have no val except where they result in increased profit or quality.

Therefore, in the writer's opinion, as day-to-day costs cannot ta in all variables of increased equipment, non-productive labor, etc., better method of measuring the value of efficiency is periodically take the total productive costs, i.e., the direct, and indirect lab plus salary expense, material, a portion of the cost of new equipme etc., together with the total sales value of the articles produced duri the same period, and compare their ratio with similar ratios taken previous periods.

The engineer in charge of such work in his planning for increas efficiency, through new methods or equipment, should always carefu estimate and balance the cost of inaugurating the change against t saving to be effected and except where the methods in general already in a pretty efficient state, should pass to some more profital item, unless his projected improvements will be paid for by the savi in one year or less.

Admitting that day-to-day cost returns are valuable for referer to the managing engineer, does not their cost increase with th accuracy; and if the desired results from careful planning are ensu by the setting of proper piece rates and regulations for their enfor ment, cannot the energies of the engineer be left free, for furtl constructive work, instead of analyzing yesterday's returns and ot past history? It may thus become possible to reduce the cost partment, and employ its time more advantageously in the special i vestigation of such matters as the engineer may direct to assist him in working out future economies rather than to compile routine data to fill a filing cabinet.

FRED J. MILLER (written). The percentage of operating expense is of itself of no importance whatever; a low percentage of operating expense may mean a high total cost of product, or a high percentage of operating expense may mean a low total cost of product. Under good management conditions it is safe to say that almost any increase of operating expense results in decreased total cost.

For example, in a department of a factory in which the work is mostly done by hand with elementary low-cost fixtures or tools, labor costs will be high and operating expense or overhead charges low. Suppose that automatic machines are devised for doing this work and that almost no human agency is required for their operation. Under such conditions the percentage of operating expense might rise from say 20 to over 1000 per cent if based upon labor cost, yet under the second condition total cost would presumably be lower.

The only explanation for the persistence of the superstitious attitude maintained by many toward operating expense is that cost systems were at first, and are still, largely devised by accountants who know nothing, or next to nothing, of manufacturing operations and who simply imagine that if the percentage of so-called non-productive labor, or of the operating expense, is high, it is something that ought to be immediately looked after; whereas, those who know something about manufacturing are aware that it is the direct labor cost that needs looking after more than any other and that the only really important figures regarding costs are those which show the total per unit of product.

Where the proprietor of a factory commenced life as an accountant, he usually finds it difficult to overcome his earlier ideas on these matters, no matter how well he may become acquainted subsequently with manufacturing operations and with the real significance of figures pertaining to them.

It cannot be too often insisted upon that the term non-productive labor is a misnomer, and that there is no such thing in a well-organized and well-managed industrial establishment. The work of clerks, draftsmen, pattern makers, tool makers, and others whose immediate product is not sold in the market is usually productive labor in the highest sense.

Engineers ought so far as possible to refrain from using the term non-productive labor and to use their influence against its use by others.

H. K. HATHAWAY (written). Increased efficiency is apparent only in isolated cases. Even in such cases the benefits to society are greatly offset by periods of business depression, which while not reducing the efficiency of those workmen who retain their jobs, do very decidedly reduce the efficiency of the industrial organization as a whole. The promotion of efficiency is not alone sufficient to solve our industrial problems. A way must be found to provide continuity of employment.

There is one point which should be covered in greater detail, i.e., that, under scientific management, the ratio between direct and indirect labor is increased not only as a result of lowering the amount of direct labor through the elimination of waste effort, but by transfering to others many of the things which the workman formerly did himself, as, for example, the grinding of tools, fixing belts, planning the work, etc. This work is just as productive as if done by each machinist himself, although it is difficult to charge it directly to the various jobs to which it applies. Those who attach such great importance to the ratio of indirect to direct expense should consider that the more inefficiently those whom they class as producers do their work, the lower will be their ratio. The only satisfactory means for measuring efficiency is a comparison of work done with a task set, based on standardization conditions and accurate time study. Such comparison should be made as soon as each task is completed so that any conditions that lower efficiency may be corrected without delay.

The author points out that it has always been the prerogative of those in financial control to criticize those operating the factory without assuming any responsibility for showing how to improve conditions. This is not entirely undesirable as in an indirect way it stimulates the factory management to improve conditions. However, ignorance of the problems of production often results in injustice.

H. H. SUPLEE. Efficiency is frequently determined from the wrong end, that is, after operations have been conducted, instead of with some reasonable degree of truth beforehand. There is a method employed by a manufacturer of clothing in New York which may have some bearing on the subject. He made what he called "pants," and his method of reasoning was as follows: "I can sell these for $2.50 a pair. If I cannot sell them for that, I cannot sell them at all. I must make 50 cents profit on each garment, or I do not want to make them at all." He took out his profit first. That left $2 a pair for manufacture. Then he figured how many pairs an operator could make in a day, and how much wages he would have to pay the operator at the union rate. He figured his overhead charges, rent, clerk hire, etc., and after deducting all his expenses of this character, determined how much he had left to buy the materials, and the quality of the materials he purchased was covered by the amount at his disposal. That was his cost system. It was crude, but if the principle was followed by many who go into various businesses it would produce good results.

W. A. Polakov (written). The quintessence of the shortest paper presented at this session, but on the biggest question, is the statement that the most valuable function of the management is not finding costs, but furnishing the superintendent with information which helps him to reduce costs. Information furnished by accountants is like that which tells us why a patient has died. What is needed is a diagnosis from which the management can learn before everything is over, what, when and how the work shall be done, and therefore how much it will cost.

It was my good fortune to work for and with the author, and applying his principles to my own business of managing central stations, I have invariably found that an unprecedented increase of efficiency and reduction of costs is possible, if the operating force is supplemented by a body of "non-producers" constituting a planning department, whose office is to teach the producers what, when and how to do.

F. A. Waldron (written). The stand Mr. Gantt has taken on the expression, "ratio of non-productive to productive labor" and its interpretation as a measure of efficiency, is particularly gratifying as it is an admission that the interpretation rather than the expression is due to the lack of training of the men higher up. This has been my own experience in the last seven years during which I have been brought into close contact with the entire corporate organization of a number of different companies, from simple shop operations to the closing of books for annual statements.

At the time this phrase was coined, it meant something, as very few plants in that age and time were worked regularly up to their capacity. We were fortunate if enough business could be obtained to keep half the number of employees that the plant was capable of accommodating employed on full time the year around.

Then, corporate charges, plant charges, depreciation, salaries, etc., were not as large as they now are and the amount of non-productive labor represented much more than it does at the present time. Not only this, competition was not as keen in many lines of labor. While the rate per unit might be a little more than at the present time, the reduction in special work and the conditions that there were not so many complicated tools or draftsmen required, also that the work instead of being functionalized as it is at the present day was centered in and around one or two men who could turn to and make sketches and get ideas that were carried out by the so-called producer and non-producer prevailed. Then again, when the statistics were placed before the man at the top, he knew how to interpret and use this ratio of productive to non-productive labor in a way which resulted in real benefit. Now it means less and cannot be used even as a comparison as no two plants have the same classifications.

Twenty-five years ago the physician cured diseases but their cause was to a certain extent unknown and ignored. The discovery of these causes by the surgeon and bacteriologist and the application of the knife or antitoxin have done more to conserve life and health than any other discovery of modern science.

All treatises, including the masterpiece on Scientific Management by Dr. Taylor, suggest the means of curing by certain remedies. None, however, have gone into the cause of the conditions which demand such drastic treatment. With this in view, I have attempted to analyze what, in my judgment, is the cause of the present condition, covering the observation and experience of 37 years. They are as follows:

1. Individual selfishness and self-preservation.
2. Uncontrolled enthusiasm.
3. Poor judgment.
4. Careful consideration of the question of fact is ignored.

If the individual can be schooled and trained in the obtaining, by analysis and elimination, of the cold commercial facts and apply his judgment in the segregation of these facts with a controlled and well-directed enthusiasm and the application of a broad gage judgment and practical plan of self-preservation, his success is assured.

The cause of troubles that demand efficiency engineering at the present time is that many of the industries have had in view the instantaneous or immediate profits rather than the building of an economically operated plant and the turning out of a well made and well designed product.

Another important cause of the condition are the so-called progressive and up-to-date ideas, conceived by industrial owners, which they obtain from reading from this book or that magazine how to organize a factory, when in reality it is not the factory alone that needs reorganizing but their own mentality and judgment.

As to the phrase, "ratio of productive to non-productive labor," I believe I am right in saying that this was not coined by an accountant but by an engineer, a past-president of this Society, and the first time that the writer remembers hearing it used was in 1887. Probably Henry R. Towne is more largely responsible for progressive methods of shop accounting and analysis that are in vogue today than any other man in this country; his accounts were analyzed from the engineers' and not the accountants' standpoint and so carried through the entire organization and there is hardly a set of books or a factory today that has not the ear-marks of Mr. Towne's original work in this direction.

Today this expression holds just as much as it then did if rightly and properly interpreted in its relation to other shop expenses. In fact, it is just this ratio that influences and enables engineers to make real progress in the industrial world. If we interpret this expression as it should be interpreted and bring it to a point where, instead of standing alone, it is taken in conjunction with other figures, we find that where plants are running under certain conditions, it is a very good guide or barometer for the analyst or accountant as a straightforward and simple interpretation by those who have a broad view of the entire situation.

The Author. From the comments that this paper has brought out, I feel that it has served its purpose; for it has been made clear that engineers who have given real thought to this subject are in substantial accord, and are opposed to the theories to which the average accountant is so strongly wedded.

No. 1445

STANDARDIZATION IN THE FACTORY

By Carl Bennett Auel, East Pittsburgh, Pa.

Member of the Society

The subject of this paper covers so broad a field as to preclude its being handled within the confines of a single discussion, in any but the most fragmentary manner. Accordingly, in what follows, which is a brief outline of a few of the ways and means employed by a large electrical establishment in their work of standardization, no reference will be made to the standardization of the company's products. Rather will attention be directed to a description of certain methods and processes which it is hoped may prove of interest to manufacturers in general, regardless of their particular wares.

DRAWINGS

2 In the early days of this company, it was the custom to make all drawings for apparatus as complete and self-contained as possible. Opposite each item a note was placed specifying the material required to manufacture it. When drawings for new apparatus were made and any of the old parts could be used, these parts were shown again on the new drawings in complete detail so that the workmen would not have to refer to any other drawing. Such a system was admirable from the standpoint of the workmen; but, it is obvious that errors could be and were committed in transfering old parts to new drawings, and considerable time was required for such reproduction; furthermore, variations occurred in the copying process due either to the ideas of the individual designers or to the fact that they were unable to locate drawings showing the old parts.

3 With the development of the electrical art, this method of making drawings was found to involve more and more a duplication of drafting and clerical work, for the reason that the newer apparatus, though differing from the older apparatus when completed, had nevertheless an increasing number of pieces or parts in common.

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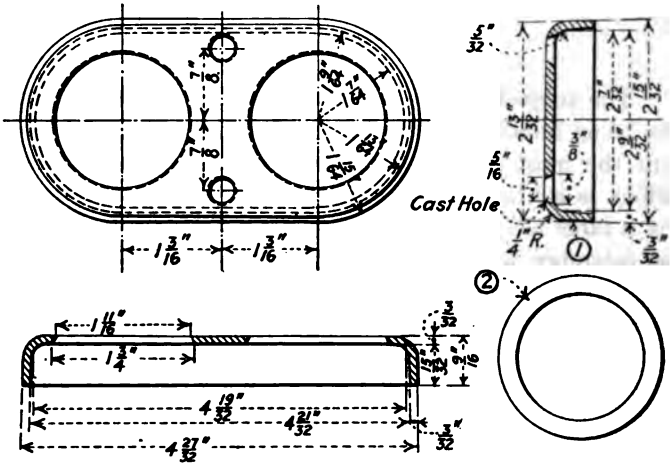
The scheme of making elemental drawings, that is, making but one piece on a drawing was next considered; but, while this would insure the greatest accuracy in the duplication of a piece at any time, it has the disadvantage that there are too many drawings to handle, an especially serious matter when the apparatus is at all complicated. A compromise arrangement was therefore adopted, consisting of a



Drawing No. 181577	BILL OF MATERIAL		Sub. No. 1		
Item	Description and Material	Pat No.	Req.	Dwg. No.	Tool No.
1	Flange C.I. S-No. 99665	U-8266	1		
2	Felt Washer S-No. 42053		2		

FIG. 1 MERCURY RECTIFIER OUTFIT. DOUBLE FLANGE FOR TRANSFORMER PORCELAIN BUSHING

natural grouping of pieces or parts on a single drawing. Each piece is assigned an item number and a list of the material involved is located conveniently on the drawing arranged numerically according to item numbers, as shown on Fig. 1. In the absence of recognized standards, the company arbitrarily fixed upon four sizes of drawings, the smaller being subdivisions of the larger. All blueprints from these are not only made by machine but are further washed, as well as dried by machine, many being also ironed, and are issued to the works unmounted. Fig. 2 shows a standard drawing of a line of wing nuts, arranged, however, in such manner that the various items may be cut into cards and issued to the workmen who can attach them to the belt-shifters of their machines while working. It might be suggested that a simpler form of drawing would consist of one picture only, each part being lettered, a statement immediately below containing the differing dimensions of each size of nut. While this is true, experience shows that with tabulated data of this kind, there is a decided tendency for the workmen to misread dimensions, taking perhaps one of them from the line immediately above or below the proper line. As would be expected a very complete reference index is maintained, so that the danger of duplicating items is reduced to a minimum.

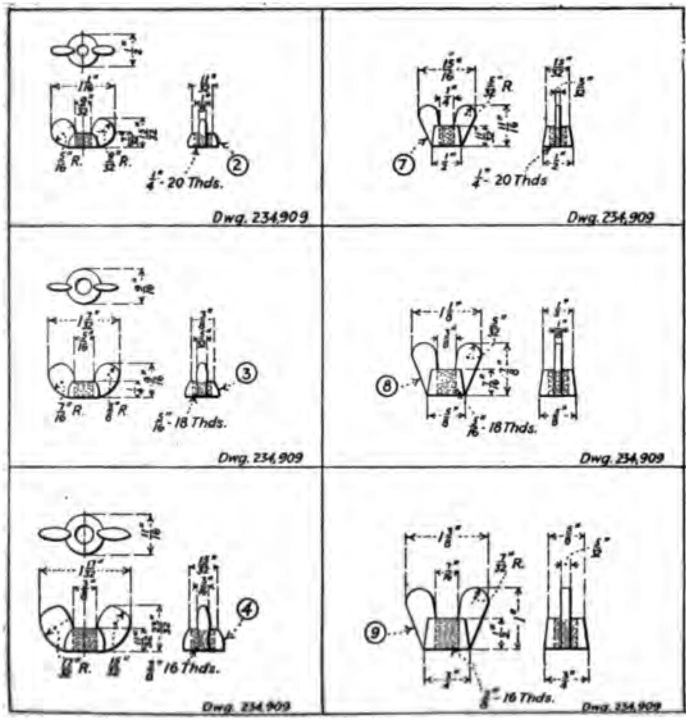
MANUFACTURING INFORMATION

4 All apparatus and parts are built to so-called manufacturing information. This consists of a specification setting forth the drawings to be worked to, with a list of the various kinds and amounts of material required. Copies of such portions of these specifications and drawings as pertain are issued to all departments having work to do in connection with an order, which specifications are closed when the order is completed. Exceptions are, however, made to this general procedure, for all apparatus or parts which have been standardized and the orders for which are, therefore, likely to be repeated. In such latter cases, the specification is issued to the manufacturing departments in permanent form but for a single unit only, to which is assigned a style or catalogue number. By this arrangement when standard apparatus or parts are wanted, orders may at once be forwarded to the works, simply by reference to the style number and without being sent to the engineering or drafting departments for information, thus avoiding a useless burdening of these departments as well as saving considerable time in the ordering of the material and the commencing of work.

SPECIFICATIONS

5 Materials used throughout the works are arbitrarily divided into two classes, productive and expense, the former entering directly into the manufacture of the company's products, the latter but indirectly; as examples of each may be mentioned axle steel for armature shafts and leather for machinery belting; occasionally, however, material may belong to both classes.

6 When either the quantity or the importance of the items warrant, specifications are carefully prepared for the purchasing and the inspection departments who use them in the purchase and



WING NUTS

Item	Description and Material	Style No.	Pat No.	Req.	Ref. Dwg.	Tool No.
2	Wing Nut, Pressed St. M 2194	197938		1		
3	" " " " "	197939		1		
4	" " " " "	197940		1		
5	" " " " "	197941		1		
7	Wing Nut, Alloy No. 4	197943	43868-A	1		
8	" " " "	105939	U-9156-B	1		Pr. Jaws 7435 B1
9	" " " "	197944	43867-B	1		
10	" " " "	197945	43866-B	1		

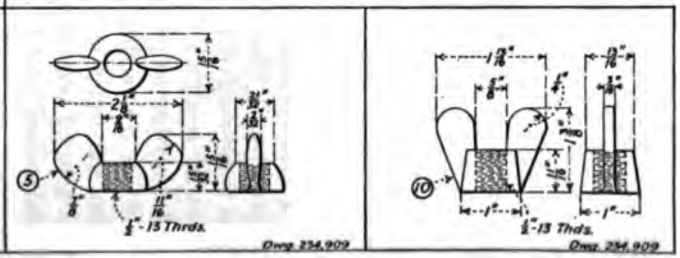


FIG. 2 SECTION OF STANDARD DRAWING OF A LINE OF WING NUTS

subsequent inspection of such materials. These specifications [uently involve a great amount of work, not only in their original [paration but in the subsequent revision of them. As a rule the [ineering departments prepare the specifications pertaining to [ductive items, while the manufacturing departments handle those [resenting expense items. A typical specification of this kind [ering cold drawn steel for automatic screw stock is shown in . 3, and it may be mentioned in passing that the general arrange[nt is in accordance with the standards of the American Society Testing Materials.

7 It will be appreciated that this work is of the very highest [portance; and similar work must be carried out faithfully by every [ustrial concern which values a reputation for uniformly high [de and consistent products. But this being admitted, it does [m as though there should long since have been taken in hand by [ne one or more of the prominent engineering societies, the prepara[n of such standard specifications, particularly for the more com[n and simple materials, which could be used throughout the [ntry by manufacturers and others, thus avoiding some of the [plication of this kind of work at present going on among many [ividual manufacturers.

8 When quotations are received, either on new materials or [m manufacturers whose goods have not previously been used, [nples are generally required. These are subjected to such tests may be deemed necessary; and if the results prove satisfactory, [e manufacturers of the materials are placed on an approved or [ndard list from which the purchasing department is free to choose [en placing orders.

SHOP PROCESSES

9 Another equally important line of work consists in the de[lopment of manufacturing processes and formulæ which, when [ndardized, are recorded in permanent form and issued to the [rious manufacturing departments involved. In this way uniform[in product is assured, there is no needless repetition of lessons or [periences previously learned, and the company is made independent any individual's knowledge. Both foremen and workmen take [ndly to the process specifications and formulæ, the former because, many cases, they helped to originate them and appreciate that [rough such media they are relieved of some of the routine re[onsibility of manufacture, the latter for the reason that they are

Westinghouse Electric & Manufacturing Company

East Pittsburgh, Pa.

Purchasing Department Specification No.

COLD DRAWN STEEL (AUTOMATIC SCREW STOCK)

1—The material desired under this specification is a free cutting steel of any specified section, suitable for high speed screw machine work, leaving a smooth finish after being machined.

I—MANUFACTURE

2—The steel shall be made by the Bessemer process. **Process**

II—CHEMICAL PROPERTIES

3—The chemical analysis shall be as follows: **Chemical Composition**

Carbon, .08% to .16%.
Manganese, .60% to .80%.
Phosphorus, about .10% not more than .13%.
Sulphur, .09% to .15%.

4—Samples for analysis shall be taken in such a way as to represent the average of a full section of one or more bars. **Test Samples**

III—DIMENSIONS

5—The variation from the specified diameter or distance between parallel faces shall not exceed the following limits: **Permissible Variations**

	Over Size	Under Size	Variation from True Section
Up to ½".......	.001"	.002"	.001"
½" to 1¼"......	.001"	.002"	.002"
1¼" to 3".......	.001"	.003"	.002"

6—Ordinarily the material will be ordered in 10 foot lengths, with allowable variations as follows:

At least 70% shall be 10 feet long, 30% may be furnished in shorter lengths, but no rod shall be less than 8 feet long.

IV—FINISH

7—All rods shall be cold drawn, so as to leave a bright, smooth surface.

8—The rods shall be free from injurious defects, such as cracks, rough surfaces, seams, etc., and shall be straight and true to section. No crop ends will be accepted. **Finish**

V—PACKING AND MARKING

9—Rods up to ⅝ inch diameter, inclusive, or other sections up to the same cross-sectional area (.307 square inch) shall be shipped in bundles weighing not more than 125 pounds each. **Packing**

VI—REJECTION

10—The Westinghouse Electric & Manufacturing Company reserves the right to reject any portion or all of the material which does not conform to the above specification in every particular, and to return the rejected material to the manufacturer or seller for full credit at price charged f.o b. point of delivery specified by the purchaser. If the material is to be replaced, a new order will be entered at prices, terms and conditions acceptable to the purchaser. **Rejection**

Approved, *, 190*
Revised, *, 191*
Revised, *, 191*

Chief Engineer.

FIG. 3 SPECIFICATION COVERING COLD-DRAWN STEEL

Westinghouse Electric & Manufacturing Company
East Pittsburgh, Pa.

'rocess Specification No. ......, 191

TREATING COILS WITH CRYSTAL INSULATING VARNISH

GENERAL

This specification covers the process to be followed in treating coils with Crystal Insulating 'arnish.

The number of Varnish Treatments required will be specified in the Insulation Specification.

PROCESS

'perations:
- Tinning
- Singeing
- Dipping Leads
- Heating
- Soaking
- Draining
- Baking
- Sanding
- Tinning

'inning:
Tin the leads as per Process Specification 50615. Tinning is to be done only previous to the rst varnish or gum treatment given to the coil.

ingeing:
Singe the coils all over to remove any fleece that would cause any roughness to the varnish oating.

'ipping Leads:
Dip the leads in plastic varnish (M No. 1781) until the cotton covering is thoroughly saturated. 'urbo coils, gum treated coils or coils that have been treated in plastic varnish previous to applying his process will not require this operation.

Ieating:
Heat the coils in an oven at a temperature of 101-107° C. (215-225° F.) for one to one and one-alf hours. This operation is to be done only previous to the first dip, and is to be omitted if the oils have had other varnish or gum treatments previous to applying this process.

oaking:
Immerse the coils in Crystal Insulating Varnish (M-2229) and soak until all bubbling ceases 10 to 30 minutes). Keep the specific gravity of the varnish at .85. When thinning is necessary. se benzine.

'raining:
Drain the coils for thirty minutes at room temperature before placing in the oven.

aking:
Bake the coils in an oven at a temperature of 101-107° C. (215-225° F.) for five to ten hours epending upon the size of coil and the number of dippings.

anding:
Sand the coil just before applying the last varnish treatment. The number of times to apply his varnish treatment will be specified in the Insulation Specification.

'inning:
Re-tin the leads after the last varnish treatment has been properly applied.

Material	Material No.
Black Plastic Varnish	M 1781
Crystal Insulating Varnish	M 2230
Benzine	P. D. Spec. 1609.

'pproved: .... Accepted: ....

Engineer Manager of Works

FIG. 4 PROCESS SPECIFICATION COVERING METHOD OF TREATING COILS WITH INSULATING VARNISH made acquainted with the best methods. These specifications an formulæ are, like the material specifications, revised from time t time as added experience, new equipment or other reasons dictat

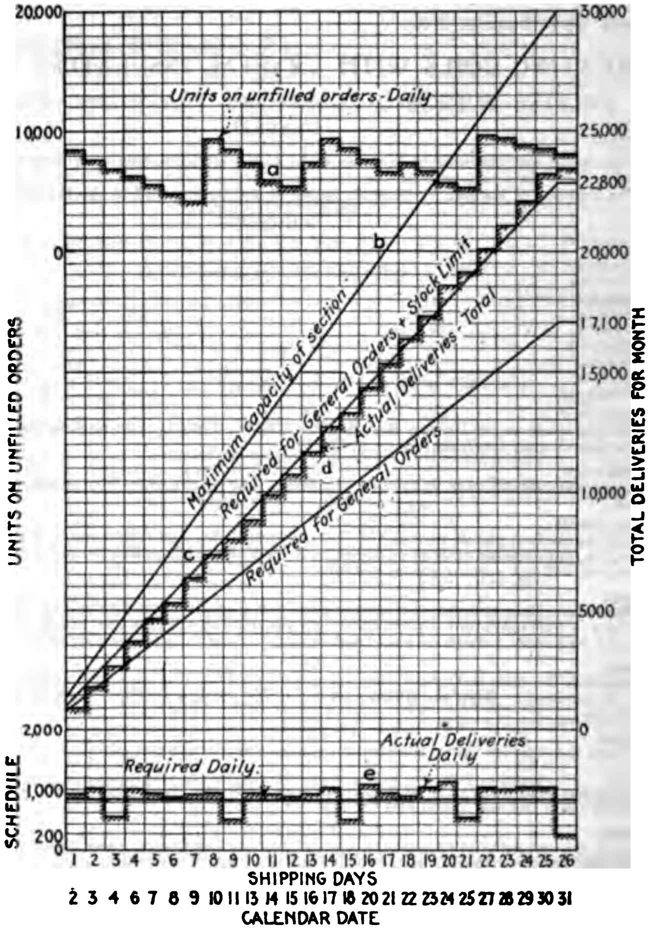


FIG. 5 LOAD DIAGRAM

and further, like them, are made use of by the inspection departme in checking the company's products during the course of manufactu Fig. 4 shows a process specification covering the method of treati coils with insulating varnish.

VISIBLE PRODUCTION CHARTS

10 Everyone who has had to do with production, has felt the ›d of a means of portraying in some simple manner the actual ›put of a department and of comparing it with past as well as with ired performance. To many shop men figures appeal more ›ibly than do curves, since they are usually more readily under- od; but it is believed those shown by Fig. 5 are so plain as to clude any objection on such score. Curve *a* is the daily total of illed orders, machines or pieces obtained by adding the number re- ved each day to the total on hand and subtracting the number pped. Curve *b* shows the maximum possible output of which the ›artment is capable in a month. Curve *c* is the desired output the same period. While these two latter are both straight lines, ›ir shape could of course, be altered, though with a loss in sim- city. Curve *d* indicates the actual output and a comparison be- een it and curve *c* tells whether the department is working up to its ›edule or falling behind. Curve *e* is that of actual daily deliveries. ›ese load diagrams, as they are called, have been standardized and › used quite generally throughout the works, though there are of urse, certain departments where their use would mean but little.

METHODS OF STANDARDIZATION

11 Owing to the obvious need for having certain standard sizes ›d kinds of materials, including wire, screws, bolts, nuts, rivets, ›tter-pins, sheet metals, finished parts and the like, the first steps . standardization naturally fell largely upon the drafting depart- ›ent. As the necessity for further standardization along such lines ›ecame apparent, the work was transferred to the engineering de- artments where the scope was very much broadened; and, in order ›at full advantage should be taken of the results of such standardiza- .on, standard books and card indexes were prepared and placed in very department where needed. As the benefits of standardization ›ere still further appreciated, a standards division of the engineering epartments and a Standards Committee were created, whose unctions are the standardization of existing materials and parts, ›ut in nowise interfering with or having to do with, the development f apparatus as such.

12 This Standards Committee has but two permanent members, chairman and a secretary. Subjects which seem suitable for tandardization either originate with the permanent members of the

FIG. 6 STANDARDIZED CUTTING TOOLS

committee or else are called to their attention by various members of the engineering or manufacturing departments. Sub-committees whose members are drawn from the engineering, manufacturing, purchasing, storekeeping and other departments, are then appointed by the permanent chairman and furnished with instructions and suggestions pertaining to the work to be undertaken. The chairmen of these several sub-committees form the temporary members of the Standards or main committee, which passes upon all reports presented by the sub-committees. As a report is accepted, the corresponding sub-committee is dissolved, its chairman at the same time ceasing to be a member of the Standards Committee.

13 The work of the Standards Committee has been varied in the extreme, such matters as punched circular washers, thumb and wing nuts, oil-hole covers and hinges, furniture, anchor holes in bearings, wood handles, sizes of tap drills, stresses in eye-bolts, thickness of babbitt in bearings, liners, trucks, etc., having been successfully handled.

CUTTING TOOLS, DIE AND JIG PARTS, ETC.

14 No one, it is believed, will dispute the arguments in favor of standardizing cutting tools. Such work means not alone increased and uniform production from machines of the same class, but it means also that savings are effected in the making of the cutting tools themselves and in the kinds and amounts of raw materials from which they are made. Fig. 6 shows the cutting tools that have been thus standardized.

15 There may, however, be some scepticism as to the feasibility of attempting the standardization of die and jig parts, etc., but the extent to which this can be carried, without overdoing it, will prove upon investigation, especially in a large shop, to be rather surprising. Fig. 7 is simply indicative of a few of the many items used in large quantities, and which have been found to lend themselves admirably to standardization. Among them may be noted dies and die shoes, punches and punch holders, punch and stripper plates, jig boxes and bushings, drill press chucks and shanks, etc. For shaft grinding machines, wheels are now purchased for the largest size and used with them until the diameter is reduced to a certain predetermined figure, when they are returned to the storerooms to be issued in due course, for use with the next smaller size of shaft grinder and so on. On milling machines, mandrels and collets have been standardized, and on lathes effort is now being put forth to standardize the spindles

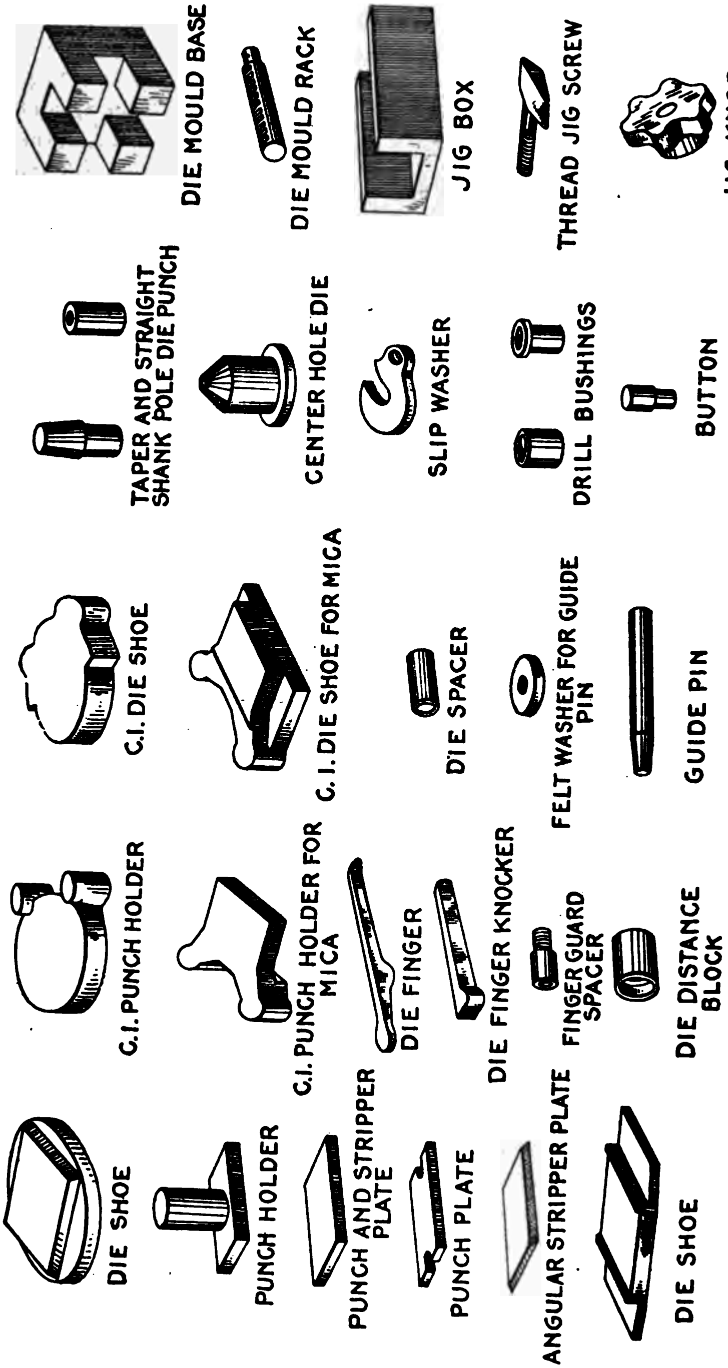


Fig. 7 Similarity of Parts, Showing Feasibility of Standardization

with respect to the diameters and the number of threads per inch so that chucks may be used interchangeably. Much more might be said along similar lines but enough examples have been given to indicate that standardization is possible, to some extent at least, in what would be considered at first glance as a very infertile field.

ALLOWABLE VARIATIONS FROM DRAWING DIMENSIONS FOR STANDARD PARTS

16 Endeavor has been made, and with considerable success, in connection with certain classes of apparatus, to place on working drawings the allowable variations from drawing dimensions for standard parts. In most manufacturing establishments, it will be found that working drawings call for single dimensions only, and, as it is impossible to work to mathematically exact measurements, permissible variations are largely a matter of judgment on the part of the foremen, inspectors and workmen. As a result, it is obvious that work may at times be accepted which should be rejected and vice versa. Again, when uncertainty exists as to the advisability of passing material that varies from drawing dimensions, conferences of those interested are called to determine the question and as records are not usually made of the decisions reached, the same ground is liable to be covered again and again. This is especially true when changes occur in the personnel. Furthermore, with definite information as to the permissible variations from exact dimensions, both workmen and inspectors can work to better advantage in every way, there being no doubt as to what is wanted in the matter of accuracy. Such reasons as these were deemed sufficiently important to warrant the placing of limiting dimensions on drawings for standard parts.

17 The method which has been adopted consists in placing the nominal dimensions first, followed by the limiting dimensions in brackets: thus $4\frac{1}{4}''\left\{\begin{matrix}4.251''\\4.248''\end{matrix}\right\}$. There has, however, been a certain preference expressed for a slightly different method, namely $4\frac{1}{4}''\left\{\begin{matrix}''+0.001\\''-0.002\end{matrix}\right\}$, but the objection to this method is that whoever uses these dimensions must add or subtract the allowance each time same are used.

18 At present it is the custom to specify drawing dimensions in feet and inches, but the advisability of changing to inches only has been under discussion for some time. Among the arguments in

favor of such a change are: Increased accuracy in actual manufacturing, since there would be no translating from feet to inches; the dimensioning of drawings would be simplified especially if the designating mark for inches (") were omitted; it is already the custom to specify inches for some kinds of sheet material, as for example 24" by 96"; storeroom accounts for certain items would be rather more easily reckoned; there would be less danger in making mistakes when ordering many items, especially where the quantities were small. However, the fact that no decision has yet been reached shows there are adverse arguments to be considered as well.

ALLOWANCES FOR EXPENSE MATERIALS

19 The monthly consumption of various expense materials, such as oils, greases, waste, incandescent lamps, janitor's supplies, etc., has been estimated for the individual manufacturing departments, based on normal production. From these investigations, allowances have been set on each item and a department is permitted to draw from the storerooms on requisitions up to its allowance. Anything in excess must first receive the approval of the superintendent of the department. Of course, when production rises or falls abnormally, the allowances are changed accordingly. The main idea in a scheme of this kind is to aid the superintendent of the department in keeping down expense items by calling his attention to such as are overrun, thus affording him an opportunity to investigate the matter either at or close to the time of its occurrence, rather than at a remoter period when the details are no longer remembered by those concerned.

HANDLING MATERIALS

20 Considerable attention is being given to the economical handling of the smaller materials; and while the problem is one whose complete solution is still far removed, nevertheless certain gains have been made over previously existing methods, a few of which may be worth enumerating. Much of the very small material is packed preparatory to transportation, in misprint cloth bags which can be purchased at very low figures and used many times. These have the advantage over wrapping paper or paper bags in that they do not tear readily when the material is oily, as is usually the case. Larger material is placed directly in tote boxes, either with or without wheels; and, while originally of wood these are now being made of metal, those without wheels being telescopic for economical stacking.

For transporting, besides the standard gage steam and narrow gage electric storage battery cars, three forms of trucks are used, hand, platform-lifting and electric storage. Before installing the electric storage trucks, careful tests were made to determine the possible saving over hand trucks, the result being that a single electric storage truck with a crew of two men was found equivalent to two hand trucks with a total of four to five men. Expressed somewhat differently, the electric storage trucks returned a handsome profit by the end of the second year. One of the marked indirect gains made by the use of these trucks was in the receiving or unloading department, where the ability to remove material almost as fast as unloaded from incoming freight cars, eliminated from consideration the necessity of providing additional floor space for a department that with only hand truck facilities had become badly congested.

21 A very complete central storage warehouse for oils has recently been erected. From it radiate to the various manufacturing buildings supply pipes, several of which are approximately one-quarter mile in length. By means of a system of remote electrical control, an operator standing at the delivery end of one of these pipes, can start an electrically driven pump in the central storage warehouse and cause to flow a supply of oil of any amount desired. The operator being stationed at his post during certain hours of each day, it is an easy matter for any manufacturing department to send to him for whatever may be required, thus making a short haul out of what would otherwise be a long one. A further improvement will be made in this scheme, however, by having one or more electric storage trucks fitted with oil tanks which will be filled from time to time at these supply stations. These trucks will then cover certain routes, delivering oils to the various manufacturing departments direct. It is at once obvious that a still further amplification of the scheme will be the delivering of material from storerooms to departments and between departments.

22 For the handling of shop mail, a central post office has been established with pneumatic tubes running to substations in all of the principal departments. From these points, girls in turn carry the mail matter to the individual foremen's desks.

SAFETY METHODS

23 While it would be overstating the case to say that work along the lines of safety has been standardized, nevertheless, certain well-defined steps have been taken with the object of a systematic handling

of it. In commencing this work originally and on a routine basis, it was properly assumed that certain precautions or safeguards had been omitted. All tools or equipment were therefore, arbitrarily divided into three classes: (1) those which were dangerous in the extreme; (2) those in which there was liability of injury though slight in character; (3) those in which the liability of injury was so very remote as to be negligible. A supervisor of safety appliances was appointed to take direct charge of this work and a monthly appropriation issued to cover the cost involved. Further, a ruling was made that no new tools should be erected nor any old tools replaced without adequate safeguards being provided; and, purchasing specifications for new tools were made to state that preference would be accorded to properly guarded tools. With such arrangements effectively in force, it is obvious that dangerous tools or equipment must gradually be eliminated; and, to such an extent has this now been carried that an analysis of the accidents for the past year shows but three-tenths of one per cent to have been caused by the absence of safeguards. In this connection, it is of importance to note that this same analysis also shows that by far the largest percentage, namely, 21½ per cent, were due to the carelessness of the injured themselves, so it means a campaign of education must be undertaken. This is being accomplished in several ways, as for example through the medium of small yet striking Safety First metal plates which have been placed in a prominent position on every machine —usually the ram, in the punch shop. Signs bearing this and similar legends have been recently standardized by several national societies, among them Founders, Manufacturers, Metal Trades, and Electric Light, and these have been adopted by us for use at suitable locations throughout the works. First-aid kits and a method of resuscitation have also been adopted and lectures on the application of both are given to such employees as are at all likely to be called upon to make use of this knowledge, each one being put through the actual movements involved. These lectures are repeated to the same individuals at intervals of six months, so that the subject matter will not be forgotten.

INACTIVE MATERIALS

24 All stock ledgers are regularly scrutinized by the storekeeping department and such items as are considered slow-moving or inactive submitted to a materials disposition department that investigates not only the cause of the inactivity with a view to preventing a re-

rence but at the same time endeavors to dispose of the material the best advantage. Quarterly "clean-up" inventories have also n instituted throughout the works, at which times all partially npleted materials which have become inactive due either to canlation, hold, reduction or change in design of orders, are investied by this same department with a view to their quickest and most vantageous disposal.

CONCLUSION

25 It has been truly said with respect to the electrical and mechanl industries that the only thing constant is change. It is well to ar this fact in mind when carrying on the work of standardization. op standards, regardless of their name, should be considered as ative, not absolute, and should therefore admit of a certain degree flexibility, being capable of revision from time to time. Further, attempt should in general be made to make them retroactive but ther should they apply to new work only. In this way opposition the part of those whose work will be affected will be minimized d a greater degree of coöperation secured.

DISCUSSION

H. B. Lange (written). The broad scope of the field of standardation in works operation and its far-reaching effects will be more early recognized when it is noted that in many works organizations ere are engineers whose sole functions are to further this condition, t only with respect to design of parts but also with individual maine operations, routine functions, etc.

The general trend of the paper would indicate that the examples ven are in repetition work. Coming to the drawing arrangements, should be that these are in conformity with, and express the unrlying principles of manufacture that are being followed in any ven case, especially in so far as work on parts is concerned. For petitive work it has often been demonstrated that production can accomplished at minimum cost by dealing with parts production dividually without reference to final assembly. This assumed the orking to prescribed limits of allowable variations in dimensions to sure interchangeability. Where this is so, the most convenient awing arrangement is for the drawing of one part on a single awing. The size of such a single drawing may be most conveniently ken as $8\frac{1}{2}$ in. $\times$ $11\frac{1}{2}$ in. in order to conform to standard letter size paper for filing with correspondence, etc. In the drafting room, however, the master drawing sheets will consist of, say, two horizontal rows of four drawings each with a bottom margin for title, etc. Then for use in the shops, individual part drawings would be available for the production operations between raw material and assembly without reference to any other part and it will be seen that in this way there can be no confusion to the machine operator, as he only has before him the necessary instructions for the particular part in process. If it is admitted that the true function of a detail drawing is for the purpose of ascertaining dimensions only, it should be, then, that the drawing number, part number, material symbol and brief title should alone appear, together with the usual dimensions. Assembly information is then embodied in a part list and an arrangement drawing. This method of drawing of parts, in addition to providing for low cost production methods, is also of great value as an agency for furthering standardization. Prints are taken off each detail drawing and are filed under the heading under which they may be included, such as bearing boxes, pulleys, hangers, levers, brackets, saddles, yokes, stuffing boxes, glands, etc. When new product is designed reference to such a file will facilitate the selection of parts already in use where otherwise a new part might be adopted. Such a collection under any classification will also be of great aid to the engineer dealing with standardization by revealing the existence of a number of parts of like character but differing only slightly in essential dimensions and which might be consolidated into one part for standard adaptation.

The question of expense for this arrangement lies almost entirely in drawing materials and becomes in many cases negligible when compared to the benefits that accrue. In the shops these part drawings can be mounted on straw board, about 3/32 in. thick, shellaced on one side and filed in the tool crib, or time keeper's booth or some other place where the workmen would necessarily go before commencing work on a job. The increased filing space so required is more than compensated for by the saving in prints as their life is greatly increased and replacement copies are called for less frequently than when prints are unmounted.

A great aid to standardization of design is in the use of letter dimension sheets of certain classes of parts, the arrangement being alluded to in the paper as "... one picture only, each part being lettered, a statement immediately below containing the differing dimensions . . ." Such sheets should be prepared at least for purchased which are dealt with in assembly operations only or treated ly as merchandize. Such items as hardware, pipe fittings, valves, les, washers, keys, pins, etc., lend themselves particularly to this ngement. These sheets should contain only those sizes which are used in connection with product, and designers by reference to will avoid adoption of new sizes. This is important. A col-on of these sheets suitably bound forms a private catalogue of a proportion of parts dealt with and, by their distribution to stores stock, purchasing, designing, production, and certain other de-ments, they afford a simple and condensed means of imparting ntial information.

ndeed the value of the letter dimension scheme is so great in ain cases that the advisability of extending it to parts made in the s should be considered. Whilst it is necessary to assure that in-nation should be "foolproof" yet provision may often be made to inate the likelihood of misreading dimensions by referring to the above or the one below that to which reference should be made.

L. D. Burlingame said that the paper illustrated the transition n the old-time method when the man in charge knew every part could fit all parts to make a completed unit, to the new method naking parts, in widely separated departments, from a carefully pared drawing with sufficient information thereon so that when mbled the final unit will come together satisfactorily. It brings further, the present time method of manufacturing parts in e quantities at one time and having them available when needed.

The question is raised as to which of the two methods of figuring wings is the more satisfactory. The gage system, where the gages neasuring instruments are marked in decimals, corresponding to first method suggested by the author, should be used in figuring n drawings. Where the ordinary measuring instruments are used the work is done without gages, the second method of figuring nches is in the writer's belief the correct one. Neither of the two hods should be adopted to the exclusion of the other.

Due to the simplification in always figuring in inches, it has been gested that the use of inch marks can be dispensed with and this been done in large factories for many years and has simplified work and saved time.

We should be able to adapt our drawing rooms to modern methods conditions rather than hang on to the old methods simply be-se they suited the needs in the past.

THE AUTHOR. In closing I desire to point out, as typified both by the paper and the discussion, that individual manufacturers are being compelled to develop many standards of their own, because there is as yet no official clearing house to which they can apply for the data they require.

It is of course recognized that certain of such standards would in any event be of interest only to the individual manufacturer, but there is, nevertheless, a great deal of this work that would prove of general advantage and would, furthermore, be willingly exchanged by manufacturers, did they but know one another's wants.

Every one of the large engineering societies has already done some good work along this line, yet, compared with what can be done, the surface has been but slightly scratched, and the author desires to express the hope that this Society will, in connection with others, endeavor to advance the work of standardization, if necessary by the appointment of one or more national committees on the subject.

No. 1446

OPERATION OF GRINDING WHEELS IN MACHINE GRINDING

By Geo. I. Alden, Worcester, Mass.

Member of the Society

Long experience in the use of grinding wheels has developed d established facts regarding the action of such wheels when used modern grinding machines. These facts, however, have been ated only as empirical rules. Such rules are easily forgotten or nfused by operators because they are not related in any obvious ay to any known principles by which results may be predicted. or example, what is the effect upon a wheel of increasing the speed work, or of increasing the diameter of the work, or of diminishing e diameter of the wheel? The following analysis of the action of e grinding wheel when operating upon cylindrical or plane surface ork, reveals a principle which leads at once to the answers to estions like the above. In all cases the term "speed," whether ferring to work or to wheel, means peripheral speed.

2 In Fig. 1, let

C = the center of the wheel and

c = the center of the work

he arrows indicate the direction of motion of wheel and work spectively.

OP = the radial depth of cut, and

OQ = the arc of contact of wheel and work

3 Each of these dimensions is much exaggerated in the figure, e real dimensions in actual work being exceedingly small. Assume r a moment that there is but one abrasive grain or cutting point the surface of the wheel, and that this one grain is at O. On ccount of the revolution of the wheel, the point O will move to Q a certain time, but on account of the revolution of the work, the oint Q on the work will move toward P to the point W. As the

Presented at the Annual Meeting, December 1914, of The American Society of Mechanical Engineers.

speed of the work is usually very much less than the speed of the wheel, this distance *QW* will be much less than *OQ*. The cutting point will remove from the work a chip represented by *OQW*. From the outline or shape of the chip it appears at once that when the cutting point begins to act at *O*, its depth of cut is nothing, but that the depth of cut of the grain increases gradually to its maximum

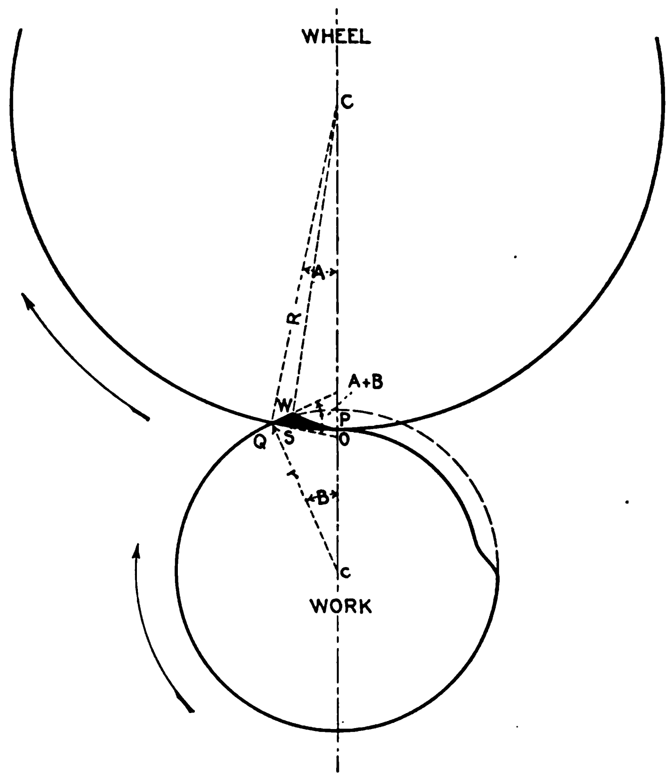


Fig. 1 Action of Grinding Wheel when Operating upon Cylindrical Work

WS. As the abrasive grain in a grinding wheel is set or fixed in the bond of the wheel, it is clear that the deeper the grain cuts into the work, the more the bond will be disturbed, or worn away. I have called the distance *WS* the maximum grain depth of cut, or, for brevity, the grain depth of cut. Of course, there are actually a number of cutting particles between *O* and *Q*, but each acts in the same manner as the single grain we have considered. The grain depth of cut of each particle, however, will be the distance *WS* divided by, the number of cutting grains or particles in action at once, or the number between O and Q. When a grinding wheel is working properly, we may consider the abrasive grain in the wheel as cutting small chips from the work, and the surface of the work as cutting or wearing away the bond of the wheel. Now, it is quite evident that the greater the grain depth of cut, the more effective

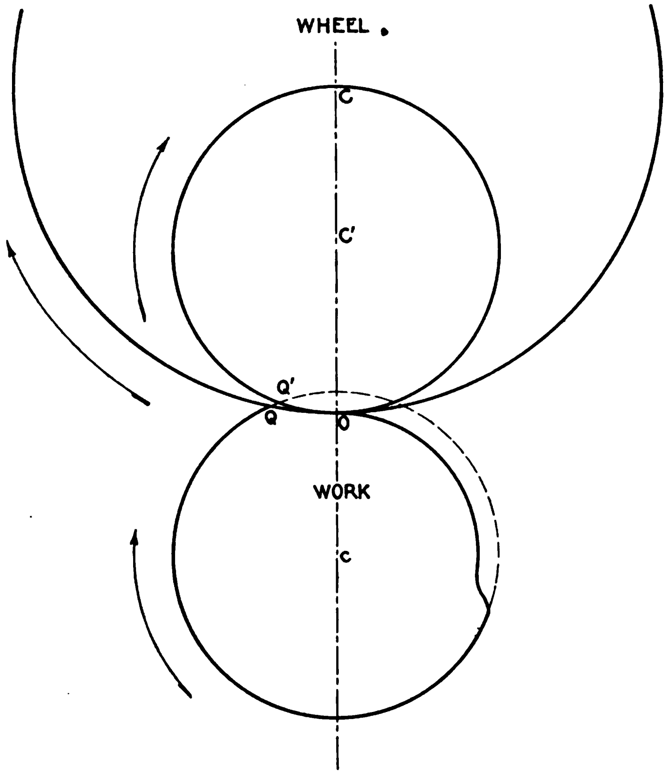


FIG. 2 EFFECT OF CHANGES IN DIAMETER OF WHEEL OR WORK

will be the action of the work upon the bond of the wheel. So long as the bond is being worn away just as fast as the abrasive grains of the wheel are being worn down, the wheel will continue to work well. If the bond is cut away too rapidly, the wheel will appear too soft, and will wear away too rapidly. If the cutting grains wear down faster than the bond is cut or worn away, the face of the wheel will become glossy, and the wheel will not cut freely. These considerations lead directly to the conclusion that the action of a given wheel on a given kind of work is almost entirely dependent upon the grain depth of cut. If the grain depth is too great, the wheel wears away too rapidly. If the grain depth is too small, the wheel may glaze. It is therefore important to know how the grain depth of cut may be regulated.

4 Referring again to Fig. 1, it appears that WS will increase if QW increases and vice versa; but QW depends upon the speed of the work. Therefore if the speed of the wheel remains constant, and the speed of the work increases, WS will increase. The correct working of the wheel therefore depends upon the relation of QW to OQ, or upon the relation of work speed to wheel speed. If the wheel speed and all other conditions except work speed remain constant, the grain depth will increase as the work speed increases, and diminish as the work speed diminishes. Also the work speed and all other conditions except wheel speed remaining constant, the grain depth of cut will increase as the wheel speed diminishes and vice versa.

EFFECT OF CHANGES IN DIAMETER OF WHEEL OR WORK

5 In Fig. 2, let

C = the center of a grinding wheel
C' = center of a smaller grinding wheel
c = the center of the work

6 Suppose the wheel whose center is at C to have worn down until its center is at C', the work diameter remaining the same. Let the radial depth and work speed also remain constant. This insures the same rate of production in each case. Let the wheel speed also be the same in each case. It will be seen from Fig. 2 that the smaller wheel will have a shorter arc of contact with the work than has the larger wheel, or that OQ' is less than OQ. Since the wheel speed in both cases is assumed to be the same, the number of chips cut from the work each minute will be the same; but as the chips cut by the smaller wheel are shorter, and as the volume of all the chips cut each minute is the same, it follows that the thickness of the chips cut by the smaller wheel is greater than the thickness of the chips cut by the larger wheel. In other words, the grain depth of cut increases as the wheel diameter diminishes. Therefore the bond should wear away faster as the wheel gets smaller, and the smaller wheel should appear softer.

7 In many cases as the wheel wears down, the speed of the wheel is allowed to diminish, and when this is the case the grain depth of cut will be increased on account of the diminished wheel speed,

as well as because of the smaller wheel. Following the same line of reasoning as above it is easily shown that if the work diameter is increased (all other factors remaining the same) a longer chip will be cut from the work, and as the number and volume of chips remain constant for each unit of time, the thickness of the chips must diminish, or the grain depth must be less. Therefore a wheel, other conditions being the same, should appear harder as the diameter of the work increases. A proper increase of work speed on the larger work will bring up the grain depth of cut to what it was on the smaller work.

8 Summarizing these conclusions, to which we are led by purely theoretical considerations, we can say:

a Other factors remaining constant, increase of work speed increases grain depth of cut, and makes a wheel appear softer

b Similarly, a decrease of wheel speed increases grain depth of cut

c Similarly, diminishing the diameter of the grinding wheel increases grain depth of cut, and increasing the diameter of the wheel decreases grain depth of cut

d Similarly, making the diameter of work smaller increases grain depth of cut. Conversely, making the diameter of work larger makes grain depth of cut smaller

9 In the above analysis no account has been taken of certain factors that no doubt modify to a degree the results arrived at. For example, chips cut from the work by the abrasive particles of the grinding wheel are not entirely free to escape. Referring to Fig. 1, the arc *OQ* will, in practice, contain several cutting points, so that several chips are in the process of being cut off at once. Before these chips all escape, some of them may be forced into spaces between the cutting particles in the face of the wheel, causing the wheel to "load." This loading may at times be such as greatly to reduce or even practically to destroy the cutting quality of the wheel. Even though the wheel does not "load," the presence of loose chips of metal between the wheel and the work may impair the cutting action of the wheel or the quality of the ground surface produced; but the statements *a–d* inclusive are recommended as giving correct relative results.

10 In applying the principle that grain depth of cut is the main factor in all the phenomena of a good grinding wheel, it must be remembered that the correct relative speeds of work and of wheel

must be found by trial for each wheel and each kind of work. When this has been done, the principle of grain depth of cut will enable one to know the direction in which to make the changes of work speed or wheel speed, to adapt the wheel to changes in its own diameter, or to other sizes of the same kind of work.

FINISHING

11 Thus far it has been assumed that the object of grinding is to remove stock rapidly or, in other words, to get a high rate of production. Often, however, the character or finish of a ground surface is of primary importance. From the point of view of grain depth of cut, we should reason that to get a very smooth surface by grinding, the grain depth of cut should be very small, and therefore that the work speed should be relatively slower for finishing than for roughing.

12 That the bond may be worn away by a very small grain depth of cut, we should expect that generally a softer wheel would be used for fine finishing than for roughing. A very hard glazed wheel may sometimes produce a mirror-like surface on the work; the action in this case being a sort of burnishing process.

MATHEMATICAL ANALYSIS

13 A general equation for grain depth of cut may be obtained as follows: Referring again to Fig. 1, let

$OQ = l =$ arc of contact of wheel and work

$n =$ no. of cutting particles per unit length of circumference of wheel

$V =$ surface velocity of the wheel

$v =$ surface velocity of the work

$T =$ time it takes point on *wheel* to go from O to Q and also time it takes point on *work* to go from Q to W

$d =$ grain depth of cut

Then

$$l = VT \text{ or } T = \frac{l}{V} \qquad [1]$$

$$QW = vT \qquad [2]$$

and

$$WS = vt \sin (A + B) \qquad [3]$$

$$d = \frac{WS}{nl} = \frac{vT}{nl}\ (\sin A + B) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [4]$$

Substituting T from [1]

$$d = \frac{v}{Vn} \sin (A+B) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [5]$$

14 Equation [5] shows that grain depth of cut varies directly as work speed; inversely as wheel speed; and directly as sin $(A+B)$.

15 To give the reader an idea of the dimensions of some of the quantities entering into equation [5] and also a means of determining from [5] the change in grain depth of cut due to changes in radial depth, Table 1 giving lengths of arcs of contact of wheel and work

TABLE 1 ARCS OF CONTACT

Radial Depth of Cut, Inches		0.0005	0.001	0.0015	0.002	0.0025	0.003
	Work Diam., Inches	Arcs of Contact					
12-in. Wheel	½	0.0158	0.0210	0.0270	0.0307	0.0346	0.0378
	1	0.0212	0.0318	0.0373	0.0429	0.0482	0.0526
	2	0.0291	0.0413	0.0507	0.0584	0.0654	0.0711
	3	0.0346	0.0490	0.0600	0.0692	0.0775	0.0848
	4	0.0386	0.0547	0.0689	0.0775	0.0866	0.0949
	6	0.0448	0.0634	0.0774	0.0894	0.1001	0.1095
	8						
	12						
	24						
	∞	0.0775	0.1095	0.1342	0.1549	0.1732	0.1898
18-in. Wheel	½						
	1	0.0220	0.0311	0.0377	0.0436	0.0485	0.0533
	2	0.0299	0.0428	0.0521	0.0598	0.0669	0.0735
	3	0.0362	0.0504	0.0620	0.0717	4.0801	0.0878
	4	0.0401	0.0574	0.0699	0.0810	0.0900	0.0990
	6	0.0477	0.0672	0.0824	0.0950	0.1061	0.1162
	8						
	12						
	24						
	∞	0.0948	0.1341	0.1638	0.1897	0.2121	0.2324
24-in. Wheel	½						
	1						
	2	0.0294	0.0423	0.0521	0.0604	0.0676	0.0742
	3	0.0364	0.0515	0.0631	0.0728	0.0814	0.0892
	4	0.0407	0.0582	0.0714	0.0827	0.0925	0.1013
	6	0.0489	0.0691	0.0846	0.0977	0.1095	0.1189
	8	0.0546	0.0773	0.0947	0.1095	0.1224	0.1340
	12	0.0631	0.0895	0.1093	0.1264	0.1413	0.1549
	24	0.0777	0.1095	0.1342	0.1549	0.1731	0.1896
	∞	0.1097	0.1548	0.1896	0.2189	0.2448	0.2682

for three different diameters of wheels, and Table 2 giving the values of sin $(A+B)$ for the dimensions of wheel and arcs of contact given in Table 1, are appended.

16 *Values of Sin* $(A+B)$. To show how grain depth varies by the changes of radial depth in special cases, three examples are computed with the following results.

Example 1. $R=9$ in ; $r=4$ in.
Radial depth 0.0015; sin $(A+B)=0.03285$
Radial depth 0.003; sin $(A+B)=0.04650$

In this case double radial depth gives an increase of only about 40 per cent in grain depth.

Example 2. $R=9$ in.; $r=2$ in.
Radial depth 0.0015; sin $(A+B)=0.04271$
Radial depth 0.003; sin $(A+B)=0.06051$

Increase of about 40 per cent

Example 3. $R=9$ in.; $r=1$ in.
Radial depth 0.0015; sin $(A+B)=0.05793$
Radial depth 0.003; sin $(A+B)=0.08167$

Increase of about 41 per cent

TABLE 2 SIN $(A+B)$

Radial Depth of Cut, Inches		0.0005	0.001	0.0015	0.002	0.0025	0.003
	Work Diam., Inches	Sin $(A+B)$					
12-in. Wheel	½	0.06581	0.09678	0.10999	0.12807	0.14379	0.15724
	1	0.04686	0.06888	0.08084	0.09287	0.10439	0.11396
	2	0.03394	0.04822	0.05914	0.06816	0.07626	0.08294
	3	0.02879	0.04075	0.04997	0.05768	0.06453	0.07066
	4	0.02573	0.03649	0.04589	0.05163	0.05769	0.06323
	6	0.02238	0.03167	0.03868	0.04469	0.05002	0.05475
	8						
	12						
	24						
	∞	0.01291	0.01826	0.02236	0.02582	0.02886	0.03162
18-in. Wheel	½						
	1	0.06394	0.06596	0.07948	0.09210	0.10231	0.11224
	2	0.03321	0.04751	0.05793	0.06645	0.07430	0.08167
	3	0.02813	0.03916	0.04842	0.05578	0.06229	0.06830
	4	0.02448	0.03501	0.04271	0.04951	0.05497	0.06051
	6	0.02119	0.02981	0.03661	0.04221	0.04715	0.05163
	8						
	12						
	24						
	∞	0.01053	0.01490	0.01826	0.02108	0.02356	0.02582
24-in. Wheel	½						
	1						
	2	0.03246	0.04582	0.05647	0.06541	0.07322	0.08903
	3	0.02731	0.03861	0.04730	0.05462	0.05817	0.06687
	4	0.02375	0.03394	0.04167	0.04822	0.05395	0.05910
	6	0.02036	0.02877	0.03535	0.04069	0.04564	0.04997
	8	0.01821	0.02575	0.03155	0.03651	0.04080	0.04467
	12	0.01576	0.02238	0.02731	0.03160	0.03531	0.03872
	24	0.01294	0.01826	0.02238	0.02582	0.02885	0.03160
	∞	0.00914	0.01290	0.01580	0.01824	0.02045	0.02235

17 Examples might be multiplied, but those cited are sufficient to show that increase of radial depth does not increase grain depth in the same proportion as the radial depth increases. In the first example, doubling the radial depth gives only about 40 per cent

ıcrease in grain depth. Resuming the equation $d = \frac{v}{Vn} \sin (A+B)$ ɾhich is equation [5], we see that if sin $(A+B)$ is increased say 40 per ꞏent by doubling the radial depth, we might diminish $\frac{v}{V}$ by about 30 per cent without changing the grain depth; but these changes, which have not varied the theoretical value of grain depth d have increased the rate of production 40 per cent. This indicates that production may be increased without increasing grain depth of cut, by increasing the radial depth of cut, and at the same time diminishing the work speed a less per cent than the radial depth is increased. In practice this method of increasing production supposes that the work and the machine are reasonably rigid.

SUMMARY

18 All the above results, which have been obtained from purely theoretical considerations, are based on the principle that the successful working of a grinding wheel depends upon securing in its operation the correct grain depth of cut for that particular wheel on a specified kind of work. It remains for expert users of wheels to decide from practice the correctness of these theoretical results. While the matter of clearance and of the unequal diameters and irregular arrangement of the abrasive grains may modify to some degree the theoretical results, it is confidently believed that the theory based on the idea of grain depth of cut will always lead in the right direction, and that it gives to empirical rules for changes of work and wheel speeds, a rational basis, and affords the operator an opportunity to do by thought and reason what heretofore he has done by memory alone.

19 This brief paper may suggest a line of investigation which, with the aid of sufficient data from practical experience, will lead to some definite directions for the use of standard grinding wheels on cylindrical and plane surface work.

DISCUSSION

C. H. NORTON. I wonder if those interested have caught the thought offered. It all has to do, in the operation of grinding machines, with the selection of the speed of the work, in a given radial depth of the wheel. The paper states that you can increase the production by slowing the working speed and increasing the radial depth, without destroying the wheel as rapidly as you would if you attempted to cut a greater depth or with a rapid revolution of the work. In making our grinding machines we have tried to follow that principle, but our customers and operators generally feel that they will accomplish more work when the wheel flies around fast, which has rather forced us against our will to follow their wishes to a certain extent; but otherwise we feel that it is the wrong way to get production of the grinding wheel.

M. D. Hersey. May I ask the author, as a matter of information, what effect the pressure with which the wheel is forced against the work has on the results. Also, just how important it is that the support of the working wheel should be rigid.

The Author. The question of pressure will depend upon the freedom with which the wheel cuts. In machine grinding the pressure is regulated by the conditions and according to the depth it is proposed to cut. If the wheel is cutting very badly, you will require a very heavy pressure, and if the wheel is cutting freely you will need much less pressure.

Rigidity, of course, is the main thing in grinding, and it is secured largely in the best machines by means of the back-rest. Rigidity and strength are of very great importance to production and good work.

C. H. Norton. In regard to rigidity, that affects the life of the wheel of any given grade, the amount of effective work and the rapidity with which it produces it in a given time. Some prefer to use wheels of a hard bond. Of course, hard bond wheels require a more rigid support and also more power to accomplish the same result, because the pressure will be greater. If we lack rigidity, however, the life of the wheel will be shortened.

No. 1447

FRICTION LOSSES IN THE UNIVERSAL JOINT

By P. F. Walker, Lawrence, Kans.

Member of the Society

and

W. J. Malcolmson, Lawrence, Kans.

Student Member

As a form of mechanism for the transmission of power the universal joint is well recognized. Its extensive use in automobile construction where it operates continuously for long periods of time as high rates of speed, under heavy loads and varying angles of deflection, gives it a significance as a piece of power equipment which it did not possess when its application was limited to more slowly moving machinery in intermittent service. Manufacturers of automobile parts have given much attention to its design, with a view to perfecting its mechanical details and to furnishing protecting covers for the bearing surfaces, and by this means a reduction of wear in the joints as well as an actual saving of power in transmission has been effected. In principle, the form used is a simple adaptation of Hooke's joint.

2 During the past three years two standard makes of joints have been under observation and test in the laboratory of the Mechanical Engineering Department of the University of Kansas. The results of the last series of these tests were formulated by W. J. Malcolmson, his report being used in full for a large portion of this paper. The object in view has been to determine the loss of power due to friction in the joint while operating under such loads and speeds as are common in automobile service In these final results it is believed that all appreciable errors have been eliminated and that they give representative values of what may be expected as friction loss in the operation of transmission joints, operating under

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conditions of good lubrication and within the limits of the loads for which the size of bearings is appropriate.

3 The two joints which have been tested are standard forms of the joint, although somewhat different in general design. No. 1, Fig. 1, was encased in a polished steel cover to exclude the dust, while No. 2, Fig. 2, of heavier design was protected by felt washers and grease cups at the ends of each bearing. In the clear atmosphere of the laboratory any difference in effectiveness of these methods of excluding dust would be without effect. The results do not indicate any noticable difference in the losses, No. 1 having an efficiency of 97 per cent and No. 2 98 per cent, when operated at 800 r.p.m. and transmitting 12 k.w. with an angle of deflection of 12 deg. In each case two complete joints connected by an intermediate shaft were employed, so that in service during the tests power was transmitted through the set from the primary shaft to a parallel secondary shaft, Fig. 3. All observed data relate therefore to the loss occurring in two joints. The main dimensions were as follows:

	Joint No. 1	Joint No. 2
Diameter intermediate shaft	$1\frac{1}{2}$ in.	$1\frac{3}{4}$ in.
Length of shaft	22 in.	13 in.
Dimensions of each bearing	$\frac{3}{4} \times \frac{3}{4}$ in.	$\frac{11}{16} \times 1\frac{1}{2}$ in.
Maximum angle of deflection	15 deg.	14 deg.
Horsepower rating	16 h.p.	30 h.p.
Lubricant used	hard grease in each	

4 A study of the kinematic relationships embodied in the Hooke's joint show that when a shaft is rotating uniformly and is driving through the joint a shaft not in the same straight line but making an angle with it, there is a variation in the angular velocity of the second shaft, the period of vibration being one-quarter revolution, and the extent of the variation depending directly on the angle made by the second shaft and a straight line projected along the first shaft. When used commercially for power transmission, on account of this variation in angular velocity, the single universal joint gives rise to vibratory and unsteady motion. To obviate this, whenever possible two such joints and an intermediate shaft are used, and the two main shafts, the driving and the driven, are always parallel to each other, but the perpendicular distance between the two, being a function of the tangent of the angle made by the intermediate shaft and the main shaft, can be freely varied between certain limits. While the intermediate shaft, the same as before, rotates with a vibratory motion, the double joint

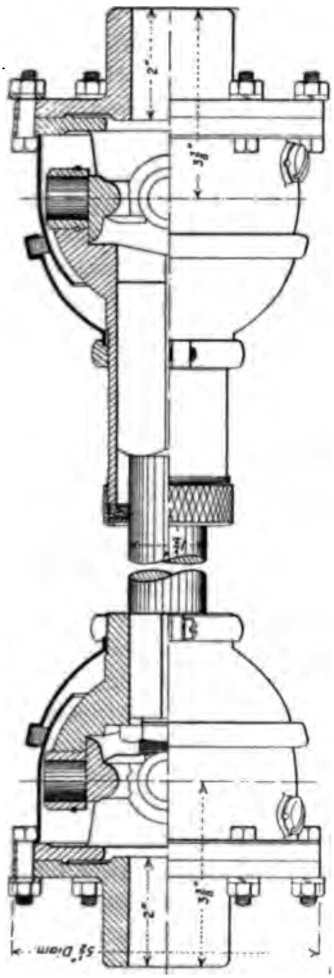

FIG. 1 JOINT No. 1

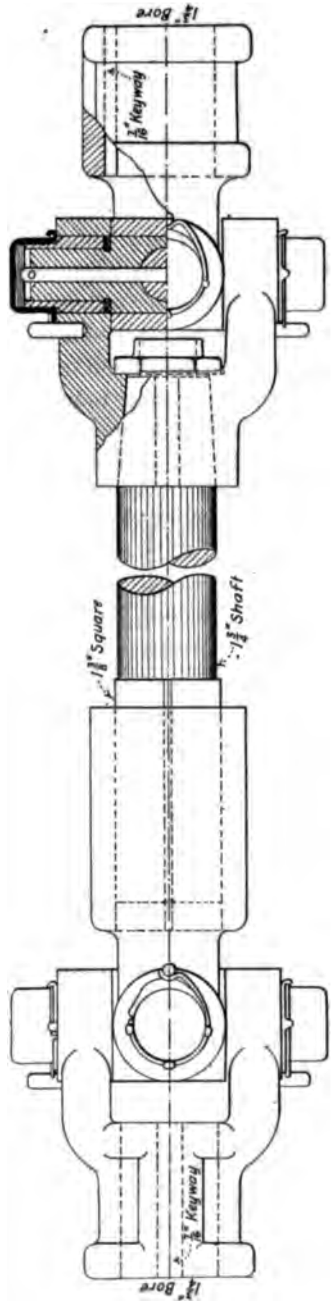

FIG. 2 JOINT No. 2

eliminates all variation in the velocity ratio between the two main shafts, providing that the forks on the intermediate shaft lie in the same plane. All variation between the two main shafts is also eliminated when the two main shafts make an angle with each other, providing the angles between the intermediate shaft and the two main shafts are equal. However, as is evident from a little study of the matter, if the forks on the intermediate shaft are at right angles to each other, the variation in angular velocity in the intermediate shaft is multiplied in the transmission to the second main shaft, and the velocity variation between the two main shafts is then twice as great as that if but one universal joint had been used. This point is not appreciated by the average person using machinery that contains universal joints and little care is shown in assembling the joints, about half of the joints being wrongly assembled, the forks on the intermediate shaft being

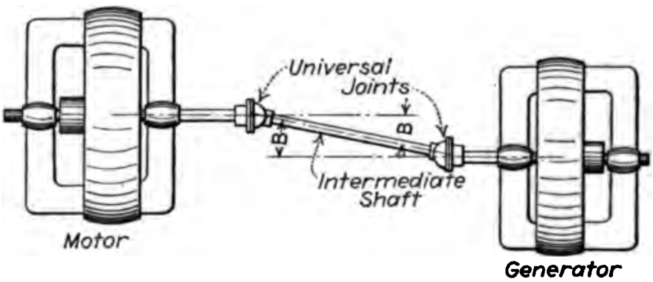

FIG. 3 ARRANGEMENT OF MACHINES

at 90 deg. or some other angle to each other. This gives rise to unsatisfactory operation and the joints of the machine are often indiscriminately condemned.

5 The universal joint finds extensive use in certain classes of machinery such as agricultural machinery, milling machines, multiple drill presses, steel mill rollers, testing machines, etc. At present, however, the most important use of the universal joint is in automobile construction, where it is often employed in place of chain or straight shaft drives to transmit the power from the crank or engine shaft to the driving shaft geared to the back axle. Usually these two shafts are parallel but do not lie in the same straight line nor at a fixed perpendicular distance apart. The objections are often made by men in the automobile industry that the use of the universal joint causes large transmission loss and also detracts

m smooth running conditions. How true these objections are is rd to say, for, while much data are available on the economy and iciency of gear or chain transmission, very little is known concern- g the economy and comparative efficiency of universal joints when ed in power transmission. The latter objection, that the use of e universal joint detracts from smooth running conditions, is obably due more to the improper proportioning and assembling the joints than to any fault of the joint itself.

6 In using the universal joint in automobile transmission there always a certain transmission loss, part of which is caused by fric- n in the joints. Friction losses occur in the joints at the points sliding contact which are between the grips of the forks and the ds of the square cross. The amount of movement depends upon e angular displacement of the two forks of the single joint and also on the speed of rotation or angular velocity. Theoretically the ction depends upon the amount of movement, the pressure between e forks and arms, the material and finish of the rubbing surfaces, e temperature, and the lubrication.

7 The actual determination of the friction losses in universal ints, such as are used in automobile power transmission, under oper conditions of speed and load requires extreme delicacy and re. The difficulty in this problem lies in the fact that the amount power dissipated in the joint, as friction loss, is very small compared th the amount of power transmitted. Practically the only way measure the loss in the joints is to determine the power delivered one of the shafts and the power delivered by the other end. The sses would then be the difference between the input and the output. s these two quantities are comparatively very large and very arly equal, any small error in their determination would produce relatively large error in the derived value of the loss. In the tual performance of any experimental work to determine this loss power in the joints as friction, the problem becomes that of measur- g accurately the power supplied to, and that received from the ction of shafting which includes the joints.

8 In considering the several possible methods of measuring the wer transmitted by line shafting the accuracy required to de- rmine the relatively small value of the friction losses in the uni- rsal joints put the general class of dynamometers out of the ques- n, and it was early decided that to obtain any accuracy what- er with the facilities and time available, electrical methods should used throughout. Bearing in mind the equipment and time

available it was decided to use the Puffer Modification of the Kapp Load-Back Method of Testing, as described in Foster's Electrical Engineer's Pocket Book (1908 ed.). Briefly, in this method of testing, two machines, preferably of the same size, make and rating, are both electrically and mechanically interconnected (see wiring diagram, Fig. 4). One machine operates as a motor and drives the other mechanically as a generator. The current generated by the generator is loaded back on the motor supply line. Used as a method of loading the generator, this saves power, avoids the necessity of providing load resistance for the generator, and offers a simple and effective method of changing the load on the generator, this being done by merely changing the generator field. Since one machine takes power as a motor and the other returns power as a generator, the net power taken from the line is only that which is required to supply the total losses of the system. If the two machines are similar in construction, size, and rating and providing that there were no transmission loss, then the losses of one machine would be equal to half the total losses except for a small error due to the opposite effects on armature reaction in the two machines. Then very approximately the power transmitted from the motor to the generator would be the load on the generator plus one-half of the total power supplied by the line. The transmission losses could then be determined by a method of substitution, as will be explained later.

9 This method of conducting the tests has the following advantages over other methods that might be used:

- *a* The quantity to be measured is often as low as 25 per cent of that usually involved by other methods and the errors in the readings taken would be correspondingly less
- *b* It is more economical of power and is more convenient to operate than most other methods
- *c* It makes possible the carrying out of the substitution method for determining the friction losses in the transmission, and in so doing the actual losses of each machine need not be determined, or need be determined only to a degree of accuracy sufficient to give the desired knowledge of the power being transmitted

10 The apparatus was originally arranged with the load-back method of testing in view. Later several improvements were made, the most important of which was the installation of a variable water rheostat in the line which supplied the losses. This was done

in order to provide for proper voltage regulation of the motor field. The apparatus used was as follows:

Motor: Siemens & Halske, 125 V., 520 A., 800 r.p.m.
Generator: Siemens & Halske, 125 V., 120 A., 1025 r.p.m.
Wire resistance rheostats for motor field
Wire resistance rheostats for generator field
Water rheostat in line, used for motor voltage control
Ammeter: 0–100, used to measure line current
Ammeter: 0–3; 0–15, used to measure motor field
Ammeter: 0–150; 0–300, used to measure circulating load
Millivoltmeter with 0–15 amperes shunt for generator field
Voltmeter: 0–150, to measure voltage of system
Centrifugal tachometer (hand type) to measure speeds ranging in r.p.m. 10–40; 30–120; 100–400; 300–1200; 1000–4000.

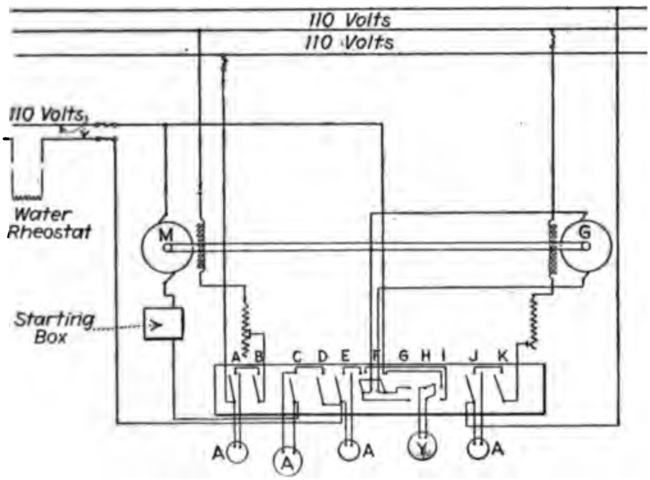

FIG. 4 WIRING DIAGRAM

9 The water rheostat consisted of two 52-gal. barrels filled with a solution of salt and water. For low speeds the barrels were connected in series, for intermediate speeds but one barrel was used, and for high speeds the barrels were connected in parallel.

10 Mechanically the two machines were connected by the universal joint set, consisting of two joints and an intermediate shaft, Fig. 3. The motor was bolted, without any rails, in a fixed position to the floor. The generator was mounted on rails and could be offset so that its shaft was always parallel to the motor shaft. As the generator was somewhat smaller than the motor its rails had to

be blocked up in order to make its shaft lie in the same horizontal plane as the motor shaft, and to secure a deflection of the intermediate shaft, the generator was offset by moving it along its guide rails. The amount of offset to give the required angular displacement on the intermediate shaft was determined by a simple trigonometric calculation of the tangent of the angle in terms of the

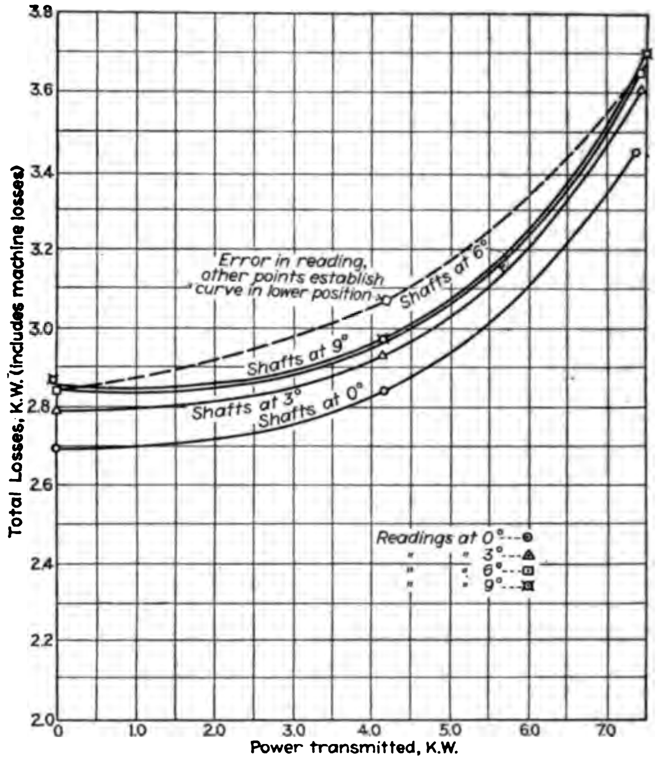

FIG. 5 JOINT NO. 1. TOTAL LOSSES, FORKS IN SAME PLANE, 800 R.P.M.

perpendicular lateral distance between the two shafts, this distance being always constant. The change in distance between the ends of the two main shafts, measured on the diagonal, was provided for by the slip of the square end of the shaft in the sleeve of the joint fork.

11 The actual procedure in carrying out the experiments consisted in first running the machines with all shafts in the same straight line and determining the total losses of the system as a whole.

ith the main shafts kept parallel, and keeping as nearly constant possible all other conditions, such as speed, temperature, lubrican, and general conditions, the losses of the system were again termined for a certain angular displacement of the intermediate aft. Readings were taken at different angular displacements and nilar runs were then made for various speeds and loads. Experients were made for both sets of joints both with the forks on the termediate shaft at 90 deg. to each other and with the forks in the me plane. Assuming, correctly, that the losses in the joints are ro for conditions of straight line drive, with all other conditions maining the same, the friction losses for a certain displacement of e intermediate shaft would be found by subtracting from the otal losses of the system at that displacement the total losses under onditions of straight line drive.

12 Before any readings were taken the machines were allowed to in from three to four hours at a speed of from 700 to 900 r.p.m. his was done to make sure that the losses and temperatures in the achines had become practically constant. As a preliminary step, fore taking readings the machines were thrown together, or eleccally interconnected, and the motor and the generator fields adsted to give the desired conditions. No trouble was experienced keeping the motor field constant. The speed was then accurately justed to the proper value by manipulating the water rheostat. veral adjustments had to be made usually between the generator ld and the speed as the load on the generator is dependent on the eed as well as the strength of the field. After making an adjustent or changing any of the quantities involved, sufficient time was lowed to pass to permit conditions to reach a state of equilibrium. ith the circulating current (hereafter designated as the "load"), eed, angular displacement, motor field and other general condins kept as nearly constant as possible, readings were taken of the ltage and line current. Readings were taken simultaneously and fficient in number and over a sufficient length of time to insure a e average value. In all cases from 4 to 12 readings of the variable antities involved were taken and an arithmetical average was found nich was then used as the accepted reading. All the data given e averaged data obtained in this way. Similar readings were ken for both sets of joints for different loads, different speeds, fferent angular displacements and different assembly of the forks the intermediate shafts. All external conditions that might posbly affect the accuracy of the results were, as far as possible, taken

into account and kept constant. After running a few tests it was found that the cleaning of the commutators would often cause considerable difference, and thereafter they were lightly cleaned before each set of readings.

13. As a preliminary study of results, all data obtained were plotted on cross-section paper using the total losses, or line current times the voltage, and the "load," or circulating current times the

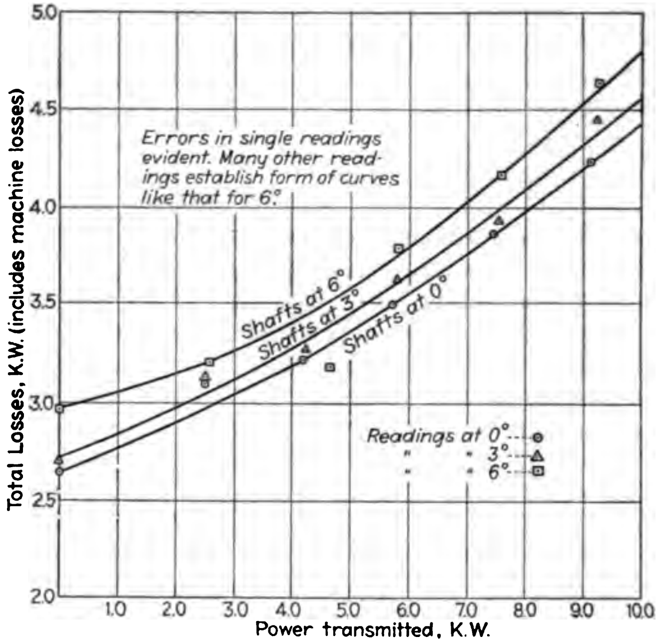

FIG. 6 JOINT NO. 1. TOTAL LOSSES, FORKS AT 90 DEG. 800 R.P.M.

voltage, as coordinates. A study of these curves showed that for a given set of imposed conditions the losses of the system varied noticeably on different days. Hence it was decided that data taken on different days could not be compared accurately unless they were referred to a common base line. To obtain a base line it was assumed, as already mentioned, that the losses in the joint under a straight line drive were zero, no matter whether the forks on the intermediate shaft were at 90 deg. or in the same plane. The actual losses in the joints, credited as friction losses, were then obtained by subtracting from the total losses at a certain deflection, the total es at straight line drive for the same imposed conditions of load, ed, etc. There is no criticism of this assumption and method of ining the actual losses when the joints are properly assembled, is when the forks on the intermediate shaft are in the same e. However when the forks on the intermediate shaft are at leg. to each other, as already mentioned, the motion transed when there is any angular displacement is not uniform, but atory in nature. In the actual operation of the machines with joints so arranged, there was noticeable a distinct vibration and king which was not present when the joints were properly mbled. This vibration increased as the angle of deflection insed, sometimes becoming so pronounced for the larger angles it was found to be unsafe to try to operate. When the joints

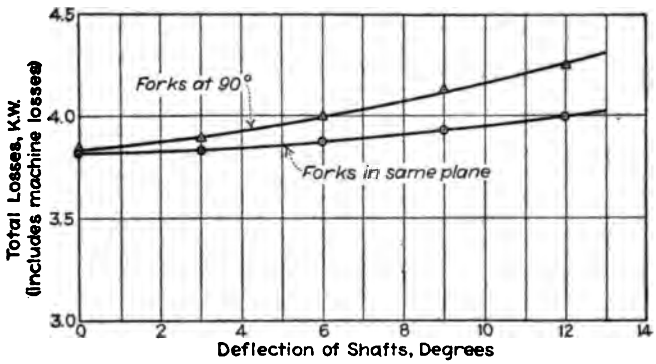

FIG. 7 JOINT NO. 1. TOTAL LOSSES, CONSTANT LOAD, 800 R.P.M.

e so operated it was also noticed, on plotting the curves, that data obtained were somewhat more uncertain and the exact ıre of the curves could not be determined as accurately as when joints were properly assembled. Then with the forks on the rmediate shaft at 90 deg. the assumption made as to the actual es in the joints would not be exactly correct, as such vibrations knocking that were present would cause the total losses of the em to vary more or less. However, as the total losses could not analyzed with the method and apparatus being used, and as it the opinion of the authors, after a careful study of the conditions the data obtained, that the true state of affairs could not differ eptibly from the results obtained, the assumption was allowed tand with the above criticism.

14 During the entire period through which these joints h been under investigation a very large amount of data have b secured. Those which appear in the following paragraphs are tions which have been selected from the report of Mr. Malcolm

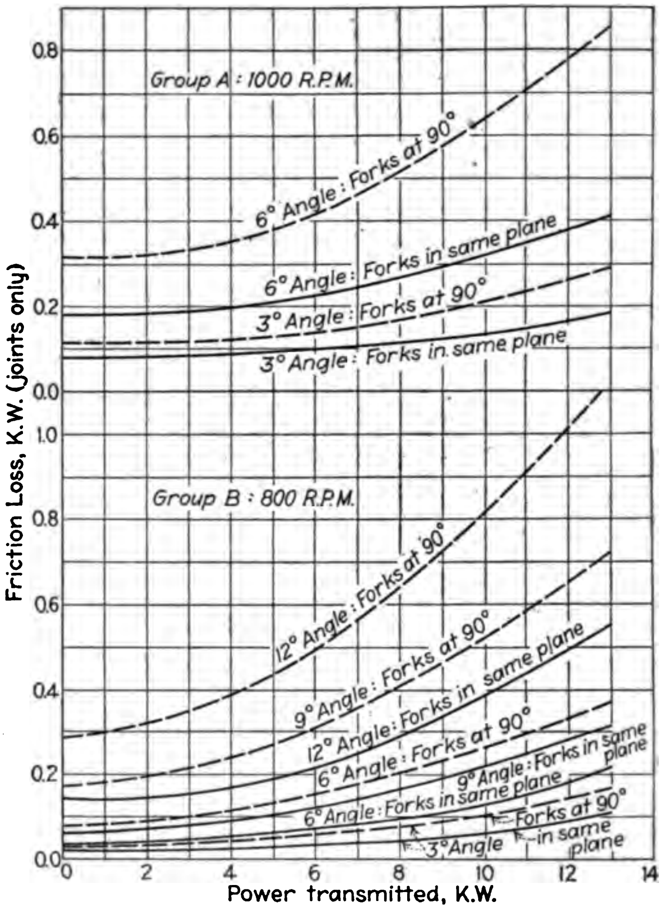

FIG. 8 JOINT NO. 1. FRICTION LOSS AT VARYING ANGLES. VALUES DE FROM AVERAGES

which was limited to a single speed and moderate variation of l Since it was impossible to hold all conditions constant througl the several months which elapsed while the work was in prog each year, the data secured on successive days had to be brou

ABLE 1 JOINT NO. 1, WITH FORKS IN SAME PLANE, 800 R.P.M.

	Line Current, Amperes	Generator Load, Amperes	Voltage, Volts	Load Transmitted by Joints, Watts	Total Losses, Watts
drive					
	38.3	0	70.2	00	2690
	42.2	50	67.3	4150	2840
	53.2	100	65.0	7360	3460
eg.					
	39.8	0	70.0	00	2790
	43.7	50	67.0	4130	2930
	55.0	100	65.7	7430	3610
eg.					
	40.0	0	71.0	00	2840
	45.4	50	67.7	4160	3070
	55.7	100	65.5	7410	3650
eg.					
	40.0	0	71.3	00	2850
	47.1	50	67.3	4140	2970
	55.7	100	66.4	7500	3700

'ABLE 2 JOINT NO. 1, WITH FORKS AT 90 DEG. 800 R.P.M.

	Line Current, Amperes	Generator Load, Amperes	Voltage, Volts	Load Transmitted by Joints, Watts	Total Losses, Watts
drive					
	37.3	00	70.7	0	2638
	44.2	25	70.2	2505	3100
	47.1	50	68.3	4197	3220
	52.0	75	67.5	5883	3508
	57.1	100	66.0	7460	3767
	64.3	125	65.8	9150	4230
	72.6	150	66.2	10800	4740
eg.					
	38.0	00	71.0	0	2700
	44.3	25	70.6	2514	3130
	47.7	50	68.5	4210	3276
	53.0	75	67.8	5900	3632
	59.2	100	66.6	7524	3938
	66.8	125	66.4	9230	4447
	75.6	150	65.2	10773	4936
eg.					
	41.6	00	71.5	0	2970
	44.9	25	71.5	2540	3210
	46.9	50	69.1	4235	3240
	55.7	75	68.0	5920	3790
	62.0	100	67.2	7640	4170
	69.2	125	67.1	9300	4640
	47.8	150	66.0	10885	5140

to a uniform basis by methods which would be both tedious in their presentation and unnecessary for an understanding of the final results. Those sets of readings which are given are taken from the observations made in a single day so that comparison of losses may be made directly. The more complete results indicated by the general curves, showing the variation of the lost energy with varying load in the one case and with varying angles of displacement in the other, represent the final result secured by comparison of many individual determinations of which each is the average of many observations.

16 Two general methods for securing readings which should

TABLE 3 JOINT NO. 1, 800 R.P.M.

	Angle of Deflection, Deg.	Line Current, Amperes	Generator Load, Amperes	Voltage, Volts	Load Transmitted by Joints, Watts	Total Losses, Watts
Forks in same plane						
	0	58.1	100	65.8	7444	3820
	3	58.1	100	65.9	7450	3835
	6	58.6	100	66.3	7490	3880
	9	59.6	100	66.0	7460	3930
	12	61.1	100	65.6	7420	4000
Forks at 90 deg.						
	0	58.0	100	66.2	7480	3835
	3	58.3	100	66.7	7530	3895
	6	60.9	100	65.7	7430	4000
	9	63.4	100	65.1	7370	4130
	12	65.1	100	65.3	7390	4250

cover variations both in load and angle of inclination were followed. One consisted in lining the shaft exactly for straight line drive and under this condition of zero loss operating the joint through a wide range of loads. This being done, the driven machine would be offset to give any desired angle and the apparatus then be operated through exactly the same range of loads, speed being held constant for all conditions. This being repeated for several angles gives data recorded in Tables 1 and 2. The other method consists in holding both speed and transmitted load constant during the entire series of observations. In this case, with the shafts in direct line for straight line drive, the initial value of total loss corresponding to zero loss in the joint is determined. After this, with the machines still running, the generator would be moved to give the proper offset angle and the readings for that condition taken with but a few moments delay. This would be repeated for as many angles as de-

ed. Such a set of readings is shown in Table 3. It will be under-
ood readily that one of the most difficult conditions to maintain
such a series of tests is a constant temperature in the field coils of
e electric machines. The latter of the two methods of procedure

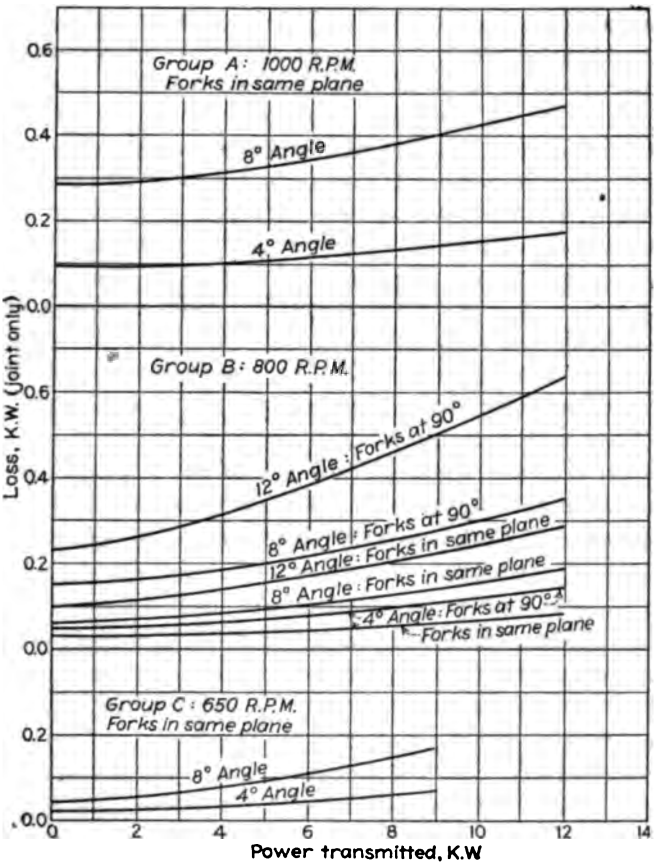

FIG. 9 JOINT NO. 2. FRICTION LOSS AT VARYING ANGLES, VALUES DETERMINED FROM AVERAGES

entioned above has a point of advantage in this regard, since a
hole series of observations throughout the range of angular varia-
on could be secured without stopping the machines or changing the
nditions of load. It may be said in passing that during the three
ears the improvements which have been effected each year have
een in the direction of standardizing the details of operation and

the adjustment of all items of the handling apparatus to the exacting requirements of the work.

18 Figs. 5, 6 and 7 show curves which represent the individual readings of total losses included in Tables 1, 2 and 3; Figs. 8 and 9 are curves showing the true friction loss. Fig. 8 pertains to joint No. 1 as operated at the two speeds of 1000 and 800 r.p.m. Fig. 9 gives corresponding information for joint No. 2. The curves represent the final results of all of the work and are located by points which are fixed by taking averages of many observations. In changing from the basis of total losses to friction loss in the joints alone, the total loss for zero angle was first deducted from all other values of total loss, determined during that particular days' work. All such differences, each representing a loss due to angularity, were then cast onto one common base line and a single representative curve established for each angle investigated. It did not seem necessary to extend the work to secure data for all conditions of load and speed for the joints improperly assembled with the joint forks set at 90 deg. on the intermediate shaft. Enough was done to demonstrate the necessity of assembling properly.

19 In the calculation of efficiency of the joints it has seemed wise to make the conclusions applicable to a complete system including the two joints necessary to secure parallel operation of the main shafts. Two joints are necessary in any system where such speeds as these under consideration are likely to occur. In other forms of application of the joints conditions are likely to be such that the question of friction loss is of no significance. In case knowledge of the efficiency of a single joint is desired, it may be assumed without sensible error that the loss is one-half of the amount here recorded and that the efficiency would be indicated for each condition by a fraction which is the arithmetical mean of the figures here given and unity. The difference between the amounts of power transmitted by the two joints is so small as to be outside any possible limits of observation.

20 The efficiency is calculated directly from the curves of derived values of friction loss. For any power and angle the friction loss in the two joints is read. The power is, in all cases, the amount transmitted at the joint, it being the sum of the load delivered by the driven generator and the losses of that machine. These latter losses have been based on separate tests made to determine the machine characteristics. It follows, therefore, that efficiency equals the

power transmitted divided by that power plus the friction loss; that is, it is power delivered divided by power received by the joints.

21 Fig. 10 shows the efficiencies of the universal joint sets in the various conditions of operation. From these curves it is noted that

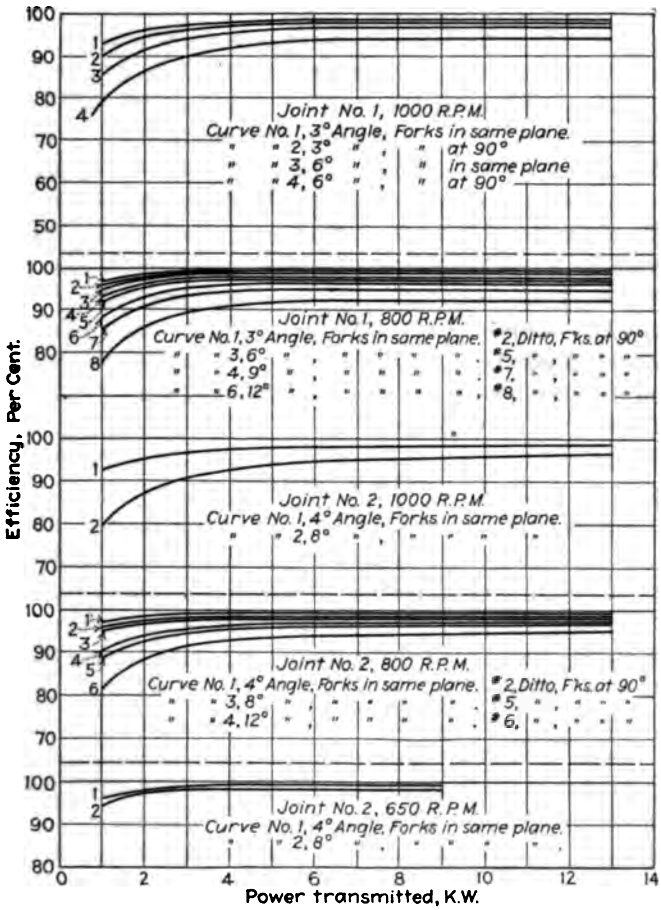

FIG. 10 EFFICIENCY CURVES

for loads amounting to one-half the rating of the set, or more, the efficiency is nearly constant and the loss very small for angles of inclination not exceeding 6 deg. For larger angles the loss becomes an appreciable amount. The constancy in the efficiency fraction indicates a constant value of the coefficient of friction on the joint journals, since the bearing pressures are proportional to power transmitted while speed remains constant. Under conditions of service the questions of lubrication and protection from dust are important. In the efficiency calculation a downward tendency was noticeable at the largest loads although it is not visible on the curves. Doubtless it marks the point where the bearing pressures on these journals make lubrication imperfect. The rocking motion of the journals tends to squeeze out the oil.

22 The investigation has been a trying one, prolific in difficulties. It has been one of the kind which demands a multitude of single observations in order to establish the law of averages. The work of the four investigators engaged during the first two years has been of great value to the authors, and it is desired to accord full credit to them. All were student members of the Society. They are L. L. Browne and C. G. Martinson of the class of 1912 and Earl Carson and E. S. Rush of the class of 1913. The joints were furnished for the tests by the manufacturers, who have co-operated in every possible way and contributed in no small degree to the success of the investigations.

DISCUSSION

Rossiter R. Potter[1] (written). The authors have certanly furnished the profession with some new and valuable information. Par. 4 of this paper is one that should be carefully studied by all users of universal joints. Profound neglect and ignorance in regard to the point of the proper positioning of the joints on the intermediate shaft seems to be the rule.

In par. 3 the authors make a statement which is not borne out by the results of the test as given in the curves of Figs. 8 and 9. They state that the results do not indicate any noticeable differences between the two joints. It is true that the efficiency of both joints was high and the friction loss very small. However, inspection of Figs. 8 and 9 shows that the curves for joint No. 2 are much flatter than those for No. 1. The difference becomes even more pronounced upon closer study. Take the curves for 12 deg. angle, forks in same plane, for example. When transmitting 10 kw. the friction loss for No. 1 joint is about 0.39 kw. while for joint No. 2 it is only 0.25 kw. The friction loss for No. 1 is 56 per cent greater than that for No. 2. This is certainly more than a minor difference.

[1]Universal Joint Dept., Blood Bros. Machine Co., Allegan, Mich.

To find the reason for this difference it should suffice to compare the construction of the two types of joints tested. The most important difference between the two joints is in the size of the working bearings. The bearings of No. 2 joint had more than twice the projected area of No. 1. Putting it another way, the pressure per square inch on the bearings of No. 2 joint was at least 40 per cent less than on No. 1 when transmitting the same power.

Another important difference is in the lubrication of the two joints. On joint No. 2 there is no pressed steel cover, but the working bearings themselves are enclosed between a closely-fitting felt washer at the inner end and a threaded grease cap at the outer end. It should be noted that in this construction the lubricant is positively applied to each bearing individually; while in the case of the sheet steel cover, the splash system of lubrication is depended upon.

The expanation for the smaller loss of power in No. 2 joint is readily found in the larger area of the working bearings, the more positive system of lubrication and the elimination of the friction loss at the jointure of the steel cover.

C. W. Spicer wrote that he wished to emphasize the results shown in the paper that, when properly designed and applied, the universal joint forms one of the most efficient methods for the mechanical transmission of power for many purposes. Most difficulties that have occurred in its use can be directly traced to lack of care or knowledge of suitable design or application. When the conditions have had due consideration the friction losses in universal joints are very much less than is popularly supposed.

F. H. Sibley (written). Not only are the results shown in this paper valuable and interesting but also is the method used to obtain them. The load-back method here described as a means for testing transmission apparatus promises much in the way of accurate determination of efficiencies.

Two points in the paper deserve special emphasis, first, that the forks on the intermediate link must lie in the same plane. It is not unusual to see shop tools in operation where this fact is not understood or ignored. Even if the kinematic effect at low speeds is not important, vibratory strains must be thrown upon the machines which might be avoided.

Second, the difficulty of maintaining a constant temperature in the field coils of the electrical machines is indicated. Unless this is done the results obtained will be unreliable or worthless for purposes of comparison.

The load-back method of testing transmission apparatus lends itself readily to testing the efficiency of involute gear teeth.

In spite of the statement made in the paper that much data are available on gear efficiencies, whoever tries to follow up the subject will be impressed with the scarcity of reliable *experimental* results. A possible exception to this statement may be made, however, in the case of worm gears. Theoretical results are somewhat discredited by the fact that learned demonstrators, starting with different sets of assumptions, have arrived at diametrically opposite results in respect to the efficiency of a given form of gear tooth. In such experiments as have been made some form of mechanical dynamometer has been used to measure the load transmitted. All who have had experience with such dynamometers will appreciate the difficulty of getting results that are accurate within one per cent. This matter is brought out forcibly in the Sellers' experiments, described by Wilfred Lewis in Volume VII. of the Transactions of the Society.

During the spring of 1914 tests were begun at the University of Kansas on involute spur gears, the apparatus being the same as that used by the authors of this paper. The load-back method used will probably allow of finding gear efficiencies within a error of one-half of one per cent. This preliminary study of the problem has enabled us to design apparatus of the same general form but better adapted to the work in hand.

The great number of possible tests and the impossibility of making them all within a reasonable time shows the desirability of undertaking the most practical things first. Any suggestions as to the best pitch and diameter of gear, whether tests should be made on a given pitch and at varying load, or on a variety of pitches, each at its maximum safe working load, will be most welcome.

The Authors. The points of difference between the friction losses in the two joints under investigation referred to by Mr. Potter are of significance, if one is considering joint differences. The real point at issue in the tests, however, is the general one of the extent to which losses occur in transmission of power through the universal joint as a type of transmission mechanism. With this as the main idea, it seems clear that in neither joint under test was the loss such as to be a factor of importance. In comparing the two joints, however, this other element should be taken into account.

Joint No. 2 has larger bearing areas and hence is suitable for transmitting larger loads than is No. 1. Therefore, in comparing friction losses, it would be more just to take the loss of .25 kw. for No. 2 at 10-kw. load and compare with No. 1 at about 6-kw. load where the loss is about .22 kw. These losses do not mean equality of efficiency, of course, but they do signify that the losses are dependent mainly upon journal friction which varies with the bearing pressure. When we hold in mind the fact that it is the joint as a type and not as a special mechanism that was under test it seems clear that the generalized statements as to the small and essentially equal losses in the two makes are safe.

An important conclusion from the discussion is one bearing on design. The larger joint does operate with less friction at any stated load above 3 or 4 kw. This means that, in general, bearings should be given generous proportions. The actual savings will be small, however, so that the returns to offset additional weight and cost are small.

Both joints gave most satisfactory results and there has been no thought of making distinctions. Rather is it the thought that an average of the two should be considered in forming general conclusions.

No. 1448

STEAM LOCOMOTIVES OF TODAY

EPORT OF THE SUB-COMMITTEE ON RAILROADS

:ecent progress and improvement in the efficiency and capacity eam locomotives has been of such remarkable character and ıt that a record in the proceedings of this Society is justified.

Steam and electric locomotives as rivals in the same field has a favorite subject for discussion before engineering societies it is easy to start arguments in favor of each of these rivals ng the partisans interested. Whether or not the steam loco-ve is to be displaced by the electric is, of course, an important tion which will in time be settled by the court that settles all questions, that of the treasurer's figures. For the present :or the immediate future the burden of transportation falls and continue to fall upon the steam locomotive. If the steam ıotive is to be perpetuated it is fitting that it should be im-ed to the utmost limit. If it is to be finally displaced it is g that it shall be so improved in order that progress to some-; better shall be intelligently developed upon a solid founda-

This discussion will be confined to the steam locomotive, its ress in the recent past and its possibilities for the near future.

PROGRESS IN CAPACITY

While efforts individual in character and extent were made is country before that time, the first consistent and systematic to secure the utmost power of locomotives within given re-tions of weight and cross-section clearance was inaugurated ears ago. This plan began with an eight-wheel or American passenger locomotive, built for an eastern railroad in January

This locomotive weighed 116,000 lb., with 74,500 lb. on driv-'heels. It provided a tractive effort of 21,290 lb. While this ıotive was not the most powerful in passenger service at that it was the first of a chain of passenger locomotives leading in a

esented at the Annual Meeting, December 1914, of THE AMERICAN SO-OF MECHANICAL ENGINEERS.

connected series, by the same builders, up to and including recen designs of the Mountain type, representing the largest passenger typ of present practice. This type has four-wheel leading trucks, eigh driving wheels and two trailing wheels. The largest of the Mountai type weighs 331,500 lb. with 240,000 lb. on driving wheels and pro duces a tractive effort of 58,000 lb., or about three times the tractiv effort of the first design of the series built during a period of 20 years

4 In the year 1898 the engineering and railroad world was in terested by the appearance of the largest and most powerful locomo tive built up to that time. This was of the Consolidation type wit a two-wheel leading truck and eight driving wheels. This loco motive was built in Pittsburgh and for a number of years was th largest and most powerful of its type, and the largest and mos powerful locomotive in the world. Its total weight is 330,000 lb weight on drivers 208,000 lb. and tractive effort 53,300 lb.

5 Today the most powerful freight locomotive has two leadin and two trailing wheels and 24 driving wheels. It gives a tractiv effort of 160,000 lb. and weighs 410 tons. This locomotive ha hauled a train of 251 freight cars weighing 17,912 tons, exclusive o the locomotive. The total length of the train was 1.6 miles; the maxi mum speed attained was 14 miles per hour. This required a maxi mum drawbar pull of 130,000 lb. This locomotive has six cylinder and three groups of driving wheels.

6 A freight locomotive has recently been built having tw cylinders and a single group of driving wheels which develop a tractive effort of 84,500 lb. Such has been the progress i capacity.

7 This progress has been rapid, perhaps somewhat too rapi with respect to improvements in operating facilities and progres in other features of railroad equipment. It has been rendere possible by corresponding developments of factors making for greate efficiency in boilers and in engines. During the past 20 years i this country locomotive development in capacity and in efficiency particularly during the past five years with respect to efficiency has been remarkable and is worthy of record with progress in marin and stationary engineering.

8 In Europe the relatively high cost of fuel led to efforts to im prove efficiency before this problem aroused serious attention i this country, but physical limitations more rigidly restricted th size and weight of locomotives in Europe. Our problem is to secur maximum efficiency combined with great size, great weight an

great power which is more difficult. Since the development in the size and weight has been tremendous, even though these limits may not yet have been reached, it is now appropriate to concentrate on efficiency.

9 For a number of years the physical capacity of the fireman to shovel horsepower through the fire door determined the capacity of the locomotive at high speeds. Mechanical stokers have removed that limitation. It is now possible to fire six tons, and more, of coal per hour into a locomotive firebox. This has changed the problem into one of getting the maximum amount of heat out of the coal and using it economically in the cylinders. With the large figures now prevailing for drawbar pull and weight it is fitting that closest attention should be given to the best possible use of every pound of metal and every pound of coal. Due to recent application of several economy producing and capacity increasing factors great improvements have already been made with promise of more to come. Then the great work of building up the efficiency of the average locomotive to the standard of the best will follow.

10 Among these economy producing and capacity increasing factors are the following improvements:

- Boiler design in relationships of the factors making up heating surface
- Firebox design
- Front end design, draft appliances, exhaust nozzles
- Ashpan design as to air openings
- Superheating
- Compounding
- Feedwater heating
- Firebriok arches and circulating supporting tubes
- Valve gear
- Detail design to secure reduced weight of reciprocating parts and other parts
- Use of high-grade alloy steels to reduce weights
- Mechanical stokers
- Labor-saving devices for the engineman and fireman
- Improved counterbalancing to permit of greater weight on driving wheels by reducing dynamic stresses
- And yet to come is powdered fuel with possibilities unknown in scope and in importance. Powdered fuel is in reserve, promising the ideal method of complete combustion under control more perfect than is possible with present

methods other than oil burning and perhaps with economies impossible to obtain with oil.

PROGRESS IN EFFICIENCY

11 Valuable comparisons may be drawn from the best results of ten years ago and of today. At the Louisiana Purchase Exposition in 1904 the tests made by the Pennsylvania Railroad revealed important figures concerning locomotive performance at that time. It was shown to be possible to obtain equivalent evaporation from and at 212 deg. of 16.4 lb. of water per sq. ft. of heating surface, indicating the power of locomotive boilers when forced. It was shown that when the power was low, the evaporation per pound of coal was between 10 and 12 lb., whereas the evaporation declined to approximately two-thirds of these values when the boiler was forced. These results compared favorably with those obtained in good stationary practice, whereas the rate of evaporation in stationary practice lies usually from 4 to 7 lb. of water per sq. ft. of heating surface per hour. In steam consumption the St. Louis tests showed a minimum of 16.6 lb. of steam per i.h.p. per hr. In coal economy the lowest figure was 2.01 lb. of coal per i.h.p-hr., the minimum figure for coal per dynamometer h.p-hr. was 2.14 lb. These records were made after the superheater had become a factor in locomotive practice and they represent economies attained by aid of the superheater in one of its early applications. This is important in the light of the recent development of the superheater. These remarkable figures have never received the attention which they deserve from engineers. They serve, however, to show that 10 years ago a steam locomotive had attained results which were worthy of the best attention of the engineers of the time. Since then greater progress has been made and today locomotives of larger capacity than those concerned in the St. Louis tests have given better results.

12 Voluminous records of recent investigations of locomotive performance taken from the Pennsylvania Railroad test plant at Altoona show that the best record of dry fuel per i.h.p-hr. down to the present date is 1.8 lb. with a large number of less than 2 lb., while the best performance in dry steam per i.h.p-hr. is 14.6 lb. with a large number less than 16 lb. A reduction of 10 per cent in fuel and 12 per cent in water is remarkable as a result of a development of 10 years. This coal performance was recorded by a Class E 6 S Pennsylvania Railroad locomotive while running at 320 r.p.m. and developing 1245.1 i.h.p. The same locomotive gave a fuel rate of

. while running at the same speed and developing 1750.9 i.h.p. ›est water rate was given by Class K 2 S A Pennsylvania Rail- locomotive while running at 320 r.p.m. and developing 2033.1

These high powers indicate that the locomotives were not ed as to output of power in order to show high efficiencies, but high efficiencies accompany actual conditions of operation in ɜ service. As to power capacity expressed in terms of evapora- it is interesting to note that the maximum equivalent evapora- rom and at 212 deg. per sq. ft. of heating surface per hour on ltoona test plant is 23.3 lb. These figures of high efficiency were ɑed from locomotives which represented not only very careful al and detail design, but their design included several of the ›vements making for greater capacity and higher efficiency, ut which the results could not have been attained.

: Having in mind the facts that steam locomotives are power ȝ on wheels, built to meet rigid limitations of weight, both static ynamic, and that the use of condensers is impossible, engineers ɪeral must admit the high character of the work of locomotive ɪers which has attained these results.

Greater efficiency which is revealed on the test plant and gh reports of engineers would be important because it proves progress is being made in the possibilities of locomotive per- ınce. Improvement which is revealed by operating statistics ʼhich, therefore, appears in the records of the treasurer's office real test in this case. It is important to know that increased : of locomotives attained largely through the development of my producing and capacity increasing factors has produced s which the financial reports of railroads prove beyond question. ently published list of train tonnage on 45 prominent railroads ıtes that 16 of these roads have increased their average freight loads by over 30 per cent during the last five years. Credit be given to the improvement in the locomotive for most of this opment. These figures reveal the value of increased power fficiency of steam locomotives and the end is not yet in sight.

WHAT REMAINS TO BE DONE

ȷ American locomotive development to its present state would been impossible without the use of the improvements already ioned. It is believed that all these are capable of still further opment, making for still greater economy in the use of fuel and, fore, promising greater power capacity. It is the object of your

Committee to present these possibilities for discussion by those who are engaged in perfecting and improving steam locomotive practice in this country. It is the hope of your Committee that engineers who are devoting their attention to the design of locomotives as a whole and those who are engaged in the development of the various details which have contributed to the high efficiency of the steam locomotive of today will discuss the progress of the recent past and reveal possibilities for future development and improvement in capacity and efficiency.

G. M. Basford
F. H. Clark
W. F. Kiesel, Jr.
} *Sub-Committee of Railroad Committee*

DISCUSSION

GENERAL BOILER DESIGN

F. F. Gaines in a written discussion stated that boiler and firebox proportions must be carefully studied and chosen so as to produce capacity as well as efficiency. These proportions are now being worked out on a scientific basis. Modern large engines have a ratio of tube heating surface to total heating surface as high as 20. On small engines with deep fireboxes this ratio formerly ran as low as 8. A desirable figure for this ratio is 12. This can be obtained by the use of a combustion chamber which lengthens the firebox and shortens the flues. Where large grate areas are required, as in the large Erie Triplex, it is almost impossible to provide a wheel arrangement that would not necessitate the firebox extending over the drivers. With the use of a combustion chamber this can easily be accomplished, as the mud ring may be as high or higher than the bottom waist line of the boiler. The ratio of total heating surface to grate area should not be over 80, and more economical results are obtained if it is 65.

With ample grate area and firebox heating surface the desired results cannot be obtained unless the affiliated parts are correctly designed. The grates should be of such mesh as the grade of fuel requires, the mesh being as large as possible without the fuel dropping through. The grates should also have the maximum of possible air openings as well as air openings in the side bearers. The opening on the top should be a minimum and expand as it goes down, so that any ash, slate or clinker that can pass through the top will easily pass through and not clog the grates. Ash-pan openings are generally restricted and do not admit sufficient air for economical or maximum combustion. The proper arrangement of front ends is very essential to the uniform drafting of the fire; the lower the exhaust pipe, the less the back pressure and consequently the greater the mean effective pressure.

In this country feedwater heating is confined to a limited number of cases and cannot be said to be recognized generally as a factor in fuel economy. Experiments made on several engines by the writer showed about 10 per cent economy, which was considerably offset by difficulties in maintenance.

The feedwater heater in question was composed of two elements, the first being a pair of condensers in the form of long drums applied underneath the running boards. The steam from air pumps, boiler feed pumps, and some of the main exhaust was condensed in them and the heat taken up by the feedwater. The second element consisted essentially of a double nest of tubes in the smoke box, similar to a Baldwin type superheater. The feedwater from the tank was forced through the condensers and smoke box heater, and from the heater through the regular boiler check, into the boiler. Some trouble was experienced with the operation of the pump and it was also found that the type of pump used was not altogether suitable for the purpose, wearing very rapidly and having considerable slippage. The smoke box heater tubes were objectionable from the standpoint of obstructing draft and filling up with soot and cinders between the tubes, also cutting out very rapidly by the action of the exhaust. There was a further objection due to the fact that the condensed steam from air pumps and boiler pump exhaust was still at temperature sufficient, in cold weather, to give off considerable clouds of steam; and as this water had to be wasted, the result was a cloud of steam around the engine, obscuring the view of the engineer. These heaters were used some two or three years, and tests were made which showed them to have an actual fuel economy somewhere in the neighborhood of 10 per cent. But on account of the mechanical difficulties mentioned, they were finally abandoned, more especially because greater economy can be obtained by using the smoke box for superheating steam.

Eventually, however, we will develop a type of feedwater heater that will eliminate the objections. It would appear that the most feasible plan would be a type of open feedwater heater, located between the frames of the engine and underneath the boiler, and using the exhaust from the air pumps, boiler feed pumps, and part of the main exhaust. In carrying this out it is thought that ultimately instead of using the present form of exhaust draft to effect combustion, with its consequent back pressure due to restriction of nozzle, a form of forced draft of the blower type will be used. Under these circumstances the exhaust openings from the cylinder to the atmosphere can be made without any restriction whatever, thereby greatly eliminating back pressure. The steam required for operating the auxiliary and forced draft would use but a small proportion of the horsepower gained. Previous experiments would also indicate that a type of centrifugal pump would be much more effective and positive for boiler feeding than one of the reciprocating type.

American railroad practice is averse to adding anything to the locomotive in the way of additional apparatus which complicates its operation or adds to its complexity. The demand for the utmost economy will eventually bring about a satisfactory method of feed-water heating so that in connection with superheating, liberal firebox heating surface, and possibly compounding, we can obtain the maximum possible economy from the fuel used.

F. J. Cole (written). It is impossible, in the time allowed for a discussion of this kind, to touch more than briefly upon the general aspects of this subject, because the questions involved in the matter of steaming capacity, heating surface, ratios, etc., are so numerous that it would require a paper by itself, illustrated by numerous diagrams, to do the subject even scant justice. The writer will therefore merely outline a few of the most important features.

In recent years, locomotives have increased so much in power that methods formerly employed are no longer adequate in proportioning the grate, heating surface, length and diameter of tubes, etc., or to predetermine how a locomotive boiler can best be designed to suit certain requirements, when the class, tractive power and limitations of weight are known.

The size of cylinders is usually fixed by the permissible axle load allowed upon the track or bridges, in connection with the type of locomotive, driving wheel diameter, boiler pressure and factor of adhesion. After these fundamental features are decided upon, the boiler proportions must be outlined to see whether the required amount of heating surface can be obtained without exceeding the limits of weight.

There are two general questions involved in the consideration of this subject, namely, how many pounds of steam per hour are required to supply the cylinders in order to develop the maximum horsepower, and what proportion of grate, firebox and tube heating surface will best produce this amount of steam.

The locomotive, unlike most steam engines, is a variable speed and a widely variable power plant. It must be able to run at any intermediate speed between starting and its full velocity and at the same time develop all degrees of tractive power within its capacity. At slow speeds the maximum pull must be exerted in order to start the trains easily, and for this reason the live steam is admitted to the cylinder during 80 to 87 per cent of the stroke. As the speed increases it is necessary to reduce the admission period, thereby increasing the expansion of the steam. Therefore for any speed there is some point for the valves to cut off the live steam, at which the engine will develop its maximum power. There is also some minimum velocity at which the full horsepower of the locomotive is attained; after this velocity is reached the horsepower remains constant or slowly decreases. This critical point may be taken at 700 to 1000 ft. per minute piston speed.

It has been customary to use certain ratios, based on cylinder volume, for locomotive proportions. These ratios left to individual preference such matters as rate of combustion per square foot of grate, length of flues, evaporative value of firebox heating surface or value of tube or flue heating surface in relation to the length, making it desirable to proportion boilers upon more uniform methods in which these variable factors are given due consideration.

Four or five years ago the writer collected a considerable amount of data on this subject and drew up a report with the object of reducing this matter to a more uniform basis, substituting, for the ratios hitherto employed, cylinder horsepower requirements. Suitable values were assigned to grate area, firebox and tube heating surface, etc., with corresponding evaporative values, so that the balance between the amount of steam required by the cylinders and the amount of steam which the boiler was capable of generating could be expressed in percentage of cylinder horsepower. The tests made on sectional boilers on the Northern Railway and the Paris, Lyons & Mediterranean Railway of France, those of Dr. Goss on a Jacobs-Shupert boiler, and tests by the Pennsylvania Railroad on the Altoona testing plant were examined in order to obtain data on which to base the evaporative values of different points of the boiler. It is obvious that the evaporative value of a boiler tube of given diameter varies greatly with its length. The temperature of the firebox is fairly constant under similar conditions of draft and rate of combustion, therefore the temperature of the smokebox will be reduced with an increase in the tube length. While some additional draft will be required to draw the gases through the tube, yet the net result is a greater temperature absorption between the firebox and smokebox. The thermal efficiency of the engine is increased within certain limitations by the use of long flues. The economical length of tube is determined mostly by the number and arrangement of wheels of the engine required and only partly by thermal conditions.

About 1899 the wide firebox Atlantic (4-4-2) type was introduced. Because the firebox was placed behind the driving wheels, the grate surface could be made to suit the power of the locomotive. It was, therefore, no longer necessary to force the rate of combustion as heretofore to 180 and 200 lb. per sq. ft. per hour. Very uneconomical results had been obtained when high rates of combustion were necessary, because much unburned coal was drawn through the tubes into the smokebox and thrown out through the stack by the violent draft. With the Atlantic, tubes of 15 and 16 ft. and sometimes longer were necessary. While at first some apprehension from leakage was felt with tubes of this length, it was soon found that there was no more difficulty in maintaining long tubes in good condition than short tubes. With the introduction of the Pacific (4-6-2) type, the Mikado (2-8-2) type and other locomotives having trailing trucks, still longer tubes were required. Tests made on long tube boilers, compared with older locomotives having shorter tubes, showed a noticeable reduction in smokebox temperature.

Instead of the old arbitrary and unsatisfactory method of designing heating surface by cylinder ratios, the idea of using the cylinder horsepower suggested itself as forming a very desirable basis. Curves were prepared from the most recent available data showing speed factors or drop in m.e.p. in relation to velocity. With saturated steam the average maximum horsepower is reached at about 700 ft. piston speed per minute, speed factor 0.412; constant horsepower is obtained at 700 to 1000 ft. piston speed, and then slightly decreasing at higher velocities for average conditions when engines are especially constructed for the highest speeds. For superheated steam the average maximum horsepower is reached at 1000 ft. piston speed, speed factor

.445 and constant horsepower at higher speeds. Because the horse-ɔwer is based on piston speed, the stroke and diameter of wheels are mitted in the following figures, the horsepower calculation for ıturated steam becoming by cancellation:

$$\text{h. p.} = \frac{0.85\ P\times0.412\times1000\times2A}{33{,}000} = 0.0212\times P\times A$$

ı which

A = area of one cylinder in sq. in.
P = boiler pressure in lbs. per sq. in.
0.412 = speed factor

In a similar manner the horsepower calculation for superheated ;eam becomes

$$\text{h.p.} = 0.0229\times P\times A$$

sing 0.445 as the speed factor.

The maximum horsepower can sometimes be increased when the ›comotive is operated under the most favorable conditions. It is ›nsidered safer to take figures which represent average conditions ıther than the unusual figures obtained when all conditions are most ıvorable.

The horsepower basis affords many additional advantages in de-gning locomotives. For instance, in determining the maximum mount of water and coal required per hour, the size of the grate is ɔund to be proportional to the amount of coal that can be burned to he best advantage, to be varied according to the quality. Knowing he amount of coal required per hour directs attention to the question f hand firing or the use of a mechanical stoker. Knowing the .mount of water evaporated per hour determines the location of vater stations, size of tender and tank, size of injectors, safety valve :apacity, and size of steam pipes, and also forms the basis for other 'eatures of the boiler, such as stack, etc.

From the reports of the Pennsylvania Railroad testing plants at St. Louis and Altoona, and from road tests, the conclusion is reached ;hat a horsepower-hour can be obtained from 25 to 29 lb. of saturated steam in simple cylinders with piston speeds of 700 to 1000 ft. per ninute. A fair average value has been taken as 27 lb., and in a cor-:esponding way 23½ lb. for compound engines, 20.8 lb. for steam superheated 200 deg. and over, and 19.7 lb. for superheated steam used in compound cylinders. These figures provide steam for aux-iliaries. While careful tests show that the evaporation can be increased under the most advantageous conditions, it is considered better practice to take the lower figure in order to provide a margin for average conditions.

The great increase in length of tubes which took place with the building of these trailing truck locomotives naturally directed attention to the values of the heating surface of different lengths of tubes and emphasized the fact that a sq. ft. of heating surface in short tubes, say 10 or 11 ft. long, had a much greater evaporative value than in tubes 18, 20 and 22 ft. long.

Before definite temperature tests were made in different positions of boiler tubes, the temperature was assumed to vary inversely as the square root of the length, but pyrometer tests recently made on the testing plant at Altoona with several locomotives, having tubes and flues of various lengths and diameters, show the incorrectness of this assumption. Curves have been drawn which show the temperature decrease from the firebox to the smokebox and from these curves the relative evaporation has been calculated.

Short tubes have much greater evaporative value per square foot of heating surface than long tubes, but they discharge the gases into the smokebox at much higher temperatures. Therefore, while the heat absorbed per foot of length is much greater for short than long tubes, it is not so economical, and the short tube boiler, other things being equal, requires more coal for a given evaporation. Where tube lengths of 12 or 14 ft. were common 14 or 15 years ago, lengths of 20, 22 and even 24 ft. are used in the modern locomotive. The result is that the smokebox temperatures have decreased from 750 or 800 deg. to 550 or 600 deg., the only increase of energy required being the slightly greater draft in the smokebox to pull the gases through the long tubes. This is not intended as a defense of the long tubes in modern engines, especially of the 4-6-2, 4-8-2, Mallet and other types, because in these cases the construction requires long boilers. Nevertheless tests show that economy results from the better utilization of heat in the modern engine than in older types because the range of temperature between the furnace and the stack is greater with the long tube locomotive.

As a result of these investigations, conclusions have been arrived at as follows:

Firebox Evaporation. An evaporation of 55 lb. per sq. ft. of firebox heating surface, combustion chamber and arch tubes has been adopted. The greater absorption of heat, per unit of area, by the fire-x than by the rear portion of tubes, is largely due to radiant heat. his varies as the square of the distance from the surface of the e to the sheets separating the gases from the water. Again it is obable that within certain limitations, the amount of heat absorbed independent of the heating surface and is a function of the grate ea or the area of the bed of live coals. Assuming that there is sufcient heating surface to absorb the radiant heat, it is probable that ry little additional heat will be absorbed by increasing the firebox ating surface. It therefore follows that the relatively greater area of e fire in proportion to the absorbing surface in wide firebox locootives is more efficient than in the old narrow firebox.

Diameter, Length and Spacing of Tubes and Flues. The evapative value in pounds of water per square foot of outside heating rface has been approximately calculated for 2-in. and 2¼-in. tubes, d for superheater flues of 5⅜ in. and 5½ in. The range of length 10 to 25 ft., and the spacing 9/16 in. to 1 in. The best available ta show that the evaporative value of a tube or flue varies considerly with differences in length, diameter and spacing. Curves of temrature compared with length have been used as a basis for detering the evaporation for different lengths of tubes and flues. The te of evaporation on this basis will vary directly as the difference temperature of the tube or flue gases and that of the steam conined in the boiler.

Tubes and flues from 10 to 24 ft. long, spaced 9/16 in. to 1 in., outde diameter 2 in., 2¼ in. and 5½ in., will evaporate from 7.50 to 1 lb. per sq. ft. per hour.

Grate Area. Grate area required for bituminous coal is based on e assumption that 120 lb. of coal per sq. ft. of grate per hour is a aximum figure for economical evaporation. While 200 and 225 lb. ave at times been burnt in small, deep fireboxes and the engines ade to produce sufficient steam, this is wasteful of fuel and it has een found, after numerous and careful tests, that the evaporation per ound of coal under these conditions is very low. If the rate of comustion is too slow, economical results will not be produced owing to e fact that at least 20 per cent of the coal burned produces no useul work in hauling trains, but is consumed in firing up, or in waiting t roundhouses, terminals or on side tracks, or to the fact that during he greater portion of the time locomotives are used at considerably ss than their maximum power.

For hard coal the grates should be proportioned for a range of from 55 to 70 lb. of coal per sq. ft. per hour, according to the grade of the fuel.

Complete tables of horsepower for saturated and superheated steam, of evaporation of tubes and flues of various length, diameters and spacing, and diagrams of temperature of flue lengths have all been prepared to facilitate the calculations in determining the proportions of grate, firebox, tube and flue heating surface.

It must be remembered, however, that the boiler capacity for a locomotive, when other things are in proportion, cannot usually be made too large within the permissible limits of weight, and it can be shown by numerous tests that such increase in boiler capacity makes for considerable economy in the use of fuel and steam. For passenger service the capacity of the boilers may often be made with advantage over 100 per cent.

In a general way, a boiler will have ample steam making capacity if proportioned by this 100 per cent method provided the grate is sufficiently large and deep so that the rate of combustion at maximum horsepower does not exceed 120 lb. per sq. ft. of grate per hour for bituminous coal of average quality. For gas coal a smaller grate may be used, but it is better practice to use the larger grate and brick off a portion at the front end in order to obtain sufficient volume of firebox for proper combustion, because nearly all large modern engines are deficient in firebox volume.

C. D. YOUNG, in discussing Mr. Cole's remarks, pointed out that the tendency at the present time should be to increase the firebox heating surface, as it should be realized that this is of comparatively greater effectiveness at mean and low rates of working than the remaining surface of the boiler.

Some few years ago, when large boilers were designed, the tendency was to make the ratio of the firebox heating surface to the total heating surface less than 6. This practice resulted in locomotives which, while efficient in evaporation, were not free-steaming, as they lacked capacity unless very heavily drafted. Firebox heating surface should be at least 7 per cent of the total heating surface of the boiler. When this ratio is attained, good results will follow provided the tube heating surface has been properly proportioned. When working at high rates of evaporation, the tube surface is fully as effective as firebox surface, and for large capacity a large tube heating surface is necessary.

Beyond a certain length of tube there is too great a sacrifice of boiler capacity in the interest in economy in coal. The long tube preents a very serious resistance to the flow of the gases, and beyond a certain length—which appears to be about 100 internal diameters—this resistance increases without a corresponding increase in evaporation. The locomotive with a long tube is a slow steamer and a higher draft must be furnished in order to create an active fire. This rule—length of tube to be 100 times the internal diameter—has been applied to three new classes of Pennsylvania locomotives with exceedingly gratifying results, and confirms the earlier experiments made by the Pennsylvania Railroad upon this subject, as well as those made by M. A. Henry of the Paris, Lyons & Mediterranean Railroad of France.

FIREBOX DESIGN

J. T. ANTHONY[1] (written). From a furnace point of view, the principal points to be considered are grate area, flameway or volume, firing clearance and air supply. From the boiler point of view we must consider the extent and location of the heating surface.

In order to secure high efficiency, the grate area should be sufficent to keep the maximum rate of combustion below 100 lb. per sq. ft. per hour at full boiler capacity, as the losses due to imperfect combustion, cinder discharge, front end gases, radiation and unaccounted for losses increase rapidly above this rate with a corresponding decrease in boiler efficiency.

The Master Mechanics' Association in 1897 recommended a ratio of heating surface to grate area of 60 with bituminous coal locomotives; but this ratio on the modern superheater locomotives ranges from 70 to 80 and higher. This is due in part to the decrease in coal consumption brought about by the introduction of the superheater, and in part to the prevailing idea that large grates, in addition to requiring more coal for firing up, waste more coal when standing idle. It is possible, though, that the higher efficiency due to the large grate and low rate of combustion will more than offset the larger amount of coal used when firing up and standing idle.

High efficiency at lower rates of combustion is due not only to a reduction in the heat losses enumerated above, but also to the relatively large proportion of the total evaporation that takes place around the firebox. Most of the heat received by the firebox heating surface is radiated directly from the fuel bed and luminous flames, only a small amount being due to convection or direct contact. The amount of heat received by radiation depends on the area of the radiating

[1]Mgr., Service Dept., American Arch Co., 30 Church St., New York.

surface and the difference in temperature between the radiating and cooling surface.

Flues receive their heat by convection, and the amount of heat so received, other things being equal, depends on the weight of the gases going through them. This varies with the rate of combustion, and as this rate increases the flue evaporation increases. Under the same conditions the firebox evaporation increases somewhat, due to the slightly higher temperature and increase in mass of flames, but not nearly as fast as the flue evaporation.

High firebox evaporation means high boiler efficiency, for the high heat absorption by the firebox reduces the temperature of the gases entering the flues; and, for any one boiler, the temperatures of the gases entering and leaving the flues are directly proportional when reckoned above steam temperature. Hence a lower temperature of entering gases means lower front end temperatures and an increase in efficiency.

A large percentage of the bituminous coal burns above the grate as gas. The rapidity and completeness of the combustion of this gas depend upon the amount of oxygen present and the thoroughness of the mixing. In a firebox with 60 sq. ft. of grate, with a rate of combustion of 60 lb. of coal per sq. ft. of grate per hour, an air supply of 20 lb. per lb. of coal and an average firebox temperature of 2000 deg., the volume of the gases evolved is about 1200 cu. ft. per second. A firebox of this size would have a cubic capacity of about 200 ft., and would have to discharge and be refilled with gases about 6 times per second. The average time available for combustion of each particle of gas would be insufficient for complete and proper mixing by diffusion. With the short time allowed, it is necessary to mix the gases by mechanical means, and this is generally accomplished by an arch or baffle which forces the gases through a restricted area, this area being not less than the net flue area.

Mere firebox volume is not sufficient of itself. It is necessary to have a flameway of such cross-section and length as to mix the gases intimately and provide sufficient space for burning before gases reach flues. In an ordinary firebox, without baffle or combustion chamber the average length of flameway is only 5 or 6 ft. By the introduction of baffles and combustion chambers, this length can be increased from 10 to 15 ft., which results in not only more complete combustion but also in increased radiating surface, with a corresponding ase in firebox evaporation and a lowering in temperature of the)ing gases.

A Pacific type locomotive with 55 sq. ft. of grate area, tube suped arch and an average flameway of 8 ft., had an average firebox)erature, covering a range of 25 tests, of 2100 deg. This tempera- was taken from the center of the firebox at about the end of the . The temperature of the gases entering the flues showed an age of 1725 deg., or a drop in temperature of 375 deg.

Another Pacific type locomotive with the same size grate and supported arch, but with a 3-ft. combustion chamber, giving an age flameway of 11 ft., showed over same range of tests an aver- firebox temperature of 2185 deg., with the temperature of the s entering the flues at 1485 deg., or a drop of 700 deg. between center of the firebox and the flue sheet, due to the increased eway.

High efficiency is obtained at low rates of combustion in spite of large air excess. The firebox absorbs a larger percentage of the evolved, and the amount so received depends primarily on the)erature of the fuel bed. It is possible that this temperature is er with large air excess, due to the cutting and scrubbing action ie air upon the burning coals.

The firing clearance, or vertical distance between fuel bed and r flues or arch, has been materially increased by the introduc- of our modern types of locomotives with trailing trucks, as this permitted the firebox to be placed behind the drivers and the es dropped lower. This one step has probably offset to some extent high ratio between heating surfaces and grate area which we in our modern locomotives.

Firebox evaporation depends primarily upon the extent and tem- ture of the radiating surfaces and not on the extent of the heat- surface. Increasing the firebox heating surface without in- sing the grate area or flameway will result in very little increase vaporation. An evaporation of 60 lb. of water per sq. ft. of fire- heating surface per hour requires a difference of less than 100 between the water and the fire side of the sheet. If sufficiently ı firebox temperatures or large radiating surfaces could be ob- ed, it would be possible to increase this high rate of evaporation ıout forcing the heating surface to its capacity.

In the Coatesville tests, the two fireboxes gave an evaporation as ı as 58 lb. of water per sq. ft. of heating surface per hour. There was practically no difference in the total evaporation by each of the fireboxes when working at the same rate of combustion and with the same grate area, although one of the fireboxes had 12 per cent more heating surface than the other.

Unless the fuel is materially changed, we are not likely in the near future to see any radical departures from the present type of firebox. Any improvement in firebox efficiency will be obtained by paying particular attention to and making ample provision for grate area, firing clearance, gas mixing, flameway or combustion chamber space, and air supply.

FRONT END DESIGN

H. B. MacFarland in a written discussion called attention to the amount of experimental work that has been done to determine the most efficient arrangement of drafting appliances, and yet it has been often and thoroughly demonstrated that the best arrangement for a front end for any given locomotive can be determined only after careful tests in service.

Pioneer work in this country in establishing scientifically the fundamental principles of front end action was done in the locomotive testing laboratory of Purdue University. The rapid development of powerful locomotives in the past few years calls for such an increase in the boiler capacity that it was questioned whether these recommendations were still applicable to the newer types of power. In order to demonstrate the best type of drafting, the Pennsylvania Railroad recently made a series of front end tests. Definite results and recommendations were obtained only after a very well worked out series of tests with a large number of different front end arrangements. From results obtained, however, they were not able to establish recommendations governing a proper design of front end appliances which may be generally applied to all classes of locomotives, so that such an arrangement has to be left to individual tests for each class.

That the present practice of locomotive drafting is accomplished at the expense of back pressure acting against pistons has been generally understood for a long time and although it was generally known that this back pressure exists in all locomotives, the magnitude of the power loss due to it has not been generally recognized.

Effective locomotive capacity was first increased with the use of high steam pressures. The tendency in later years has been to lower steam pressure. To increase the locomotive capacity effectively, it s first necessary to increase the capacity of the boiler, which has en accomplished usually by increasing the heating surface without proportionate increase in grate area. Designs of this kind have cessarily imposed an increased rate of combustion, thus involving an crease in drafting requirements. The intensive duty is well illusated by considering that there are locomotive boilers in service pable of developing 2000 sustained boiler h.p. with a grate ea available of not over 100 sq. ft. The intensive burning of the fuel further brought out when it is considered that in a stationary plant presenting the latest developments, to develop 2000 boiler h.p. ually requires four boilers of 500 h.p. each, occupying an aggregate or space of 35 by 35 ft. To develop this high locomotive boiler rsepower with the space available, necessitates drafts ranging from to 10 in. of water with coal burning, and from 4 to 12 for oil urning locomotives.

Since draft is a function of the front end arrangement in general d of the exhaust tip in particular, it naturally follows that the eration of the high powered locomotive boilers of the present day is the expense of a very pronounced back pressure due to restricted). This is particularly true when the locomotives are operated at ch rates of power as to force boilers to their maximum. Data were llected from tests conducted upon 18 different locomotives repreiting as many different types and working under such varied contions as are encountered upon the Sante Fé System. These data ow that for every 100 h.p. used as actual tractive power, there are h.p. wasted through the exhaust, over 70 per cent of which may be edited to the excessive back pressure necessary to produce draft for e locomotive boiler.

In order to demonstrate some of the basic principles governing e increase in boiler capacity, to show that the controlling factor in creasing capacity is the draft, a comparison was made of the perrmance obtained from a type of large locomotive boiler operating ider stationary and road conditions. Tests were not made on the me boiler, but figures were obtained from separate tests made on fferent boilers of the same class. These boilers are standard for the inta Fé or 2-10-2 type locomotives, with general dimensions as folws: Heating surface, 4796 sq. ft., of which 4587 sq. ft. was tube eating surface, and 209 sq. ft. was firebox heating surface; grate was practically no difference in the total evaporation by each of the fireboxes when working at the same rate of combustion and with the same grate area, although one of the fireboxes had 12 per cent more heating surface than the other.

Unless the fuel is materially changed, we are not likely in the near future to see any radical departures from the present type of firebox. Any improvement in firebox efficiency will be obtained by paying particular attention to and making ample provision for grate area, firing clearance, gas mixing, flameway or combustion chamber space, and air supply.

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Pioneer work in this country in establishing scientifically the fundamental principles of front end action was done in the locomotive testing laboratory of Purdue University. The rapid development of powerful locomotives in the past few years calls for such an increase in the boiler capacity that it was questioned whether these recommendations were still applicable to the newer types of power. In order to demonstrate the best type of drafting, the Pennsylvania Railroad recently made a series of front end tests. Definite results and recommendations were obtained only after a very well worked out series of tests with a large number of different front end arrangements. From results obtained, however, they were not able to establish recommendations governing a proper design of front end appliances which may be generally applied to all classes of locomotives, so that such an arrangement has to be left to individual tests for each class.

That the present practice of locomotive drafting is accomplished at the expense of back pressure acting against pistons has been generally understood for a long time and although it was generally known that this back pressure exists in all locomotives, the magnitude of the power loss due to it has not been generally recognized.

Effective locomotive capacity was first increased with the use of high steam pressures. The tendency in later years has been to lower ıe steam pressure. To increase the locomotive capacity effectively, it as first necessary to increase the capacity of the boiler, which has een accomplished usually by increasing the heating surface without proportionate increase in grate area. Designs of this kind have ecessarily imposed an increased rate of combustion, thus involving an ıcrease in drafting requirements. The intensive duty is well illusrated by considering that there are locomotive boilers in service apable of developing 2000 sustained boiler h.p. with a grate rea available of not over 100 sq. ft. The intensive burning of the fuel ; further brought out when it is considered that in a stationary plant epresenting the latest developments, to develop 2000 boiler h.p. sually requires four boilers of 500 h.p. each, occupying an aggregate loor space of 35 by 35 ft. To develop this high locomotive boiler orsepower with the space available, necessitates drafts ranging from to 10 in. of water with coal burning, and from 4 to 12 for oil urning locomotives.

Since draft is a function of the front end arrangement in general nd of the exhaust tip in particular, it naturally follows that the peration of the high powered locomotive boilers of the present day is t the expense of a very pronounced back pressure due to restricted ip. This is particularly true when the locomotives are operated at uch rates of power as to force boilers to their maximum. Data were ollected from tests conducted upon 18 different locomotives repreenting as many different types and working under such varied conlitions as are encountered upon the Sante Fé System. These data how that for every 100 h.p. used as actual tractive power, there are 6 h.p. wasted through the exhaust, over 70 per cent of which may be redited to the excessive back pressure necessary to produce draft for he locomotive boiler.

In order to demonstrate some of the basic principles governing he increase in boiler capacity, to show that the controlling factor in ncreasing capacity is the draft, a comparison was made of the perormance obtained from a type of large locomotive boiler operating ınder stationary and road conditions. Tests were not made on the ame boiler, but figures were obtained from separate tests made on lifferent boilers of the same class. These boilers are standard for the Santa Fé or 2-10-2 type locomotives, with general dimensions as folows: Heating surface, 4796 sq. ft., of which 4587 sq. ft. was tube ıeating surface, and 209 sq. ft. was firebox heating surface; grate area, 58½ sq. ft. California crude oil having a calorific value of from 18,650 to 19,650 B.t.u. was used in all cases.

Results of the three tests mentioned are summarized in Table 1, and demonstrate the influence of the intensity of the draft on the boiler capacity.

TABLE 1 RESULTS OF TESTS ON DRAFT

Means of Producing Draft	Draft, in Water		Oil Burned per Hr., Lb.	Water Evaporated per Hr., Lb.	Ratio Water to Fuel	Boiler H.P Developed
	Smokebox	Firebox				
Natural	0.93	0.61	974	12,727	13.07	445
Natural and 1½-inch steam Blower	1.10	1.00	1360	15,895	11.70	570
Locomotive Front End	9.00	7.25	3270	33,900	10.70	1180

The total capacity of a locomotive boiler has been greatly increased during the past 10 years by the development of auxiliary apparatus such as superheater, brick arch, feed-water heater, stoker and other labor saving devices. An increase in boiler capacity has also been accomplished indirectly by improving the efficiency of the locomotive through improvements made in the valve gear and cylinder designs, and by properly designed steam passages, etc. With all the developments and improvements, however, the fact remains that the determining factor in increased boiler capacity is, under the present arrangement, increased draft, and it follows that the most efficient method of producing this draft should be given serious consideration.

During complete tests made in the summer of 1914 of four different Prairie type locomotives, experiments were made to determine the effect of changes in front end arrangement. In each instance a number of runs were first made with the front end, as far as possible, in accordance with recommendations of the American Railway Master Mechanics' Association. Changes were then made in the front end arrangement to make each locomotive conform generally to the latest recommendations of the Pennsylvania Railroad.

Diagrams showing the front end arrangement of one of the locomotives before and after changes are shown in Figs. 1 and 2.

Assuming an efficiency of 100 per cent for the original arrangement, the tests show that a draft of 6 in. in the front end was produced with the new arrangement at a saving of 34.5 per cent in back pressure produced in the cylinders.

ts show what may be accomplished by changes in front nent, but when it is considered that the efficiency of the very low from a thermodynamic standpoint, these gains

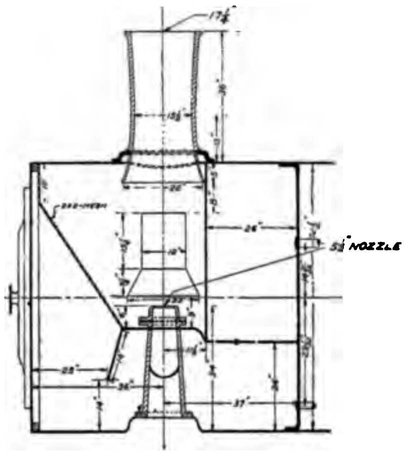

FIG. 1 FRONT END ARRANGEMENT

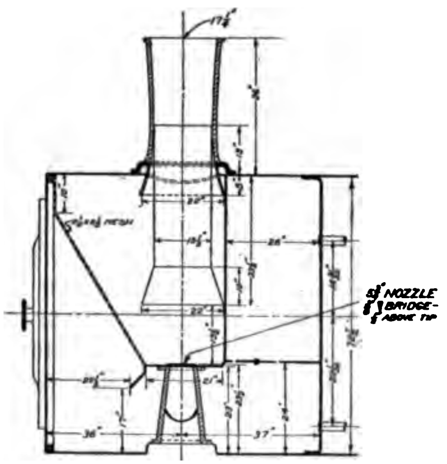

FIG. 2 FRONT END ARRANGEMENT

have very little effect on the total efficiency of the loco-

'er performance curves for one of the locomotives tested s maximum power was reached at a speed of 35 miles per hour, the locomotive developing 1350 i.h.p. and having 190 back-pressure h.p. There was a gain of 35 per cent in front end efficiency with the new front end arrangement. This means that the same draft was produced with a reduction of 35 per cent in back pressure, or at a saving of 66 h.p. This results in an increase of but 5 per cent in the capacity of the locomotive.

Curves taken from tests on a 2-8-8-2 Mallet show that maximum power was developed at a speed of approximately 17 miles per hour and that drawbar horsepower and back-pressure horsepower equalized at a speed of approximately 25 miles per hour. At this speed the locomotive exerted 950 drawbar h.p. and an equal amount was required to draft the boiler.

These tests have forcibly demonstrated the inefficiency of the present front end arrangement when viewed from a thermodynamic standpoint. Its chief advantage is mechanical efficiency, that is, it is free from any complicated parts and requires only minor adjustments. It is this feature alone that has enabled the present front end to exist to the present day.

In view of existing conditions, attention was attracted to the possibility of drafting by some method of forced or induced draft. Because of the impracticability of installing a system of forced draft, this form was abandoned. Induced draft has been successfullly applied in stationary and marine service. The development of the steam turbine and progress in theory and construction of centrifugal fans make it seem logical that if the system could be so successfully applied to other fields it would find ready application to the locomotive. When the problem was presented to the manufacturers, they were able to calculate the size of the fan and the horsepower necessary to drive it to burn the required amount of coal. But when the space that such an apparatus would occupy was taken into consideration, they were unable to furnish either data or apparatus to meet the requirements satisfactorily. For this reason it was absolutely necessary to start in at the beginning and to develop such an apparatus.

After many experiments the MacFarland fan draft was developed. The diaphragm, nozzle pot, netting and other draft appliances were removed, leaving the front end clear for the reception of the turbo-fan unit. The smokebox proper was divided into two compartments by means of a sheet iron, air-tight partition, which made connection between the intake opening in the fan casing and the inner ring of the smokebox arch. The compartment next to the front tube thus made separate and constituted the front end proper, the opening being directly into the inlet of a high-speed direct-ected, centrifugal fan. The remaining compartment acted as ıeral housing for the fan and its operating power unit. Cylinder ust was led directly to the atmosphere by means of pipes lead- from the front heads of the steam chest to a common stack ed just ahead of the fan exhaust stack on top of the boiler. n the locomotive was working, the steam for the turbine was ı directly from the superheater; when the main throttle was d the turbine was supplied through the blower line. While the ɹsed during this experiment was not mechanically correct or of ient capacity to develop the maximum power of the locomotive, ɔught out many valuable points relative to the general perform- to be expected from a system of this kind.

'he experience gained led to the design of a larger fan unit which ıpplied to a New York Central switcher and a comparative test made before and after installation. This installation was never :actory from a mechanical standpoint, because the unit em- ·d was not adapted to the size of the smokebox on this partic- locomotive. The test further demonstrated, however, the pos- ties of this form of draft for locomotives and justified the follow- ·onclusions:

(*a*) That the engine could be successfully drafted with the MacFarland fan draft. A maximum of 9 in. of draft was developed in the front end, with an average of 8¼ in. throughout one of the test runs, and the fan operated successfully against depths of fire ranging from 6 to 18 in.

(*b*) That the exhaust could be muffled to any desired point by the introduction of proper netting stages.

(*c*) That the engine could be operated practically smokeless.

(*d*) That the engine burned a uniform and intense fire.

(*e*) That full operating steam pressure was readily maintained.

(*f*) That the back pressure on the engine was entirely eliminated.

(*g*) That it was not necessary to use the exhaust steam for drafting the engine.

'hese tests have furnished data for the design of a special unit ɾercome the mechanical difficulties which have been brought out.

drifting, the automatic damper is an essential feature for the protec tion of the superheater elements.

There has been a tendency of late to use exhaust nozzles havin other than circular openings. The plain circular nozzle forms steam jet which is too nearly cylindrical, or is the shape of the stack and the use of such a shaped nozzle as a rectangular one appears t break up the continuity or form of the jet and causes the nozzle t draw out a larger volume of gases. Both rectangular nozzles an nozzles of the dumb-bell shape have been used with success and wit an increase in evaporation over that with the circular form. Ther has recently been developed on the testing plant a nozzle, having fou internal projections, which appears to be more satisfactory than som of the irregular forms. With nozzles having other than a circula outlet, an increase in the evaporative capacity of the boiler of fro 15 to 25 per cent has been obtained. In recent tests upon a larg Pacific type, a nozzle with four internal projections has given a maxi mum capacity in equivalent evaporation, from and at 212 deg., o 87,414 lb. per hour. This is an evaporation of 18 lb. of water per sq ft. of heating surface per hour. With this capacity, an i.h.p. of 318 was obtained. This same locomotive with a circular nozzle develope a maximum equivalent evaporation of 62,719 lb. of water per hou resulting in an i.h.p. of 2501. No change, other than in the exhaus tip, was made in the locomotive. The back pressure in both cases wa practically identical. The nozzle had about the same area as th equivalent circular nozzle, which meant that it was large enough t take care of the internal projections. There was a difference of 0.0 lb. of back pressure in one case compared, which is practicall negligible. The limited capacity of the circular opening was 250 h.p., whereas with the other form it was 3200.

ASHPAN DESIGN

C. D. Young called attention to ashpan design as to air open ings. He remarked that the air openings into the ashpan should be a least 15 per cent of the area of the grate. When the openings are o this size, the ashpan vacuum will be considerably less than one inch o water at the maximum evaporative rates.

This ratio has been found to be too large for the requirements o some switching engines. By installing ashpan dampers along the ai inlets at the mud ring, this difficulty has been overcome. If the ai inlets in the ashpans of locomotives which stand around a large par of the time were not reduced, it would be difficult for the fireman to prevent a large amount of steam from escaping from the safety valve.

SUPERHEATING

G. L. Bourne (written). Locomotive boilers present many limitations that have an important bearing on the design and construction of the superheater. The development of the locomotive, within certain fixed clearances, has been dependent upon the size of the boiler. As the boiler increased, wheels have been added to obtain proper weight distribution. Consequently, the boiler is no larger than is absolutely necessary and in the majority of cases it is insufficient in evaporating surface.

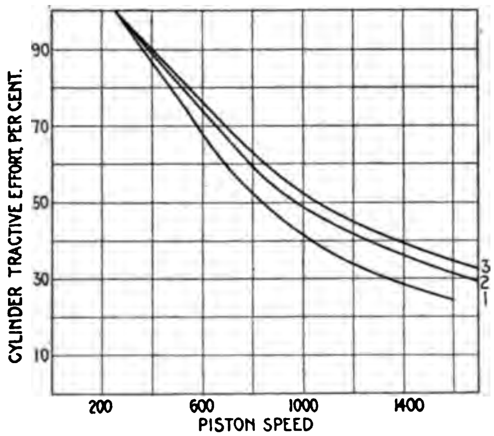

Fig. 4 Cylinder Tractive Effort—Piston Speed

The application of a superheater to this boiler necessitates a reduction of about 15 or 20 per cent in the tube heating surface. Furthermore, a certain percentage of the gases, which formerly was available for evaporation of the water, must now be used for superheating the steam.

Taking this boiler with its deficiencies, the superheater has produced an economy of 25 per cent in fuel as a direct result of saving 33½ per cent of the total water evaporated per unit of power. As a result of this fuel economy, greater capacity of the locomotive has been brought about.

As an illustration of this fact Fig. 4 shows cylinder tractive power in per cent plotted against piston speed. The lowest curve No. 1

very fairly represents the speed factor for an average saturated steam locomotive. Curve No. 2 similarly represents that of the average modern superheated steam locomotive using between 200 and 250 deg. superheat. A longer cut-off being possible on superheater engines accounts for the greater available tractive power. The limiting factor at the usual speeds is the ability of the boiler to furnish steam.

These results have been accomplished in the face of boiler limitations, of parts of the locomotive not being adaptable to the use of highly superheated steam, and of lack of experience in the organization which must handle the locomotive. The problems incident to these conditions are being rapidly worked out, and results shown by the superheated steam curve will soon be as basic as the saturated steam curve was a few years ago. The future holds a possibility for further saving by increasing the degree of superheat. For some time past large passenger locomotives have been operated very successfully with steam chest temperatures between 750 and 800 deg. This corresponds to 350 to 400 deg. of superheat.

The superheater engineer has only made use of the same variety of flue sizes as was used by the locomotive designer for tube sizes. If the superheater designer should be permitted the use of a size different from the two present standards, it would be possible to obtain, in a superheater boiler, evaporating surface practically as great as in the saturated steam boiler. In this case the superheating surface would be a distinct net gain to the heat absorbing surface of the boiler. With a boiler and superheater thus arranged, greater capacity may reasonably be expected, and a curve approximately as No. 3 may be confidently looked forward to in the near future.

C. D. Young remarked that it is now known that the economy due to superheating increases almost directly with the degree of superheat; and the usual type of fire-tube superheater produces its maximum superheat only when it is forced to the limit of boiler capacity.

This condition is not altogether desirable as the maximum economy should be obtained when the locomotive is working under moderate or average conditions and at an economical cut-off. A superheater that would give a uniform superheat under all conditions of working would apparently produce ideal results.

If our materials in valves, cylinders and packing, as well as the lubrication, will withstand a certain high degree of superheat, there is no reason why we should not furnish this degree of superheat regardless of the boiler rate in order to effect the greatest economy in steam.

With the usual Schmidt superheater we have observed steam temperatures as high as 670 deg., corresponding to a superheat of 291 deg. at a steam chest pressure which was 180 lb., while the boiler pressure was 206 lb. With these conditions the steam rate per horsepower hour was 19.3 lb., the speed 47 miles per hour, and the cut-off 50 per cent. With this superheat and a cut-off at 25 per cent, it is reasonable to suppose that a water-rate approximating 15 lb. could be obtained. For this reason the desirability in future designs of superheaters is to produce, if it be possible, a superheater that will give us a uniform superheat regardless of the evaporation of the boiler. Until such a superheater has been produced the maximum economy and capacity from the boiler cannot be obtained under all working conditions.

COMPOUNDING

C. J. Mellin (written). In the course of progress in steam engineering it was but natural that the compound engine, which had been so successfully introduced into marine and stationary service, should find its way to the locomotive.

Difference in conditions under which the locomotive operates as compared with the marine and stationary engines, in that the greatest resistance is in starting, was not fully realized in earlier attempts to introduce the compound into railway service. Various means were later employed to compensate for this difference, but for many years the compound was looked upon with suspicion.

Very little improvement, however, was made in the simple engine until the compound commenced to show its superiority by hauling heavier freight trains with the same weight on drivers as the simple engine and with a considerable reduction in fuel and water consumption, reduction in boiler repairs, improvement in smooth riding qualities, and the practical elimination of jerks in starting, thus making a saving in car and draft gear repairs.

To compete with these advantages the simple engine was enlarged both in boiler and cylinder capacity, necessitating an increase in weight, and for a number of years the contest for supremacy was on, ending only when the limit of the right of way stopped the further enlargement of the low-pressure cylinder of the cross-compound engine, the permissable diameter being 36 in., or an equivalent to a 21-in. simple engine. The Vauclain four-cylinder compound, the four-cylinder balanced compound and the tandem compound followed, but all soon found their limitations.

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The three-cylinder compound would have been the natural suc-

cessor to the cross-compound but for the complications involved in applying the central main rod across the main axle, as was necessary on other than four coupled engines. Its introduction was, therefore, deferred indefinitely. Nevertheless, various designs of this type have been worked out to the equivalent of a 26-in. simple engine.

Instead of entering on this complication, a step still further in advance was taken about 12 or 13 years ago, when, after close investigation as to the best means of employing two low-pressure cylinders, the Mallet method of articulation was selected. The first design was made during the summer of 1902, retaining the American Locomotive Company's compounding system and American methods of construction throughout.

Up to this time there were few engines with higher tractive power than 40,000 lb. The bold idea of stepping up to 72,000 tractive power in compound gear and 86,000 in emergency was severely criticized. After long and serious consideration the Baltimore and Ohio Railroad decided to have an engine built to these proportions. Hardly had the engine started in regular service when its real qualities were discovered and its performance viewed with surprise. Reports of the result obtained caused personal investigations to be made by railway officials and resulted in a decided reversal of an unfavorable opinion to one of recognition of its advantages. At present 115,000 lb. in tractive power in compound and 138,000 lb. in emergency are being produced in very successful service and plans are worked out, ready when required, for engines of this type giving 140,000 lb. tractive power in compound and 168,000 lb. emergency power.

The next step for heavy power, where road conditions permit, is triple articulation, using the tender as the third unit. One engine of this type has been built having 160,000 lb. tractive power, but as yet it may be considered as experimental. On account of the limited boiler capacity on such engines, it may be necessary to make the tender engine independent of the other two units, subject to regulation at will, in order to get the maximum amount of steam for fanning the fire. The exhaust from the tender engine has very little effect by the time it reaches the stack and may therefore be carried direct from engine to atmosphere. Mechanical draft could probably be applied to advantage as a further means of increasing the boiler capacity at the slow speeds at which such an engine would naturally operate. By this means a tractive power of over 200,000 lb. could be obtained.

In the meantime the superheater has proved to be of great ad-
ıntage in compounding. Practically all the superheat in the steam
ın be used before its final exhaust, and condensation during the
tter part of its extended expansion is eliminated. This combina-
on of compounding and superheating, when proper cylinder pro-
ɔrtions have been observed, affords the greatest economy in loco-
ıotive operation.

Mechanical stokers have made possible the further enlargement
f engines. It is also probable that mechanical draft, in combination
ith a feedwater heater, will be an additional feature in the direc-
ion of economy, because of the possibility of running the boiler to
s required capacity regardless of the speed of the engine. It also
emoves the unavoidable loss of power caused by back pressure in the
ylinders, which loss increases with the size of the engine.

FEEDWATER HEATING

H. H. VAUGHAN. You probably all know the experiments that
re being made with exhaust steam heaters and waste gas heaters on
ıe front end by Mr. Trevithic on the Egyptian Railways. With the
aste gas heater he has been able to put the water into the boiler at
50 deg. and obtain 22 per cent economy.

On the Canadian Pacific, experimental open heaters in a tank
ıve given a fair amount of satisfaction. We also applied exhaust-
eam injectors to some engines with fair results, but found that
operate them satisfactorily we should have a variable exhaust nozzle.
e have since been advised by the manufacturers that our troubles
ere because of our having applied too large an injector. While ex-
ıust steam injectors work fairly well under certain conditions, yet
ere would be difficulties where the amount of water consumed
ould be variable.

Experiments on an open heater showed that 40 deg. of the tem-
erature obtained from the exhaust steam was due to the exhaust
eam from the feed pump. A temperature of 200 deg. in the feedwater
the equivalent of 160 deg. when water is put into the boiler by an in-
ector with 100 per cent efficiency. By heating the water at the in-
ection suction to 120 deg., we got 6 per cent economy using injectors,
hich we thought preferable to 10 or 12 per cent using a pump.
ately we have experimented with an ordinary closed feedwater
ıeater.

Feedwater heating is a subject which railroad people on this side have neglected. It has the advantage of not only saving coal but increasing the capacity of the boiler, as the temperature of the water in the boiler would not be materially changed. My feeling is that we will see the heater coming into larger use not only with exhaust steam but with waste gas.

FIREBRICK ARCHES AND CIRCULATING SUPPORTING TUBES

J. P. NEFF (written). About ten years ago very few railroads were consistently using brick arches. A number of roads were tolerating them in a very small percentage of their engines, and a large number had discarded them entirely.

As the locomotive itself has been greatly improved during the last ten years, so has this particular device. It has been shorn of many of its original faults, leaving its never disputed virtues standing out all the more prominently.

Briefly, the arch insures more nearly complete combustion. The combustion of high volatile coal at the rapid rates necessary to meet the demands for large hauling capacity is fraught with considerable losses due to incompleteness. That represented by the CO content in front end gases is only a part. Losses from incomplete combustion of hydrocarbons may easily be four times that represented by the CO per cent in the gas analysis. Anything that will mitigate these losses without introducing too high air excess reflects at once in higher furnace temperatures. Combustion chambers help by lengthening the flame travel, but the arch, especially the arch on water tubes, not only doubles the average length of the flame travel, but in addition possesses the more important virtue of a mechanical mixer.

That eminent authority, Dr. Breckenridge, in his treatise entitled A Study of 400 Steaming Tests, states: "Mere length of combustion chamber counts for little compared with some device for thoroughly mixing the gases of the flame stream; one good mixing wall or baffle is probably worth many feet of undisturbed flow." A study of the full text of this work impresses one with the thought that the above statement was not made with the intention of belittling the importance of combustion chamber length or flame length but with the idea of emphasizing the importance of mixing the different strata or ribbons of the gas stream mechanically.

By enhancing combustion over the fuel bed, considerable more heat is involved, and higher firebox temperatures result. Authentic s have shown that with certain coals this increase in temperature ' be 15 per cent. As a rule, these higher firebox temperatures are accompanied with higher front end temperatures. Thus the ble result of creating more heat and causing it to be absorbed, is ımplished. See Fig. 5.

Circulating tubes or arch pipes not only present the most efive heat transmitting surface, but the circulating effect is very ɔrtant, especially at high rates of combustion. As the particles of s must quickly touch the heat absorbing surface and give way intly to other particles, so must the water on the opposite side of

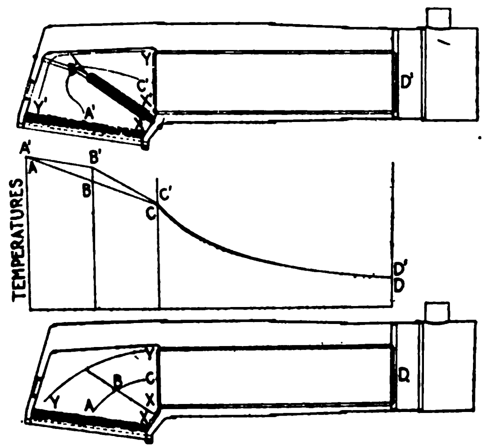

FIG. 5 EFFECT OF BAFFLE ON FIREBOX TEMPERATURES

surfaces, if a high rate of heat transfer is to be accomplished. edited circulation will insure this favorable condition. A locove boiler cannot give high duty per square foot of surface when gases move leisurely.

Arch tubes, as they are now, give much aid, but there is still more e done in this direction. Arch tubes or circulating water tubes ugh the firebox may be used in still greater number with good lts, if properly arranged and disposed so as to aid in mixing meically and in circulating without too quickly lowering the temture of gases.

Information from three different authentic sources shows that the k arch, together with its circulating water tubes, produces an inse in maximum boiler capacity of approximately 15 per cent.

side have neglected. It has the advantage of not only saving coal but increasing the capacity of the boiler, as the temperature of the water in the boiler would not be materially changed. My feeling is that we will see the heater coming into larger use not only with exhaust steam but with waste gas.

FIREBRICK ARCHES AND CIRCULATING SUPPORTING TUBES

J. P. Neff (written). About ten years ago very few railroads were consistently using brick arches. A number of roads were tolerating them in a very small percentage of their engines, and a large number had discarded them entirely.

As the locomotive itself has been greatly improved during the last ten years, so has this particular device. It has been shorn of many of its original faults, leaving its never disputed virtues standing out all the more prominently.

Briefly, the arch insures more nearly complete combustion. The combustion of high volatile coal at the rapid rates necessary to meet the demands for large hauling capacity is fraught with considerable losses due to incompleteness. That represented by the CO content in front end gases is only a part. Losses from incomplete combustion of hydrocarbons may easily be four times that represented by the CO per cent in the gas analysis. Anything that will mitigate these losses without introducing too high air excess reflects at once in higher furnace temperatures. Combustion chambers help by lengthening the flame travel, but the arch, especially the arch on water tubes, not only doubles the average length of the flame travel, but in addition possesses the more important virtue of a mechanical mixer.

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By enhancing combustion over the fuel bed, considerable more heat is involved, and higher firebox temperatures result. Authentic ests have shown that with certain coals this increase in temperature may be 15 per cent. As a rule, these higher firebox temperatures are not accompanied with higher front end temperatures. Thus the double result of creating more heat and causing it to be absorbed, is accomplished. See Fig. 5.

Circulating tubes or arch pipes not only present the most effective heat transmitting surface, but the circulating effect is very important, especially at high rates of combustion. As the particles of gases must quickly touch the heat absorbing surface and give way instantly to other particles, so must the water on the opposite side of

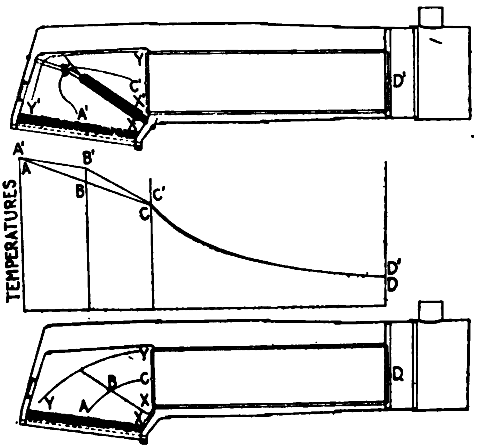

FIG. 5 EFFECT OF BAFFLE ON FIREBOX TEMPERATURES

these surfaces, if a high rate of heat transfer is to be accomplished. Expedited circulation will insure this favorable condition. A locomotive boiler cannot give high duty per square foot of surface when the gases move leisurely.

Arch tubes, as they are now, give much aid, but there is still more to be done in this direction. Arch tubes or circulating water tubes through the firebox may be used in still greater number with good results, if properly arranged and disposed so as to aid in mixing mechanically and in circulating without too quickly lowering the temperature of gases.

Information from three different authentic sources shows that the brick arch, together with its circulating water tubes, produces an increase in maximum boiler capacity of approximately 15 per cent.

The four 3-in. arch tubes reported on from one of these sources were held to be responsible for one-third of this increase.

CYLINDERS AND VALVE GEARS

G. W. Rink. While every effort is being made to increase the efficiency of the boiler, it appears that the economical distribution of steam in the cylinders has also received some attention. In general, however, we are not getting the good results such as are obtained in good stationary engine practice. This is due to long steam ports and the use of a single slide or piston valve which has to control admission, cut-off, release and compression.

A design of cylinder overcoming these objections has been introduced in recent years and is known as the Hobart-Allfree cylinder. A comparative test was made on the Jersey Central with an engine fitted with this type of cylinder and slide valves as against another engine fitted with the regulation cylinder and slide valve. These tests showed an economy in fuel and water consumption of approximately 12 per cent. Tests conducted on other railroads with Mallet engines equipped with the same style of cylinder and slide valve showed, with practically the same amount of coal per ton mile, an increase of 13½ per cent in tonnage hauled with an increase in speed of 4.3 per cent and a saving of water per ton mile of 11.1 per cent.

Valve gears have received a great amount of attention in recent years and a design which has apparently met with considerable success is known as the Baker valve gear. This gear was designed with a view of replacing the old inside link motion. It has also been applied in preference to the Walschaert gear in many instances owing to objections due to links or sliding blocks. The Baker gear has all bearings provided with pins and bushings which are more readily inspected and repaired.

DETAIL DESIGN TO SECURE REDUCED WEIGHT.

W. E. Woodard. In all designs it is necessary to get as large a boiler as possible, consistent with the proper design of the other parts of the locomotive. This leaves a certain amount of weight, in many cases, to be taken out of other parts, with the result that the designer scans all points where he can safely make a reduction.

Increased weight due to the slight increase in the detail parts has been brought to our attention in the past by the way certain features in locomotives creep up. A locomotive is built for a railway and it

›erates satisfactorily. The railroad duplicates the order several mes and the weight will creep up 8000 or 10,000 lb., due to increased ze or weight of parts here and there. This increased weight is made ithout any change in the vital dimensions of the locomotive.

In one case a systematic study of a design was made. As a result was found that 2500 lb. could be taken out without impairing the ficiency of the details or of the locomotive as a whole.

Cast steel cylinders offer a possible means of weight reduction, though they have not been used to any considerable extent. For rge size locomotives, they would probably reduce the weight of the linders 4500 lb. per pair. There are a number of details, such as nd boxes, boiler fronts, etc., where material reductions can be made. e have been able to do much in the way of steel shapes for sand ›xes. Wooden cabs and running boards can be used but there is a eater desirability in using steel.

Another thing is the question of changing existing standards ring to new devices. We have under consideration the question reducing the size of the cab, following the introduction of power screw reverse gears. We have already been able to reduce them from : in. and 90 in. down to 72 in. The Pennsylvania has started on this ıe and we may see quite a little done in this way in the future.

USE OF HIGH-GRADE ALLOY STEELS TO REDUCE WEIGHT.

H. V. WILLE (written). Many railroad metallurgists do not conder that the possibilities of high-grade carbon steel have been utilized › the fullest extent by designers. This is no doubt due to the fact ıat designers and metallurgists view the properties of steel from enrely different points. The metallurgist wishes a steel of great duclity with a good elongation and reduction of area, or in other words, steel that will readily flow under limiting loads; whereas the degner desires a stiff steel, one of high elastic ratio or a steel that will ot readily flow under loads above the elastic limit. The metallurgist ıerefore specifies a steel with a high elongation and reduction of rea and to meet these conditions the manufacturer is compelled to se a steel of medium carbon.

As for possibilities of improvements, a decided reduction in weight s well as the elimination of failures would result from a modification of existing specifications for forgings for the purpose of permiting the use of steel of high tensile strength and elastic limit even t a sacrifice of ductility as measured by the elongation and reduction of area. These views are sustained by the results of an elaborate series of tests on the endurance of rotating shafts conducted by the United States Government at the Watertown Arsenal by Jas. E. Howard.

These experiments required years to make and the results from the different yearly reports are tabulated in Table 2.

Enormous increase in endurance following the use of material hav-

TABLE 2 TESTS ON THE ENDURANCE OF ROTATING SHAFTS

Car	Nickel	Treatment	Fiber Stress	Rotations	Elastic Limit	Tensile Strength	Elongation	Contraction
0.26	3.282	Annealed	40,000	1,847,500	51,500	81,370	28.75	61.09
0.26	3.282	Oil Quenched and Annealed	40,000	1,815,200	66,950	90,640	26.9	65.04
0.25	4.514	Annealed	40,000	2,366,000	61,610	95,490	24.8	57.13
0.25	4.514	Oil Quenched and Annealed	40,000	3,296,700	101,860	120,190	20.8	60.05
0.29	5.661	Annealed	40,000	4,388,400	90,090	108,840	22.5	58.71
0.29	5.661	Oil Quenched and Annealed	40,000	3,795,200	117,610	131,410	19.65	59.88
0.539	27.353	Annealed	40,000	2,495,600	48,060	104,820	47.5	63.10
0.539	27.353	Oil Quenched and Annealed	40,000	1,088,200	46,850	97,780	43.35	60.80
0.24	......	Annealed	40,000	229,300	40,560	71,240	32.3	59.81
0.24	......	Oil Quenched and Annealed	40,000	348,000	45,170	74,440	33.15	69.93
0.42	......	Annealed	40,000	225,900	44,290	80,885	23.0	56.7
0.42	......	Oil Quenched and Annealed	40,000	655,600	55,000	92,180	26.05	57.22
0.46	......	Annealed	40,000	976,600	48,060	94,600	21.15	47.65
0.46	......	Oil Quenched and Annealed	40,000	1,657,500	61,110	102,880	13.05	51.27
0.66	......	Annealed	40,000	3,689,000	65,205	124,200	7.15	17.28
0.66	......	Oil Quenched and Annealed	40,000	4,323,600	92,040	154,920	13.5	31.48
1.094	......	....	30,000	50,000,000	......	......	.....	.....
0.733	......	....	30,000	12,547,600	......	......	.....	.....
0.824	......	....	30,000	16,336,200	......	......	.....	.....
0.824	......	....	35,000	13,871,000	......	......	.....	...
0.094	......	....	35,000	19,152,300	......	......	.....	.....

ing high elastic limit and tensile strength is notable and it is shown that a 0.66 carbon steel shaft exhibits as much endurance as a 5.6 per cent nickel steel one.

When steel forgings were first proposed for use in locomotives, a soft grade of steel was generally employed, the purpose being to secure a steel of similar properties to the iron formerly employed.

The use of this material resulted in an unusual number of failures of axles, pins and rods. After studying these failures, Dr. C. B ey, S. M. Vauclain and S. T. Wellman experimented with higher n steels. This led to the general adoption of steel of 80,000 ten- rength for locomotive work, with the result that the failures were nated and the great superiority of this steel over the softer steels lemonstrated notwithstanding the great difference between the teels in elongation and contraction of area. This grade of steel il being universally employed and any changes made were for the se of increasing the ductility requirements rather than the tensile rements, thus handicapping the manufacturer in the develop- of this grade of steel.

specifications were revised to permit the use of a 0.66 carbon there would be but little necessity to employ the expensive alloy .

1 sketching the development of the art with respect to increase in ity, sufficient stress is not laid upon the development of the r truck locomotives with the attendant possibilities of improve- in boiler design. It is now generally recognized that the use of r trucks has permitted boilers of great capacity. Were it not for levelopment in boiler design, there would be a very limited use of heaters in the modern locomotives because of the restriction to capacity. When the first trailer truck engine was built but a decade ago it was received with a storm of criticism and the ers stood almost alone as the advocates of this type. The use of railing truck is a logical development of the use of wide fire- .

Vide fireboxes originated with the invention by Wootten in 1877 of oiler which bears his name. The original designs of the well n Wootten or wide firebox boiler contained a combustion chamber. ten considered this feature essential. Later, A. E. Mitchell modi- this design by omitting the combustion chamber and employing aight flue sheet which was subsequently changed to the offset flue . These types of boilers were the predecessors of the modern firebox engine and it is interesting to note at this time that so of these engines held world records for speed and capacity.

The Atlantic or 4-4-2 type was designed in 1895 and was first em- d by the Atlantic Coast Line and derived its name therefrom. At the design was received with criticism, but the advantages in the ruction of large fireboxes and large boilers were so manifest that s rapidly followed by the design of a Prairie or 2-6-2 type engine he C. B. & Q. Railroad. The Pacific or 4-6-2 type was naturally developed from this type in 1901 for the New Zealand Government Railways to burn inferior fuel. In 1895 the Mikado or 2-8-2 type was also designed to burn inferior fuel of a lignite nature from the Iwaki and Iryana mines of the Japan Railway Company.

In 1903 the first 2-10-2 or Santa Fé type locomotive was built for the Atcheson, Topeka & Santa Fé Railway. While this type was so successful as to warrant the continuation of many duplicate orders for this company, only in recent years have other railroads begun to employ this most powerful of all single unit coupled locomotives.

The reason for the success of these locomotives is not far to seek. The relative steaming capacities of different types of locomotives bear some inverse ratio to the percentage of total weight carried on drivers. This rule, if such it may be called, is not strictly true, for a constant value yet to be determined should be subtracted from the weights before calculating the percentage and the application of the rule will give the minimum increase in horsepower capacity to be derived from the use of trailer trucks.

TABLE 3 TOTAL WEIGHT CARRIED ON DRIVERS

Type		Percentage of Total Weight on Drivers	
		Trailer Truck	No Trailer Truck
American	4-4-0	....	65
Atlantic	4-4-2	55.5	....
10-Wheel	4-6-0	63	....
Pacific	4-6-2	....	76
Consolidation	2-8-0	....	88.5
Mikado	2-8-2	77	....
Decapod	2-10-0	....	89.5
Santa Fé	2-10-2	80	....

Table 3 shows the percentage of total weight which is carried on drivers for various types of trailer truck and its corresponding non-trailer truck engine.

From Table 3 is derived Table 4, showing increased capacities of trailer truck locomotives.

TABLE 4 INCREASE IN HORSEPOWER CAPACITY TO BE DERIVED FROM THE USE OF TRAILER TRUCKS

Type	Percent Increase of Capacity
Atlantic over American...........	17
Pacific over 10-Wheel.............	22
Mikado over Consolidation........	15
Santa Fé over Decapod...........	12

C. D. Young in discussing the above subject called attention to the ordinary annealed carbon steel as used generally for locomotive forgings. The minimum physical properties may be considered as follows: Tensile strength, 80,000 lb. per sq. in.; elastic limit, ½ the tensile strength; elongation in 2 in., 22 per cent; reduction of area, 30 per cent.

With properly quenched and tempered carbon steel we may expect an increase in the elastic limit of 30 per cent or more, about 15 per cent increase in tensile strength, the elongation remaining the same and the reduction of area increasing about 50 per cent. These are conservative figures and a great deal better elastic limit and tensile strength may be obtained, depending upon the chemical composition of the steel and the heat treatment.

From alloy steels, such as chrome vanadium or chrome nickel, we may expect to obtain the following physical properties after heat treatment: Tensile strength, 95,000 lb. per sq. in.; elastic limit, 75,000 lb. per sq. in.; elongation in 2 in., 20 per cent; reduction of area, 50 per cent.

On an average, these alloy steels will show an increase in physical properties over those of annealed carbon steel of 20 per cent or more in tensile strength, 80 per cent or more in elastic limit, with elongation in 2 in. about 9 or 10 per cent less than that of the carbon steel, and the reduction of area of 75 per cent or more greater. These figures are subject to modification on account of variation in the chemical composition of the steel and the heat treatment.

In carbon steel castings approximately the same per cent increases in physical properties as were given for carbon steel forgings may be obtained after proper heat treatment. The experience with alloy steel castings has been too limited to furnish any satisfactory data. Up to the present time the majority of users of heat-treated steels seem to have made but little, if any, use of the increased physical properties as determining the fiber stresses used in design, though some of the larger builders of locomotives have made such increases in fiber stresses for both heat-treated carbon and alloy steels. In certain parts where heat-treated carbon steel has been used, the fibre stress has been increased about 25 per cent above that used for annealed carbon steel, and in the case of heat-treated alloy steels an increase of as much as 50 per cent has been made. In some cases, depending upon the design and service for which the forging is intended, it is preferable to allow no increase in the fibre stress, but to consider the excess

TABLE 5

Parts	Grade of Material	Working Fiber Stress in: Tension or Compression	Working Fiber Stress in: Bending	Minimum Ultimate Tensile Strength	Minimum Elongation in 2 inch
Main and Parallel Rods	Annealed 0.45 carbon	8,000	10,000	80,000	1,800,000 / T. S. 20
	Quenched and Tempered 0.52 carbon	10,000	14,000	85,000	2,000,000 / T. S. 20
	Quenched and tempered alloy	12,000	18,000	100,000	....
Piston Rods	Annealed 0.45 carbon	9,000	......	80,000	1,800,000 / T. S. 20
	Quenched and tempered 0.52 carbon	10,000	......	85,000	2,000,000 / T. S. 20
	Quenched and tempered alloy	12,000	......	100,000	....
Driving Axles	Annealed 0.45 carbon	Combined bending and torsion in starting	18,000	80,000	1,800,000 / T. S. 20
	Quenched and tempered 0.52 carbon		20,000	85,000	2,000,000 / T. S. 20
	Quenched and tempered alloy		25,000	100,000	 20
Crankpins	Annealed 0.45 carbon	......	13,500	80,000	1,800,000 / T. S. 20
	Quenched and tempered 0.52 carbon	......	16,000	85,000	2,000,000 / T. S. 20
	Quenched and tempered alloy	......	20,000	100,000	 20
Cast Steel Parts	Annealed 0.28 carbon	8,000	Tension	60,000	1,400,000 / T. S. 22
	Quenched and tempered 0.28 carbon	10,000		75,000	1,800,000 / T. S. 20
				Transverse Strength	Bend Test, Degree
Springs	Drawn 1.0 carbon	70,000		90,000	25
	Quenched and tempered 1.0 carbon	90,000		120,000	25
	Quenched and tempered alloy	100,000		150,000	50

Note: Maximum figures for working fiber stress may be 20 per cent in excess of those shown.

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Vhile there is no objection to the change of the present standard n, it would seem, with our present knowledge of heat-treated rial, that it would be entirely safe to use certain increases in the stresses when designing locomotive parts. As a suggestion as to could be done in this respect, Table 1 shows what is recom-led for three grades of steel as to working fiber stresses and the num ultimate strength and elongation. This has been tabulated he grades of 0.45 annealed carbon, quenched and tempered 0.52 n and quenched and tempered alloy steels.

'he results shown in Table 5 seem to indicate that heat-treated n and alloy steels will show greater resistance to wear and to the ue stresses in service than is shown by annealed carbon steel; it is our opinion that the increase in resistance to wear is about roportion to the increase in Brinell hardness which is brought t by the heat treatment.

MECHANICAL STOKERS

LEMENT F. STREET (written). The most important things which toker has done for the locomotive are first, increased the earning r of existing locomotives, and second, removed practically all ations, from a fuel quantity standpoint, on the size of locomo- which can be built.

locomotive designer must always keep in mind the fact that dollar earned in the operation of a railway is earned by its loco-ves, and therefore in the above I have given first place to the ase in the earning power of existing locomotives. Many instances l be cited to prove this statement, but one will suffice as an illus-on.

locomotive providing about 54,000 lb. tractive power when run- with saturated steam, had a tonnage rating over a certain division 750 tons. Superheaters were applied to this locomotive, and the age increased to 5,000; stokers were applied and the tonnage in-ed to 5,250, then 5,500, then 5,750, and finally 6,000. In the

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Springs	Drawn 1.0 carbon	70,000		90,000	25
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	Quenched and tempered 0.28 carbon	10,000		75,000	$\frac{1,800,000}{\text{T. S.}}$	20
				Transverse Strength	**Bend Test, Degree**	
Springs	Drawn 1.0 carbon	70,000		90,000	25	
	Quenched and tempered 1.0 carbon	90,000		120,000	25	
	Quenched and tempered alloy	100,000		150,000	50	

Note: Maximum figures for working fiber stress may be 20 per cent in excess of those shown.

strength of the heat-treated material as contributing to increase life in service, or to safety.

Recent practice has indicated that it is desirable, when using heat-treated designs, to study carefully the section, so as to avoid abrupt changes, and also in the cases of larger shafts, such as axles, or crank-pins, that they shall be hollow-bored in order to provide for better treatment and to relieve shrinkage strains which occur during the quenching process.

While there is no objection to the change of the present standard section, it would seem, with our present knowledge of heat-treated material, that it would be entirely safe to use certain increases in the fiber stresses when designing locomotive parts. As a suggestion as to what could be done in this respect, Table 1 shows what is recommended for three grades of steel as to working fiber stresses and the minimum ultimate strength and elongation. This has been tabulated for the grades of 0.45 annealed carbon, quenched and tempered 0.52 carbon and quenched and tempered alloy steels.

The results shown in Table 5 seem to indicate that heat-treated carbon and alloy steels will show greater resistance to wear and to the fatigue stresses in service than is shown by annealed carbon steel; and it is our opinion that the increase in resistance to wear is about in proportion to the increase in Brinell hardness which is brought about by the heat treatment.

MECHANICAL STOKERS

Clement F. Street (written). The most important things which the stoker has done for the locomotive are first, increased the earning power of existing locomotives, and second, removed practically all limitations, from a fuel quantity standpoint, on the size of locomotives which can be built.

A locomotive designer must always keep in mind the fact that every dollar earned in the operation of a railway is earned by its locomotives, and therefore in the above I have given first place to the increase in the earning power of existing locomotives. Many instances could be cited to prove this statement, but one will suffice as an illustration.

A locomotive providing about 54,000 lb. tractive power when running with saturated steam, had a tonnage rating over a certain division of 4,750 tons. Superheaters were applied to this locomotive, and the tonnage increased to 5,000; stokers were applied and the tonnage increased to 5,250, then 5,500, then 5,750, and finally 6,000. In the meantime the tonnage rating of the shovel-fired superheater locomotives was increased to 5,500. This shows an increase of over 20 per cent in the tonnage rating of this locomotive after the stokers were applied and the locomotive today, stoker-fired, is hauling 10 per cent more tonnage than when shovel-fired. The increase in the tonnage rating of the shovel-fired locomotives is very interesting and brings out strongly one of the indirect advantages of the stoker. It shows very clearly that before the stokers were applied, the shovel-fired locomotives were not doing anything like what they should do and as soon as the stoker came into use, it not only increased the tonnage rating of the locomotives to which it was applied, but also brought about an increase in the rating of all others on the division.

Along this same line, the stoker is making it possible to approach much nearer to theoretical conditions in regular operation. It is well known that there is a wide difference between the earning power of a locomotive under test conditions and under average road conditions. The writer has in mind one case in which it was found that under test conditions a certain locomotive could haul 4,000 tons comfortably over a certain division. When this locomotive was put into regular service, however, it was found impossible to operate it with more than 3,500 tons over the same division. With a mechanical stoker this locomotive easily handles 4,000 tons in regular road service.

The fact that the stoker has removed limitations in the size of locomotives which can be built can be brought out by referring to several of the locomotives mentioned in the report. The Mountain type locomotives were fitted with stokers when they were built, have always been stoker-fired, and no attempt has ever been made to shovel-fire them. The locomotive referred to in par. 5 would never have been built had it not been known that a stoker could be secured which would fire it. There are thirty of the locomotives referred to in par. 6 now in regular operation, and they too would never have been built had it not been known that a stoker could be secured which would fire them. A number of other locomotives now in regular operation, notably the most powerful Pacific type as yet built, would never have been contemplated without a stoker.

In reference to the amount of coal which can be fired, as high as eight tons have been put in a fire box with an existing machine and without working it to its capacity. There is no reason why any desired quantity of coal cannot be fired by the use of the stoker, and the limitation of amount of coal which can be fired is entirely removed in connection with the design of new locomotives.

The stoker as yet has not progressed far enough to bring forth lefinite figures regarding its efficiency. Wherever it has been inroduced, the question of increased tonnage has been more important han that of fuel economy, and the latter has, therefore, been given ery little consideration. This, of course, is only a temporary conition, and as more stokers are applied the question of fuel economy ill become more important. The development of the mechanical toker has gone far enough, however, to show that the stoker will urn a much cheaper grade of coal than it is possible to use with and firing, and that it will give a more uniform rate of fuel conumption on locomotives performing the same service.

It is a well-known fact that there is a difference of from 25 to 50 er cent in the amount of coal burned by different firemen for perorming the same work. The stoker is eliminating this great variaion and making the results more uniform.

When all locomotives on a railroad are being worked to their full apacity, the earning power of that road is at its maximum. In this ountry today there are very few, if any, shovel-fired locomotives aving a maximum tractive effort of 50,000 lb., or over, which are eing worked to their full capacity. Wherever stokers have been pplied the earning power of the locomotives on which they have been laced has been increased from 10 to 20 per cent. There is no intance where stoker-fired and shovel-fired locomotives are being operted under identical conditions. The stoker-fired locomotives are, in very case, hauling increased tonnage, or using a cheaper fuel, or vorking at higher average speeds than the shovel-fired locomotives.

E. A. Averill (written). In the report of a test on a large loconotive at the Altoona test plant it is stated that the results indicate hat the capacity of the boiler was limited by the ability to burn the oal on the grates and not any failure of the heating surface to absorb he heat supplied. While in this case the limit was marked by the mpossibility of supplying sufficient air through the grates to burn the uel properly, there are operating in this country today a reasonably arge number of locomotives which are running at less than full oiler capacity because of the physical inability of the fireman to upply the amount of fuel that can be burned.

Ten classes of locomotives, built during the past three years, nd typical of the general size and capacity of all the larger freight ngines built in that time, were selected at random. These are shown n Table 6. The American Locomotive Company's standard practice

in connection with steam per horsepower hour and evaporation per pound of coal has been used. Also the percentage of tractive effort and maximum horsepower at various piston speeds and the evaporation per sq. ft. of heating surface for the firebox and tubes. It is assumed that each locomotive is working at the speed indicated on a 0.5 per cent grade and that the cars in the train each weigh 70 tons with its lading.

When each of these locomotives is delivering the power it is easily capable of, if in good condition, it will be seen that it requires from 4900 to over 8000 lb. of good quality coal an hour. The locomotives are actually getting from 4500 to 5000 lb. an hour, and handling trains of a proportional size.

A number of locomotives like these, all of the same class, and operating on the same division, will have a tonnage rating in proportion to the ability of the average poorest fireman that is assigned to them rather than to the average best fireman. While there may be a few firemen on the division who are capable of developing the full boiler capacity, the group of engines as a whole may be daily working much below their actual capacity.

The acceptance of the opportunity to supply at all times the desired quantity of coal to these locomotives that is offered by the stoker will have the same practical effect on operating expense as would a new order of more efficient, larger locomotives.

A reduction in the cost of conducting transportation follows this increased locomotive capacity in a number of the principal items when presented on a ton-mile basis. The stoker itself offers an opportunity for further savings particularly in the cost of fuel, reduced claims for damage or accident and the recruiting of men of higher caliber for locomotive service.

An instance of the possible savings in the cost of conducting transportation, through increased locomotive capacity following the application of a stoker, is found on a certain division where 10 tonnage trains are sent one way over the road each day with hand-fired locomotives. Application of stokers has permitted an increase of over 11 per cent in the tonnage of a train. The return movement is largely empties. The application of stokers will give a direct saving, from wages and train supplies alone, of about $100 per engine a month on this division. If advantage is taken of the increased capacity of the division for tonnage without the addition of more locomotives, the saving will be considerably larger.

TABLE 6

Type	Cylinders, In.	Steam Pressure, Lb.	Diameter Drivers	Maximum Tractive Effort	Maximum Cylinder H.P. *	Normal H.P. from Heating Surface †	Coal per Hr. at Maximum H.P. ‡	Speed for H.P.	On Grade of 5 per Cent: Speed M.p.H.	Tons in Train	H.P. Required	Coal per Hr., Lb.	Coal Sq. Ft. Grate Area, Lb.	Water per Sq. Ft. Heating Surface, Lb.
2-8-2	25×32	180	63	48600	2027	2210	6587	35	25	1930	1945	6320	112	9.88
2-8-2	28×32	170	63	57460	2400	2310	7507	35	25	2382	2290	7440	106	11.5
2-8-2	27×30	175	63	51700	2296	2269	7374	37.5	25	2183	2160	7020	100	11.05
0-8-8-0	26×41×28	200	51	105000	....	3032	8759§	32.5	15	6050	2860	8240§	82.4	10.6
4-8-2	28×28	185	69	50000	2613	2451	7965	44	35	1403	2390	7767	124	12
2-6-6-2	21½×34									**				
	×32	200	57	67500	2533	2312	7514	32	15	3820	1940	6300	111	9.2
2-8-2	28×32	180	64	60000	2542	2418	7858.5	36	25	2470	2410	7840	100	10.8
2-8-0	26×30	185	57	55900	2251	2167	7242	34	15	3120	1765	5750	86	10.4
2-8-8-2	26×40×30	200	57	87600	....	2942	9561	34	15	5060	2390	7800	92	9.2
2-8-0	25×30	180	57	50328	2027	1848	6006	34	15	2920	1510	4900	87	11

* Horsepower + 0.01798 Pd^2 at 1000 ft. piston speed

† Normal horsepower from heating surface = evaporation, lb. per hr. ÷ 20.8 lb.

‡ 3.25 lb. coal per h. p.-hr.

§ 7.2 lb. water per lb. of coal

** Passenger train

Naturally one of the first features to be investigated by a railroad considering the application of stokers is the cost of maintenance. In general, the machine of any kind with the fewest parts, properly designed, will cost the least for maintenance, inspection or repairs. During the past year and a half has been made a distinct advance in connection with the simplification of the stoker apparatus. The latest type of locomotive stoker consists of a comparatively few strong, heavy parts and a very few wearing surfaces.

There has been much discussion of the amount of coal consumed on stoker-fired locomotives. In some cases these do burn more coal per trip and the mistake of making the comparison on pounds of coal consumed per 1000 ton miles has led to the deception of some investigators. Accurate tests permitting the comparison of shovel and stoker-firing to be made on the basis of pounds of coal per indicated horsepower hour, have shown widely varying results with different designs of stokers. Some carefully conducted evaporative tests with the most recent design of stoker are very encouraging in this particular. These tests were made with the locomotive in regular service. Comparing the average of five hand-fired runs and four stoker-fired runs on the basis of actual pounds of water evaporated per 1,000,000 B.t.u. supplied, the stoker gave an increase of nearly 7½ per cent. In another case the increase in evaporation with the stoker was nearly 12 per cent. From these figures, as well as from observations in regular daily service, it would appear that some saving in coal can be expected from this stoker. These tests were made with run-of-mine coal.

A stoker should successfully handle the coal in any condition in which it may be put on the tender. It should make no difference if the coal be all dust or clean lumps of larger size; soaking wet, slightly damp or bone dry. The stoker should take the coal as it finds it the same as a fireman does. The development of stokers in this direction during the past year or two has been particularly satisfactory and ordinary run-of-mine coal is now being used with complete success.

The use of lower and cheaper grades of coal is quite general on the stoker locomotives of a number of roads which report a net saving from the practice.

Calculations that have been made of the movement of the gases in a firebox equipped with a brick arch, show that velocities of 265 ft. a second will be present over the end of the arch when burning

)00 lb. of coal an hour on 70 sq. ft. of grate area. The velocity ›creases as the fire bed is approached and at a point 2 ft. above the ·ate the gases have an average velocity of about 33 ft. a second. his clearly indicates the importance of injecting the fuel charge low down in the firebox as possible to reduce the loss by fine coal ıssing through the flues partially burned. The more recent development in stokers has given this feature the attention it deserves.

Opportunities for economy in connection with the reduction in .mage claims follow the better lookout from the locomotive by the 'eman being left free to watch signals, crossings and operation of e machinery on the left side. One of the essentials in this connec- ›n is noiseless operation. The stoker should not prevent free con- rsation across the cab nor make any noise that can be heard when e locomotive is running. The development of the past year or 'o has shown a wonderful improvement in this particular and okers are now being applied which are essentially noiseless in their ›eration.

The stoker should be 100 per cent efficient; it should do all the :ing, handle all the coal from the tender with the minimum atten- on and not require alteration of the distributing means after it once properly adjusted. The fireman should be free to attend the duties mentioned above and should be able to control the oker operation from a position on the seat box.

It is well established in manual firing that small quantities of ›al fed frequently and distributed by the "cross fire" method gives ıe most perfect combustion. The stoker should follow this method ıt perform the operation more exactly than it can be by hand. ecent development shows a full appreciation of this requirement ıd at the same time provides a flexibility that allows the stoker meet exactly the conditions of combustion at the various parts the grate. If 70 per cent of the coal is being burned on one side the grate, the stoker should discharge that proportion of the fresh .el on that section. If more fuel is being burned in front than in ıck, the stoker should distribute to suit. This flexibility is essential r 100 per cent stoker work.

Another feature of improvement in the most recent of the atter type stokers is the absence of any part of the stoker on the ›iler head or in the cab. Stokers are now being applied which show :actically nothing in the cab and thus allow the best arrangement ' the many instruments and appliances required on a modern locomotive. This also permits the proper inspection of all the staybolts and their renewal if necessary without the removal of any part of the stoker.

FUTURE OF THE STEAM LOCOMOTIVE

J. E. MUHLFELD (written). In my opinion the available energy in superheated steam, and the necessity for economy in first cost and for operation, will cause the self-contained steam locomotive to remain for a long time the principal motive power for moving heavy tonnage trains long distances. For this reason, the next few years will probably see it substantially improved through the development of Mallet articulated types, superheating, compounding, feedwater heating and pumping, boiler circulation, valve motion gear, reciprocating and revolving parts, combustion, automatic stoking of pulverized fuels, and standardization.

G. R. HENDERSON pointed out that 15 or 20 years ago it was thought that we had reached the limit of size and capacity in locomotives. Shortly afterwards we had some gain in compounding but we had large locomotives giving only from 1000 to 1500 h.p., whereas the size would have led us to think that we could get double that power.

Superheaters, coalpushers, firedoor openers, etc., have all helped to increase the capacity of the locomotive. In a few years very probably we will have largely extended the use of powdered coal. The present limitations of height and width will not differ to a marked degree but the length can be increased without any special alterations except for turn tables and things of that sort where we can easily increase the length.

Our boilers can be increased in length, and there comes in Mr. MacFarland's idea of an exhaust fan at the front end to give the necessary draft in the firebox. Powdered coal will help a great deal in assisting in lengthening the firebox and giving a greater amount of evaporative surface.

If we consider the present limitations of drawbar strength, length of siding, and legislative restrictions, I think by this lengthening it is possible to build a locomotive of any desired tractive force, even up to 250,000 or 300,000 lb.

THE BIG STEAM LOCOMOTIVE

J. B. ENNIS (written). Twenty-five years ago the largest steam locomotive in service had a total weight of about 154,000 lb. and a

:tive power of 34,000 lb. At that time, a locomotive of these portions represented the improvement of 60 years of effort in this : of steam engineering, and while this advance had been gradual, ras a series of progressive steps leading up to the building of this gest locomotive in the world." This 60 years of progress had been eriod in which the main object seemed to be increased capacity y. Aside from the fact that the number of wheels was increased the parts were made larger and heavier, a locomotive of this iod in its essential details followed closely the established practice years before. Detail design had been constantly improving, but that time no general effort had been made toward improvement the efficiency of the machine. A pound of drawbar pull meant burning of the same amount of coal as it had a quarter of a tury before.

During the past 25 years conditions have materially changed and demands made on the locomotive have been such that the pross in its development was to be rapid. From 1889 to 1899 the ıl weight increased from 154,000 lb. to 232,000 lb. and the power proportion. It was during this period that it was first realized t increase in capacity could not go on so rapidly unless acıpanied by some efforts toward economy. The first general step this direction was the introduction of the compound principle; ious systems were brought out and for years large numbers of se engines were built, many of which gave decided economies in rice as well as increase in power. Although the movement to pt this principle was advocated by many, the simple locomotive still preferred and gradually increased in weight and power until ras thought by many that the limit of capacity had been reached.

Fifteen years ago, we find instances of locomotives built where, order to maintain full power for any length of time, the amount coal burned was so large as to call for considerable activity on part of the fireman. Perhaps fortunately, stoker designs had been perfected, although the time could not have been greatly ıyed when consideration was to be given to other devices to bring ut efficiency.

In Europe, superheating had demonstrated its economies in locotive service and about ten years ago the first applications were de in this country. For some time its use was very limited, after it was proven that high temperature superheaters would e increased capacity and great economy in fuel that would not be offset by high maintenance expense, and that the economy could be obtained in all classes of service, the movement to adopt this principle became widespread. As a result of this improvement, combined with others that followed, we now have passenger and freight locomotives giving at least one-third more power at the draw-bar than would have been possible 10 years ago with simple locomotives using saturated steam and consuming the same amount of fuel.

This increase in weight and power continued and the locomotive soon reached a size where it became necessary to consider, in many cases, some other means of feeding the coal than by hand. The mechanical locomotive stoker was demanded and produced. It is no longer an experiment and is capable of delivering all the coal that the present day locomotive requires.

As examples of the big steam locomotives of today, we have simple freight locomotives giving tractive powers 50,000 lb. greater than the maximum of 25 years ago; an experimental articulated locomotive for pushing service designed to give a tractive power of 160,000 lb.; articulated locomotives for road or pushing service with tractive powers of 115,000 lb.; the simple Pacific type with 46,500 lb. and simple Mountain type with 58,000 lb. Individual wheel loads have steadily increased until we have nearly 70,000 lb. weight per pair of drivers. Our locomotives are as high and as wide as clearance limitations will permit, and yet it would be unwise to say that the limit has been reached.

The big steam locomotive of the future will probably not be the locomotive of the past. Today we can see possibilities toward further refinement in design and further economies that may be obtained s that the locomotive designer is not yet ready to acknowledge that has been accomplished.

For freight and pushing service on heavy grade, past performances show the adaptability of the articulated compound engine. This design of locomotive is still in the course of development and it will, without doubt, be the generally accepted type for these conditions for some time to come. With the exception of the experimental articulated locomotive already referred to, locomotives recently built for the Virginian Railway are the largest of the type. A few particulars of their performance may be of interest. Designed originally for pushing service on grades of over 2 per cent and normally rated at 115,000 lb. tractive power working compound, ese engines have proven themselves capable of handling on a grade 0.6 per cent a train load of 7180 tons, requiring a drawbar pull of proximately 110, 000 lb. On lighter grades and at higher speeds er 3000 i.h.p. have been obtained. Work of this magnitude necesates locomotives of exceptional weight and power, and yet the ssibilities of this type have by no means been exhausted. As contions arise in the future in which more power will be required, e use of the articulated engine can yet be extended.

For freight service on easy grades where the capacity of the ticulated engine is not required, we already have exceptionally ge locomotives of the 6, 8 and 10 coupled types. Simple cylinders erating at 200 lb. pressure have reached a diameter of 30 in., d in order to transmit this power a main axle 13 in. in diameter s been used. Main crankpins, rods and other details are of enormous e. With the increase in the diameter of cylinders, the cylinder nters have gradually increased and frame centers decreased. This s resulted in higher stresses of parts than those caused by piston rust only. The weight of revolving and reciprocating parts has ached the point where, in some cases, proper counterbalancing bemes very difficult. It is doubtful whether much more capacity n be obtained in these types if designed along the present lines, d here it would seem that attention could profitably be given to finement in design and its relation to the careful selection of aterials.

Modern passenger locomotives have reached a high development, d yet there is one problem still to be solved that has been recognized r many years—that of the effect on the rail of the vertical unlanced forces in a two-cylinder engine. At present our largest d most powerful passenger locomotives have two simple cylinders to 29 in. in diameter, giving maximum piston thrusts of approxitely 117,000 lb., with static wheel loads higher than ever before d, with few exceptions, reciprocating parts of much greater weight.

The four-cylinder balanced compound was introduced about 10 ars ago as a possible solution and for a few years a large number these locomotives were built. There is no doubt as to the results tained, as far as balancing was concerned, and yet recently very v have been constructed. Four-cylinder simple locomotives have o been tried out, but in both these types the capacity is limited on count of the available space between the frames, making it prac-

tically impossible to provide the power now given by the largest simple two-cylinder engines.

Little consideration has been given to the advantages of the three-cylinder arrangement, although a few locomotives of this type are in successful service today. As compared with the four-cylinder engine, either simple or compound, the three-cylinder type offers first the possibility of increased power. With one cylinder located between the frames ample room is provided for a properly designed crank axle and main rod which cannot be arranged for in the four-cylinder type beyond a certain limit. As compared with the two-cylinder engine, the advantages are, briefly, a more even turning moment, an ideal counter-balancing condition and the opportunity to furnish maximum power with the minimum destructive effect on the rail. The power obtained in a two-cylinder engine with cylinders 27 in. in diameter and a maximum piston thrust of 117,000 lb. can be obtained in a three-cylinder engine with cylinders 22 in. in diameter and a maximum piston thrust of 78,000 lb. This decrease of 33 per cent in thrust means a corresponding reduction in the individual weights of all of the machinery, particularly the weights of reciprocating parts.

It is true that much progress can yet be made in the two-cylinder engine towards reducing the weights of reciprocating parts by the careful selection of materials and proper design. The three-cylinder engine, however, offers advantages possessed by no other arrangement, and it would seem that, for high-speed passenger service at least, this type is well worth considering for the future.

No. 1449

THE FUTURE OF THE POLICE ARM FROM AN ENGINEERING STANDPOINT

By Henry Bruère[1], New York City

Non-Member

With the single exception of education, the field of public service in which most stability has been achieved and the nearest approach to a formulated technique evolved is the engineering field. Of all professions, engineers have alone found a permanent vocation in municipal work.

2 To engineers must be credited the great achievements in municipal government. They have built the cities, often unskillfully and without imagination, too often harassed by politicians and special interests, but they have built them. They have constructed waterworks. They have constructed piers, docks and harbors. They have brought into civil government the spirit of workmanship and the ideals of science, and they have been the first to utilize a scientific method in the conduct of the day-by-day routine of public administration.

3 In making these statements I am not unmindful of the great opportunities that still remain for further development of engineering service in cities, and for weeding out incompetency, charlatanism and subserviency to improper ideals. The municipal engineer, perhaps more than any other group or class of engineers, has been forced to opportunism. But notwithstanding this fact, municipalities are distinctly the debtors of the engineering service. I wish to refer on this occasion to the obligation of New York City's police department to an engineer. To a very large extent the beginning of systematic methods in handling the business of the police department and the beginning of the end of the proverbial confusion prevailing in the management of

[1]City Chamberlain.

Abstract of paper presented at the Annual Meeting, December 1914, of The American Society of Mechanical Engineers.

the New York police force, took place when the department was in the hands of an engineer, General Theodore A. Bingham.

4 My justification for discussing the problems of police administration at a meeting of mechanical engineers is this: Scientifically, the most neglected field of public service in America is the police department. There is no part of municipal administration, not itself in the engineering category, that more urgently needs the aid of engineering method than does the "police arm." I make this assertion on two assumptions, with which there may not be general agreement. The first assumption is expressed in a definition of the substance of the "engineering method." The second assumption is expressed in a definition of the functions of the police arm.

5 It is my understanding that the purpose of the engineering profession is primarily to develop the facilities and conditions of civilized life. Engineering is the application of formulated scientific knowledge to the practical problem of administering to human needs and developing the physical resources of the world. The function of the police on the one hand is to protect the institutions of civilization and to eliminate conditions hostile to civilized life, and on the other hand to make available for the freest expression and highest efficiency that greatest of all natural resources, the collective and coöperative life of a community.

6 Let me state more succinctly, before elaborating my argument, my understanding of (*a*), the nature of the engineering method, and (*b*), the police problem:

a The engineering method consists of applying scientifically determined knowledge to the execution of a particular problem, and the use of ordered and analyzed facts as a basis for formulating conclusions in respect of that problem. As a result of the repeated application of the engineering method to like or similar problems a technique is established for achieving a particular object repeatedly, with least waste of energy and resource

b The function of the police arm of government is to ascertain all the facts regarding the phenomena of crime and disorder, and by the use of those facts as a basis for action, direct and collateral, to minimize and extirpate crime and disorder

7 I shall not attempt a justification of my definition of the engineering method. Numerous better definitions have been formulated.

But I believe the definition that I have submitted is adequate for the purpose in hand. It will be necessary, however, to elaborate and perhaps to justify the definition which I have offered of police work, for the definition in itself implies a change in the objectives of police service.

8 Generally, until now, the functions of the police have been assumed to be something as follows:

a General enforcement of certain laws and ordinances

b Enforcement of certain other laws and ordinances selectively, according to the feasibility of their enforcement and the state of public opinion regarding them

c Enforcement of certain other laws and ordinances on complaint of persons injured by their infraction, with particular respect to the perpetrators of the injury

d Repression or prevention of crime and disorder, by the process of tacit intimidation; in other words, the brass buttons and swinging night stick

e Physical and militaristic suppression of express disorder, such as riots and street brawls

f Investigation of crime committed for the purpose of tracing, identifying and apprehending the criminal

g Performance of inspections, regulation of traffic, rendering aid to citizens, and miscellaneous other incidental functions that are committed to the police as matters of convenience, and are not generic to the police problem

9 In other words, police work has heretofore in the main been irected to repairing the wear and tear of social friction instead of to bviating the causes of friction. A single illustration which will give mphasis to the general statement because it is an exception to the sual practice, is the regulation of traffic. Unregulated, Fifth Avenue, few York City, in heavy traffic hours would be a maelstrom of conusion, and nervous energy, personal property and bodily safety would e impaired. Friction is eliminated, and wear and tear saved by tilizing the traffic police. Other illustrative exceptions are developing n police practice in this city under the leadership of the present highly ompetent commissioner, Mr. Arthur Woods. To these I shall resently refer. But in the main, present and past police work has oncerned itself not with causes, but merely with efforts.

10 Now, it is to bring about a change in the emphasis and tech-

nique of police administration that I suggest the application of what I describe as the engineering method to all phases of police work.

11 The engineering or scientific method has already been applied in a measure to one branch of police service, namely, the investigation of crime and the detection and identification of criminals. The use of anthropometry and the classification of human types according to physical characteristics, developed by the late M. Bertillon must, of course, be placed without question in the category of science. Similarly, the use of fingerprints and their classification in the identification of criminals, and the use of scientific processes in correlating the habits of certain criminals with the physical evidence of crime, has placed the investigative side of police work on a very much higher plane of effectiveness than the preventive and regulative branches of police service.

12 Police departments have adopted the Bertillon and fingerprint systems of identification as devices to assist in the work of the criminal police, but their adoption has not brought a scientific spirit into the police departments in the United States, as one finds it has in certain German police departments. Identification of criminals has not led American police departments to study crime, or to formulate facts regarding the habits of criminals, and the indicia of criminal types in the method and nature of a criminal act, for the scientific guidance of police work. Particularly in criminal police work, as well as in the safety and regulative sides of police work, is there both the opportunity and need for applying the engineering method.

13 For purposes of illustration I shall select several aspects of police work, indicating in what respects engineering principles may be applied to them.

DETERMINING THE OBJECTIVES OF POLICE EFFORT

14 First, the engineering method is needed to determine the direction of police activity, or, as Mr. Emerson would say, the ideals of police service. The basis of police work is law enforcement. The law to be enforced is the penal law or minor community regulations expressed in ordinances. Penal legislation is based on inherited legal canons, on moral customs, or is inspired by data gathered by special agencies not a part of the police service. In other words, the police department receives undigested, and often unrelated to existing conditions, a vast mass of penal legislation for whose enforcement it is responsible. In New York State this penal legislation is expressed in

a penal code of 2500 sections, containing a catalogue of crimes that are classified under 111 heads.

15 I have had opportunity to study half a dozen large police departments in America. In none of them have I found an institutional purpose, based on an understanding of what police work consists in and why it exists, which was alike in the minds of any two individuals concerned in the enforcement of law. The one common ideal of police service that has been developed in American cities is that the police must be physically well-conditioned and personally honest. This is about as far as any American city has gone, with the possible exception of Toledo, under the rule of Brand Whitlock, and New York City today under the administration of Mr. Mitchel and Mr. Woods.

16 In the minds of the conventional police, criminals divide themselves into four groups:

a Aliens, enemies of society violating the rights, safety and peace of a community, "to be put away," thus gotten rid of

b Native incorrigibles endowed with natural perversity, namely, the familiar thug, the gangster, the crook

c Fortuitous criminals who become subject to police action because of moral lapse or temporary aberration

or as belonging to

d A miscellaneous group including special and individual cases too numerous to catalogue, but comprehended generally in 174 items of the standard crime classification, as used, for example, by the New York police

There has been no recognition of crimes as the consequence of remediable social conditions or the effect of individual abnormalities, either physical or mental, resulting from removable causes.

17 There must be a statistical basis for police work, as there is a statistical basis for engineering work. There is nowhere in the world a collection of social data so potentially useful to the development of a community as lies in every great municipal police department, in the records of arrests, in the records of crime disposition, in the investigation of crimes, in the notebooks of policemen and in the memoranda and reports of detectives.

18 In the report of the New York police department for 1913, the only reference to these records is found in a single sentence under the heading Bureau of Records:

During the year 1913 there were received and filed in the Bureau of Records a total of 35,013 documents.

19 New York City employs 11,000 policemen who made 119,736 arrests in 1913. It has a detective bureau of 528 detectives who investigate 55,000 cases of crime a year, but it has not a single employee engaged on an analysis of the facts brought into the archives of the department in the form of reports on investigations and records of arrests. Commissioner Woods is the first police commissioner in America, so far as I know, who has thought it worth while to put in his budget a request for statisticians. Next year he will have a statistician under the supervision of a deputy trained in statistical analysis, who will study currently police conditions and police work. Not only is he taking this step, but he is utilizing every member of the force as an agent for gathering social facts respecting such matters as unemployment, destitution, improper guardianship, upon which intelligent police work must be predicated.

20 While it is generally known that economic distress and unemployment lead to an increase of small crimes against property and the breakdown of self-control, no American police department has ever analyzed its records to correlate degrees of unemployment with perpetration of crime, and thus furnish the basis for police activity with regard to unemployment. New York City, however, has had this matter forced upon its attention. Conditions of unemployment last year furnished the opportunity for anarchistic agitation, demonstrations of violence, invasions of churches and other disorderly practises, on the avowed theory that only in this way could the public be brought to realize the crucial importance of unemployment conditions.

21 These violent manifestations of disorder, which had their relation to conditions of unemployment in 1914, make it seem a natural function of the police to ascertain the facts regarding conditions of unemployment in 1915. The police department is the logical agency to call the attention of the community and other branches of the government to the need for taking some constructive steps to mitigate abnormal unemployment.

22 In New York, one of the principal problems confronting the police is control of traffic. It was never conceived by the builders of modern cities that thoroughfares, intended for residential purposes and often crowded with children, would be utilized by high powered motor trucks and automobiles, and that many streets designed for

traffic would become the thoroughfares of a vast population. As ult of this condition there are killed each year approximately 450 ɔns in the streets.

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tically impossible to provide the power now given by the largest simple two-cylinder engines.

Little consideration has been given to the advantages of the three-cylinder arrangement, although a few locomotives of this type are in successful service today. As compared with the four-cylinder engine, either simple or compound, the three-cylinder type offers first the possibility of increased power. With one cylinder located between the frames ample room is provided for a properly designed crank axle and main rod which cannot be arranged for in the four-cylinder type beyond a certain limit. As compared with the two-cylinder engine, the advantages are, briefly, a more even turning moment, an ideal counter-balancing condition and the opportunity to furnish maximum power with the minimum destructive effect on the rail. The power obtained in a two-cylinder engine with cylinders 27 in. in diameter and a maximum piston thrust of 117,000 lb. can be obtained in a three-cylinder engine with cylinders 22 in. in diameter and a maximum piston thrust of 78,000 lb. This decrease of 33 per cent in thrust means a corresponding reduction in the individual weights of all of the machinery, particularly the weights of reciprocating parts.

It is true that much progress can yet be made in the two-cylinder engine towards reducing the weights of reciprocating parts by the careful selection of materials and proper design. The three-cylinder engine, however, offers advantages possessed by no other arrangement, and it would seem that, for high-speed passenger service at least, this type is well worth considering for the future.

in connection with steam per horsepower hour and evaporation per pound of coal has been used. Also the percentage of tractive effort and maximum horsepower at various piston speeds and the evaporation per sq. ft. of heating surface for the firebox and tubes. It is assumed that each locomotive is working at the speed indicated on a 0.5 per cent grade and that the cars in the train each weigh 70 tons with its lading.

When each of these locomotives is delivering the power it is easily capable of, if in good condition, it will be seen that it requires from 4900 to over 8000 lb. of good quality coal an hour. The locomotives are actually getting from 4500 to 5000 lb. an hour, and handling trains of a proportional size.

A number of locomotives like these, all of the same class, and operating on the same division, will have a tonnage rating in proportion to the ability of the average poorest fireman that is assigned to them rather than to the average best fireman. While there may be a few firemen on the division who are capable of developing the full boiler capacity, the group of engines as a whole may be daily working much below their actual capacity.

The acceptance of the opportunity to supply at all times the desired quantity of coal to these locomotives that is offered by the stoker will have the same practical effect on operating expense as would a new order of more efficient, larger locomotives.

A reduction in the cost of conducting transportation follows this increased locomotive capacity in a number of the principal items when presented on a ton-mile basis. The stoker itself offers an opportunity for further savings particularly in the cost of fuel, reduced claims for damage or accident and the recruiting of men of higher caliber for locomotive service.

An instance of the possible savings in the cost of conducting transportation, through increased locomotive capacity following the application of a stoker, is found on a certain division where 10 tonnage trains are sent one way over the road each day with hand-fired locomotives. Application of stokers has permitted an increase of over 11 per cent in the tonnage of a train. The return movement is largely empties. The application of stokers will give a direct saving, from wages and train supplies alone, of about $100 per engine a month on this division. If advantage is taken of the increased capacity of the division for tonnage without the addition of more locomotives, the saving will be considerably larger.

TABLE 6

Type	Cylinders, In.	Steam Pressure, Lb.	Diameter Drivers	Maximum Tractive Effort	Maximum Cylinder H.P. *	Normal H.P. from Heating Surface †	Coal per Hr. at Maximum H.P. ‡	Speed for H.P.	On Grade of 5 per Cent: Speed M.p.H.	Tons in Train	H.P. Required	Coal per Hr., Lb.	Coal Sq. Ft. Grate Area, Lb.	Water per Sq. Ft. Heating Surface, Lb.
2-8-2	25×32	180	63	48600	2027	2210	6587	35	25	1930	1945	6320	112	9.88
2-8-2	28×32	170	63	57460	2400	2310	7507	35	25	2382	2290	7440	106	11.5
2-8-2	27×30	175	63	51700	2296	2269	7374	37.5	25	2183	2160	7020	100	11.05
0-8-8-0	26×41×28	200	51	105000	....	3032	8759§	32.5	15	6050	2860	8240§	82.4	10.6
4-8-2	28×28	185	69	50000	2613	2451	7965	44	35	1403	2390	7767	124	12
2-6-6-2	21½×34									**				
	×32	200	57	67500	2533	2312	7314	32	15	3820	1940	6300	111	9.2
2-8-2	28×32	180	64	60000	2542	2418	7858.5	36	25	2470	2410	7840	100	10.8
2-8-0	26×30	185	57	55900	2251	2167	7242	34	15	3120	1765	5750	86	10.4
2-8-8-2	26×40×30	200	57	87600	....	2942	9561	34	15	5060	2390	7800	92	9.2
2-8-0	25×30	180	57	50328	2027	1848	6006	34	15	2920	1510	4900	87	11

* Horsepower + 0.01798 Pd^2 at 1000 ft. piston speed
† Normal horsepower from heating surface = evaporation, lb. per hr. ÷ 20.8 lb.
‡ 3.25 lb. coal per h. p.-hr.
§ 7.2 lb. water per lb. of coal
** Passenger train

of area. These views are sustained by the results of an elaborate series of tests on the endurance of rotating shafts conducted by the United States Government at the Watertown Arsenal by Jas. E. Howard.

These experiments required years to make and the results from the different yearly reports are tabulated in Table 2.

Enormous increase in endurance following the use of material hav-

TABLE 2 TESTS ON THE ENDURANCE OF ROTATING SHAFTS

Car	Nickel	Treatment	Fiber Stress	Rotations	Elastic Limit	Tensile Strength	Elongation	Contraction
0.26	3.282	Annealed	40,000	1,847,500	51,500	81,370	28.75	61.09
0.26	3.282	Oil Quenched and Annealed	40,000	1,815,200	66,950	90,640	26.9	65.04
0.25	4.514	Annealed	40,000	2,366,000	61,610	95,490	24.8	57.13
0.25	4.514	Oil Quenched and Annealed	40,000	3,296,700	101,860	120,190	20.8	60.05
0.29	5.661	Annealed	40,000	4,388,400	90,090	108,840	22.5	58.71
0.29	5.661	Oil Quenched and Annealed	40,000	3,795,200	117,610	131,410	19.65	59.88
0.539	27.353	Annealed	40,000	2,495,600	48,060	104,820	47.5	63.10
0.539	27.353	Oil Quenched and Annealed	40,000	1,088,200	46,850	97,780	43.35	60.80
0.24	......	Annealed	40,000	229,300	40,560	71,240	32.3	59.81
0.24	......	Oil Quenched and Annealed	40,000	348,000	45,170	74,440	33.15	69.93
0.42	......	Annealed	40,000	225,900	44,290	80,885	23.0	56.7
0.42	......	Oil Quenched and Annealed	40,000	655,600	55,000	92,180	26.05	57.22
0.46	......	Annealed	40,000	976,600	48,060	94,600	21.15	47.65
0.46	......	Oil Quenched and Annealed	40,000	1,657,500	61,110	102,880	13.05	51.27
0.66	......	Annealed	40,000	3,689,000	65,205	124,200	7.15	17.28
0.66	......	Oil Quenched and Annealed	40,000	4,323,600	92,040	154,920	13.5	31.48
1.094	......	....	30,000	50,000,000	......	......	.....	.....
0.733	......	....	30,000	12,547,600	......	......	.....	.....
0.824	......	....	30,000	16,336,200	......	......	.....	.....
0.824	......	....	35,000	13,871,000	......	......	.....	...
0.094	......	....	35,000	19,152,300	......	......	.....	.....

ing high elastic limit and tensile strength is notable and it is shown that a 0.66 carbon steel shaft exhibits as much endurance as a 5.6 per cent nickel steel one.

When steel forgings were first proposed for use in locomotives, a soft grade of steel was generally employed, the purpose being to secure a steel of similar properties to the iron formerly employed.

The use of this material resulted in an unusual number of failures of axles, pins and rods. After studying these failures, Dr. C. B.

dley, S. M. Vauclain and S. T. Wellman experimented with higher bon steels. This led to the general adoption of steel of 80,000 ten- strength for locomotive work, with the result that the failures were ninated and the great superiority of this steel over the softer steels demonstrated notwithstanding the great difference between the steels in elongation and contraction of area. This grade of steel still being universally employed and any changes made were for the rpose of increasing the ductility requirements rather than the tensile uirements, thus handicapping the manufacturer in the development of this grade of steel.

If specifications were revised to permit the use of a 0.66 carbon el there would be but little necessity to employ the expensive alloy els.

In sketching the development of the art with respect to increase in acity, sufficient stress is not laid upon the development of the iler truck locomotives with the attendant possibilities of improvement in boiler design. It is now generally recognized that the use of iler trucks has permitted boilers of great capacity. Were it not for s development in boiler design, there would be a very limited use of erheaters in the modern locomotives because of the restriction to ler capacity. When the first trailer truck engine was built but a rt decade ago it was received with a storm of criticism and the ilders stood almost alone as the advocates of this type. The use of trailing truck is a logical development of the use of wide fire- kes.

Wide fireboxes originated with the invention by Wootten in 1877 of boiler which bears his name. The original designs of the well own Wootten or wide firebox boiler contained a combustion chamber. otten considered this feature essential. Later, A. E. Mitchell modi- d this design by omitting the combustion chamber and employing traight flue sheet which was subsequently changed to the offset flue eet. These types of boilers were the predecessors of the modern de firebox engine and it is interesting to note at this time that so my of these engines held world records for speed and capacity.

The Atlantic or 4-4-2 type was designed in 1895 and was first em- yed by the Atlantic Coast Line and derived its name therefrom. At st the design was received with criticism, but the advantages in the struction of large fireboxes and large boilers were so manifest that was rapidly followed by the design of a Prairie or 2-6-2 type engine the C. B. & Q. Railroad. The Pacific or 4-6-2 type was naturally developed from this type in 1901 for the New Zealand Government Railways to burn inferior fuel. In 1895 the Mikado or 2-8-2 type was also designed to burn inferior fuel of a lignite nature from the Iwaki and Iryana mines of the Japan Railway Company.

In 1903 the first 2-10-2 or Santa Fé type locomotive was built for the Atcheson, Topeka & Santa Fé Railway. While this type was so successful as to warrant the continuation of many duplicate orders for this company, only in recent years have other railroads begun to employ this most powerful of all single unit coupled locomotives.

The reason for the success of these locomotives is not far to seek. The relative steaming capacities of different types of locomotives bear some inverse ratio to the percentage of total weight carried on drivers. This rule, if such it may be called, is not strictly true, for a constant value yet to be determined should be subtracted from the weights before calculating the percentage and the application of the rule will give the minimum increase in horsepower capacity to be derived from the use of trailer trucks.

TABLE 3 TOTAL WEIGHT CARRIED ON DRIVERS

Type		Percentage of Total Weight on Drivers	
		Trailer Truck	No Trailer Truck
American	4-4-0	....	65
Atlantic	4-4-2	55.5	....
10-Wheel	4-6-0	63	....
Pacific	4-6-2	....	76
Consolidation	2-8-0	....	88.5
Mikado	2-8-2	77	....
Decapod	2-10-0	....	89.5
Santa Fé	2-10-2	80	....

Table 3 shows the percentage of total weight which is carried on drivers for various types of trailer truck and its corresponding non-trailer truck engine.

From Table 3 is derived Table 4, showing increased capacities of trailer truck locomotives.

TABLE 4 INCREASE IN HORSEPOWER CAPACITY TO BE DERIVED FROM THE USE OF TRAILER TRUCKS

Type	Percent Increase of Capacity
Atlantic over American...........	17
Pacific over 10-Wheel.............	22
Mikado over Consolidation........	15
Santa Fé over Decapod...........	12

C. D. YOUNG in discussing the above subject called attention to the ordinary annealed carbon steel as used generally for locomotive forgings. The minimum physical properties may be considered as follows: Tensile strength, 80,000 lb. per sq. in.; elastic limit, ½ the tensile strength; elongation in 2 in., 22 per cent; reduction of area, 30 per cent.

With properly quenched and tempered carbon steel we may expect an increase in the elastic limit of 30 per cent or more, about 15 per cent increase in tensile strength, the elongation remaining the same and the reduction of area increasing about 50 per cent. These are conservative figures and a great deal better elastic limit and tensile strength may be obtained, depending upon the chemical composition of the steel and the heat treatment.

From alloy steels, such as chrome vanadium or chrome nickel, we may expect to obtain the following physical properties after heat treatment: Tensile strength, 95,000 lb. per sq. in.; elastic limit, 75,000 lb. per sq. in.; elongation in 2 in., 20 per cent; reduction of area, 50 per cent.

On an average, these alloy steels will show an increase in physical properties over those of annealed carbon steel of 20 per cent or more in tensile strength, 80 per cent or more in elastic limit, with elongation in 2 in. about 9 or 10 per cent less than that of the carbon steel, and the reduction of area of 75 per cent or more greater. These figures are subject to modification on account of variation in the chemical composition of the steel and the heat treatment.

In carbon steel castings approximately the same per cent increases in physical properties as were given for carbon steel forgings may be obtained after proper heat treatment. The experience with alloy steel castings has been too limited to furnish any satisfactory data. Up to the present time the majority of users of heat-treated steels seem to have made but little, if any, use of the increased physical properties as determining the fiber stresses used in design, though some of the larger builders of locomotives have made such increases in fiber stresses for both heat-treated carbon and alloy steels. In certain parts where heat-treated carbon steel has been used, the fibre stress has been increased about 25 per cent above that used for annealed carbon steel, and in the case of heat-treated alloy steels an increase of as much as 50 per cent has been made. In some cases, depending upon the design and service for which the forging is intended, it is preferable to allow no increase in the fibre stress, but to consider the excess

TABLE 5

Parts	Grade of Material	Working Fiber Stress in: Tension or Compression	Working Fiber Stress in: Bending	Minimum Ultimate Tensile Strength	Minimum Elongation in 2 inch	
Main and Parallel Rods	Annealed 0.45 carbon	8,000	10,000	80,000	$\frac{1,800,000}{T. S.}$	20
	Quenched and Tempered 0.52 carbon	10,000	14,000	85,000	$\frac{2,000,000}{T. S.}$	20
	Quenched and tempered alloy	12,000	18,000	100,000	....	
Piston Rods	Annealed 0.45 carbon	9,000	......	80,000	$\frac{1,800,000}{T. S.}$	20
	Quenched and tempered 0.52 carbon	10,000	......	85,000	$\frac{2,000,000}{T. S.}$	20
	Quenched and tempered alloy	12,000	......	100,000	....	
Driving Axles	Annealed 0.45 carbon	Combined bending and torsion in starting	18,000	80,000	$\frac{1,800,000}{T. S.}$	20
	Quenched and tempered 0.52 carbon		20,000	85,000	$\frac{2,000,000}{T. S.}$	20
	Quenched and tempered alloy		25,000	100,000	....	20
Crankpins	Annealed 0.45 carbon	......	13,500	80,000	$\frac{1,800,000}{T. S.}$	[illegible]
	Quenched and tempered 0.52 carbon	......	16,000	85,000	$\frac{2,000,000}{T. S.}$	[illegible]
	Quenched and tempered alloy	......	20,000	100,000	....	[illegible]
Cast Steel Parts	Annealed 0.28 carbon	8,000	Tension	60,000	$\frac{1,400,000}{T. S.}$	[illegible]
	Quenched and tempered 0.28 carbon	10,000		75,000	$\frac{1,800,000}{T. S.}$	[illegible]
				Transverse Strength	Bend Test, Degree	
Springs	Drawn 1.0 carbon	70,000		90,000	25	
	Quenched and tempered 1.0 carbon	90,000		120,000	25	
	Quenched and tempered alloy	100,000		150,000	50	

Note: Maximum figures for working fiber stress may be 20 per cent in excess of those shown.

gth of the heat-treated material as contributing to increase life rvice, or to safety.

!ecent practice has indicated that it is desirable, when using heat-ed designs, to study carefully the section, so as to avoid abrupt ges, and also in the cases of larger shafts, such as axles, or crank- that they shall be hollow-bored in order to provide for better ment and to relieve shrinkage strains which occur during the ching process.

/hile there is no objection to the change of the present standard)n, it would seem, with our present knowledge of heat-treated rial, that it would be entirely safe to use certain increases in the stresses when designing locomotive parts. As a suggestion as to could be done in this respect, Table 1 shows what is recom-led for three grades of steel as to working fiber stresses and the mum ultimate strength and elongation. This has been tabulated he grades of 0.45 annealed carbon, quenched and tempered 0.52 n and quenched and tempered alloy steels.

'he results shown in Table 5 seem to indicate that heat-treated n and alloy steels will show greater resistance to wear and to the ue stresses in service than is shown by annealed carbon steel; it is our opinion that the increase in resistance to wear is about roportion to the increase in Brinell hardness which is brought t by the heat treatment.

MECHANICAL STOKERS

!LEMENT F. STREET (written). The most important things which toker has done for the locomotive are first, increased the earning r of existing locomotives, and second, removed practically all ations, from a fuel quantity standpoint, on the size of locomo- which can be built.

. locomotive designer must always keep in mind the fact that ' dollar earned in the operation of a railway is earned by its loco-ves, and therefore in the above I have given first place to the ase in the earning power of existing locomotives. Many instances l be cited to prove this statement, but one will suffice as an illus-on.

. locomotive providing about 54,000 lb. tractive power when run- with saturated steam, had a tonnage rating over a certain division 750 tons. Superheaters were applied to this locomotive, and the ige increased to 5,000; stokers were applied and the tonnage in-ed to 5,250, then 5,500, then 5,750, and finally 6,000. In the meantime the tonnage rating of the shovel-fired superheater locomotives was increased to 5,500. This shows an increase of over 20 per cent in the tonnage rating of this locomotive after the stokers were applied and the locomotive today, stoker-fired, is hauling 10 per cent more tonnage than when shovel-fired. The increase in the tonnage rating of the shovel-fired locomotives is very interesting and brings out strongly one of the indirect advantages of the stoker. It shows very clearly that before the stokers were applied, the shovel-fired locomotives were not doing anything like what they should do and as soon as the stoker came into use, it not only increased the tonnage rating of the locomotives to which it was applied, but also brought about an increase in the rating of all others on the division.

Along this same line, the stoker is making it possible to approach much nearer to theoretical conditions in regular operation. It is well known that there is a wide difference between the earning power of a locomotive under test conditions and under average road conditions. The writer has in mind one case in which it was found that under test conditions a certain locomotive could haul 4,000 tons comfortably over a certain division. When this locomotive was put into regular service, however, it was found impossible to operate it with more than 3,500 tons over the same division. With a mechanical stoker this locomotive easily handles 4,000 tons in regular road service.

The fact that the stoker has removed limitations in the size of locomotives which can be built can be brought out by referring to several of the locomotives mentioned in the report. The Mountain type locomotives were fitted with stokers when they were built, have always been stoker-fired, and no attempt has ever been made to shovel-fire them. The locomotive referred to in par. 5 would never have been built had it not been known that a stoker could be secured which would fire it. There are thirty of the locomotives referred to in par. 6 now in regular operation, and they too would never have been built had it not been known that a stoker could be secured which would fire them. A number of other locomotives now in regular operation, notably the most powerful Pacific type as yet built, would never have been contemplated without a stoker.

In reference to the amount of coal which can be fired, as high as eight tons have been put in a fire box with an existing machine and without working it to its capacity. There is no reason why any desired quantity of coal cannot be fired by the use of the stoker, and the limitation of amount of coal which can be fired is entirely removed in connection with the design of new locomotives.

The stoker as yet has not progressed far enough to bring forth definite figures regarding its efficiency. Wherever it has been introduced, the question of increased tonnage has been more important than that of fuel economy, and the latter has, therefore, been given very little consideration. This, of course, is only a temporary condition, and as more stokers are applied the question of fuel economy will become more important. The development of the mechanical stoker has gone far enough, however, to show that the stoker will burn a much cheaper grade of coal than it is possible to use with hand firing, and that it will give a more uniform rate of fuel consumption on locomotives performing the same service.

It is a well-known fact that there is a difference of from 25 to 50 per cent in the amount of coal burned by different firemen for performing the same work. The stoker is eliminating this great variation and making the results more uniform.

When all locomotives on a railroad are being worked to their full capacity, the earning power of that road is at its maximum. In this country today there are very few, if any, shovel-fired locomotives having a maximum tractive effort of 50,000 lb., or over, which are being worked to their full capacity. Wherever stokers have been applied the earning power of the locomotives on which they have been placed has been increased from 10 to 20 per cent. There is no instance where stoker-fired and shovel-fired locomotives are being operated under identical conditions. The stoker-fired locomotives are, in every case, hauling increased tonnage, or using a cheaper fuel, or working at higher average speeds than the shovel-fired locomotives.

E. A. Averill (written). In the report of a test on a large locomotive at the Altoona test plant it is stated that the results indicate that the capacity of the boiler was limited by the ability to burn the coal on the grates and not any failure of the heating surface to absorb the heat supplied. While in this case the limit was marked by the impossibility of supplying sufficient air through the grates to burn the fuel properly, there are operating in this country today a reasonably large number of locomotives which are running at less than full boiler capacity because of the physical inability of the fireman to supply the amount of fuel that can be burned.

Ten classes of locomotives, built during the past three years, and typical of the general size and capacity of all the larger freight engines built in that time, were selected at random. These are shown in Table 6. The American Locomotive Company's standard practice

in connection with steam per horsepower hour and evaporation per pound of coal has been used. Also the percentage of tractive effort and maximum horsepower at various piston speeds and the evaporation per sq. ft. of heating surface for the firebox and tubes. It is assumed that each locomotive is working at the speed indicated on a 0.5 per cent grade and that the cars in the train each weigh 70 tons with its lading.

When each of these locomotives is delivering the power it is easily capable of, if in good condition, it will be seen that it requires from 4900 to over 8000 lb. of good quality coal an hour. The locomotives are actually getting from 4500 to 5000 lb. an hour, and handling trains of a proportional size.

A number of locomotives like these, all of the same class, and operating on the same division, will have a tonnage rating in proportion to the ability of the average poorest fireman that is assigned to them rather than to the average best fireman. While there may be a few firemen on the division who are capable of developing the full boiler capacity, the group of engines as a whole may be daily working much below their actual capacity.

The acceptance of the opportunity to supply at all times the desired quantity of coal to these locomotives that is offered by the stoker will have the same practical effect on operating expense as would a new order of more efficient, larger locomotives.

A reduction in the cost of conducting transportation follows this increased locomotive capacity in a number of the principal items when presented on a ton-mile basis. The stoker itself offers an opportunity for further savings particularly in the cost of fuel, reduced claims for damage or accident and the recruiting of men of higher caliber for locomotive service.

An instance of the possible savings in the cost of conducting transportation, through increased locomotive capacity following the application of a stoker, is found on a certain division where 10 tonnage trains are sent one way over the road each day with hand-fired locomotives. Application of stokers has permitted an increase of over 11 per cent in the tonnage of a train. The return movement is largely empties. The application of stokers will give a direct saving, from wages and train supplies alone, of about $100 per engine a month on this division. If advantage is taken of the increased capacity of the division for tonnage without the addition of more locomotives, the saving will be considerably larger.

TABLE 6

Type	Cylinders, In.	Steam Pressure, Lb.	Diameter Drivers	Maximum Tractive Effort	Maximum Cylinder H.P. *	Normal H.P. from Heating Surface †	Coal per Hr. at Maximum H.P. ‡	Speed for H.P.	On Grade of 5 per Cent					
									Speed M.p.H.	Tons in Train	H.P. Required	Coal per Hr., Lb.	Coal Sq. Ft. Grate Area, Lb.	Water per Sq. Ft. Heating Surface, Lb.
2-8-2	25×32	180	63	48600	2027	2210	6587	35	25	1930	1945	6320	112	9.88
2-8-2	28×32	170	63	57460	2400	2310	7507	35	25	2382	2290	7440	106	11.5
2-8-2	27×30	175	63	51700	2296	2269	7374	37.5	25	2183	2160	7020	100	11.05
0-8-8-0	26×41×28	200	51	105000	....	3032	8759§	32.5	15	6050	2860	8240§	82.4	10.6
4-8-2	28×28	185	69	50000	2613	2451	7965	44	35	1403 **	2390	7767	124	12
2-6-6-2	21½×34 ×32	200	57	67500	2533	2312	7514	32	15	3820	1940	6300	111	9.2
2-8-2	28×32	180	64	60000	2542	2418	7858.5	36	25	2470	2410	7840	100	10.8
2-8-0	26×30	185	57	55900	2251	2167	7242	34	15	3120	1765	5750	86	10.4
2-8-8-2	26×40×30	200	57	87600	....	2942	9561	34	15	5060	2390	7800	92	9.2
2-8-0	25×30	180	57	50328	2027	1848	6006	34	15	2920	1510	4900	87	11

* Horsepower + 0.01798 Pd^2 at 1000 ft. piston speed

† Normal horsepower from heating surface = evaporation, lb. per hr. ÷ 20.8 lb.

‡ 3.25 lb. coal per h. p.-hr.

§ 7.2 lb. water per lb. of coal

** Passenger train

Naturally one of the first features to be investigated by a railroad considering the application of stokers is the cost of maintenance. In general, the machine of any kind with the fewest parts, properly designed, will cost the least for maintenance, inspection or repairs. During the past year and a half has been made a distinct advance in connection with the simplification of the stoker apparatus. The latest type of locomotive stoker consists of a comparatively few strong, heavy parts and a very few wearing surfaces.

There has been much discussion of the amount of coal consumed on stoker-fired locomotives. In some cases these do burn more coal per trip and the mistake of making the comparison on pounds of coal consumed per 1000 ton miles has led to the deception of some investigators. Accurate tests permitting the comparison of shovel and stoker-firing to be made on the basis of pounds of coal per indicated horsepower hour, have shown widely varying results with different designs of stokers. Some carefully conducted evaporative tests with the most recent design of stoker are very encouraging in this particular. These tests were made with the locomotive in regular service. Comparing the average of five hand-fired runs and four stoker-fired runs on the basis of actual pounds of water evaporated per 1,000,000 B.t.u. supplied, the stoker gave an increase of nearly 7½ per cent. In another case the increase in evaporation with the stoker was nearly 12 per cent. From these figures, as well as from observations in regular daily service, it would appear that some saving in coal can be expected from this stoker. These tests were made with run-of-mine coal.

A stoker should successfully handle the coal in any condition in which it may be put on the tender. It should make no difference if the coal be all dust or clean lumps of larger size; soaking wet, slightly damp or bone dry. The stoker should take the coal as it finds it the same as a fireman does. The development of stokers in this direction during the past year or two has been particularly satisfactory and ordinary run-of-mine coal is now being used with complete success.

The use of lower and cheaper grades of coal is quite general on the stoker locomotives of a number of roads which report a net saving from the practice.

Calculations that have been made of the movement of the gases in a firebox equipped with a brick arch, show that velocities of 2-65 ft. a second will be present over the end of the arch when burning

000 lb. of coal an hour on 70 sq. ft. of grate area. The velocity ecreases as the fire bed is approached and at a point 2 ft. above the rate the gases have an average velocity of about 33 ft. a second. 'his clearly indicates the importance of injecting the fuel charge s low down in the firebox as possible to reduce the loss by fine coal assing through the flues partially burned. The more recent de- elopment in stokers has given this feature the attention it deserves.

Opportunities for economy in connection with the reduction in amage claims follow the better lookout from the locomotive by the reman being left free to watch signals, crossings and operation of ıe machinery on the left side. One of the essentials in this connec- on is noiseless operation. The stoker should not prevent free con- ersation across the cab nor make any noise that can be heard when ıe locomotive is running. The development of the past year or wo has shown a wonderful improvement in this particular and tokers are now being applied which are essentially noiseless in their peration.

The stoker should be 100 per cent efficient; it should do all the ring, handle all the coal from the tender with the minimum atten- ion and not require alteration of the distributing means after it s once properly adjusted. The fireman should be free to attend o the duties mentioned above and should be able to control the toker operation from a position on the seat box.

It is well established in manual firing that small quantities of oal fed frequently and distributed by the "cross fire" method gives he most perfect combustion. The stoker should follow this method ut perform the operation more exactly than it can be by hand. Recent development shows a full appreciation of this requirement nd at the same time provides a flexibility that allows the stoker o meet exactly the conditions of combustion at the various parts f the grate. If 70 per cent of the coal is being burned on one side f the grate, the stoker should discharge that proportion of the fresh uel on that section. If more fuel is being burned in front than in ack, the stoker should distribute to suit. This flexibility is essential or 100 per cent stoker work.

Another feature of improvement in the most recent of the catter type stokers is the absence of any part of the stoker on the oiler head or in the cab. Stokers are now being applied which show ractically nothing in the cab and thus allow the best arrangement f the many instruments and appliances required on a modern locomotive. This also permits the proper inspection of all the staybolts and their renewal if necessary without the removal of any part of the stoker.

FUTURE OF THE STEAM LOCOMOTIVE

J. E. MUHLFELD (written). In my opinion the available energy in superheated steam, and the necessity for economy in first cost and for operation, will cause the self-contained steam locomotive to remain for a long time the principal motive power for moving heavy tonnage trains long distances. For this reason, the next few years will probably see it substantially improved through the development of Mallet articulated types, superheating, compounding, feedwater heating and pumping, boiler circulation, valve motion gear, reciprocating and revolving parts, combustion, automatic stoking of pulverized fuels, and standardization.

G. R. HENDERSON pointed out that 15 or 20 years ago it was thought that we had reached the limit of size and capacity in locomotives. Shortly afterwards we had some gain in compounding but we had large locomotives giving only from 1000 to 1500 h.p., whereas the size would have led us to think that we could get double that power.

Superheaters, coalpushers, firedoor openers, etc., have all helped to increase the capacity of the locomotive. In a few years very probably we will have largely extended the use of powdered coal. The present limitations of height and width will not differ to a marked degree but the length can be increased without any special alterations except for turn tables and things of that sort where we can easily increase the length.

Our boilers can be increased in length, and there comes in Mr. MacFarland's idea of an exhaust fan at the front end to give the necessary draft in the firebox. Powdered coal will help a great deal in assisting in lengthening the firebox and giving a greater amount of evaporative surface.

If we consider the present limitations of drawbar strength, length of siding, and legislative restrictions, I think by this lengthening is possible to build a locomotive of any desired tractive force, even up to 250,000 or 300,000 lb.

THE BIG STEAM LOCOMOTIVE

J. B. ENNIS (written). Twenty-five years ago the largest steam locomotive in service had a total weight of about 154,000 lb. and a ractive power of 34,000 lb. At that time, a locomotive of these proportions represented the improvement of 60 years of effort in this ine of steam engineering, and while this advance had been gradual, t was a series of progressive steps leading up to the building of this 'largest locomotive in the world." This 60 years of progress had been period in which the main object seemed to be increased capacity nly. Aside from the fact that the number of wheels was increased nd the parts were made larger and heavier, a locomotive of this eriod in its essential details followed closely the established practice f years before. Detail design had been constantly improving, but t that time no general effort had been made toward improvement n the efficiency of the machine. A pound of drawbar pull meant he burning of the same amount of coal as it had a quarter of a entury before.

During the past 25 years conditions have materially changed and he demands made on the locomotive have been such that the progress in its development was to be rapid. From 1889 to 1899 the otal weight increased from 154,000 lb. to 232,000 lb. and the power n proportion. It was during this period that it was first realized hat increase in capacity could not go on so rapidly unless accompanied by some efforts toward economy. The first general step n this direction was the introduction of the compound principle; various systems were brought out and for years large numbers of hese engines were built, many of which gave decided economies in ervice as well as increase in power. Although the movement to dopt this principle was advocated by many, the simple locomotive was still preferred and gradually increased in weight and power until t was thought by many that the limit of capacity had been reached.

Fifteen years ago, we find instances of locomotives built where, n order to maintain full power for any length of time, the amount of coal burned was so large as to call for considerable activity on he part of the fireman. Perhaps fortunately, stoker designs had not been perfected, although the time could not have been greatly delayed when consideration was to be given to other devices to bring about efficiency.

In Europe, superheating had demonstrated its economies in locomotive service and about ten years ago the first applications were made in this country. For some time its use was very limited, but after it was proven that high temperature superheaters would give increased capacity and great economy in fuel that would not be offset by high maintenance expense, and that the economy could be obtained in all classes of service, the movement to adopt this principle became widespread. As a result of this improvement, combined with others that followed, we now have passenger and freight locomotives giving at least one-third more power at the draw-bar than would have been possible 10 years ago with simple locomotives using saturated steam and consuming the same amount of fuel.

This increase in weight and power continued and the locomotive soon reached a size where it became necessary to consider, in many cases, some other means of feeding the coal than by hand. The mechanical locomotive stoker was demanded and produced. It is no longer an experiment and is capable of delivering all the coal that the present day locomotive requires.

As examples of the big steam locomotives of today, we have simple freight locomotives giving tractive powers 50,000 lb. greater than the maximum of 25 years ago; an experimental articulated locomotive for pushing service designed to give a tractive power of 160,000 lb.; articulated locomotives for road or pushing service with tractive powers of 115,000 lb.; the simple Pacific type with 46,500 lb. and simple Mountain type with 58,000 lb. Individual wheel loads have steadily increased until we have nearly 70,000 lb. weight per pair of drivers. Our locomotives are as high and as wide as clearance limitations will permit, and yet it would be unwise to say that the limit has been reached.

The big steam locomotive of the future will probably not be the locomotive of the past. Today we can see possibilities toward further refinement in design and further economies that may be obtained so that the locomotive designer is not yet ready to acknowledge that all has been accomplished.

For freight and pushing service on heavy grade, past performances show the adaptability of the articulated compound engine. This design of locomotive is still in the course of development and it will, without doubt, be the generally accepted type for these conditions for some time to come. With the exception of the experimental articulated locomotive already referred to, locomotives recently built for the Virginian Railway are the largest of the type. A few particulars of their performance may be of interest. Designed originally for pushing service on grades of over 2 per cent and normally rated at 115,000 lb. tractive power working compound, gines have proven themselves capable of handling on a grade :r cent a train load of 7180 tons, requiring a drawbar pull of nately 110, 000 lb. On lighter grades and at higher speeds 0 i.h.p. have been obtained. Work of this magnitude neces- ocomotives of exceptional weight and power, and yet the ties of this type have by no means been exhausted. As con- arise in the future in which more power will be required, of the articulated engine can yet be extended.

freight service on easy grades where the capacity of the ed engine is not required, we already have exceptionally omotives of the 6, 8 and 10 coupled types. Simple cylinders g at 200 lb. pressure have reached a diameter of 30 in., rder to transmit this power a main axle 13 in. in diameter used. Main crankpins, rods and other details are of enormous ith the increase in the diameter of cylinders, the cylinder have gradually increased and frame centers decreased. This lted in higher stresses of parts than those caused by piston nly. The weight of revolving and reciprocating parts has the point where, in some cases, proper counterbalancing be- ery difficult. It is doubtful whether much more capacity obtained in these types if designed along the present lines, it would seem that attention could profitably be given to nt in design and its relation to the careful selection of s.

rn passenger locomotives have reached a high development, here is one problem still to be solved that has been recognized y years—that of the effect on the rail of the vertical un- forces in a two-cylinder engine. At present our largest t powerful passenger locomotives have two simple cylinders in. in diameter, giving maximum piston thrusts of approxi- 17,000 lb., with static wheel loads higher than ever before 1 few exceptions, reciprocating parts of much greater weight. four-cylinder balanced compound was introduced about 10 as a possible solution and for a few years a large number locomotives were built. There is no doubt as to the results , as far as balancing was concerned, and yet recently very been constructed. Four-cylinder simple locomotives have tried out, but in both these types the capacity is limited on of the available space between the frames, making it prac-

tically impossible to provide the power now given by the largest simple two-cylinder engines.

Little consideration has been given to the advantages of the three-cylinder arrangement, although a few locomotives of this type are in successful service today. As compared with the four-cylinder engine, either simple or compound, the three-cylinder type offers first the possibility of increased power. With one cylinder located between the frames ample room is provided for a properly designed crank axle and main rod which cannot be arranged for in the four-cylinder type beyond a certain limit. As compared with the two-cylinder engine, the advantages are, briefly, a more even turning moment, an ideal counter-balancing condition and the opportunity to furnish maximum power with the minimum destructive effect on the rail. The power obtained in a two-cylinder engine with cylinders 27 in. in diameter and a maximum piston thrust of 117,000 lb. can be obtained in a three-cylinder engine with cylinders 22 in. in diameter and a maximum piston thrust of 78,000 lb. This decrease of 33 per cent in thrust means a corresponding reduction in the individual weights of all of the machinery, particularly the weights of reciprocating parts.

It is true that much progress can yet be made in the two-cylinder engine towards reducing the weights of reciprocating parts by the careful selection of materials and proper design. The three-cylinder engine, however, offers advantages possessed by no other arrangement, and it would seem that, for high-speed passenger service at least, this type is well worth considering for the future.

No. 1449

E FUTURE OF THE POLICE ARM FROM AN ENGINEERING STANDPOINT

By Henry Bruère[1], New York City

Non-Member

ith the single exception of education, the field of public service iich most stability has been achieved and the nearest approach formulated technique evolved is the engineering field. Of all ssions, engineers have alone found a permanent vocation in muni- work.

To engineers must be credited the great achievements in muni- government. They have built the cities, often unskillfully without imagination, too often harassed by politicians and l interests, but they have built them. They have constructed works. They have constructed piers, docks and harbors. They brought into civil government the spirit of workmanship and the of science, and they have been the first to utilize a scientific od in the conduct of the day-by-day routine of public adminis- n.

In making these statements I am not unmindful of the great tunities that still remain for further development of engineering e in cities, and for weeding out incompetency, charlatanism and rviency to improper ideals. The municipal engineer, perhaps than any other group or class of engineers, has been forced to rtunism. But notwithstanding this fact, municipalities are dis- tly the debtors of the engineering service. I wish to refer on this sion to the obligation of New York City's police department to an ineer. To a very large extent the beginning of systematic methods andling the business of the police department and the beginning e end of the proverbial confusion prevailing in the management of

y Chamberlain.

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tract of paper presented at the Annual Meeting, December 1914, of ERICAN SOCIETY OF MECHANICAL ENGINEERS.

the New York police force, took place when the department was in the hands of an engineer, General Theodore A. Bingham.

4 My justification for discussing the problems of police administration at a meeting of mechanical engineers is this: Scientifically, the most neglected field of public service in America is the police department. There is no part of municipal administration, not itself in the engineering category, that more urgently needs the aid of engineering method than does the "police arm." I make this assertion on two assumptions, with which there may not be general agreement. The first assumption is expressed in a definition of the substance of the "engineering method." The second assumption is expressed in a definition of the functions of the police arm.

5 It is my understanding that the purpose of the engineering profession is primarily to develop the facilities and conditions of civilized life. Engineering is the application of formulated scientific knowledge to the practical problem of administering to human needs and developing the physical resources of the world. The function of the police on the one hand is to protect the institutions of civilization and to eliminate conditions hostile to civilized life, and on the other hand to make available for the freest expression and highest efficiency that greatest of all natural resources, the collective and coöperative life of a community.

6 Let me state more succinctly, before elaborating my argument, my understanding of (*a*), the nature of the engineering method, and (*b*), the police problem:

a The engineering method consists of applying scientifically determined knowledge to the execution of a particular problem, and the use of ordered and analyzed facts as a basis for formulating conclusions in respect of that problem. As a result of the repeated application of the engineering method to like or similar problems a technique is established for achieving a particular object repeatedly, with least waste of energy and resource

b The function of the police arm of government is to ascertain all the facts regarding the phenomena of crime and disorder, and by the use of those facts as a basis for action, direct and collateral, to minimize and extirpate crime and disorder

7 I shall not attempt a justification of my definition of the engineering method. Numerous better definitions have been formulated.

But I believe the definition that I have submitted is adequate for the purpose in hand. It will be necessary, however, to elaborate and perhaps to justify the definition which I have offered of police work, for the definition in itself implies a change in the objectives of police service.

8 Generally, until now, the functions of the police have been assumed to be something as follows:

a General enforcement of certain laws and ordinances

b Enforcement of certain other laws and ordinances selectively, according to the feasibility of their enforcement and the state of public opinion regarding them

c Enforcement of certain other laws and ordinances on complaint of persons injured by their infraction, with particular respect to the perpetrators of the injury

d Repression or prevention of crime and disorder, by the process of tacit intimidation; in other words, the brass buttons and swinging night stick

e Physical and militaristic suppression of express disorder, such as riots and street brawls

f Investigation of crime committed for the purpose of tracing, identifying and apprehending the criminal

g Performance of inspections, regulation of traffic, rendering aid to citizens, and miscellaneous other incidental functions that are committed to the police as matters of convenience, and are not generic to the police problem

9 In other words, police work has heretofore in the main been directed to repairing the wear and tear of social friction instead of to obviating the causes of friction. A single illustration which will give emphasis to the general statement because it is an exception to the usual practice, is the regulation of traffic. Unregulated, Fifth Avenue, New York City, in heavy traffic hours would be a maelstrom of confusion, and nervous energy, personal property and bodily safety would be impaired. Friction is eliminated, and wear and tear saved by utilizing the traffic police. Other illustrative exceptions are developing in police practice in this city under the leadership of the present highly competent commissioner, Mr. Arthur Woods. To these I shall presently refer. But in the main, present and past police work has concerned itself not with causes, but merely with efforts.

10 Now, it is to bring about a change in the emphasis and tech-

nique of police administration that I suggest the application of what I describe as the engineering method to all phases of police work.

11 The engineering or scientific method has already been applied in a measure to one branch of police service, namely, the investigation of crime and the detection and identification of criminals. The use of anthropometry and the classification of human types according to physical characteristics, developed by the late M. Bertillon must, of course, be placed without question in the category of science. Similarly, the use of fingerprints and their classification in the identification of criminals, and the use of scientific processes in correlating the habits of certain criminals with the physical evidence of crime, has placed the investigative side of police work on a very much higher plane of effectiveness than the preventive and regulative branches of police service.

12 Police departments have adopted the Bertillon and fingerprint systems of identification as devices to assist in the work of the criminal police, but their adoption has not brought a scientific spirit into the police departments in the United States, as one finds it has in certain German police departments. Identification of criminals has not led American police departments to study crime, or to formulate facts regarding the habits of criminals, and the indicia of criminal types in the method and nature of a criminal act, for the scientific guidance of police work. Particularly in criminal police work, as well as in the safety and regulative sides of police work, is there both the opportunity and need for applying the engineering method.

13 For purposes of illustration I shall select several aspects of police work, indicating in what respects engineering principles may be applied to them.

DETERMINING THE OBJECTIVES OF POLICE EFFORT

14 First, the engineering method is needed to determine the direction of police activity, or, as Mr. Emerson would say, the ideals of police service. The basis of police work is law enforcement. The law to be enforced is the penal law or minor community regulations expressed in ordinances. Penal legislation is based on inherited legal canons, on moral customs, or is inspired by data gathered by special agencies not a part of the police service. In other words, the police department receives undigested, and often unrelated to existing conditions, a vast mass of penal legislation for whose enforcement it is responsible. In New York State this penal legislation is expressed in

a penal code of 2500 sections, containing a catalogue of crimes that are classified under 111 heads.

15 I have had opportunity to study half a dozen large police departments in America. In none of them have I found an institutional purpose, based on an understanding of what police work consists in and why it exists, which was alike in the minds of any two individuals concerned in the enforcement of law. The one common ideal of police service that has been developed in American cities is that the police must be physically well-conditioned and personally honest. This is about as far as any American city has gone, with the possible exception of Toledo, under the rule of Brand Whitlock, and New York City today under the administration of Mr. Mitchel and Mr. Woods.

16 In the minds of the conventional police, criminals divide themselves into four groups:

a Aliens, enemies of society violating the rights, safety and peace of a community, "to be put away," thus gotten rid of

b Native incorrigibles endowed with natural perversity, namely, the familiar thug, the gangster, the crook

c Fortuitous criminals who become subject to police action because of moral lapse or temporary aberration

or as belonging to

d A miscellaneous group including special and individual cases too numerous to catalogue, but comprehended generally in 174 items of the standard crime classification, as used, for example, by the New York police

There has been no recognition of crimes as the consequence of remediable social conditions or the effect of individual abnormalities, either physical or mental, resulting from removable causes.

17 There must be a statistical basis for police work, as there is a statistical basis for engineering work. There is nowhere in the world a collection of social data so potentially useful to the development of a community as lies in every great municipal police department, in the records of arrests, in the records of crime disposition, in the investigation of crimes, in the notebooks of policemen and in the memoranda and reports of detectives.

18 In the report of the New York police department for 1913, the only reference to these records is found in a single sentence under the heading Bureau of Records:

During the year 1913 there were received and filed in the Bureau of Records a total of 35,013 documents.

19 New York City employs 11,000 policemen who made 119,736 arrests in 1913. It has a detective bureau of 528 detectives who investigate 55,000 cases of crime a year, but it has not a single employee engaged on an analysis of the facts brought into the archives of the department in the form of reports on investigations and records of arrests. Commissioner Woods is the first police commissioner in America, so far as I know, who has thought it worth while to put in his budget a request for statisticians. Next year he will have a statistician under the supervision of a deputy trained in statistical analysis, who will study currently police conditions and police work. Not only is he taking this step, but he is utilizing every member of the force as an agent for gathering social facts respecting such matters as unemployment, destitution, improper guardianship, upon which intelligent police work must be predicated.

20 While it is generally known that economic distress and unemployment lead to an increase of small crimes against property and the breakdown of self-control, no American police department has ever analyzed its records to correlate degrees of unemployment with perpetration of crime, and thus furnish the basis for police activity with regard to unemployment. New York City, however, has had this matter forced upon its attention. Conditions of unemployment last year furnished the opportunity for anarchistic agitation, demonstrations of violence, invasions of churches and other disorderly practises, on the avowed theory that only in this way could the public be brought to realize the crucial importance of unemployment conditions.

21 These violent manifestations of disorder, which had their relation to conditions of unemployment in 1914, make it seem a natural function of the police to ascertain the facts regarding conditions of unemployment in 1915. The police department is the logical agency to call the attention of the community and other branches of the government to the need for taking some constructive steps to mitigate abnormal unemployment.

22 In New York, one of the principal problems confronting the police is control of traffic. It was never conceived by the builders of modern cities that thoroughfares, intended for residential purposes and often crowded with children, would be utilized by high powered motor trucks and automobiles, and that many streets designed for

local traffic would become the thoroughfares of a vast population. As a result of this condition there are killed each year approximately 450 persons in the streets.

23 It is peculiarly the function of the police department to work out means of preventing this appalling condition, because the police department is charged with responsibility for regulating traffic. Up to January 1st of this year, New York City's police did not record information necessary for an intelligent analysis of the conditions surrounding the death of persons in the streets, although they are required to report the facts regarding each occurrence as a part of the coroner's investigation.

24 By focussing the attention of police captains and patrolmen on the incongruity of using congested traffic streets for play spaces for children, the present police commissioner obtained from patrolmen and their officers suggestions concerning the use of vacant lots for play purposes and for closing to traffic during certain hours of the day streets used by children for play. The mere fact that the police themselves formulate such suggestions and assist in putting them into effect, brings about a psychological change in the attitude of the policeman to his community relationships which is full of the greatest possibilities for the development of police service. It is merely another illustration of applying the scientific or engineering method to a particular problem, instead of continuing along from year to year, from generation to generation with fatalistic resignation to whatever may happen.

25 It is not cynicism to say that there will always be criminals in a sense that there will be men and women who cannot bring themselves into conformance with necessary social regulations, and there will always be mental, moral and physical degenerates who will have to be restrained and dealt with through penal processes.

26 I am chiefly concerned with youth and with tomorrow. To prepare for tomorrow I wish to utilize the energy and capacity of the 11,000 selected men composing New York's police force, who are well paid, to devote their thought and energies to public service during the prime of their lives, helping New York City reach an understanding of the adverse social conditions which go to make up the police problem.

27 I am confident, moreover, that a very considerable part of present criminality can be eliminated by intelligent preventive action. This preventive action, I believe, should be initiated, if not actually

taken by the police. To initiate it intelligently, the police must act not on general information or impressions, but on carefully gathered data. These data will not in every instance point to clear conclusions or be capable of definite analysis. The work of correlating crime to social conditions is practically untried. If law and order lie at the basis of industry, if social adjustments are essential to economic welfare and civic development, then no section of the community can ignore the police problem. It is particularly important that engineers who are the expert advisers of our industrial and economic life should make their special experience available to police administrators in formulating a method for arriving at the facts underlying the police problem.

28 The spirit of engineers must be put into police service. Police service must be provided with a technique, it must be given recognition by the community as a specialized field of professional service. The new science may become the science of police engineering. The police have heretofore suffered from the same kind of concentration on detail that has kept women under the thrall of domestic drudgery for years, leaving it to men to work out labor saving devices for doing away with or mitigating this drudgery. Police administration has lacked the perspective which it needs to be socially efficient. To obtain this perspective it requires facts of the character that I have attempted to indicate. Gradually, in this way, a public policy regarding police problems will be evolved.

ESTABLISHING EFFECTIVE POLICE ORGANIZATION

29 The second field in which the engineering method is needed in police administration is in establishing an effective organization for police work. This subject is in itself so involved and far-reaching that I can only touch upon it. The outstanding fact regarding conventional police organization is that it is military, and the outstanding fact regarding military organization is that it is not intended to accommodate itself to shifting social development, to relate itself intimately to community life, to be sympathetic and understanding, or to be flexible. Military organization deals with individuals as subservient members of a group and not as self-governing factors coöperating in the execution of an undertaking. In police departments it has aimed at the one consideration everywhere recognized as fundamental in police work, namely, personal integrity. The military assumption of moral and mental dependence of subordinates on superior officers, has, how-

ver, been one of the great weakening forces of police work. In the use of policemen, personal integrity results from exercise of self-restraint in inhibiting an impulse to accept a bribe, to connive at a violation of the law, or to practice extortion. The faculties needed to resist temptations of this character must be developed through a process of self-reliance, through a formulated, even though rudimentary, philosophy of personal conduct. The soldier ceases to be responsible for his moral conduct once he places himself under the command of a superior officer. This condition, while of course less marked in police service than in a purely military organization, still prevails to a certain degree, and has been a conspicuous embarrassment to the development of individual police initiative in larger American police departments. Mr. Woods, New York's present police commissioner, has no military training or proclivities, and is dealing with the officers and men of his department on the assumption that they are self-controlling and self-initiating centers of police thought and police work. This method is a promising contrast to the policy of the martinet, or a policy of easy tolerance, that customarily prevails in police work, and stands out against the old conditions as strikingly as the modern, enlightened, employer's policy in industrial management does against the old time shop boss method of dealing with workmen.

30 Under the military theory of organization, a police inspector responsible for an inspection district comprising a group of precincts, or a police captain responsible for a precinct, was expected either to obey without question orders transmitted from the commissioner's office, or with whatever mental reservations the character of the order implied, or he was held responsible for maintaining a theoretically complete state of order and compliance with law in his district, a condition which he knew could not be sincerely expected of him and which both his superiors and himself were convinced could not be attained. For the honest officer this condition was demoralizing and disheartening. For the dishonest officer it furnished a continuing opportunity for profitable discretion in the enforcement of laws.

31 Non-military administration is bringing about group consideration of particular problems, and joint working out of methods for dealing with those problems. It is bringing about the fixing of feasible standards, gradually to be improved and advanced, by which police work is to be judged, and is doing away with the old hypocrisy which pretended to do what every member of the department, from the commissioner down to the newest patrolman knew could not be done.

32 The principal objects to be achieved in framing police organization are:

a Fixing responsibility

b Enforcing discipline

c Maintaining the integrity of the individual members of the force

d Devising a method for the most efficient performance of the several functions for which the police are responsible

Under the last heading there are questions too numerous for discussion at this time. Under a purely military system the first three objects are sought to be attained by surveillance, by action on complaints, and by requiring submission of reports from the commanding officers. Surveillance and complaints are the principal means, and reports are chiefly used for crude statistical purposes.

33 Consider how vast is the field for developing standards for police conditions by which to test the effectiveness of police service in any particular locality. It may always be necessary to employ some means of determining whether or not a particular patrolman is faithful to his responsibilities to the extent of his being present on the beat assigned to him, but of greater use as a means of testing a patrolman's work will be an examination of conditions existing on his post by independent inspection made openly and with no attempt at concealment, and by an analysis of occurrences on his post as shown by the statistics of the department.

34 Engineering ability is therefore needed to work out a method for establishing a standard for police service in a specific locality and for devising means for testing the maintenance of this standard.

35 The next important administrative need of the police department is to determine means of utilizing the brains and experience of every member of the police force in developing police technique and police program. How this can be done effectively in a force consisting of 11,000 men, or 5000 men is a problem fraught with difficulties. Modern industrial organization points the way. Just as the inspectors forming the committee on prevention of crime that I have referred to were able to furnish definite suggestions for police work with regard to the whole city, so the individual policemen should be able to furnish suggestions for police work regarding his own section or beat. To develop and utilize this latent power will require more energy and resource on the administrative side of a police department than it is now customary to provide.

36 Engineers, as advisers to managers of industrial establishments and the responsible officers of industrial enterprise, share with police administrators an interest in the development of tests for executive capacity. The New York police department and the civil service commission would be greatly helped by having made available to them the experience of American engineers in this field.

37 Other elements involved in the organization and management of the police force which find their analogies in private industrial and business administration are:

a Enforcement of discipline which, to a large extent in the police service, consists of the imposition of fines

b Methods of compensation, and the relative advantage of a uniform wage scale and a flexible scale depending on the efficiency of service performed

c Effect of automatic increments in compensation based on length of service

d Organization of welfare activities

(1) Educational and cultural work to provide mental stimulus to members of the force apart from vocational training

(2) Medical supervision for the upkeep of proper physical condition

(3) Provision of insurance against disability and pensions for retirement

38 With the exception of those special conditions of service which result from the risks inherent in police work and the brevity of the service period due to rigorous physical demands, these groups of wage and welfare problems in police management are analogous to the wage and welfare problems in industrial management. Provision of wholesome, satisfactory and just working conditions is as essential in public enterprise as in private enterprise. Protection against old age and incapacity for service, protection against injury in service, provision for dependents in case of death, all must be considered in establishing a just plan of employment in private management. Public sentiment has sanctioned their recognition as conditions of public employment, but they have not been soundly and scientifically established. Thus, for example, pension systems provided for public employees are generally established without regard to their ultimate cost or the capacity of the plan to meet its future liabilities. This is conspicuously true in New York City where the pension funds are each year making greater demands upon taxpayers and have been

organized and carried along without regard to the city's ultimate ability to finance them. To meet this condition an exhaustive and expert study is now being made of the employment history of all city employees, together with actuarial and insurance statistics gathered with respect to them. This study will furnish pension data not only indispensable to the city of New York in establishing proper pension systems, but of great suggestive value to private industry. The coöperation of industrial managers and the engineering advisers of industry will be most valuable in formulating a definite program of welfare activities with regard to public employees and especially police employees.

39 The future development of the police arm, if police work is to be constructive and to fulfill its possibilities, must be along the lines of the engineering method. The police department through its multitude of agents is the best equipped of all social agencies for apprehending sympathetically and certainly those adverse social conditions in the community which can be remedied only through community attention.

40 The police department of a great city should be the nerve center of the city's government, capable of acting with vigor when a situation demands vigorous treatment, strong to protect the safety of the public against disorder and the unruly, informed on conditions which manufacture crime and criminals, in order that these conditions may be remedied where remedies are possible; aggressive instead of defensive, courageous instead of fatalistic, organized for achievement instead of for mere opportunism, militant but not military, except in the sense of obedience to necessary rules and responsive to discipline; free to deal honestly with conditions in the light of those conditions instead of in the light of statutes written by dead hands; coöperating intelligently with charities, correction, health, hospitals, and educational departments.

41 To bring these things about, the police problem must be broken up into its proper functional divisions. Crime when perpetrated by professional criminals must be dealt with differently from crime committed by those who stray temporarily from the paths of rectitude. There should be organized a national service for the detection of criminals and crime prevention along the lines of similar service now engaged upon forestalling and detecting counterfeiters.

42 Above everything else, back of police work there must be developed a scientific spirit, the true engineering spirit; in place of cunning and cudgels there must be substituted a policy based upon a

knowledge of needs, standards of service feasible of attainment and organization devices to accomplish them, methods of administration and the plant to facilitate their accomplishment, and the genius to capitalize the initiative and individuality of every man on the force.

43 I have only sketched the police arm of the future, not of the far-distant future, but of the immediate future, for in New York City now this forecast is in process of realization.

DISCUSSION

REGINALD P. BOLTON (written). I congratulate the author upon his discovery of the fact that there is a purpose in engineering methods, and that there is also the possibility of advantage to one department of city government in the utilization of engineering methods.

The rights of a citizen extend to the exercise of police powers on the part of any individual, and the police are no more than paid delegates of citizens, performing this duty for them.

The question as to whether these men should be regarded from a militaristic or departmental view has more than one side, the advantage of military organization consisting in the addition of *èsprit de corps* to the moral character of the police officer, while the provision of weapons is of dubious value, and certainly tends towards suggestive imitation on the part of other persons.

The author's suggestion that the police should be charged with the study and dissection of the causes of crime would lead to dubious results, since the work is in itself a function of scientific investigation, and the local police would be confined to the study of local causes which might be misleading. The proposal would only result in additional jobs in scientific bureaus added to the police department, and publicity given to such statistics and information, might have an unfortunate result in suggestive inducements to crime.

Some of the accidental deaths in the public streets are due to the neglect on the part of the Department of Public Works to provide proper isles of safety, in view of the crowded conditions of traffic.

The difficulties experienced in upbuilding the character and in extending the usefulness of the police force are attributable to causes entirely different from those advanced by Mr. Bruère. My own observations are derived, not from the study of city departments, but from conversation with the men themselves. I have found the prevailing feeling among them to be that they are denied a recognition of loyal service on the part of their superiors and of the public, and are subjected continuously to unfair treatment.

The suggested application of engineering methods to the problems of the police would probably prove somewhat of a disappointment, inasmuch as those principles would include prior to the question of efficiency the recognition of the value of loyalty, of merit and long service, and also the establishment of a system of fair treatment of the members of the police force.

CLEMENT J. DRISCOLL[1] (written). While I am in agreement with Mr. Bruère as to the need for the application of engineering methods in the management of the police departments of America, I do not believe that the shortcomings of America's police have been entirely due to the absence of engineering methods of management, nor do I concede that the mere application of the engineering method in police management will remedy them.

The cause of police inefficiency in New York City can be found in the fact that in thirteen years the police department has had ten commissioners. Not one of these doubted the efficiency of the engineering method or lacked ability to apply the engineering method, or did not fully realize before he retired, or was forced to retire, from the department that the police problem of the city was such that only careful, patient application of scientific methods would solve it. All of them would say to the engineers gathered here that in administering police problems all the methods known to science would be of little avail while the control of the police department was in the hands of the political powers of a community.

The Panama Canal stands today as one of the supreme feats of engineering. It was made possible only because the engineer-in-charge remained in his position long enough to work out the engineering problem. But even Col. Goethals would not have mastered the police problem of the City of New York by the application of the engineering method if he had been subjected to the same conditions under which all the administrative heads of the department have had to work. It was only because Surgeon General Gorgas was continued in control of the application of methods of sanitation in the Panama region long enough to establish the efficiency of that method that yellow fever was practically annihilated and malaria brought under such control that white men could live there. Hence, of what use

[1]Bureau of Municipal Research, New York City. Former Deputy Police Commissioner.

would the application of the engineering method to the New York police department be unless provision were made to keep in charge of that department the man applying the engineering method long enough to prove its efficiency.

To summarize, I would say that Mr. Bruère's recommendation as to the application of the engineering method to police administration is sound, but that the hope for the solution of the police problem in America is not to be found entirely in this recommendation. I would urge, as the first step toward increasing the efficiency of the police, the adoption of statutes providing for a more permanent tenure of office for the administrative head who will then be in a position to apply the engineering method to enforce the laws as written; second, the complete separation of the police department from the mayor's office, placing the full responsibility for the administration and conduct with the police commissioner or administrative head, regardless of his title; third, the application of the engineering method; and, fourth, the complete abolition of the system now in vogue throughout the country of adopting policies of law enforcement which will not result in the enforcement of the statutes as written.

Alex C. Humphreys said there was no fundamental inconsistency between Mr. Bruère's paper and Mr. Driscoll's discussion, though some other inconsistencies are apparent in connection with the discussion. He suggested to the New York citizens present that they had better not take upon themselves the task of being their own policemen; they might get into trouble. They can, however, advise and they can educate the public as Mr. Bruère had advised, and here he differed from the last speaker. He saw no reason why Mr. Bruère's suggestion that the police should study the causes of crime cannot be carried out. The directing of this study would have to be in the hands of a man qualified for scientific investigation. Under such direction of such a man the facts could be gleaned from the rank and file of the force. This would involve no inconsistency but might be a tremendous agency for the education of the public; and if the public could be sufficiently educated, the politics of the situation would be taken care of. The speaker said that he agreed absolutely that the present troubles in connection with police control are largely due to the interference of politicians. He paid a tribute to Mr. Bruère for his paper.

The Author. I disagree with Mr. Driscoll that one of the greatest difficulties in this matter is politics. The real difficulty is that the police department does not know what its problem is, and nobody fully knows it. The thing that is most needed is not the elimination of politics, but more of the kind of politics that engineers would uphold.

In answer to Mr. Bolton I suggested that there be given to the police department the facts regarding outside conditions, not gathered by impressions, but based upon the actual experience of the department. There is no problem which Mr. Bolton has ever been called on to face that he does not or should not reach in the same way. My plea is merely this: that we proceed with regard to this whole question not on the basis of passion or sentiment or politics or impulse or judgment, but on the basis of facts. I came here not to ask you to find the way of putting on the shoulders of others the responsibility for existing conditions, but to ask you to take it on your own shoulders. We are never going to succeed in police administration in the police department merely by having, as Mr. Driscoll suggested, a commissioner continuously in office. If we had had one man for ten years, he could not have understood his problem merely by continuity of service. To arrive at an understanding of it, he would have to employ this method that I advocate, the engineering method. No commissioner is going to succeed, whether his term be for six months or six years, until he does employ this method.

I hope that as a result of this conference the gentlemen present will give some thought to getting a fact basis for police administration, each in his own community, so that in dealing with this most easily complicated division of city government, we shall not have to act merely upon passion and impulse.

No. 1450

SNOW REMOVAL

A REPORT OF THE COMMITTEE ON RESOLUTIONS OF THE SNOW REMOVAL CONFERENCE HELD IN PHILADELPHIA APRIL 16 and 17, 1914.

Early in March, 1914, Mr. Morris L. Cooke, Director of the Department of Public Works, Philadelphia, wrote to a number of the leading Eastern cities suggesting the need of a conference on the subject of snow removal and pointed out, that in view of the very apparent lack of engineering methods generally employed in a problem which so clearly calls for engineering study, it might be profitable if those in charge of the matter of snow removal in the larger cities could be brought together, and that at least an approximation of a definite policy of snow removal might result from such a meeting.

2 The suggestion met with such favor that a snow removal conference was held in Philadelphia on April 16 and 17, 1914, attended by delegates from New York City, Boston, Mass., Harrisburg, Pa., Pittsburgh, Pa., Newport, R. I., Scranton, Pa., Portland, Ore., Springfield, Mass., Chester, Pa., Trenton, N. J., Washington, D. C., Wilkes-Barre, Pa., Wilmington, Del., Wilkinsburg, Pa., Newark, N. J., and Philadelphia.

3 A Committee on Resolutions was appointed to submit a report, which would be the result of papers, discussions and recommendations made at this conference, and the Committee makes the following report:

4 The problem of snow removal must obviously be considered differently in different cities as its solution is dependent upon such variable elements as climate, population, width of streets, density and character of traffic, location of sewer systems, available disposal places and other local conditions, to say nothing of the financial policy of the municipality.

5 It would seem impossible to formulate anything but the most general suggestions, and yet it is found that even so vital a matter

Presented at the Annual Meeting, December 1914, of The American Society of Mechanical Engineers.

as the financial policy does not affect the main problem, except in the extent of the work. This is amply illustrated by comparing the experience of two of the largest Eastern cities during the storms of February and March of 1914. One of these cities undertook to clean 570 miles of streets, and the other city—of about one-third the population of the first—undertook to clean only 40 miles of streets; and, although the variable elements mentioned do unquestionably affect the problem, it is possible to make certain definite recommendations which may be considered the result of the experience of the leading cities of the East, as shown by papers read in the conference and upon which the report of the committee is based.

6 The difficulties which beset the official handling the work may be seen when the uncertainty of everything connected with the problem is considered. For instance, in New York City in 1900 and 1901 there were 9.2 in. of snow in 25 days, while in 1906–1907, 52.04 in. of snow fell in a period covering but 53 days.

7 Climatic conditions greatly affect the work. If there is a continuous thaw after the snow-fall, or if there is a thaw on account of rain, that is a great help; whereas, if there is a thaw followed by freezing, it is quite another matter. In a few words then, the first step in a snow removal problem is to formulate a system and draw up specifications for the removal of an indeterminate amount of material at unknown periods of time under unknown conditions, and added to this is the fact that the material itself is of a variable nature, whose weight according to the American Engineers' Handbook is from 5 to 12 lb. per cu. ft. for freshly fallen snow. Compacted or wet snow weighs from 15 to 50 lb. per cu. ft. In the Borough of Manhattan last year it was found by actual tests that compacted snow carried in wagon loads during 1914 weighed 36 lb. per cu. ft.

8 The work of snow removal is generally done by contract under the supervision of city officials, payment being made according to the quantity removed as tallied by wagons hauling to the disposal dumps, the forces and equipment consisting of men with shovels, horses and wagons. In some cities, scrapers and plows are used to push the snow to the side of the street, relieving traffic and making it easy to pile, or to load without piling.

9 Salt is generally and very extensively used for the removal of snow in Liverpool, London, Paris and other European cities. The very general practice is to broadcast coarse salt on the streets during

and immediately after a snow storm, and when the snow has been reduced to slush by the action of the salt, the streets are flushed with water and the slush washed down the sewers; but in those cities they do not have very heavy snows and it is doubtful whether it would be practicable here where we have a much greater depth of snow. There is also very serious objection to the use of salt by the Societies for Prevention of Cruelty to Animals and in some of the cities it is prohibited by ordinance. It is questionable whether the use of salt has been given a fair trial in this country for the removal of snow and there is little doubt but that it would be useful in light snow storms.

10 Much thought has been given to the design of apparatus for melting snow and, also, to special machinery for scraping, loading and transporting. Inventors, designers and manufacturers should be encouraged to continue in the endeavor to produce equipment which will render practical and efficient service, but the amount of snow is so variable and the equipment is in use for such a short period of time that it is desirable it be so designed as to be useful for other work at different seasons of the year. Pending improvement in the types of equipment, the general consensus of opinion seems to be that it is desirable to utilize equipment which is ordinarily employed for other purposes by the city or private individuals, but temporarily out of commission on account of the snow, and which, although not specially designed for the purpose, can be made of service; such as carts, wagons, motor trucks, etc., for hauling; graders and road scrapers, and road machines; wheel and slip scrapers for piling snow in windrows near the curb or for dumping the snow into sewer manholes; machine brooms of the street cleaning department for light snows; ordinary gondola cars to haul snow from the street by rail; and garbage carts, some of which are available as the accumulation of garbage is less in winter than in summer, the unloading stations being utilized as dumping points. Also, special equipment which has been found of practical use, such as sidewalk and gutter plows, or the rotary plows used by railroad companies.

11 The problem confronting the public officials is the removal of snow in the shortest time and in such a manner as not to interfere with traffic, and at a minimum cost. Therefore, using the method of scraping, shoveling into trucks or carts and hauling to dumps, the length of haul becomes a most important factor and it can readily be seen that the utilization of sewer manholes as dumps, and the sewer system to carry the material to the rivers, is the most economical method which can be devised as it reduces both the haul and

the handling to a minimum. The authorities in charge of the sewer systems have, as a general thing, apprehensions regarding the use of the sewer as a snow carrier.

12 The Borough of Manhattan, New York, Bureau of Sewers, however, made experiments during the winter of 1914 which seem to prove that, within certain limits, such apprehensions are ill-founded. Their results indicate that snow may be dumped by wagons loading into sewers carrying 10 ft. per sec. or more. Panning can be carried on where the flow is at least 3 cu. ft. per sec. and the velocity greater than 1½ ft. per sec. Shoveling can be done where the flow is at least 2 cu. ft. per sec. and the velocity more than 1½ ft. per sec. Under ordinary circumstances if the flow is sufficient to carry snow away, melting will occur within 300 ft. (temperature 60 deg. fahr.).

13 Gas and chemical combinations in the sewers have little effect on the rate of melting. Two cubic yards per minute is the maximum rate at which snow can be shoveled into a 24-in. manhole. Tidal sewers can only be used to advantage when the tide is low, in which case the factors of the ordinary sewer apply. Siphon sewers can be used as well as the ordinary type.

14 Where difficulty is experienced with an insufficient flow in the sewers, or where the flow decreases or stops, the water plug may be opened in the drainage area of the sewer above the manhole in use, until the volume of water is sufficient to carry off the snow, but it has been found that the most efficient use of water may be had where water jets are constructed in the manholes into which the snow is dumped. The problem of getting the material into the manholes in the least time with the least interference with traffic opens up a field for the consideration of a special form of manhole to be used satisfactorily for this purpose. Pittsburg and St. Louis both use a special form of manhole.

15 The following is a brief outline of the experiences of some of the cities and railway companies in the winter of 1914, which covers in a general way all the methods at present in vogue:

PHILADELPHIA[1]

16 In Philadelphia the area to be cleaned other than the work done by the regular street cleaning force consists of approximately 20 miles of streets and is divided into 19 districts, of which no one contractor is awarded more than two. The removal of snow is

[1]From papers and discussion at Snow Conference, April 16-17, 1914, Philadelphia, Pa.

under the supervision of the Bureau of Highways and Street Cleaning and the entire engineering force, consisting of 200 men, is engaged in supervising the work. One assistant engineer or inspector is assigned to each snow district to act as squad leader, and to each of these leaders is assigned a number of inspectors divided into first and second call men, with the understanding that in case of snow the squad leader is to get in touch with the inspectors and also the contractor for his district and then to communicate with his respective division engineer for orders to start work. As soon as the snowfall has covered the pavement and is increasing in depth, the contractors are ordered to start work with the scrapers or plows in their respective districts. The snow is plowed to the side of the street, after which the teams and laborers are ordered to proceed with the work of removal. In this way, it is possible to keep ahead of the storm on all the main business thoroughfares and to succeed in having the streets opened to traffic when the snow has ceased falling. This, of course, necessitates the entire engineering force working night and day in two 12 hour shifts.

17 The specifications require that within one hour after notice to proceed is given, the contractor shall have in each district a sufficient number of foremen, laborers, scrapers and plows to plow the snow to the side of the roadway, and that within two hours the contractor shall have working in each district a certain minimum number of wagons with sufficient foremen, laborers, etc., and that he shall be required to furnish additional teams up to double the amount of the minimum number specified, if so ordered.

18 A certain portion of the sewer manholes were used as dumps, but unfortunately all of the manholes could not be utilized because of the small flow of water in the sewers. A further study has been made with a view to having water connections placed inside of many sewer manholes to facilitate the flow of water, thus permitting the use of fifty per cent more manholes than were available in 1913.

19 To each of the 19 districts are assigned certain specific dumping places and the contractor for that district may only use these dumping places; this avoids any confusion.

20 The main idea in Philadelphia is to put the scrapers and plows to work in the earliest stages of the storm and to fight it, instead of waiting until the snow stops falling, which not only results in tying up the traffic, but makes the work all the more difficult.

21 An endeavor is also being made to have street railway companies place extensions on their plows so that when they clean their

tracks, they will also sweep 8 or 10 ft. on each side of the tracks. which would do away with the necessity for scrapers and plows on railway streets and would be a great help towards solving the problem on such streets.

NEW YORK[1]

22 The City of New York operated in February and March on 570 miles of streets. The Commissioner of Street Cleaning of New York has stated that immediately after the first snow started to fall in February the street cleaning force of the department was doubled each sweeper bringing with him or being furnished with a helper to clear cross-walks and intersections, open gutters, clear around sewer basins and fire hydrants, and assist generally on snow removal work. After the serious character of the first storm of February 13 was realized and the inadequacy of the trucking force became apparent, plans were immediately made to secure the use of sewers other than the 28 allowed in the Manhattan contract for the disposal of snow. In previous years permission to use sewers for snow disposal was refused by the various bureaus of sewers on the ground that past experience justified the closing down of sewers for snow removal, as the force engaged on snow work has no regard for the proper maintenance of sewers and filled the conduits with solid matter, resulting in choking and seriously injuring the sewers and damage to the property owners, whose cellars were flooded. However, by arrangement with the engineers in charge of the various sewer bureaus of Manhattan, the Bronx and Brooklyn, plans were made after the first storm of this year to place a sewer inspector at each manhole used by department snow gangs, in order that no material might be allowed to fall into the manhole which would block the sewer.

23 Tests have been made on previous occasions to determine the feasibility of using small-pipe sewers, 12 in. in diameter, but there was no general agreement as to whether or not this could be done successfully. It was conceded by the Sewer Bureau officials that with large brick sewers, having a steady flow of sewage of a sufficient depth to carry off snow, such sewers could be used and were approved for snow disposal, but that with small pipe sewers tests had not been so successful. Further trials, however, were arranged in conjunction with the sewer engineers and finally it appeared that some simple apparatus designed to regulate the flow of sewage and snow, aided

[1]New York data from article in Engineering Record, March 28, 1914, by Street Cleaning Commissioner.

by a stream of water from a hydrant, would permit use of the small pipe sewers and would possibly afford a means for their continued use for fresh snow disposal in the succeeding years. These experiments were quite successful and by using a wire basket or a can on small pipe sewers, where there was no flow of sewage, snow was disposed of by a hose stream with reasonable rapidity and at decidedly decreased cost over haulage by truck.

24 Very little snow removal equipment is now owned by the Department of Street Cleaning, except 60 road scrapers, which are available for use during or immediately after a snow-fall. These machines did very good work in clearing the main portion of the principal arteries, but after the first two days they were discarded and not used afterward except to pile slush during a short thaw. No other apparatus for snow removal or snow fighting existed in the Department of Street Cleaning, but it was quite apparent, after sewers were secured for snow disposal, that ordinary pan scrapers used by sweepers and drag scrapers drawn by a single horse would prove advantageous and economical in hauling snow over short distances to sewer manholes, which nominally are about 115 ft. apart. A number of drag scrapers were secured and tests made therewith indicated that snow could be removed at a cost not to exceed 10 cents. per cu. yd., where sewers were available. This is about one-fifth the amount paid for carting of snow.

25 The Commissioner further states that there are two phases relating to snow work: snow fighting and snow removal. By the term "snow fighting" is meant an organized effort to remove snow from thoroughfares as the snow falls. At present the city waits until the snow-fall is over and traffic congested before it begins to dig itself out. To have every sewer in town available for the disposal of snow as it falls and to secure a sufficient number of men to keep snow moving into the sewers as it falls appear to be the most feasible ways of meeting the snow-removal problem. It has been demonstrated this year that even small pipe sewers can be used for the removal of snow, and as the maximum rate of snow-fall seldom exceeds 1 in. per hr. (or approximately 0.1 in. of water per hr.) the capacities of the sewers on the whole should not be overcharged by a maximum snow-fall.

BOSTON[1]

26 In Boston, because of the narrowness of the business streets,

[1]From papers and discussion at Snow Conference, April 16-17, 1914, Philadelphia, Pa.

it is necessary to remove the snow once for all, and not pile it up to await a thaw. The large water front of the city provides ample dumping places within a short haul, so that most of the snow is disposed of in this way and not dumped into the sewers.

27 To handle a 6 or 8 in. fall, the regular city forces of about 1000 men and 300 carts are sufficient. For a light snow, machine sweepers are used to move the snow to the gutters for loading. As the snow becomes heavier, ordinary road scrapers are used to pile the snow on the smoothly paved streets.

28 To provide help in case of heavy storms, bids are received every fall for the removal of snow from each of the six districts in which the city is divided, at so much per cu. yd.

29 The equipment consists of single and double dump carts, pungs and motor trucks, classified in accordance with their capacities in cubic yards and properly marked in accordance with the specifications. The contractor is required to coat the inside of each vehicle with heavy oil or grease.

30 The street railway company renders some assistance because a city ordinance forbids the depositing of snow in any street unless it is left in a safe condition. The snow plows of the company leave a ridge which must be removed, in accordance with this ordinance, so this snow is loaded into carts and pungs and hauled away. In addition, at night, the railway company hauls the snow in gondola cars that carry it to one of the numerous bridges where it is dumped into the water, a method of removal which is the most efficient of any in vogue.

31 In the suburbs the work consists of plowing out the gutters, cleaning cross-walks, and, when the snow is deep enough to warrant it, breaking out the street with a breaker or leveler usually drawn by six horses. This suburban work is done by the regular city forces.

SCRANTON[1]

32 In Scranton the experience with the flushing method is reported quite successful. Within a radius of one-half mile of the City Hall, there are about 120,000 sq. yd. of asphalt paving, and this area was cleaned, during the past winter, by flushing. The sewers are of sufficient size and the grades of many of the streets are steep.

33 The sweepers of the Scranton Street Railway piled the snow

[1]From papers and discussion at Snow Conference, April 16-17, 1914, Philadelphia, Pa.

to great depths between the car tracks and the curb lines, hindering instead of assisting the work of removal.

34 Lackawanna Avenue, the principal business street, was flushed by streams of water, at a pressure of 75 lb. per sq. in., flowing through fire hose. The stream was directed to the open catch basin, from which the grating had been taken and the trap removed, providing a 10-in. opening direct to the sewer. The men were stationed about 10 or 15 ft. apart and loosened and removed the snow and ice, leaving the pavements entirely clean. In 13 hours 24 men cleaned 14,440 sq. yd. notwithstanding the fact that the snow was in places heaped as high as 8 ft. Taking an average depth of 3 ft. over the above area, 43,320 cu. yd. of snow and ice were removed at a cost of less than 25 cents a cu. yd.

35 On Penn Avenue, the same force, working 8 hours, removed 22,420 cu. yd. at a cost of a trifle over 21 cents a cu. yd.

36 The experience on these streets convinced the authorities of the practicability of this method and they commenced in a systematic manner to clean all the streets of the city.

SNOW REMOVAL BY AN ELECTRIC RAILWAY COMPANY[1]

37 The Public Service Railway Company of New Jersey operates about 865 miles of single tracks running through 140 municipalities whose population is about 2,000,000. The territory is divided into six divisions, extending from Jersey City to Camden and the area is approximately 1100 sq. miles. The property is operated from a central office so the procedure is generally the same in all of the districts, although there are slight variations due to local conditions. No special supervisory organization is required, the regular force of employees is enlarged. Early in the fall the officials of the division meet and make coördinate plans of action; the men in all the various departments are assigned to their proper stations and the snow fighting equipment, put in good condition during the summer, is run over the lines.

38 As soon as the snow begins, the men are assembled in the various car houses, some are started on the work of cleaning switches and the sweepers begin work when the snow has become about 2 in. deep. The transportation department keeps in continual touch with

[1]From papers and discussion at Snow Conference, April 16-17, 1914, Philadelphia, Pa.

the operations on all of its lines. During snow removal work the company sees to it that their men are properly fed.

39 Snow on the sides of the tracks is forced away from the tracks (if the storm continues) by means of levelers attached to the sides of the sweepers and plows or special workcars. The rotary plows are reserved for attacking extra heavy drifts occurring usually on suburban or outlying lines. If the snow falls faster than it can be handled, the outlying lines are abandoned first and the forces concentrated on the city service.

40 As soon as the snow is piled in any quantities, the work of removal begins, usually being done with teams. In some places arrangements have been made with the municipality whereby it removes the snow from some streets while the railway company removes it from others. In some places the municipality removes all the snow and charges the company for its share removed from along the company's lines.

41 Future improvements in snow removal by the railway company will probably be made along the lines of strict planning, inspection and supervision of the work.

PENNSYLVANIA RAILROAD COMPANY[1]

42 The Pennsylvania Railroad Company have been using several snow-melting devices on their Philadelphia Terminal Division. One of these devices might be made particularly applicable to municipal work; the others are peculiar to railroad work such as the melting of snow in switches with burning oil, and the disposal of snow in snow melting pits located in their yards. Also a device on a locomotive by which the snow is blown away from the tracks with live steam sent through a pipe located between the wheels and near the tracks, but the idea of equipping a car with steam pipes for melting snow is one which is worthy of attention for municipal work.

43 The Railroad Company use a gondola car, the inside dimensions being about 38 ft. 2 in., by 9 ft. 3 in. and 3 ft. 9 in. deep, and about 1 ft. below the top of the car is a false bottom, forming a pan, which is used for the steam pipes, and for storing hot water. The steam pipes are various lengths and are open at the ends. This arrangement distributes the steam directly over the entire pipe. The first snow is melted by the steam and in a short time the accumulated water is boiling. The snow is then melted by the boiling

[1]From papers and discussion at Snow Conference, April 16-17, 1914, Philadelphia, Pa.

water. In the center of the pan is a small manhole 11 in. high through which the water overflows to the lower part of the car which is about 2 ft. 6 in. in depth, and is used for the storing of the accumulation of snow water.

44 The amount of snow that can be melted in the car before letting the water out is equivalent to approximately 25 car loads of the type of car generally used by them for this purpose, depending somewhat upon the compactness of the snow. With 20 men, this car has been filled with water three times in a day of 10 hrs. Water can be dumped at any plug, pit, or, when the ground is frozen, at any point where it will readily drain away. A single car has a distinct advantage over a long train in congested districts. It also frequently happens that a car can be emptied at points where there is snow to be loaded. In this way, more snow is being disposed of while the car is emptying itself. Naturally, the best results are obtained by handling the snow while it is new and before too much dirt is mixed with it.

45 The car has been in use for two winters and last winter it was used continuously after each snow storm until the accumulation of snow had been removed. During all of the snow storms last winter the railroad company did not haul one shovelful of snow from the Pennsylvania Terminal yard, and considering the actual necessity of keeping these tracks practically entirely clear of snow, particularly around switches, the railroad company feels that this shows conclusively the advantages of the various snow melting devices which they are using.

CONCLUSIONS

46 In considering the problem and in making their recommendations, the Committee assume that the area to be cleaned has been decided upon, and that sufficient money has been appropriated to carry on the work over this area.

47 Assuming that the area to be cleaned has been fixed, that the work will be done by contract system, that the contractor is to be paid by the number of loads dumped into the manholes or at disposal points, it is the consensus of opinion that in large cities it is seldom that one contractor can be found who has facilities for handling the entire city, and that, generally speaking, the area to be cleaned should be divided into districts, only a limited number of which should be awarded to any one contractor.

48 Therefore, as a result of the experiences and views expressed at the conference and which have since come to the attention of the Committee, the general principles which should underlie the conduct of this work may be outlined as follows:

1st. The plan of organization and the system to be employed should be worked out in advance of the snow season. This preliminary work should involve: (a) plan of coöperation of all branches of the municipal government; (b) the formation of a skeleton organization composed of all the available city forces, such as engineers, inspectors, time-keepers, laborers and teams. (c) the division of the city into zones and the determination of a definite method of work for each zone. The various members of the organization should be assigned to these zones and the responsible officials familiarized with the duties expected of them.

The character of work to be performed in the different zones may consist of merely the regulation of opening cross-walks and gutters and otherwise generally assisting pedestrian traffic and the run-off of the snow, or it may consist in the complete removal of the snow from the streets. Owing to the general increase in motor traffic and the concentration of business in definite office districts and to the general public demand for increased urban facilities, the present tendency is to increase the scope of the work involving the complete removal of snow from all main thoroughfares and business streets.

2nd. The work of removal should commence as soon as the snow has covered the pavements and the indications point to the storm continuing and the operations should be carried on continuously. This as a principle is successfully followed by street railways in the removal of snow from their track space and by some cities.

3rd. The carrying capacity of the sewer system should be utilized as far as possible to get the snow away from the streets.

The use of the sewers which reduces both the haul and handling to a minimum involves two operations: namely, getting the material to the catch basins or manholes, and then putting the material into the sewers. The first operation can best be done by loading into wagons or trucks and hauling to suitable manholes or by the use of scrapers or graders. The problem of getting the material into the manholes in the least time and with the least interference with traffic opens up a field for consideration of the question of special forms and special locations of manholes designed to be used solely for this purpose.

The method of flushing the snow with fire hose into catch basins may have a limited application but it is too unreliable to have any general value as it depends on weather conditions.

4th. When practicable, where there is only a small area to be cleaned, the work should be performed directly by the municipality by day labor. This method of operation is the most flexible and the most easily administered and it obviates the necessity of measurements and checking involved under the contract system. The work can also be performed by day labor in large areas by adopting the following method: The department to advertise and go out into the open market and hire teams to haul the snow for so much per yard, the price to be determined on by the department and to represent a fair estimate of the cost of the work and a fair profit. This, of course, would throw the work open to anyone owning one team, or a hundred or a thousand or more teams, depending upon the amount of work to be performed, and would not leave the department dependent upon any one or more contractors. In this method, as well as when the work must be performed by contract system, a method of measurement as simple and accurate as possible should be used. The practicability of having work done by the municipality will depend among other things on the immediate availability of an appropriation. It is essential for the proper conduct of the work whether by day labor or contract that appropriation for snow removal should be made in advance of necessity for the work.

5th. Coöperation should be sought with the traction companies and use made of adjustable plows and sweepers to open roadways adjacent to street railway tracks at the time that the work of clearing the tracks is being carried on.

6th. Effort should be made to obtain the coöperation of the public and to instruct the householders in the method of the removal of snow from private premises in such a way as to least impede the city's work. Where sidewalks are of greater width than would be necessary to handle the reduced volume of pedestrian traffic, which may be expected after a heavy snow, the snow instead of being entirely cleared from the sidewalk and piled in the roadway should be left on the sidewalk near the curb line to be later removed by the city when opportunity presents itself.

7th. The police force of the city should coöperate with the street cleaning force and the services of patrolmen as inspectors should be utilized as far as possible. The police in particular should give attention to the enforcement of regulation governing the removal of snow from the sidewalks or from a portion thereof.

8th. It is recommended that a standing committee be appointed to collect and receive data upon this subject, to examine into and report upon such methods or apparatus for the conduct of this work as may be presented to it, and further that a conference upon this subject be held next spring for an interchange of experiences in handling the removal of snow during the winter of 1914 and 1915, and to make further recommendations to be available before advertising the work for the succeeding winter.

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R. B. HAMILTON, Vice-President, Philadelphia Rapid Transit Company.
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Committee on Resolutions

DISCUSSION

J. T. FETHERSTON[1] (written). New York City has tried almost every method of contracting for snow work, from the area system to the direct haulage method on vehicle capacity basis. Dividing the city

[1] Commissioner, Dept. of Street Cleaning, New York City.

ıto relatively small districts, larger districts and boroughs has been ried, and it would appear that the responsibility and experience of he contractor were of greater importance than the area or district ssignments. In other words, an experienced contractor, with the ucleus of the necessary snow removal equipment, as a rule is in etter shape to remove snow rapidly and control sub-contractors than s the municipality. More important still, he usually has sufficient ontrol of funds to pay promptly all men employed. It would seem hat experience, control of equipment and responsibility are the main actors to be considered, rather than the area basis, for the assignnent of contracts.

The statement of general principles contained in the committee's eport would be clarified if the work were separated into these livisions: (1) contract work, (2) street railway assignments, (3) nunicipal work. Necessarily under each head the plan, organization nd management should be worked out in advance, and every reaonable contingency covered by the assignment of the most uitable means of snow removal adapted to particular areas, treets or districts of the city under consideration. All municipal lepartments should be called in to assist the street cleaning division y the assignment of officers for the supervision of contract work articularly, leaving the street cleaning department as free as possible to perform the work for which its own force is best fitted.

As a general comment on the report, it is suggested that, if posible, engineers or street cleaning officials should receive from an auhoritative source, such as the Society, a summary of conclusions overing:

(1) A statement as to what types of streets should be cleared of now, and how far the municipality is justified in removing snow rom minor thoroughfares at public expense.

(2) A statement setting up the reasonable depth of snow for which a municipality should have equipment available, and in general he time limits within which streets should be cleared, so as to avoid economic loss, and coupled with this, a maximum depth of snowfall beyond which all citizens and transporting agencies should be required to place their services at the disposal of the municipality at cost.

(3) A compilation of snow statistics for various parts of this country, and if possible a summary of attending weather conditions.

Each city must work out its own salvation regarding snow removal and disposal methods. The problem is so complicated by uncertainty as to weather conditions that no particular method is best fitted for all cities and all conditions.

E. D. Very[1] in a written discussion pointed out that an endeavor should be made to define the extent to which snow removal should be carried on in a municipality. This definition should not be made in units of mileage or of square yardage but rather in terms of necessity. In this regard the financial policy so affects the main problem as to deserve considerable study, as the extent to which the work shall be carried on depends largely upon the amount of money a municipality can afford to spend. This question must be answered before we may assume that the area to be cleaned has been decided upon and the appropriation of money must be predicated upon an understanding of the actual need in this regard. We should go further and discuss the manner in which funds for the work should be raised. It is suggested that the tax for such purpose should be levied; a part by a general tax and a part by tax on property immediately benefitted. Such a method would restrain the indiscriminate demand for unnecessary service for personal benefit.

Whether the work is to be done by contract or by the municipal forces is a question of local condition and must be solved independently by each locality. It is well to remember that where the force engaged in removing accumulations in the street has also the duty of removing the household wastes, the latter item must be considered as of equal importance with the former and the force employed in the latter work must not be reduced by transferring any part of it to the performance of the former. This is especially true when the use of sewers is to be made for the disposition of the snow, as, if wastes are not removed, they will find their way into the snow bank and so become a menace in the clogging of the sewers.

For the purpose of supervision, the division of the work into districts is the proper method, but to limit a contractor to one district is of questionable value provided the contractor is able to handle more than one district. The fewer contractors on a given area results in less friction, and labor and vehicles are more easily distributed where there is a common interest in the success of the whole work.

Where the work is performed by contract it is well to confine the contractor to the removal of the large accumulations and to employ a

[1]Sanitary Engr., 17 Battery Place, New York City.

municipal force in clearing cross-walks, keeping catch basin inlets open and removing snow from the immediate vicinity of fire hydrants

If this conference does nothing else but successfully impress the officials in charge of sewers that it is their duty to permit the free use of the sewers for the disposition of snow, it has given ample reason for its existence. Flushing snow into catch basins is not favored as it has not been proven that such work may be practically accomplished without interfering with the necessary use of these devices.

As to the hiring of teams by the city for snow removal, it is believed that this is a matter of local condition. New York City has had sad experience in that line.

As to having an available appropriation for this work, the idea of municipal policy today is to suspect the official of not being worthy of trust in the handling of money, so they limit his appropriation to his actual needs and where the amount which he may need is indeterminate, they hesitate in taking any chance of putting an amount in the hand of the official more than sufficient for his needs for fear that he may spend more than is required.

Police assistance would be most valuable and in the matter of enforcement of sidewalk cleaning regulations the police find themselves very busy but moderately successful. An amendment is suggested that coöperation of police magistrates be employed to the end that police activity may be made effective.

WM. GOLDSMITH.[1] In the report mention is made of the snow disposal experiments in Manhattan Borough Sewers, an account of which appears in the Oct. 29, 1914, issue of Engineering News. I wish to bring out that, when it is proposed to use sewers for the disposal of snow, the methods outlined will give the desired information, but as the experiments were made in March 1914 when the snow was well compacted and more like ice, the results should therefore be taken as applying only to well-compacted snow.

It is proposed to make further experiments with loose snow; these may or may not bear out the results found with well-compacted snow. It is true that loose snow has a greater tendency to clog a sewer than well-compacted snow, but then it may melt quicker.

The speaker hopes that additional data may be brought to light giving sewer temperatures, quantity and velocity of flow, size of

[1]Asst. Engr., Dept. of Public Works, New York City.

sewer, depth of sewage and nature of the snow. This information is necessary to formulate rules for the disposal of snow in sewers.

In par. 14 of the report, mention is made of enlarging manholes for the quick disposal of snow. In the Manhattan experiments, it was shown that 2 cu. yd. of snow per min. can be shovelled into a 24-in. manhole and that 2560 cu. yd. were dumped into one sewer by means of 3 manholes in an 8-hr. day. This seems to indicate that a 24-in. manhole is large enough. Besides, the effect of an enlarged manhole on the pavement must be considered, the majority of defects in street surfaces being due to manholes of one kind or another, and it seems to me that an elimination rather than an increase of these in pavements should be striven for.

F. KINGSLEY pointed out the fact that the same old cart-and-horse methods for snow removal seem to be used that were adopted when the problem became serious some twenty years ago. It is interesting however, to note the success of the snow-melting device on the Pennsylvania Railroad, because the melting of snow seems to be the most likely path along which improvement can take place.

The cost of fuel to melt snow is only some 15 per cent of cost of handling it under present methods. The basis for this is that a cubic yard of snow as removed weighs approximately 1000 lb. and would require about 200,000 B.t.u. to reduce it to water, allowing a liberal margin over the latent heat of ice. Coal at $4 per ton provides about 67,000 B.t.u. for one cent in a perfect furnace, or 27,000 B.t.u. with 40 per cent furnace efficiency. At the latter rate the fuel cost for melting would only be 7 1/2 cents per cu. yd. or 15 per cent of the present apparent cost of handling it. This does not include interest or labor charges but these ought not to be insurmountable obstacles.

The problem is peculiarly one that mechanical engineers should be able to solve. It appears to be largely a balancing of the cost of heating surface against interest charges, and 1 sq. ft. of heating surface can transmit heat (as demonstrated by existing locomotive boilers) at an approximate rate of 20,000 B.t.u. per sq. ft. per hr. With less efficient but more rapid transmission, twice this rate does not seem impossible. On this basis, apparatus capable of melting 100 cu. yd. of snow an hour would require 500 sq. ft. of heating surface. Certainly there is nothing abnormal involved in the provision of heating surface in such amounts as this.

One hundred cubic yards of compacted snow appears to be equivalent to about 450 cu. yd. of snow as it falls, and in a 3-in. snowfall this amount would cover 500 linear ft. of street. The subject obviously seems to be one that is worth consideration by the various cities in the country, and it would be interesting to see some thoroughgoing experiments along this line.

Martin Schreiber[1] (written). One of the most important considerations regarding snow removal from the viewpoint of a street railway company is a proper and thorough coöperation with all departments of the municipality. The committee has recognized this in its 5th conclusion. To further illustrate, it is plain that the first duty of the street railway company is to clear the roadway of snow to not only allow the operation of cars but also provide a passage for vehicles. The railway may go further, if there is sufficient snow, and level the depth to 6 in. for a distance of 8 or 10 ft. from the track by means of levelers. These latter are easily and cheaply provided by equipping working cars with two wings, one on each side and each about 10 ft. long and 12 in. wide. Leveling the snow back in ridges nearly to the curb insures reasonably clear passage for the cars and vehicles and also allows the removal of snow without interfering with traffic. This method is rapid and economical.

The street railway company can coöperate further with the municipality by hauling the snow with cars, at least during the night. On the other hand, the municipality may ordain that only the snow removed from the sidewalk and private property shall be allowed in the streets. It may also help to remove trees and obstructions across tracks, streets and walks, so that patrons of the railway may have reasonable access to the cars.

The police may do their share by properly directing the vehicle traffic so that the railway tracks are not unreasonably monopolized. The dragging of cars caused by vehicles on the tracks not only discommodes the public, but also ties up the car traffic and often renders it difficult in a storm to get the regular cars and the snow fighting apparatus moving again. To sum up, whatever may be the method of snow removal, honest team work is required; and the viewpoint that satisfactory accomplishment of the whole task is more important than solving any one portion of the problem should ever be before all parties interested.

[1]Public Service Railroad Co., Newark, N. J.

No. 1451

THE NEW CHARTER FOR ST. LOUIS

BY EDWARD FLAD, ST. LOUIS, MO.

Member of the Society

On June 30, 1914, the city of St. Louis by a majority vote of the :ens adopted a new charter in which the engineering profession is n unusual recognition. The charter provides for a Board of lic Service composed of a president and four directors and specifies the president and two of the directors "shall be engineers of nical training, of at least ten years' experience, and qualified to ;n as well as to direct engineering work." The members of the :d are appointed by the mayor and will each receive a salary of)0 per annum.

The Board of Public Service has charge of all engineering, truction and reconstruction work undertaken by the city and exer- supervision and control over (*a*), the department of public utili- including the waterworks and city lighting; (*b*) the department reets and sewers; (*c*) the department of public welfare, including livisions of health, of hospitals, of parks and recreation, and of :ction; and (*d*) the department of public safety, including the e and excise divisions when so permitted by the State, the di- ns of fire and fire prevention, of weights and measures, and of ling and inspection.

The members of the Board are appointed for a term of four s and are subject to removal only for cause. Each director is 1 charge of a particular department under the general control of Board.

No ordinance for public work or improvements of any kind or irs thereof, shall be adopted unless prepared and recommended by 3oard of Public Service with an estimate of cost endorsed thereon, the Board is given authority to let all contracts for public work.

The charter provides for a measure of popular control by the

resented at the Annual Meeting, December 1914, of THE AMERICAN So- OF MECHANICAL ENGINEERS.

initiative referendum and recall. All city officers and employees except those specifically placed in the unclassified service are appointed and advanced under the merit system controlled by an Efficiency Board composed of three members appointed by the mayor. A single legislative body is provided composed of 28 members elected from districts, and a president elected at large. The only other officers elected are the mayor and comptroller, all others are appointed either by the mayor or by the heads of departments or divisions.

6 The new charter replaced the one adopted in 1876. The Board of Public Service replaces the Board of Public Improvements provided by the old charter, with added duties and responsibilities.

7 The city of St. Louis has been singularly fortunate in having its public work controlled in the past by a board of six men, the majority of whom have always been engineers, although the charter required only one of the members to be an engineer. The provision in the new charter requiring three of the five members of the Board of Public Service to be engineers is a recognition of the valuable services rendered in the past by the engineer members of the Board of Public Improvements. The writer was a member of the board of 13 freeholders by whom the new charter was prepared.

No. 1452

THE ENGINEER AND PUBLICITY

By C. E. Drayer,[1] Cleveland, Ohio

Non-Member

With the unifying of society by more rapid means of communication, there arises a demand for knowledge. Publicity is the response. It is the channel through which knowledge reaches the masses.

2 Let us see what interest publicity may hold for the engineer. In the first place, the public is deeply interested in the things we are doing. People are glad to know not only of the advance in science but also about the men who make it possible and to give credit where it belongs. If then we can make use of publicity with the definite intention of placing the engineering profession in a higher position in the vision of our employer, the public, a point of interest has been found.

3 In the second place, we find an opportunity and duty to render service to the public by giving it dependable information about technical subjects. The ordinary newspaper uses the same reporter to write crime, politics, sport, invention, and technical achievement. An editor of one of our Cleveland papers once gave us as his opinion that one reason why news of an engineering nature does not get into the daily papers is because the ordinary reporter has not the technical knowledge to handle it. News, it must be remembered, is nothing more than ideas and facts put into interesting reading.

4 Here, then, are the two elements of a bargain. The public and the engineering profession have something to exchange and both sides will receive substantial benefit. The engineering profession will find itself in a better position by having the public appreciate the important service it is rendering; the public will find itself deeply

[1]Chmn., Publicity Comm., Cleveland Engrg. Society, Chamber of Commerce Building.

Presented at the Annual Meeting, December 1914, of The American Society of Mechanical Engineers.

interested in the information we are able to give, because it advances public welfare.

PUBLICITY WORK IN CLEVELAND

5 Before further statement of the problem or its solution is attempted, let us review the publicity work of The Cleveland Engineering Society, extending now over a period of two years. Our experiences there are the same as might be expected in any similar situation.

6 Our first step was to get acquainted with the managing editors of the two leading papers in the city. They were told that the Society had about 500 members, many of whom are at the head of large undertakings on which the growth and prosperity of the city depend. They were told that the Society stood ready to coöperate with them in obtaining such engineering news as would be of interest to the community. We were assured that the newspapers welcomed our assistance, and were advised to have the Society try being its own reporter.

7 It so happened that the outcoming issue of the Society's Journal contained the report of a special committee on technical education in Cleveland. Naturally, a large number of people in the city were interested in what engineers had to say about their technical schools. Abstracts to make about three-quarters of a column were written, ready to set in type, and were handed to the editors of the two morning papers. They were printed without alteration. A third paper printed its own abstract and an editorial. If the committee had something to say which the public would be benefitted in knowing, surely 200,000 papers with authentic information was a better medium than the 1500 copies of the Journal read largely by technical men.

8 Another subject of great interest to the public, although it might not appear so from the title, was discussed in R. H. Fernald's paper on The Relation of the Gas Producer to Low-Grade Fuels and Concentration of Power at the Mines. When an abstract appeared in the paper on the Sunday following the lecture, it was headlined as shown on the next page.

9 Reference to the paper printed in the Journal of The Cleveland Engineering Society will bear out the assertion that the headlines do not exaggerate the statements made by Dr. Fernald. Our task was merely to make news of plain facts. To the citizens of any large industrial center like Cleveland, smoke elimination and fuel

:rvation are mighty live questions. News, as was said before, : turning of facts and ideas into interesting reading.

0 Probably the largest service to the community performed ıe publicity committee of the Cleveland Society was the publish- ›f 14 inspirational articles by prominent local engineers on En- :ring as Life Work. The articles appeared on successive Sun- in the magazine section of a local paper. Beneath the title ıch was an editor's note stating the purpose of the series and

PRODUCER-GAS TO ELIMINATE SMOKE AND SAVE FUEL

United States Engineer of Mines Tells Local Society of Broad Conservation Plan

MILLIONS OF TONS OF COAL WASTED YEARLY

Production of Gas at Mines From Coal Now Unmined Would Solve Problem

they were published under the auspices of the Society. Among :ontributors were two past-presidents of The American Society of ıanical Engineers and a past-president of the American Rail- Engineering Association. The theme of the series was to tell young man about to choose life work what is before him in the ›us branches of the engineering profession. Besides appearing he local paper, most of them were published in the Scientific :rican and the Case Tech, the student publication of Case School ıpplied Science. Some appeared in other periodicals over the country. A young immigrant wrote to one of the contributors and asked for permission to translate his paper into French and Russian to send to those countries.

11 While we might multiply instances like the above where our work was distinctly a service rendered the public, we shall pass to an enumeration of the tangible benefits to the Society and to the profession growing out of the publicity work.

12 A higher standing in the estimation of the people and of those in authority in the affairs of the community is one gain. In Cleveland, the coöperation of the Society is usually sought in the solution of questions of public welfare where engineers are qualified to speak.

13 To cite an instance, the Civil Service Commission early in the present year asked the Society to assist it by taking charge of the preparation and marking of papers for engineering positions. The first request was for 10 examinations, and the results to both the Commission and to the Society were very gratifying. The Commission secured the service of experts at no cost to the city, but which were worth more than it had available funds to employ. The secretary of the Commission told us that the candidates were satisfied with the fairness of the examination. Concerning previous examinations complaints have been made that proper relative weights had not been given to experience and theoretical training. Our publicity committee saw to it that the public learned through the newspapers of the arrangement between the Civil Service Commission and The Cleveland Engineering Society. Credit was given where it was due.

14 Somebody has said that the public is unreasonable only when it is uninformed. It is hardly possible that any sudden gust of public disapproval would arise where engineers are concerned if the public felt that it was well acquainted with them. When the local society engages in publicity work, a revival in the interest of its members in the activities of the society will be apparent. The indifferent members find they have some pride in their society when its activities, of which they approve, are described in the daily paper. It is said on good authority that the publicity campaigns undertaken by Memphis and Des Moines, to present to business men their advantages for a location, resulted in a renewed city spirit equal in value to the new business acquired.

15 Due largely to the publicity work, there has been a sub-

stantial increase in percentage of attendance at the meetings. One estimate was 15 per cent. To stimulate attendance, the committee furnishes the papers advance notices of the meetings, consisting of a picture of the speaker and some 150 words of text telling about him and his subject.

16 During the last two years some 250 new members have been added to the roll, an increase of over 50 per cent in a society last 30 years old. Of course, it is difficult to say just what per cent of increase in an organization recently very active in all its functions may be credited to publicity work.

ANALYSIS FOR EXTENDING THE WORK

17 We have enumerated some of the benefits accruing to the profession and to the public from publicity work conducted along a definite plan in one locality. Let us now turn our attention to a statement and suggestion of a solution of the problem in its application to a broader field.

18 It is possible at this time to know only the general nature and approximate limits of publicity with any degree of accuracy. They may be determined in accordance with the laws of psychology. For instance, it is the province of the educator and psychologist to formulate the laws involved in the mental processes between appeal and response. They are also able to measure memory in a practical manner. It is sufficient to say that considerable study should be given to the technical aspect of our problem before active work in a large way is undertaken.

19 We can, however, enumerate the various channels by which information of an engineering nature may be placed before the public. It is also possible to give approximate relative values to them. In the matter of choosing mediums we are inclined to lay down this broad general principle: When one man has something to tell another, the telling of which will do them both good, he may employ the most direct honorable means. It may be either the written or spoken word.

20 Under the written word we would include newspapers, periodicals, such as national magazines, and pamphlets. The spoken word would be confined to a rather narrow field and would consist for the most part of talks by engineers before high school classes, classes in Y.M.C.A.'s, and lectures before clubs, at special gatherings in churches and the like.

21 *Newspapers.* Everybody reads. If they read nothing else, they read the newspapers, so it is the most direct way to reach the greatest number. An important point in favor of the newspaper is that it is local and offers an opportunity for the local engineering society to place in its columns engineering news that has an especial appeal to the community. Most people have a friendly attitude toward one of their local papers and are ready to take to heart what they read in its columns, particularly when they know the source is authentic. So the community will learn about its citizens who are engineers and what they are doing to promote its welfare. For these and other reasons, such as frequency of appeal, we are inclined to give newspapers the place of first importance in publicity work for engineers.

22 *National Magazines.* The national periodical or magazine has a quality of permanence which the newspaper lacks. Each issue is likely to be before the public for from a week to a month, whereas, at least in our large cities, each issue of the newspaper is being read but part of one day. On the other hand, care must be taken in the selection of magazines for publicity purposes unless the plan is to reach a particular class. If a magazine has an article on a special subject, it is unlikely that any considerable space will be alloted to the same subject during the same year. It has been demonstrated that the first appeal must be reinforced by subsequent ones for the memory to retain a definite impression.

23 *Pamphlets.* Pamphlets or monographs possess an important advantage over newspaper and magazine publicity in that their contents do not have to pass a possibly unsympathetic censorship. They can be placed directly and quickly into the hands of those for whom they are intended. While they should have attention holding power able to compete with the newspapers for the readers' interest, they are free from the competition due to a multiplicity of appeals existing in every magazine and paper. It is probable that effective work could be done by using pamphlets for engineering publicity.

24 *Lectures by Engineers.* It is doubtful if memory is more retentive and the mind more plastic at any time in life than during the high-school age; also at that time information is eagerly sought for making a choice of life work. Here lies an opportunity to tell the future leaders in all walks of life what it means to be an engineer as well as to warn away those who have been captivated merely by its romantic side.

25 In every city there are a great many opportunities to talk before clubs of many kinds. We are aware that a good deal is being done in the way of popular lectures on scientific subjects, but more might be done, as a part of our service to the community. Where possible the local engineering society might let it be known that it could by arrangement furnish speakers on certain subjects.

26 *Miscellaneous.* There remain a variety of ways by which information may be placed before the public. For the most part they have not been analyzed, some not even suggested. In this miscellaneous class may be mentioned the exhibit and moving pictures. We are inclined to believe that both have possibilities which would be discovered when once the work was undertaken.

CONCLUSIONS

27 We have shown that the public and the engineering profession are in a position to make an exchange at a profit to both parties. A record of results in one locality where it has been tried points to what may be expected through coöperation in a larger field. Mediums of exchange have been discussed. There remains yet to be suggested a preliminary plan by which systematic and effective work may be done.

28 Inasmuch as all the profession will share in the benefits of a closer relation with the public, we assume that the efforts of all should be united on a common ground. More definite plans may be worked out by representatives of leading national engineering organizations at such a time and place as is deemed best. In general we believe that the local society working in coöperation with a central national organization will produce the most satisfactory results.

DISCUSSION

ALBERT J. HIMES[1] (written). Mr. Drayer has set forth quite clearly some of the ways and means of securing publicity, and it might be of interest to consider, from the viewpoint of the engineer, the need of and reasons for publicity.

We have devoted our thoughts to physical science and the arts of engineering. We have built great structures and created engines of marvellous intricacy and power. These achievements have been attained through great tribulation because of the primary lack of knowledge, the mass of misinformation and false data, which, like cobwebs

[1]Valuation Engineer, N. Y. C. & St. L. R. R., Cleveland, O.

and superstition, had first to be swept aside. We know that we cannot build a bridge, a locomotive or a steamship, without a proper observance of certain mathematical and physical laws. Bending moments, grate area, heating surface and draft, position of metacenter, must all be truthfully determined in order that these creations may properly serve.

Having this very definite and concrete knowledge of the imperative necessity of correct information to carry on our work, it seems strange that earnest attention has not been directed to the means of attaining other ends no less essential to our welfare and happiness. I refer to the study of psychological laws and their practical application just as we have studied the laws of physics and applied them in engineering art. These psychological laws should be analyzed, then formulated and applied in practical operations. When this has been done there will be at our command a new pathway in the forest of uncertainty and doubt and along this we can thread our way to achievements more marvellous than anything that has gone before.

The great lesson of science and its practical application is the necessity and usefulness of true information and knowledge. Let us eliminate falsehood, that is, error, in social relations as it has been eliminated from engineering art and then we can hopefully expect an advance in civilization not incomparable in magnitude to the wonderful progress in material things which has rendered the last hundred years unique in the world's history. Results may then be sought directly and with certainty as great as in the design and construction of engineering works.

An example of the effect of publicity in engineering is the development of The Cleveland Engineering Society. At the beginning this Society was moribund and a negligible factor in the municipal life. A few courageous spirits of uncommon vision inspired it to assume new obligations in moving to more commodious and attractive quarters and undertaking the publication of a journal, and during two or three succeeding years it prospered and the change was abundantly justified.

Then in course of time there came clouds in the sky. Expenses were increasing, a goodly increase of membership under the new conditions had been succeeded by a lull and it was clear that something should be done. A careful study of the situation led to a conclusion that the larger part of the responsibilities of the Society was being carried by a few enthusiastic optimists who were beginning to feel the strain. The remedy proposed was to transfer the strength to the ranks, to put a foundation under the superstructure, and this was done in the following manner:

The activities of the Society were stimulated by holding additional meetings, for which it was necessary to enlist the assistance of personal friends to lead the way. The meetings were conducted with spirit and when discussions were slow there was no hesitation in calling on men of experience to give their views of the subject in hand. A school for practice in discussing papers was developed at informal meetings which were in some cases equal in interest to any of the regular course. Monthly visits to engineering works about the city were made a feature. Members were taught, against much opposition, to wear tags on the lapels of their coats.

Now all these good things were effective, but they were made many times more so by the labors of the Publicity Committee, of which Mr. Drayer was chairman. Of this work Mr. Drayer has already told you so well that no further description need be given here. Let it suffice to say that as the result of it the membership of the Society increased more than 50 per cent, that the interest increased in a much greater ratio and whereas formerly only by dint of much persuasion were new members induced to join, they now seek out the membership committee and are pleased to be admitted to membership.

Publicity should eliminate error concerning engineering from the minds of the layman and the public and thus clear the way for a proper utilization of engineers' services. Many people are handicapped in their desire to make use of our wares because they cannot talk with us familiarly of the things which they desire to do. We must therefore learn their language to properly explain our works.

It is a waste of time to deny either the need or the value of advertising, but among professional men the subject is hemmed in with so many restrictions that we hesitate to make use of this method of securing business. Advertising has been frowned upon by the great and the near great and we feel that should we dare to try it our caste would be forever lost. The value of advertising is undisputed, and consequently, objections thereto must be founded upon the manner in which it is done, as it is this which is often wrong.

Professional men have always considered it proper to reap the advertising rewards that accrue from their activities in societies and public affairs. A paper of unusual value for the information it contains and the excellent work of its author is a good advertisement, and a much better one than a paper of less merit, with smaller chance of adding to the general store of professional knowledge, often written chiefly for advertising purposes.

The engineering profession suffers from certain misconceptions of its patrons, including the public, of which I will enumerate the following:

First: It frequently happens on some important work that the preliminary estimate of cost is exceeded in the construction. For this the engineers are roundly denounced. The cause, which never appears in print, is frequently a change of plan or increase of quantities for which the engineer has no responsibility whatever; in other cases, estimates are stated by men in authority to contain provisions which have not been included, and on some occasions the difficulties encountered are beyond the powers of human foresight.

Second: There is frequently an unreasoning demand for the beginning of construction immediately after an appropriation is made without any regard for the necessity of first making surveys and plans. Of this the Panama Canal was a notable example. The evils attendant upon such a course need not be pointed out to engineers.

Third: Bombastic and unwise laudation of engineering achievement has developed a popular idea that engineering is mathematically precise. In court and before legislative bodies, engineers of prominence are sometimes led to declare their ability to determine by formula with precision things concerning which it is only possible to make general deductions. Stresses in rail joints may be cited as an example. If the public knew that calculation of some things, as, for instance, rail-joint stresses, is beyond the powers of mathematical analysis, engineers would not be condemned because such stresses have not been figured.

Fourth: In the general discussion of the government valuation of railroads, the statement has been frequently made by men high in the councils of the nation that the opinion of an engineer is incompetent testimony in valuation proceedings, except where it relates to actual quantities which he has measured himself.

It is unnecessary here to point out the absurdity and injustice of these misconceptions and the very great injury to the whole profession which results therefrom. The purpose is to call attention to the necessity for publicity, a publicity that will give to the layman a knowledge of engineers' work.

If the public knew that plans once made are seldom changed without increased expense, it would demand of its servants that plans should be made in accordance with the original estimates and then carefully adhered to. It would then become important that the first estimate should be right, and that when exceeded the reason therefor should be sound. If the public knew that engineers followed every step of construction work, from the wielding of a pick and the swinging of a maul to the development of the whole programme for the construction of a thousand miles of railroad and the cost accounting therefor, no judge or statesman could make it believe that the best results in valuation can be secured without free use of engineering experience.

How can the public mind be disabused of these misconceptions of engineering work and be supplied with correct ideas of the possibilities and the limitations of engineering art?

On the western plains, in the days when railroad-building was in its prime, every man was interested in railroads. The engineer was at home in the land. Everyone talked with him and eagerly sought his information and it was the daily unremitting discussion of railroad affairs that made every man a critic of grades and grading and a judge of engineering skill. Here then is the lesson. Talk more about your work and let people know what you are doing. Talk to reporters, write for the papers, journals and magazines. It will pay you in money, pleasure and the satisfaction that comes from the performance of a useful deed.

Are the events of an engineer's life less interesting than the mass of crime and gossip with which the daily papers are filled? Do you not know that the most startling thoughts of the wildest imagination have been surpassed by the actual performances of engineers? Do you not know that these achievements have changed the course of history and added untold wealth and happiness to the human race? The mass of rubbish that comes to our homes every day in the form of news is an appalling evidence of the paucity of worthy thought among those who cater to our need for information. You have thoughts to spare and you must share them with your fellow men. Tell the truth and do away with the shameful waste and maladministration of ignorant incompetent adventurers. The country is burdened with the wasteful and wanton exploitation of engineering skill. It is time for the profession to assert itself.

Engineering projects of public importance should be passed upon by the engineering societies. Shall we advertise? By all means. We should use every medium at our command and seek to place before each citizen correct information about engineering work. We should make our profession familiar to all who have an interest therein and rightfully expect that the increased respect and confidence arising from a more intimate knowledge of such work would greatly enhance our material prosperity.

Coöperative advertising, by engineering societies, conducted on broad lines for the benefit of the public and so as to put the profession on a more substantial basis, is an aim that is worthy of the highest traditions.

HUNTER McDONALD[1] (written). The engineers of Cleveland are fortunate in having among their number one who possesses, in addition to his engineering skill, the taste and willingness to clothe bare technical facts in such garments that they challenge popular attention and interest. If each community were equally fortunate, publicity of engineering matters would be easier. Few engineers possess this gift or the willingness to devote their time to the task. Many are quite decided in their opinions that there is no need of publicity; they proceed upon the well-established theory that virtue is its own reward and are usually compelled to content themselves therewith.

The writer strongly advocates the participation by engineers in public affairs. They are qualified to guide public policy in matters where their training is of value, but, as a class, they have so far failed to convince the public that such is the case.

Their position as a class has been that of an instrument in the hands of other men who have made a specialty of the study of mankind rather than physics. If engineers can master technical details, they can also learn the laws that control human actions.

I believe the recognition we need is not to be altogether obtained by keeping ourselves and our work before the public in newspaper columns, but by earnest and effective work as organized bodies in every community. That work should consist of carefully watching the manner in which the public affairs involving engineering are administered, taking vigorous organized action looking toward the stopping of the waste of public moneys and the shaping of legislation involving engineering and industrial matters. Let us convince the public that we are willing to aid in the proper adjustment of such matters and to give, without selfish motive, sound advice on matters of public policy and the opportunity will not be lacking.

[1]Ch. Engr., N., C. and St. L. Ry., Nashville, Tenn.

Before we can command the confidence of the public we must convince them that we are to be trusted. We must re-establish and maintain that reputation for fearlessness and honesty which until recent years has been our stronghold and heritage. Instances are not lacking in which professional opinions have been subordinated to the demands of commercialism. Public officers of today have difficulty in finding engineers upon whom they can rely for unbiased advice on matters in which organized capital is affected. To merit and obtain confidence we must be willing to tell the truth under all circumstances even though starvation stares us in the face.

It is only such a professional reputation which warrants us in making ourselves the sole arbiters in preparing specifications and if we would preserve that reputation we must live up to its requirements.

Charles Whiting Baker. The engineer needs to learn the lesson taught by this paper of the value of publicity. If he wants to get public support for what he is doing, he must know how to reach the ear of the public in the right way.

About twenty-five years ago, the worst of all the many departments of municipal government, so far as efficiency was concerned, was the street cleaning department. About that time there came into office a reform mayor in New York who selected Col. Waring, an engineer, as head of this department. The colonel put the workers in the department into white uniforms. The idea spread all over the country and made the street cleaning department known as it had never been before and gave the employees a new respect for themselves. I think that little device, small in itself, has had the biggest influence in reforming our street cleaning departments the country over and has done more towards putting them on a better basis than anything else. That is just an instance of what a proper appreciation of publicity may do in a wise engineer's hands.

E. H. Whitlock. It has been my good fortune for the past two years to watch the results accomplished in Cleveland under the author's able leadership, and I can heartily commend the work done there.

Just how far this work of publicity should be carried on is a question. Publicity can be differentiated from advertising. The engineer is becoming more and more interested in the doings of the general public of today, and the public is also seeking an education along engineering lines. If a campaign of publicity is to be inaugurated, perhaps the local societies can do the most good by standing out in their local sections, getting the engineer before the public in that way, and then I feel quite sure that, if the results are anything like those we had in Cleveland, it will be profitable for the national societies to take up this work.

CALVIN W. RICE. It may be of interest to know that our Society takes special pains to give publicity to all of its proceedings. Over sixty technical and daily papers in the United States are given copies of everything published or read at its meetings. In addition, special work has been done for this meeting and one of the New York newspapers has published over a column in every issue this week.

THE AUTHOR. Any plan of publicity to be successful, must be consecutive and must continue for a considerable period of time. Engineering information must be given the public on a definite plan, otherwise the newspapers will not pay much attention to us.

Material has been presented before the Society at this and the session of Wednesday evening to suggest enough articles to a good publicity man to occupy his time for several months. He must, however, work from the standpoint of the newspaper man. Journalism is a profession, and newspapers are not reformers; they collect news for the purpose of selling it at a profit, hence they are extremely responsive to and in harmony with the demands of the people.

It is difficult for the engineer to speak to the public in its own language. He is not a story teller by word of mouth as is the lawyer or the preacher, nor does he often come in close contact with people as does the doctor. He thinks in plans and specifications. To tell his story he must resort largely to the written word. Nor should he hesitate to employ broad statements where necessary, or to add high lights and shadows to the picture to bring out needed contrast. We cannot apply the laws of sines and cosines to influencing men, nor will the answers to our efforts often be couched in terms of mathematical precision. This is psychology.

No. 1453

THE HANDLING OF SEWAGE SLUDGE

By George S. Webster,[1] Philadelphia, Pa.

Non-Member

In modern cities the wastes of domestic life and of industry collected by the sewers are conveyed to water courses for disposal. The discharge of the crude sewage into water courses may cause a menace to the public health through water supplies taken from such sources without adequate purification, from the pollution of shell fish layings and from the use of the water for bathing purposes. Also, sewage discharged into rivers and streams may cause nuisance to sight or smell, either through inadequate velocity of flow, permitting the formation of deposits of sewage solids, or through the insufficiency of the volume of diluting water to provide the oxygen necessary for its purification.

2 The rapid growth of cities and towns and the popular demand for more healthful conditions of living are making obligatory the treatment of sewage prior to its discharge into the water courses, in order to prevent the development of these conditions.

3 Usually the first processes of sewage treatment consist in the removal from the sewage of the solid matter in suspension by means of screens or by sedimentation in tanks or basins. When more refined treatment is required it consists in the oxidation of the liquid portion of the sewage together with the fine suspended matter not susceptible of settlement. This latter phase of the sewage problem will not be considered in this paper.

4 In sewage treatment, the material collected on the screens and the deposit in the bottom of sedimentation tanks is called sludge. As removed from tanks it is a dark, slimy mass, containing about 90 per cent moisture, and its consistency is such that it cannot be shoveled but can be readily pumped.

[1]Ch. Engr., Bureau of Surveys.

Presented at the Annual Meeting, December 1914, of The American Society of Mechanical Engineers.

5 To grasp the magnitude of the problem of handling the sludge produced by large cities, it is but necessary to state the quantities produced by some of the great cities of the world. London, with a population of 6,000,000 tributary to the works, produces by chemical precipitation 2,597,000 tons of wet sludge of 92 per cent moisture per annum. The District of Birmingham, England, with a population of 950,000, treats and disposes of 427,000 tons of wet sludge of 94½ per cent moisture per annum. The Metropolitan Sewerage Commission of New York, in its report, states that 266,000 tons of solids are annually discharged into New York Harbor and will require collection and treatment in the near future; this amount of solids as intercepted from the sewage if in the form of 90 per cent sludge would be equivalent to 2,700,000 tons per annum from a population of 5,780,000. It is estimated that the proposed Sewage Treatment Works for Philadelphia will intercept 75,000 tons of dry solids from a population of 1,650,000, which if in the form of 90 per cent moisture sludge would amount to 750,000 tons per annum.

6 Experience with sewage works indicates that upon an average 1000 persons produce 45 tons of dry solid matter per annum. If this were deposited in tanks as sludge containing 90 per cent moisture it would make 524 cu. yd., but if the sludge contained 95 per cent moisture its volume would be 1060 cu. yd., or about double the former amount. In other words, every ton of dry solid matter contained in sludge 90 per cent moisture which is removed, requires 9 tons of water to be conveyed with it, and if the sludge contains 95 per cent moisture, it requires 19 tons of water to be handled.

7 One of the most important considerations, therefore, in handling sludge is the percentage moisture which it contains, as this is a controlling factor in its bulk. It is highly desirable to obtain sludge with as low a moisture content as possible (Fig. 1).

8 Of the dry residue in the sludge, approximately one-half is organic and one-half mineral. A large part of the organic matter in freshly-deposited sludge is highly putrescent and if improperly handled produces offensive odors. It is, therefore, also of importance that such processes of sludge treatment shall be used that reduce this offensiveness by the destruction of the easily decomposed organic matter.

9 The final disposal of sludge is accomplished by (*a*) discharge of wet sludge in the sea; (*b*) depositing wet sludge on land; (*c*) the use of partially dried sludge for filling in low waste lands, and (*d*),

where circumstances warrant, the use of sludge as a fertilizer, fertilizer base or as fuel.

10 The problem of handling sewage sludge consists in disposing promptly and economically of the watery mass which contains offensive, decomposable matter without menace to the public health or the production of foul odors or other nuisances.

DISCHARGES OF WET SLUDGE IN THE SEA

11 Large cities located near the ocean dispose of the wet sludge most economically by carrying it to sea in specially constructed tank

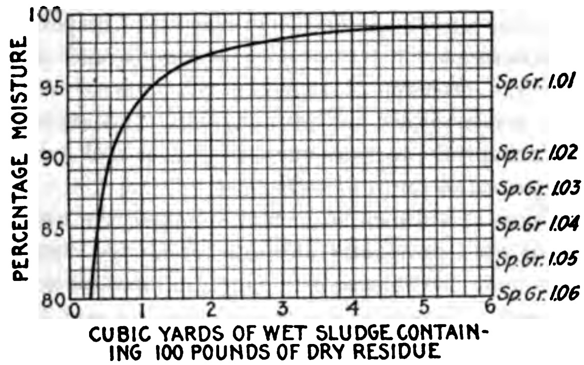

FIG. 1 RATIO BETWEEN BULK OF WET SLUDGE AND ITS PERCENTAGE MOISTURE

steamers. The sludge is pumped from the sedimentation tanks to reservoirs on the wharf from which the steamers are filled by gravity. When the boat reaches the dumping ground in the open sea the outlet valves are opened and the sludge diffused in the sea water as the boat moves along.

12 This method of sludge disposal is used at London, England, where the sewage is collected by sewers to two works located on the banks of the Thames about 12 miles below London Bridge. Chemicals are added to the sewage to form a flocculent precipitate and free it from most of its suspended matter. The sludge thus produced after settlement contains about 92 per cent moisture and is carried by 6 tank steamers 55 miles to Black Deep in the open sea, which is 20 miles below Southend. On an average 8300 tons of sludge are thus disposed of every weekday at a cost of about 9 cents per ton (including interest and sinking fund charges).

13 At Manchester, England, the sludge from the septic tanks is similarly carried by a tank steamer to the open sea beyond Mersey Bar. During the last fiscal year 215,082 tons of wet sludge were dumped at sea at a cost of $32,000 or about 15 cents per ton.

14 Among other large cities disposing of their wet sludge in this way may be mentioned Glasgow, Scotland; Salford, England; and Dublin, Ireland. The Metropolitan Sewerage Commission of New York recommended this method of sludge disposal for that city as it appears to be the most economical.

DEPOSITING WET SLUDGE ON LAND

15 For cities situated inland such method of disposal is impracticable on account of the transportation charges and they are confronted with the problem of reducing the bulk of the sludge by removing the water, either by drainage and evaporation on drying beds or by mechanical processes such as presses and centrifuges and of handling it so as to minimize offense.

16 The type of sedimentation tank adopted, the use of chemical precipitants or the opportunity afforded for sludge digestion have a marked effect upon the volume of sludge produced on account of the moisture content. Generally speaking it may be said that chemical precipitation will produce between 20 and 25 cu. yd. of wet sludge containing about 92 per cent moisture from each million gallons of sewage treated; plain sedimentation from 4 to 7 cu. yd. between 87 and 93 per cent moisture; septic tanks from 1.5 to 3.0 cu. yd. between 80 and 90 per cent moisture; and Emscher or Imhoff tanks from 1 to 2.5 cu. yd. between 75 and 85 per cent moisture.

17 The disposal of wet sludge without prior dewatering may be accomplished by its application to land in several ways. The earliest method used was called lagooning in which case earth embankments were built enclosing an area of suitable land and the wet sludge run into a depth of as great as 10 ft. The clogging of the soil preventing free drainage of the moisture; the scum formation upon the surface retarding evaporation, and the frequent great depth of the sludge, all tend to prevent the sludge from drying. As an example, there are sludge lagoons at Birmingham in which the sludge deposited many years is practically in the same condition as shortly after being placed except that a heavy crust has formed upon the surface. This method is rapidly being abandoned.

18 To overcome these objections and to dispose of the sludge

more quickly, it was run upon the surface of farm land to form a shallow layer which would dry in a reasonable time and could then be plowed in and the field cultivated. But the gross nuisance created by the exposure of such large areas of foul smelling sludge led to the adoption of what is called trenching. As practised at Birmingham, England, the trenches were dug about 3 ft. wide and 18 in. below the surface of the soil, the excavated earth forming banks between the trenches so that they can be filled to a depth of from 24 to 30 in. with wet sludge, after which the tops of the earth banks are thrown over the sludge to prevent nuisance from smell or flies. The porous earth absorbs the moisture and later the land is plowed across the trenches and placed under cultivation. This process can be repeated at intervals of from 18 months to two years.

19 The cost of trenching at Birmingham amounted to about 8 cents per ton of wet sludge. This is exclusive of the cost of sludging tanks, but includes interest on capital outlay at 5 per cent and rent of land. This method is not being used in new plants and is being abandoned in old plants on account of the area required, the interference which is caused in times of heavy storms, the increased difficulty of operating caused by winter weather and the general cumbersomeness of the method.

MECHANICAL PROCESSES FOR DEWATERING SLUDGE

20 Among the early mechanical methods of reducing the bulk of the wet sludge by dewatering was pressing in machines which consist of a number of cast-iron plates generally 9 sq. ft. in area with corrugated faces and surrounded by a machined rim so that when placed together they form water-tight cells 2 in. thick. A central pipe about 6 in. in diameter extends through the middle. Over each plate a canvas cloth is placed and sludge forced into the press and subjected to a pressure of from 60 to 75 lb. per sq in. This squeezes the water out and the resultant cake contains between 50 and 65 per cent moisture and is about one-fifth the bulk of the original wet sludge.

21 It is necessary to add to the sludge before pressing from ½ to 1 per cent of lime, the fine particles of which facilitate the passage of water, the dissolved lime agglomerating the solids of the sludge. The cost of pressing largely depends on the amount of lime added, the kind of sludge pressed and the magnitude of the works; in large cities the average cost is 10 cents per ton of wet sludge.

22 At Worcester, Mass., about 18,000,000 gal. of sewage a day is received at the chemical precipitation works. There are added 55.5 lb. of lime to each 1000 gal. of sludge which contains on an average about 90 per cent moisture when pumped from the tanks. The presses reduce the moisture to about 70 per cent and 0.167 tons of sludge cake are obtained from each cubic yard of the wet sludge. The pressed cake is hauled in electrically propelled cars about a mile and disposed of for filling low waste land.

23 Another mechanical method of dewatering sludge is by means of centrifuges which occupy less space than presses and do not require the addition of lime to the sludge. Such machines are continuous in action and the work of extracting the moisture consists of two distinct and constantly repeated periods. During the first period the wet sludge is introduced into the machine and by the action of centrifugal force the moisture content reduced. During the second period the sludge thus partly dried is automatically ejected. The final product contains about 60 per cent moisture and occupies about one-eighth the volume of the wet sludge.

24 The largest installation of these machines is in Frankfurt-on-Main, Germany, where the sewage of 400,000 people is subjected to plain sedimentation and about 310 tons of wet sludge 90 per cent moisture obtained per diem. The sludge is pumped to overhead reservoirs and kept agitated by revolving paddles. From thence it is fed to 8 centrifugal driers capable of handling 325 cu. yd. of wet sludge a day of 10 hours; after drying, it is carried by a conveyor through a tunnel heated by the exhaust gases from the power station and as a 20 per cent moisture mass resembling soft coal of a gray color is mixed with garbage and both disposed of by destructors, the steam being used for generating electricity for power and lighting.

DIGESTION OF SLUDGE

25 In the methods of sludge handling above described efforts were directed toward preventing the dissemination of the foul odors from the wet mass. Within recent years much thought has been given to devise processes of treatment by the digestion of the putrescent matters to produce an inoffensive sludge both as withdrawn from the tanks and during drying.

26 One of the methods to accomplish this purpose is to remove the freshly deposited sludge from the sewage sedimentation tanks at intervals and place it in separate tanks. Usually a scum forms upon

the surface beneath which more or less active fermentation and decomposition develops. New sludge is added and digested sludge withdrawn from time to time and placed upon underdrained sand or cinder beds for drying. On account of the digestion of the sludge it dries more rapidly and is much less offensive than when fresh.

27 This method of sludge handling is now in use at Baltimore, Md., where the sewage is freed of its settleable solids in large tanks. The accumulated sludge is removed at intervals by centrifugal pumps and discharged into adjacent concrete tanks where considerable digestion occurs as indicated by the continuous ebulition of gas which is inoffensive. At first the sludge was withdrawn from the digestion tanks and dried upon underdrained sand beds. It could be removed in a much shorter time than undigested sludge and but little offense was created. At the present time, the wet sludge from the digestion tanks is being sold to farmers for use on truck farms. The same method of separate sludge digestion is in use at Birmingham, England, the dried material being used to fill in a deep ravine between railway fills.

28 For the last 20 years it has been known that the retention of sludge in the tank in which it is deposited, which is known as the septic treatment of sewage, resulted in the reduction of the bulk and offensiveness of the sludge, but experience showed that while the sludge was benefitted, the water leaving the tank, known as the effluent, was seriously fouled by the decomposition of the organic matter in the sludge. The first attempt to obviate this fouling of the effluent was the digestion of the sludge in a separate tank above described. Another attempt was made by Dr. Travis at Hampton, England, who built a septic tank divided into upper and lower compartments; four-fifths of the sewage was passed through the upper part and the sludge settled through slots into the lower part through which the remaining one-fifth of the sewage flowed. Thus four-fifths of the sewage remained fresh but when the foully contaminated one-fifth was added to the tank effluent it frustrated the purpose. Furthermore, the passage of sewage through the lower part maintained conditions favorable to the development of sulphur bacteria and produced a malodorous sludge.

29 The separation of the digesting sludge from the settling sewage was adopted by Dr. Imhoff of Essen, Germany, with the following essential modifications:

a The slot between the upper and lower compartments was so made that the gas bubbles formed in the decomposing sludge could not rise into the settling sewage.

b No sewage was allowed to flow through the lower or sludge chamber.

c The walls of the lower chamber were carried up through and above the water surface of the upper compartment so that the gas could have a free vent.

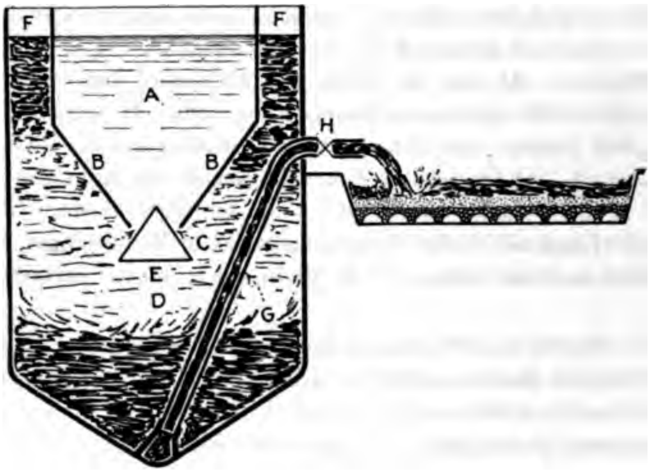

Fig. 2 Construction of Emscher Tank

d The capacity of the lower chamber was made sufficient that sludge could be retained as long as six months before withdrawal.

30 Two-story tanks of this type are known as Emscher or Imhoff tanks. Their extensive introduction in Germany and America is due to the fact that when properly operated they efficiently free the sewage of its settleable solids, yield a fresh inodorous effluent, produce sludge that is inodorous, of low water content and consequent small bulk, and which dries more quickly than any other kind of sewage sludge.

31 The principles involved in the construction of the Emscher tanks are shown in Fig. 2. The sewage to be settled flows longitudinally through the tank in the cross-section marked *A*; the solids which settle upon the sloping bottom *B* slide down through the slots *C* into the sludge chamber *D*. The gases of decomposition are prevented from entering the upper chamber by the gas baffle *E* but find free exit

ʒh the sides at *F*, in which also a scum forms. A pipe *G* extends the bottom of the sludge compartment to the outside. A quick ng valve at *H* located at a distance of over 3 ft. below the water :e in the tank permits the discharge of the digested sludge by static pressure without any pumping. The sludge is placed upon rying bed, which is composed of a layer of fine sand supported .ayer of cinders or pebbles and underdrained by the tile.

When such a tank is first put in operation it is entirely filled sewage; as there is no flow through the sludge compartment, de-)sition develops therein and the putrescent matters in solution s colloids largely destroyed. The sludge deposited in the lower artment is, therefore, covered by a water having characteristics ent from those of fresh sewage and it is the opinion of some that s the cause of the inoffensive sludge digestion. The gases evolved these conditions are principally methane and carbon-dioxide. gases while in the sludge are under a hydrostatic pressure due depth of the tank and when the sludge is withdrawn upon the g bed the bubbles expand, lightening the mass and aiding in a ation of the water which flows to the bottom and is carried away drains of the drying bed. The digestion of the sludge also re- its sticky tenacious nature and facilitates its parting with the .

In normal weather sludge from a matured Emscher tank will n sand beds in from 3 to 5 days to a consistency fit to remove. sludge from septic tanks requires at least 2 weeks' time, and from plain sedimentation tanks will require about 8 weeks in ıer and at least twice that length of time in winter, to be dry and nough to handle.

Dried Emscher sludge is suitable for filling low land or use riculture, particularly in lightening heavy soils, as it is very y in texture due to the entrained gas. But experience has nstrated that the use of air-dried sludge from any source will not 'esults comparable with those obtained from the use of artificial zers.

The rapid drying of sludge digested in Emscher tanks allows y much smaller sand beds than for other kinds of sludge; in it is usual to provide only 1 sq. ft. of bed for each three persons ary to the tank.

The first full-sized installation of Emscher tanks was at inghausen, Germany, in 1907, for a population of 30,000. The marked improvement in quality of tank effluent and sludge obtained over all previous types of sewage tanks led to the adoption of the principle at first in Germany and later in this country. The two largest installations are at Bochum built in 1908 for 145,000 people and Essen Nord built in 1911 for a population of 180,000.

37 In America this type of tank is in successful operation in Philadelphia at the Pennypack Creek Sewage Treatment Works built in 1910 as a protection to the source of supply of the Torresdale water filters which furnish three-fifths of the city's water. The plant contains two Emscher tanks designed for the sewage of 10,000 people. Notwithstanding that three large municipal institutions are tributary to these tanks which add large quantities of fat and carbonaceous material, the digestion of the sludge has been so complete that when the sludge drying bed is entirely covered with wet sludge exposing 6400 sq. ft. there is no offense created. The tanks also maintain the sewage in a fresh state, so that when it is sprayed on the percolating filters no odors are produced.

38 Emscher tanks are now being operated successfully at Atlanta, Ga., and in Batavia, N. Y.; they are also being installed at Baltimore to provide increased capacity instead of enlarging the present system of sedimentation and separate sludge digestion.

THE RECOVERY OF INGREDIENTS FROM SLUDGE WHICH MAY HAVE VALUE

39 Sludge contains ammonia, phosphoric acid, potash, grease and carbon. Generally speaking these ingredients are more costly to recover than they are worth. It has been estimated that the manurial value in the excreta of one person in a year is $2.62, but in the dilute sewage of America this would be contained in about 36,000 gal. of water. If this material is deposited as sludge of 90 per cent moisture it would weigh about 1720 lb. per cu. yd., and each cubic yard would contain only about 80 lb. of organic matter, of which only a part has any monetary value.

40 The problem of recovering the valuable ingredients in sewage sludge, therefore, involves the use of economical and efficient processes for drying or pressing to reduce the bulk for transportation; also in order to recover the grease in sewage with present methods, it is necessary to have the sludge in a very dry condition.

41 Dr. MacLean Wilson, chief inspector of the West Riding of Yorkshire Rivers Board, who has charge of the disposal of sewage from 3,000,000 persons located in the center of England, in reporting

pon the utilization of sludge, takes a hopeful view of utilizing that ırt of the valuable ingredients of sewage which can be extracted in ie form of sludge. An early solution of this problem lies, in his pinion, in the fact that there are many capable experimentors at work the effort to prevent the waste at a cost which permits the sludge to prepared and transported in a condition profitable to agriculturists.

42 H. W. Clark, Chemist of the Massachusetts State Board Health, in charge of the Lawrence Experiment Station, as a result his study expresses the opinion that sludge has some value and as processes of drying, pressing, and fat separation are improved and nitrogen advances in price, it seems inevitable that sewage sludge ll become of greater agricultural value than it is at present, es- ially as the basis of fertilizers enriched by the addition of potash, osphates, etc.

43 The Metropolitan Sewerage Commission of New York City, er an exhaustive study of the question of utilization of sludge, does t encourage the belief that any great profit can be derived, except in es where the nitrogen or fats are abnormally high. It states that der other conditions, past attempts to secure anything more than a minal revenue have as a rule resulted in failure. The crux of the blem is the separation of the water and the concentration of the uable ingredients. This is necessarily costly whether done mechan- lly or by the direct action of the heat.

44 For many years the so-called Globe Fertilizer has been manu- tured from sewage sludge at Glasgow where the sewage is precipi- ed with lime and ferrous sulphate. Most of the sludge is sent to , but part is pressed and dried by heat, passed through a pug mill d sold as fertilizer.

45 The Royal Commission of England states that it is more nomical to sell pressed cake than to make the fertilizer and less is ng made each year.

46 Bradford is the center of the wool industry in England and ge quantities of wool-washing waters are added to the sewers ounting to one-tenth of the total amount of sewage, which, there- e, contains abnormally large amounts of grease. The sludge is st treated with sulphuric acid and then heated to 212 deg. fahr. It then pressed hot and grease mostly obtained in the hot press liquor ich is then boiled with chemicals and the resultant grease sold at m $35 to $50.50 per ton. Excluding certain fixed charges, it is imed that the recovery of the grease is done at a profit.

47 Enlargement in the capacity of the Birmingham Sewage Works for handling sludge is contemplated by the use of the Dickson process as it was worked at the Dublin Sewage Outfall Works. "In this method of handling sludge about 0.5 per cent of yeast is added to the sludge as removed from the tanks and the mixture pumped through a heater which consists in a number of pipes placed in the path of the hot air from the furnace to fermenting troughs in the bottom of which are hot air ducts to keep the fermenting sludge at about 90 deg. fahr. In 24 hours, as a result of the fermentation, there is a distinct separation of water, the sludge at a density of about 83 per cent occupying the surface while the water can be readily drained away beneath. A compound of phosphates and potash in about equal proportions by weight of sludge and compound based on dry solid matter is then added and the mixture containing about 73 per cent water is then pumped to the dryer, which consists of a cylindrical vertical casing containing a series of arms and platforms revolving upon a central shaft and between fixed arms and platforms. Air at a temperature of about 450 deg. fahr. is blown into the dryer at the bottom and passes out the top. The dried mixture falls into a disintegrator which beats it up into a powder, which would be used as fertilizer."

48 Experiments made in the Philadelphia Sewage Testing Station in burning several kinds of dried sludge and in mixing wet sludge and fine coal which was burnt when dried confirm the accepted conclusion that while sludge when dried has a certain value as fuel, which is influenced by the source and amount of moisture which it contains, it is not practicable to recover completely this calorific value in actual amounts of water evaporated by the burning of the sludge.

49 Where refuse disposal plants and sewage treatment works are located in close proximity to each other, an opportunity is offered for the advantageous disposal of sewage sludge by burning it with refuse. This is now being accomplished at Frankfort-on-Main, Germany, already referred to.

50 The manipulation of sludge so as to utilize the calorific value has also been the subject of experimentation in Germany, followed by the installation of full-sized plants. Two notable plants are those at Ober-Schöneweide, and at Potsdam, both near Berlin.

51 In the former, layers of sludge of 60 per cent moisture and culm or dust of brown coal are run into a gas producer, and utilized

run a 60 h.p. gas motor generating electric energy used for wer and lighting about the plant and adjacent street lighting. e report of operation, based upon the possible sale of all power 2½ cents per kw-hr., for the plant in question, shows a profit 50 per cent on the net cost of production, exclusive of interest on ested capital. The fact of the construction of typical four-story artments across the street from the plant, after the installation, rues well for the maintenance of sanitary conditions.

52 In the other case, that of Potsdam, the brown coal is added the proportion of 1 part coal to 8 of sludge, in the sedimentation ocess, also about 150 grams of sulphate of iron per cubic meter sewage. These contribute to the separation of the solids from e liquids. The sludge thus produced is pressed into briquettes of per cent moisture having a heat value of 1500 units. The briettes form the only fuel in a city electric plant in an adjoining ilding. It is said that the cost of briquetting about equals the lue of the electric energy, the benefit being the innocuous disposal sludge without cost.

53 Experiments are to be made at Birmingham, England, to ilize the air-dried sludge by burning it in specially constructed rnaces in order to obtain heat for the separate digestion of about ie-sixth of the wet sludge by the new yeast fermentation process eviously mentioned.

THE PROBLEM IN PHILADELPHIA

54 The problem of sewage disposal confronting the City of hiladelphia is to collect and treat the sewage so as to prevent the ollution of the source of water supply and to maintain the rivers id streams in a clean condition.

55 To accomplish this it is proposed to collect the sewage and st flush of the rainfall from the present sewer system and convey to three treatment works, at two of which the solids will be removed by two-story sedimentation tanks of the Emscher type. The ioroughly digested sludge removed from the tanks will be dried on ecially prepared beds and used for filling low ground adjacent to ie works, this being the most economical and at the same time ost inoffensive way of disposing of the settleable solids in the wage under the conditions which prevail in that city. At the ird station, where a comparatively small amount of sewage will

be collected, for the present, fine screening will be adopted and the resultant sludge incinerated.

56 The most serious part of the problem of sewage disposal is the handling of the sludge which results from every known method of treatment. It is possible that in the future, in order to meet higher standards of hygiene and cleanliness, methods may be devised for intercepting sewage solids as near their place of origin as possible and before they have become offensive, and also to recover practically all of their ingredients which have value prior to their breaking up and in part entering into solution.

57 This prompt removal of organic matter from sewage will also aid greatly in the prevention of the pollution of the water courses, and will tend to promote the public health and comfort.

DISCUSSION

Calvin W. Hendrick[1] (written). The question of sludge has been and always will be one of the most serious difficulties to contend with in sewage disposal plants, and I consider that the section of the paper treating of sludge digestion is well handled.

In our plant at Baltimore, we feel we have come as near a satisfactory solution of the sludge question as in any plant that I know of. Our plant is well located and is operated entirely by electricity produced by the flow of the sewage, enabling the sludge to be handled by sludge pumps at a minimum cost. With this power available, the sludge is moved from the separation tank to the digesting tank at frequent intervals before the digestion in the separation tanks becomes a factor. We are also able to deliver the digested sludge, at about 90 per cent moisture, to our customers by gravity, reducing the cost of delivery to practically nothing. When our supply runs ahead of the demand, so far not of large quantity, we pass the liquefied sludge to underdrained sand beds, where it is dried and sold as fertilizer. In this way we are selling sludge, both liquefied and dry, as rapidly as we are manufacturing it.

The sludge produced in our separation digestion tanks is about 4 cu. ft. of 90 per cent sludge per person per annum. We are rapidly connecting up the houses to our new system, about 50,000 out of about 135,000 being already connected. It might also be of interest to know that in our efforts to produce a market for this sludge, we have tried

[1] Ch. Engr., Sewage Commission, Baltimore, Md.

to meet all the conditions of the demand. Some are taking the sludge at 90 per cent moisture; some require it in the dried state as removed from the sand beds mentioned above, and others who are considering using it as a commercial filler in fertilizers desire the moisture brought down to about 15 or 20 per cent. By the use of a centrifugal drying apparatus, known as a direct heat dryer and consisting of a revolving steel drum 36 in. in diameter and 24 ft. long, through which the furnace gases pass and come in contact with the material being dried, we have been able to extract the moisture down to about 18 per cent.

The ammonia in the sludge from the sand beds amounts to 3 per cent, and in that from the direct heat dryer, 1.8 per cent.

As this is an era of by-products, I cannot help but feel that energy should be concentrated into utilizing the valuable ingredients contained in the sludge which the land so badly needs. We therefore feel that in being able to dispose of practically all the sludge we are manufacturing, giving us a handsome revenue, we have taken a most satisfactory step in this direction.

WILLIAM L. D'OLIER. The author has aptly defined the problem of sewage disposal in his conclusions in par. 56.

Methods of intercepting sewage solids near their origin are available and are becoming more and more recognized and adopted.

The value of the ingredients is lost with the comminution, disintegration and dissolution of the solids. The prompt removal of organic matter prevents an unnecessary and undesirable fouling of the sewage flow. In this connection the speaker has in mind the discharge of certain long and expensive intercepting and outfall sewers, built with the object of discharging the sewage at some remote point; the result is the solids are so comminuted and dissolved, and the entire flow subjected to such foul and septic action, as to finally discharge the sewage in a condition which is practically beyond treatment.

In the handling of digested sludge, it has been, and is, a common practice to use sludge beds, which are, at best, a local nuisance. The working or age limit of these beds, before they become impregnated, is now a recognized feature. The care and maintenance of the beds must be of the highest order or failure is experienced; increased area is annually necessary. The cost of handling the sludge on and off the beds is a considerable item. In America, particularly in its northern countries, climatic conditions must be considered, as the winters necessitate the additional cost of providing sludge tank storage

These facts and features, existing in sludge bed practice, have urged the mechanical treatment of sludge. At Frankfort-on-Main, Germany, centrifugal machines have accomplished effective work, but their first cost, up-keep and operating costs are excessive. The introduction of that type of centrifugal into America has not met with success. Mechanical engineers recognize that the machines are too complicated in design and construction and are too costly.

The efforts of French engineers to simplify centrifugal sludge machines, have, as has been demonstrated at Ostend, Belgium, not been a success. While the machines at Ostend are very much simpler in design than those in Germany, the burden of work falls upon the operator, who must be quite skilled in the handling of the machine, with the result that operating costs are excessive.

The rotary sludge filter, which has lately been developed abroad and is now exploited to some extent in America, promises to lessen both first and operating costs, and represents a further step in mechanical treatment of sludge.

Digested sludge possesses no great manurial value, it having been spent in digestion. At best, some little humus may be added to land by the use of digested sludge, but the objectionable feature is that the grease remains in the digested sludge and is an objectionable ingredient for agriculture use. Land will not submit to continued applications of digested sludge, and the latter has, therefore, practically no value. Its frequently asserted use in filling-in low lands is nothing more than a mere disposal of the sludge; the lands are invariably so located as to be of no value when filled in.

The problem referred to in par. 41 is the problem of sewage disposal. It is admitted that sewage solids carry value in manurial ingredients and grease. The agriculturist does not want the grease and objects to it. He does want the manurial ingredients in a reduced or concentrated volume. The manurial values at most are not great, and, when diluted with from 70 to 90 or more per cent of water, are not worth the expense of handling. This applies particularly to digested sludge.

Grease from sewage solids will sell at from $40 to $60 per ton; the agriculture residue will sell at from $6 to $15 per ton in a comparatively dry state. Hence, the method of recovering the greatest amount of these values, consistent with first and operating costs, or that method producing the maximum amount of solids with the minimum water content, bids fair to be the approved method.

The author specifically mentions in par. 3 two methods of removal of solid matter—screens, which must be accepted as fine screens, and sedimentation. Sedimentation produces sludge, while screens produce screenings. Sludge contains 90 or more per cent of water and the manurial values are spent. Screenings contain 80 or less per cent of water, and, being fresh, the manurial values are not spent.

Referring to the curve, Fig. 1, of increase in volume with additional water content, screenings carrying 80 or less per cent of water content as compared with sludge at 90 and usually higher per cent of water content, represents approximately an increase of four times the volume of sludge over screenings.

The Massachusetts State Board of Health states fine screens have removed 71 per cent of matter in suspension from sewage. Abroad we have numerous records showing a removal of solids from sewage by fine screens ranging from 32 to 82 and higher per cent, which indicates the effectiveness of fine screens. Past experience with fine screens throughout the United States has not been generally successful or satisfactory due to the mechanical design or construction of the apparatus.

At Dresden, Bremen, and other installations in Germany, a type of disc screen appears not only to clarify as a screen but as a filter, and thus appears to remove a maximum amount of solids. This type of screen, operating on an inclination in the flow of sewage with a slow rotary motion, skims from the sewage a maximum amount of grease. The design of this disc screen permits draining of the screenings before they are removed from the screen. The removal by a brush without water jet insures a minimum amount of water content in screenings. Such a screen accomplishes in a most remarkable manner the requirements set forth by Dr. Wilson as the solution of the problem of sewage treatment.

At Dresden, the raw screenings have been promptly sold at a net return of $500 per year to the community. Laboratory tests showed the grease content to average 8 per cent in the summer and 12 per cent in the winter. Further laboratory tests and a subsequent installation of a commercial plant demonstrate a satisfactory by-product treatment. The raw screenings, grease recovered and degreased screenings sold in a dry state as fertilizer product at a return of $2,000 per yr. for the same volume of screenings which were formerly sold in a raw state at $500 per yr.

Methods of disposing of sludge by burning it with refuse are in many cities a common proposition, and our consulting engineers and municipal authorities should confine in one treatment plant the disposition of garbage, refuse and rubbish, and the treatment of sewage. There is no good reason why these should be treated separately, and for many reasons they should be combined in one plant.

THE AUTHOR. I will make but a very few remarks in closing, but I do want to say that whatever process is used in treating sewage or caring for sludge, the plants are not automatic and must be maintained, and if we are to prevent odors, either in the sewage or in the sludge, there must be a constant maintenance at all times on the ground. I do not want to make any of my remarks misleading, that a plant can be put up and run automatically. It must be intelligently maintained, whatever method is used in screens, tanks or chemical treatment.

No. 1454

SOME FACTORS IN MUNICIPAL ENGINEERING

By Morris Llewellyn Cooke, Philadelphia, Pa.

Member of the Society

The role which the engineer is to play in the development of our municipalities will depend primarily upon the attitude taken by the profession as a whole toward what appears to be a wonderful present opportunity and also upon the ability with which the work of the engineer is brought to the attention of the public. There is no real reason why municipal engineering should not be made to comprise most municipal undertakings.

2 The test by which the role of the engineer is to be determined will be the development in our profession of a genuine spirit of public service. The community is apparently ready to accord the engineer a leading, perhaps a controlling part, if the engineer will consider that in every decision and act there shall be the clearest possible recognition of the public interest. We should remember that democracy can use the engineer without giving him either a leading or controlling hand in affairs. This use of engineers has been conclusively demonstrated by public utilities companies, especially during the last thirty years. In most of our larger cities during this period there have been operating one or more so-called "big business" men who have built large fortunes and a certain kind of fame in the development of enterprises in which engineering was an important factor and in which it should have been the paramount and controlling factor.

3 In these enterprises engineers have necessarily been used, but not in a leading or controlling capacity. It would probably require considerable research to get the names of the engineers used by Charles Yerkes in Chicago; by Martin Maloney in Philadelphia; by Anthony N. Brady in New York and by Patrick Calhoun in San Francisco. As a profession we may as well face this problem and decide whether in the further upbuilding of our cities, we are to so serve democracy as to be warranted in demanding and to be entitled to receive a position comparable to the real importance of our work.

Presented at the Annual Meeting, December 1914, of The American Society of Mechanical Engineers.

4 Difficult as it is for some to realize it, democracy will not ultimately be deceived. In the long run democracy's sense of values is unerring and that profession which considers only its own and its clients interests without a proper regard for those of the general public will be accorded the same position which history has always given those who are led by no higher star than self interest, however enlightened that self interest may be.

5 These suggestions out of my personal experience are offered in a spirit of the fullest optimism. I firmly believe that the engineering profession is rising to meet its broader responsibilities with perhaps an even more quickened pace than that which during recent years has wrought such sweeping changes in the medical profession and that of architecture. As with everything that is worth doing, however, our course is fraught with dangers.

6 There are certain kinds of engineering in which financial and almost all other kinds of preferment depends on an attitude of mind which, while not necessarily anti-social does not provide sufficient opportunity for entertaining a virile public point of view. As a representative of public, rather than private interest, it is my duty in choosing the advisers of the city which I have the honor of serving to satisfy myself not only as to the ability of those we employ, but also as to their disinterested—yes, their public point of view.

7 No matter how able a man may be, how broad his experience nor how high his standing, his service to those who employ him must at all times be consistent with the public interest if, from my point of view, he is to be available for public employment.

8 Judged by this standard, there are in certain fields of engineering almost no engineers who are at present available for the service of the public and who at the same time have had sufficient experience for large undertakings. In the past few years we have had unusual opportunities for seeing at close range the professional attitude of those equipped with the technical knowledge required in advisers to cities on utility matters. It has been practically impossible to secure the services of those with reputations already made in the electrical field. Some of our experiences could be considered on the whole rather amusing were it not for the fact that we are left under the obvious conclusion that for the average city official to get good advice on these matters, is well nigh impossible. What is more objectionable is that this condition is one quite generally recognized as true by city officials. We hear a good deal of complaint on the part of engineers that as a

profession we are not chosen more frequently to serve on public service commissions and for similar technical work. Perhaps in our experience may be found at least part of the reason for this condition. Of course when a city wants advice on a subject such as this the matter is usually one of considerable importance, often involving large sums of money, and in reaching conclusions the city official should not be dependent for advice on Junior members of the profession.

9 I must be careful to emphasize the fact that no criticism of any individual is embraced in these remarks and that I am simply pointing out a danger almost necessarily confronting the engineering of an industry dominated by financiers having no knowledge and little appreciation of such professional standards as engineers are supposed to have.

10 The same tendency is to be noted in other branches of our profession. An eminent authority on concrete, who is in intimate touch with the men who are practising in this line, was recently asked for the name of an engineer who was not in anyway affiliated with the large manufacturers of cement and after considerable study was able to think of only one man. There is nothing necessarily improper in this situation,—it may simply mean that all the competent men in this line receive retainers from manufacturers. Some months ago I wanted to retain an engineer fully posted on the details of a certain sub-division of railroad operation. It was extremely difficult to find a man without recognized affiliations which would preclude his retention. Again I am informed that there are no asphalt experts who do not receive retainers from the manufacturers. It is a condition which should be provocative of thought by engineers.

11 The conditions reflected in these statements are undoubtedly improving and as we recognize the dangers with which the very existence of certain branches of our profession have been threatened, necessary and remedial steps will be taken. But in any consideration of the opportunities afforded by the municipal field for engineers we cannot ignore such basic considerations.

12 I would not have you think that I do not fully appreciate that our present situation is the natural outgrowth of the fact that all of the foremost engineers have become prominent through the service of private interests. Public employers up to the present have been almost a negligible factor in furnishing opportunity for employment or for the making of a reputation. It is perfectly natural, and it is in accord with former ideals that engineers should feel their first duty to be to

these private employers. But in this time of broader and deeper social consciousness, it seems to me that this standard must change.

13 The point I wish to make is that engineering has now reached the stage of development where it has become a profession in the highest sense of the word. The engineer being a scientist, his responsibility should be for the development of facts, regardless of whose advantage they may serve. I have in mind that the service of an engineer should be as the service of a judge and as opposed to the service of a lawyer who confessedly seeks out and represents the interests of his client, and often "makes the worse appear the better cause." This is justified by the fact that lawyers are not scientists, and by the assumption that there shall always be opposing counsel.

14 In the medical profession during the last generation, largely owing to the enlightened leadership of the American Medical Association, there has been inaugurated a great forward movement with the slogan of "preventive medicine." The medical profession in a way seemed to launch a campaign to wipe out its opportunity for a livelihood. There were, and I suppose still are, doctors who held that in advocating "preventive medicine" the profession was standing in its own light. The profession, however, is held in higher esteem than ever before. Under the new conditions there is a broader field for the activity of practitioners, both medical and surgical, than had ever before been available.

15 On the contrary, in inviting the attention of our profession to the municipal field, we are apparently opening the door of opportunity to tens of millions of dollars worth of work which is not now either considered engineering nor carried on by engineers. The municipal field is almost virgin soil so far as engineering is concerned. As recently as ten years ago the problem of snow removal which is being discussed as a part of this day's program, was so absolutely in the hands of thumb rule, and in many instances even of inexperienced men, that it is probably true that in no city in this country was it being attacked either by engineering methods or by engineers. Yet it will not be denied that on work of this kind, in which one city spent nearly $3,000,000 in six weeks last year, there is in reality an engineering problem of considerable magnitude.

16 If this municipal field is to be one in which engineers of ability, sincerity of purpose and high ideals are to find a permanent and satisfactory outlet for their energies, our profession acting as a profession will be one of the main agencies bringing about certain

undamental changes in the attitude of the public. In the minds of o many engineers, participating collectively in matters pertaining to unicipal engineering means "getting into politics." Architectural ork being a part of the business of The Department of Public Works n Philadelphia, we have had the coöperation of the American Institute f Architects and of its Philadelphia chapter from the beginning. We ave made many demands on them and in every case have met with enerous and enthusiastic response. This assistance has been entirely part from the help rendered us by individual architects. We have ad the constant, indefatigable and valuable support of the secretary f The American Society of Mechanical Engineers in our efforts to naintain the highest professional standards in the work of the departnent. But engineering bodies as such have given us no assistance and o far as I know have taken no part in the discussion of federal, state nd municipal engineering, except in the matter of conservation which or some reason is considered as innocuous from an engineering standoint as a prayer-meeting.

17 Many municipal engineers in this country are beginning to dopt the European system of employing non-residents for certain ighly specialized positions. Whenever this is practised it excites riticism and abuse. As yet no technical organization, so far as I now, has recognized the opening thus made for technical merit and iven moral support to the movement. Again I have tried to get suport from organized engineers in the obviously necessary procedure of mploying experts outside our regular staff, but without results.

18 From an engineering standpoint any scheme of highway contruction which does not include an ample repair program, is futile. n our community this is not at all understood because the plan has ever been followed. It would seem a proper function of an engineerng body to educate the community to this point of view. But as a natter of fact engineers as such have taken so small a part in public liscussions that the layman with us settles more engineering questions han the engineers themselves and the tax payer foots the bills.

19 The public today is undoubtedly impatient for "results." It as an unmistakable liking for men who "do things." It has little atience for experimental work. There was introduced in our Philaelphia City Councils, an appropriation of $50,000, for an experinental test roadway and the bill was defeated on the ground that I had stated that the man who was to spend the money was one of the best experts on bituminous road-work in the country. It was held

that this statement and the appropriation were inconsistent—that either the engineer was less expert than I had claimed or that we did not need an experimental test roadway. The title of the road in the appropriation bill was changed to read "service test roadway" and the bill was passed by a good majority.

20 The public must be taught that public service is not different from private service in that forward steps come frequently, even usually, as the result of a large amount of preliminary investigation. Again, the public, of which please remember we are a part, must be educated to place more responsibility on individuals, thus making it possible to do away with the great inefficiencies which inevitably accompany board and committee management. As long as we have boards and committees they will vote,—and they will insist on voting, —on matters that are not questions of personal opinion but questions of facts which ought to be determined by the facts. It is one of our duties as technical men to carry on a propaganda which will show to the public the difference between those problems of policy and public interest, that are properly settled by public opinion and those scientific problems which are improperly settled unless they are settled according to the facts. Mr. Frederick W. Taylor, Past-President of the Society, in recent lectures has very forcibly and lucidly suggested this fundamental difference. For instance, my opinion may be as good as that of any other citizen's as to how fast an automobile should be allowed to operate in different sections of a large city. The opinion of any member of this Society is as good as that of any other citizen as to the penalty which should be inflicted for false registration. On the other hand, the designs for a bridge; or the specifications for a sewer; or the plans for the laying out of a public park; or the organization of the police department; or the fighting of fires; or the elimination of mosquitoes are necessarily the work of experts. Such work will always be indifferently done if done by voting; whether the voting is by the people at large or by a committee or board acting for the people. Notwithstanding all the boards and commissions that are created in the generally approved laws of today, there should be no uncertainty as to what questions they may vote upon. It is therefore one of the duties of the educated to carry this message to the people and in doing so I do not think there will be any more powerful method than to give the great mass of the people a larger and larger knowledge of expert work.

21 Lord Kelvin is the authority for the statement that the

physicist who has discovered some great principle or invented some new process in physics should be able to explain it to the first man he meets on the street,—both what the discovery is and why it is useful; or failing in this he should go back to his laboratory and put in some more time. If Lord Kelvin could say this about discoveries in physics, surely our city officials and the public service engineers with whom they coöperate should take the position that their work is capable of being fully explained to those who are footing the bills.

22 Another difficulty confronting the engineer in public office is the restriction placed upon him in making proper expenditures. I have been given practically no money for purposes not contemplated by the City Councils at the time the appropriation was made. The result has been that whenever any emergency has come up it either had to be paid for out of private funds or we had to wait until the legislative machinery could be put to work to make the necessary appropriation. Every administrative officer occupying a position of wide range and responsibility, whether an engineer or not, should have a certain amount of money placed at his own disposal and guarded only by the necessity for ultimately explaining its expenditure. In requesting an appropriation of $10,000 for such unforeseen purposes, I agreed with our City Councils that if money were granted I would write a one-hundred word description of the purpose for which the money was used, such explanation to accompany each warrant drawn against the item. Even this does not go quite far enough as my experience has shown. There are certain legitimate and necessary expenditures for expert services which should not be divulged for months after the expenditures are made. So that unless city officials are to be placed at a serious disadvantage in their negotiations with private concerns, certain moneys (representing of course a very small, almost negligible, percentage of the total appropriation) must be placed at their disposal for a more or less free disposition.

23 Experience has shown that in our department, spending as we usually do over $10,000,000 in a single year, for instance, we could profitably spend $25,000 a year for research and investigation work and for the employment of experts. Ninety per cent of the expenditures drawn against this amount could be explained on the vouchers as drawn. It would probably be wise to allow the remaining ten per cent to be explained or not in the judgment of the administrative officer. This would only be following the practice followed in prac-

tically every city of the country in the expenditure of funds for the detection of crime.

24 Especially in engineering work almost the entire absence of what may be called a financial program is the great handicap. Private institutions can go along for years on a straight operating basis and without the necessity for undertaking any extensive construction work. But a growing city—and all our cities are growing cities—must necessarily have to spend a considerable part of its income on construction. This can be done with intelligence only by taking a long look ahead. For instance, at the present time in Philadelphia we are facing expenditures of from $20,000,000 to $25,000,000 on a sewage disposal installation; perhaps $40,000,000 for rapid transit; with extensive additions to our water supply system, not to mention other millions which could profitably be spent on sewers, bridges, grade crossing removals and a much needed program of modern highway construction. There is probably no city in the country that is even attacking this obvious business problem in an intelligent or energetic way. Reform will not be brought about until the community and especially the business part of the community is educated as to its necessity.

25 I am not one of those who feel that all our short-comings are "the fault of the people." I would rather assume my share of the responsibility for conditions as they are and then join with my professional associates and the community at large in bettering them. If we engineers are to have any prominent part in this there are fundamental changes which we shall have to make in our own equipment for the work. In the first place, we have to get rid of the now old-fashioned idea that advertising is a crime. I admit that as a part of my work as a public official I put in a great deal of thought on what may be quite properly called advertising. By that I mean that I pay less attention in my reports to dignity of form and diction than to making them sufficiently interesting to be read. It is only as we engineers who are public officials learn to make the public, sometimes against its will, understand our work, that we are to get that degree of popular support for it which will make it possible for it to be done in an efficient manner.

26 In my opinion it is going to become more and more a necessity, not only in public but in private work, for engineers to be able to popularize what they are doing. It is true today that a man who wants to do really good and efficient work can do so only after an aroused public opinion. You cannot drive people in a democracy. So

I admit that in offering employment to an engineer, other things being equal, I want what might be called a good advertiser. You can secure appropriations for work more easily when it is well advertised. The Panama Canal is a good example of this principle. Again, advertising is the best possible check against ill advised expenditures. In building our Byberry and Bensalem Service Test Roadway we erected sign-boards on each of the 26 sections giving to the layman the exact method of its construction in non-technical language. If the public knows how a street is supposed to be constructed or cleaned, you do not require as many paid inspectors on the job.

27 The development of some varieties of municipal engineering is absolutely dependent upon the development of public opinion and must proceed with it. The matter of street cleaning is largely a question of an improved public taste in the matter of street paving. Unless streets are well paved they cannot be well cleaned except at a prohibitive cost. To jump from one degree of cleanliness in this respect, to another, without a supporting public opinion, may be enough to wreck an administration and to set the tide of civic improvement running in the opposite direction.

28 The newspaper is the great educator in these matters today. But we are already using in Philadelphia moving pictures, parades and exhibitions. The possibilities of these and other means of publicity are not yet fully understood.

29 Again, more effort must be put into humanizing public administration. The engineer shares with those who have had the opportunity for education, the mistaken idea that the man at the top is in a position to tell the man at the bottom what is good for him. The fact that our country was founded and has been perpetuated on the contrary idea has not seemed to affect the situation very much.

30 Take, for instance, the movement which has led to the formation of large numbers of business men's associations and improvement associations. This affords one of the very best examples of the present vitality of American public life. Our leading men should accept them as something that has come to stay and coöperate with them in such a way as to direct their activities into profitable channels. It seems to me they afford the most promising agency through which in the first place, the thought of the public on civic questions can be crystallized and secondly through which that thought can be given expression in definite public procedure. I have found these associations ready and anxious to hear from men who had definite knowledge on matters of

public interest. It should be the attitude of any engineer who wants to play his part in the community, to affiliate with one of these organizations and to help to make it an influence. You can rest assured that the man who is in public life for his own personal advancement is bending every energy to defile and degrade these institutions and to divert them from the high mission which they have it in their power to carry out, so they need our help.

31 In such a discussion as this, one cannot ignore the civil service. It is always a pleasure to say that personally I could not hold public office if it were not for the safeguards and reliefs that our Civil Service Act affords. At the same time without repeating what I have said in other public papers on this subject, I want to call attention to one fundamental misconception under which the entire civil service question in this country apparently rests. Civil service appears to be founded on the theory that the best man for the position will apply for it. I think it is the experience of every employer of men—and this is especially true in filling the higher positions—that the best man will not apply. On the contrary you will usually have to go out on the scriptural highways and hedges to find the best man and then having found him, fall on your knees and beg him to accept the positions offering such opportunities for public service and professional independence as are most likely to secure him.

32 This is the way to get good public servants. It is almost impossible to find men who have many of the qualifications for our work combined with a willingness to enter the public employ. Even if public employment should come to be considered more desirable than it is at the present moment, I think that this difficulty in finding the best man would still be encountered. Therefore, if we are to have the highest class of men in important engineering positions we must develop some merit system by which the appointing officer is given a greater opportunity than he now has of finding *the* man for the job. In this work it is possible for our engineering societies to take an important part.

33 I believe, for instance, that if the secretaries of the four national engineering societies could be authorized by their several councils to associate themselves as a civil service board to act in an advisory capacity to federal, state and municipal civil service commissions, it would be a decided step in the right direction. Suppose the president of the Borough of Manhattan should want to secure a competent engineer to put in charge of the highway department.

Through the New York City Civil Service Commission he would state the problem to this suggested advisory board which in turn would appoint say three engineers to act as his counselors in finding the man. The appointing officer would keep these counselors in touch with the search and when he was ready to make a choice, secure their approval before entering into a contract. In this way the merit system would act as a check against favoritism but would allow the appointing officer the widest possible opportunity to search for the best man available. It would probably not be found desirable to have all of the counselors from the engineering profession and one of the engineers should probably be an expert in the particular branch of engineering to which the position to be filled belongs.

34 This procedure is a radical departure from the present idea of civil service, which is based on the assumption that it is impossible to allow the appointing officer to have anything to do with the selection of his men. Even under the most advanced forms of civil service the appointing officer is confined to a full statement of the qualifications he is trying to secure. One never exactly fills a position with just the kind of man in mind when the search started. It is a question of compromise and the appointing officer is the one who is in the best position to know where concessions can be made and which among the several requirements are the most indispensable. There would be no objection to a check on this action of the appointing officer through some kind of a written test. But to choose men for positions paying from $5,000 to $25,000 a year on the results of a written examination is absolute folly. So far as I know engineers have never taken a hand in the discussion of methods under which engineers shall be chosen for positions in the public service and it seems to me high time they should do so.

35 Now a word of warning about the growing complexity of municipal operations and administration. Gladstone, fifty years ago, described the then complexities of governmental administration in these words:

> A protracted experience of public affairs not unattended with a high estimate of the general diligence, devotion and ability of the Parliamentary as well as the civil servants of the Crown has long convinced me that of the more difficult descriptions of the public business, apart from the simple routine, it is only a small part that is transacted with the requisite knowledge, care and thoroughness. We have undertaken in the matter of Government far more than ever in the history of the world has been attempted by the children of men.

36 If he had sounded this alarm in the year 1914 he would have made it very much more emphatic. Take, for instance, any city's inspection service. In industrial establishments it has come to be recognized as desirable not only to inaugurate a full system of inspection from the inception of the work but to gather together under the direction of a single head as many as possible of those engaged on inspection work. In our cities at the present time we have a minimum of inspection and yet we already have in good sized communities at least ten or twelve different officials who periodically inspect individual houses and places of business. For instance we have building inspectors, fire marshalls, police, meter inspectors, of several different kinds, water waste inspectors, health inspectors, elevator inspectors, truant inspectors, garbage and street cleaning inspectors. These men for the most part work so independently of one another that if, on a given date, representatives of each of these types should call at the same house they might do so without any knowledge that the others had been there. In the Federal service it frequently happens that the Post-office department, Treasury department, War department (and perhaps other departments), each starts a representative from Washington to a town on the Pacific coast on relatively minor commissions, simply because the business of the Government has become so complicated that it has become impossible for us to utilize our men and resources efficiently even though we desire to do so.

37 As compared with what has become good practice in the industries our record keeping in the cities falls far short of what it should be. Even with this meagre quantity of records those that we have are practically unavailable except to those who make them. Unless some radical reorganization can take place and some sound system of record keeping can be evolved for governmental units, one is appalled at the chaos that will come about within the next generation, as memory and public opinion give way further to the reign of records and facts.[1]

38 One distinct contribution which the group of engineering societies housed in this building can make to the solution of this question would be to establish in the Engineering Societies' Library a section devoted to a Municipal Reference Library. As a beginning a single alcove could be set aside under proper supervision and provided with the necessary index. There is every reason to believe that it would

[1]See Graham Wallis's "The Great Society," The MacMillan Co., New York, 1914.

grow as rapidly as any other section of the library. At the present time there is no possible way for a city official to be sure that manuscript reports on engineering matters will be available twelve months after they are made. I have, for instance, a digest on American street cleaning methods prepared for our education by Day & Zimmerman, Consulting Engineers. It is an exceptionally valuable document. I know where it is today but there is no possible machinery provided in Philadelphia or in any other city whereby officials can be sure that they can find such a report a few months after its preparation. This manuscript would be of very great value to any city official charged with the problem of extensive street cleaning. We would be glad to deposit this report in any library properly organized to receive it.

39 The same is true of literally dozens of reports on gas, lighting, electricity, garbage disposal, city planning, police discipline and others prepared under the present administration in Philadelphia. I know that, if this suggestion is adopted and such a library is started, city officials all over the country will be glad to have extra copies made of every report which should properly belong to such a library. In this way the results of the trouble and expense taken to study any one subject in one city would be made available for engineers interested in similar subjects all over the country. This agency could be started here at such minor expense compared with the value of the service rendered that I believe it is an obligation which our Society can hardly afford to overlook, even though it should have to do it alone.

40 The more rapid promotion of municipal engineers due to moving from city to city, the development in our colleges and engineering schools of courses especially designed for those who want to follow this branch of engineering, the gradual but incessant cleaning up of city governments is going more and more to make municipal engineering a desirable calling. But nothing will go so far to remove the objections to municipal engineering as a career as the standardization of all engineering specifications. Prior to this, of course, a tremendous amount of research work must be done. Much of this can be done by the cities themselves but a large part of it should preferably be done by research laboratories. These latter may be connected either with existing technical schools or preferably be operated in municipal colleges founded sometimes in conjunction with existing colleges and universities as an aid in the great municipal movement.

41 Even a casual survey will show the municipal field not only to be a big one but one in which relatively little work has thus far

been done. I hope that these random notes of mine may be at least suggestive. The fact that we are holding this public service meeting today is proof positive that we are working in the right direction and that the engineers of the country are determined to play their part in the further upbuilding of this great republic.

DISCUSSION

ALEX C. HUMPHREYS said that while he was in sympathy with much of that presented by Mr. Cooke, he differed from him strongly as to details and in so doing he was guided by a wide experience with engineers and municipal governments.

He believed there was not the slightest difficulty in getting the right kind of engineers for the work referred to, if they were properly approached and fairly treated. If, on the other hand, one approached these men with the idea that because they have been in a certain line of work, they must necessarily be biased in their opinions, one should not expect to get the best results.

The speaker was unable to understand why it should be recommended that a library on municipal engineering should be set apart from the rest of the library. If this should be done for municipal engineering, why not for all other branches of engineering? Then, where should the lines of division be drawn. He was reminded of the advice he had given some time ago regarding a certain book on the finances of public utilities. This book was misleading in the hands of the uninformed by reason of its plausibility. The advice given to those directly concerned was to purchase the book and so be prepared to controvert its false teachings, particularly as this could be done through its own inconsistencies and contradictions.

As to the absence of standards, the speaker thought that the trouble in large measure was that sufficient attention is not given to the fact that working standards can be established only by taking all factors into account; the scientific, upon which there is so much stress laid, and also the practical factors, including the necessary limitations of application—the commercial, the financial, and the human.

If standards are being developed for the guidance of others, such work must be done cautiously and with a keen appreciation of the responsibilities assumed. Enthusiasm alone is not only not sufficient but may be most dangerous. Those who undertake this work must first of all be competent to do it, and then must secure the faith of those in control with regard to their integrity. The speaker was emphatic in saying that he resented the pervading tone of the paper, which seemed to imply that because an engineer has been in the service of public utilities he is not to be relied upon to give honest advice in connection with public affairs. He did not believe this to be true of the great majority of the engineers of the United States. He believed that those who made such an accusation were unworthy of a place in the profession.

C. E. MERRIAM.[1] I believe that every engineer engaged in public work should have in him some element of the salesman, not that he shall endeavor to advertise himself, but that he shall have a keen appreciation of the need of educating the public to the necessity and importance of the works which he recommends.

You all remember, without doubt, the tremendous Dayton disaster in 1913. Following immediately thereon, some 20,000 citizens of Dayton subscribed about two millions of dollars in order to prevent a repetition of that disaster, but three months went by and there was no evidence of any work being done. There were engineering corps in the field making investigations, but the people saw no tangible evidence of work being started. A publicity man, a young engineer, was appointed to give the newspapers the facts they could use to control the impressions going around, and which would show the value of some of the plans suggested and being criticized because they were not put into effect at once. I would have you note these two points. First, the engineers were too busy to meet the reporters; second, the data were not in such shape as to be immediately available for newspaper work. This young man was given access to the records of the contracting engineering firm that he might bring forth the facts, put them in readable form, and give them to the newspapers to demonstrate that careful investigation was necessary before any plan could be undertaken and to show the folly of all the temporary propositions which had been made. The result was that with this publicity harmony was restored. Trouble again developed, however, when it was found that a system of reservoirs was proposed, and immediately a cry went around that Dayton was trying to saddle the cost on other counties; that dams would be used, and the people in the valley would be in danger of a repetition of the Johnstown flood. Again the publicity man was called upon to show that there was absolutely no basis for these fears, and that, instead of saddling upon other counties the

[1] University of Chicago, Chicago, Ill.

cost of protecting Dayton, they were really asking all to coöperate in order that the aggregate expenditure of protecting all might be very much less.

This may be an isolated case, but all who are writing reports or are engaged in municipal work can exercise their influence and secure the proper publicity, not by presenting reams of statistics, but by picking out salient points and putting them in readable form.

Reginald P. Bolton. The author suggests that engineers take a greater part in the administration of municipal affairs, and seek municipal employment to a greater extent. Although he deservedly occupies a high position in the service of the City of Philadelphia, he indulges in suggestions throughout this paper which are not to the advantage or credit of the profession to which he belongs, and which should not go on the records of our Society without strong protest. The fact that engineers are engaged in certain lines of commercial work is no bar to their doing independent work and expressing independent opinions, whether they are employed by a municipality or by a private corporation or person. Similarly objectionable are statements such as that on the work which has been accomplished by large business interests in this country and the suggestion that they should be limited to a certain kind of fame, and that no other credit be given to them. Nor is it evident why in par. 9 there should be a reflection on the engineer employed by the financiers of that wonderful electrical industry which has set the highest standard of engineering of any industry. The author is probably not so well acquainted as is the speaker with the conditions of municipal employment of engineers in New York. The suggestion that our Society should take part in recommending or suggesting the names of engineers for appointments to municipal employment is one that has been considered adverse to the policy of our own and of other societies, but a number of societies, including the leading ones, have urged the appointment of engineers as members of Public Service Commissions. Why was not that done in this city? Because the lawyers, who have swallowed practically the whole of the political positions in the state and the city, are afraid of engineers. The conspicuous and highly talented lawyer who was at the head of the Government at that time stated that he did not appoint engineers because they were always technical and in his opinion a lawyer could always grasp enough of engineering matters to understand a technical question. The speaker believes that the best class of engineers cannot e brought into the position of taking office under municipal conditions s they are here today, because those in control do not recognize what n engineer is and what he stands for. However, the author says orrectly that engineers as a body should take a greater interest and a reater part in municipal affairs; and I agree with Dr. Humphreys nd others in saying that engineers will not do their full duty until ney recognize the fact that they are not only engineers but are citizens ho should take their proper share in the handling of public affairs nd in the formulation of public opinion.

H. S. PERSON.[1] I am in complete agreement with Mr. Cooke's rgument and rejoice to hear uttered to the members of this profession challenge which is another expression of a significant movement, hose object is to bring to the service of the people, in their civic roblems, disinterested, professional assistance of the highest type. 'he spirit is not new. Mr. Cooke has referred to the example set by ie medical profession in the development of preventive medicine. I now that the idea has long since seized upon the teaching profession, nd the number of university investigators who have given to the ublic service the discipline and knowledge resulting from their in- stigations has become noteworthy.

Why the necessity for such challenges? Why that need with respect such an important and seemingly obvious a matter? There are two asons, and both arise out of the abundance of resources and great roductivity of this country during the past century. First, a young emocracy with such economic productivity as to permit blundering nd wasteful methods of public administrations without appreciating ie cost, does not realize the necessity for expert economical assistance. tarting with the political and social theory that every man is as good nd efficient as every other, and meeting in the century's progress no reat economic crisis to refute it, we have proceeded into the twentieth entury with that ideal still in control. Older peoples with dense opulations and meagre resources, such as those of Western Europe, ave been undeceived. Second, as pointed out by Mr. Cooke, abundant esources have offered such opportunities for highly productive private perations, that expert professional service, such as is represented by ourselves, has been demanded and absorbed by private enterprises. Ve have by small increments, and unconsciously, allowed our energies o be absorbed by the demand, imperious through the rewards it offers,

[1]Amos Tuck School, Dartmouth College.

of private enterprises; and we have failed to lift our eyes for the broader survey which would compel us to see and respond to the larger opportunity to give to public problems professional assistance. Many of us, to be sure, have been employed in public operations, but it has been in most instances only a phase of private practice, not public service.

The author's paper is an exhortation to engineers to lift their eyes to see the problems, the opportunities and needs in municipal administration, the field for public service particularly demanding the expert knowledge of the engineer. Response calls for the formulation of definite plans which must embrace two main lines of operation, determined by the two reasons I have given for the necessity of the challenge. These main lines of operation, pointed out in the paper, are education of the public and education of the profession. The public needs education concerning the capacity of engineers for public administration and the profession, paradoxical as it may seem, needs to educate itself concerning its incompleteness and inadequacy for that service.

Concerning this matter of the education of the public, mere proclaiming that public activities of an engineering nature demand expert knowledge is not an educating process. Such proclaiming, if in a form which implies the unexpressed clause "And I offer my services at the usual or a little higher price," lacks the disinterestedness required in educative efforts. Furthermore, have not the proclamations been usually either on the one hand in too general terms or on the other in too professional a terminology to carry persuasion? It is to this too professional a terminology that Mr. Cooke refers when he speaks of advertising. I question the expediency of the use of that word, for it connotes a motive of private gain. The word *publicity*, on the other hand, by recent usage has come to connote public advantage. Whatever the term to be used, the meaning is clear; explain the necessity of your expert service in terms that he who is illiterate may understand. The Byberry and Bensalem Service Test Roadway is to the point. Persistent word-of-one-syllable explanation of how and why expert assistance is to the public advantage is the essence of the method of educating the public.

CHAS. DAY (written). I cannot endorse too strongly the conclusions expressed by the author. The members of the Society who, through the discharge of their professional duties, are brought in direct touch with the public, cannot fail to appreciate that these con-

·lusions have directed attention to the most vital issue now presented hrough the evolution of engineering service, and it does not seem ›ossible that they should do otherwise than accord their fullest support o measures which will bring about the highest professional standard n the field of municipal engineering.

Today we occupy the indefensible position of permitting without ›rotest the perpetuation of obsolete, inefficient and extravagant nethods with regard to municipal work involving the expenditure of nillions of dollars. It seems entirely incompatible that with a proper :ode of ethics the continuance of such abuses should be tolerated with›ut strenuous protest. Of course, in the final analysis, little progress vill be made until engineers, possessing not only the requisite ex›erience and knowledge but a deep interest in public welfare, are villing to accept municipal posts, in particular those generally asumed by city governments, such as street cleaning, removal of ashes, ighway work, etc. Probably very few of our members are engaged ıpon such work.

There is, however, another great field of activity closely related to nunicipal work which engages the attention of a large number of our ssociates, and this is the work of public service corporations. Owing o the enactment of laws providing for regulation, public service orporations in many states occupy a position in relation to the public hat imposes quite as great obligations as those devolving upon the lepartments or individuals engaged upon purely municipal work.

There is, without doubt, justification for the dissatisfaction conerning the *results which in many cases have been secured* through tate regulation of privately-operated public utilities. Certain of those esponsible for the policies of such corporations have lacked almost ntirely that recognition of the public interest which is referred to by he author. It may be that in most cases the responsibility for this ondition rests directly upon men who are not members of our proession. Nevertheless, this does not relieve us from the duty of aserting ourselves regarding placing the businesses to which we are the ›rincipal contributors upon an inherently sound and permanent basis.

There can be no doubt that the type of engineer desired by the uthor will see that justice is done to corporation and public alike hrough a frank and unbiased consideration of the apparently conflicting conditions. The qualifications he judges necessary upon the part of the municipal engineer are equally imperative for those who administer our public service corporations, and its seems that the Society can do no more important work than further the recognition of this fact in every way within its power.

CARL SCHWARTZ (written). If Mr. Cooke's paper were to be taken seriously, such statements as made in pars. 7 and 8 would be a reflection upon the integrity of engineers. It is difficult to understand the reasons for this and similar statements unless the author is not acquainted with many of the best members of the engineering profession. Should he desire, the speaker will be glad to furnish the names of prominent mechanical and electrical engineers not affiliated in any way with large manufacturers or conflicting interests. I also doubt whether it would require considerable search to obtain the names of engineers used by "big business" men in developing public utilities companies.

The success of engineers in private enterprises is largely due to the fact that the financiers have appreciation and knowledge not alone of the professional standing of engineers, but also of their good business judgment without which they would be unfit for any leading or responsible position.

Admitting that the municipal field may so far not have sufficiently attracted the attention of the engineering profession, the cause and remedy for this condition are hardly to be looked for in the author's paper. For a perhaps more reasonable explanation, the author is referred to The American Commonwealth, by James Bryce, one of the chapters of which on "Why the best men do not go into politics," covers this subject specifically. While Mr. Cooke does not claim the engineer holding a public position to be in politics, still he advocates his paying less attention in reports to dignity of form and diction than to making them of value as an advertisement, and he even proposes the engineer advertise his professional activity by means of such devices as moving pictures and parades.

While this paper may to some extent be effective upon the layman's mind, in my opinion it would be a calamity should the engineering profession accept it as a guide for the important field of municipal engineering.

The paper proposes that a municipality appropriate $25,000 a year for research and investigation work, 90 per cent of the expenditures drawn to be explained on vouchers, and the remainder to be spent perhaps without any explanation whatsoever. I would like to whether such procedure should be permitted even for public service ıpanies, not to speak of municipalities. It would not be surprising n arrangement of this kind would be found to require an additional ropriation for the detection of misapplication of funds.

ALEX. Dow said that he seemed to have awakened from a long p and that something must have happened during that sleep in way of a recession from old ideals of professional honor, which refused to believe.

In par. 10 it states that "An eminent authority on concrete, who n intimate touch with the men who are practicing in this line, recently asked for the name of an engineer who was not in any ' affiliated with the large manufacturers of this material, and ꞉r considerable study was able to think of only one man." If he been asked if any of the leading men had not shown in their work reference for one method or another, that would have been a ꞉ect answer. Asked, as an employer is, whether there was any ling man to whom the question could be put, "What in your ıion is the best method?", I don't think that any leading man) could be named would have failed to give a truthful answer, ing the truth as he knew the truth and as he saw it, and there is hing more expected of any engineer.

Here is another statement: "It has been practically impossible to ıre the services of those with reputations already made in the ꞉trical field." Services as honest advisers, or as expert witnesses? ꞉ implication is that the two are alike, which they are not. I do not ·w any men of high standing in the electrical field, and I think I ·w most of them, to whom Mr. Cooke could not have submitted a ꞉n question and had an immediate and truthful answer had the stion been brief and within the scope of existing knowledge. I e no doubt that every one of our brothers in electrical engineering ıld have so dealt with the matter, or would have said, "It is beyond time, I cannot give you the time necessary." The refusal would have been based upon an inability to tell the truth, but upon ·agements preventing the making of the investigation.

Another statement says, "Again I am informed that there are no halt experts who do not receive retainers from the manufacturers." have in Detroit an asphalt expert who is absolutely honest, and the gestion to him that he was taking a retainer from any manuadminister our public service corporations, and its seems that the Society can do no more important work than further the recognition of this fact in every way within its power.

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NEWTON D. BAKER[1] (written). There are one or two thoughts suggested by Mr. Cooke's paper which I desire to emphasize. In the first place the difficulty in having engineers with the public point of view has not been entirely with the engineers. Our American cities have not made city engineering a career in the German sense of that word, and, therefore, men who have entered the city's service and become proficient find the rewards of their professional activity greater in private employment. They soon reach the highest compensation and official dignity possible and not unnaturally are unwilling to arrest either their own development or their own progress by staying in the public service. This situation arises from various causes. Our American cities have only recently come to a realizing sense of the importance of accurate and expert service for engineers. The old theory was that a man who devoted half of his time to engineering and half of his time to politics was a better public servant, or at least more entitled to the job. As a consequence of this the public have regarded their engineers as political place-men and have not been willing to sanction the payment of salaries at all in proportion to those paid by private employers. Before we can expect the engineers as a professional body to change their attitude therefore, we must have on the part of the people a perfectly frank understanding that high-grade professional service cannot be expected out of a charitable impulse, but must be compensated in a dignified, adequate way by the public as an employer, and that men of real ability will not accept the public service if their continuance in it is to be interrupted in the midst of useful work on their part by the mere accidents of political change in the headship of city governments. I make these comments not because I do not think these changes are coming about, but because I think in justice to the engineers the entire fault should not even by inference be assumed by them, and because I am very anxious to have the people of our American cities realize their share of the burden in securing efficient and high-grade service from experts.

ROBERT B. WOLF. It is one of the most hopeful signs of the times that the engineers of this country are entering into municipal life. My own view is that the engineer is destined to work out the great

[1]Mayor of Cleveland.

ocial problems of the world as well as the industrial problems. The ollective desires of many men such as make up our engineering societies will ultimately make itself felt.

Few of us realize the wonderful opportunities presented in the iunicipal field for service to our fellowmen, and I know that few, ! any, of us have any idea of the joy and inspiration to be received rom this kind of work. The word "politics" must be made to have a ew meaning and the duty of the engineering profession is to make it ynonymous with the highest kind of idealistic service.

The reason the world must look to the engineer for the solution of iunicipal problems is that in the very nature of things his idealism s practical. His grasp of material facts and laws insures an idealism 'hich is workable and for this reason progressive in its accomplishment of social and political reforms. It is because it is the engineer's usiness to know and use the forces of nature that he, above all others, s qualified to solve the great vital problems of our municipalities.

F. W. TAYLOR wished to correct the impression that might result rom the remarks of the previous speakers that the author considered ie consulting engineers of the country, and particularly the electrical ngineers, disqualified for consulting work for our municipalities beause of their employment by the great public service corporations. 'areful reading will show that the author does not say this. The uthor says that he had been unable to obtain the services for the city f Philadelphia of prominent electrical and consulting engineers. 'his is a statement of fact, for the reply of these gentlemen was, "We re retained by the public service corporations, or are affiliated with the lectrical corporations and therefore not in a position to give you the dvice which you seek." It is no reflection either on the integrity of hese men that they were placed in a position where they could not ive their services to the city of Philadelphia. If there is any reflection t all it passes back to the owners of the companies, who in nine ases out of ten are not engineers, but are financiers who believe that f the cities secure the knowledge to regulate rates, it would ultimately e to the detriment of their companies. This view on the part of the ompanies, Mr. Taylor did not agree with, since a thorough knowledge f the facts on the part of city officials might as readily lead to a rise s to a decrease in rates.

CHARLES WHITING BAKER said that up to a comparatively recent date cities had been rich mines to be exploited jointly by the politicians and by the franchise-owning companies. Now the public is learning that our city governments may be brought up to the standards which have prevailed for many years in England and in Germany by taking advantage of the skill and ability of the engineer. Within the last five years there has been started the most hopeful movement for the betterment of city government service that has ever been undertaken in this country. He referred to the so-called city manager plan of municipal government. This was begun by the city of Staunton, Va., five years ago and there are now some two dozen cities in the United States which have established the office of city manager and have put engineers in charge of the work.

Besides this, it should be noted that in some other cities which have not formally adopted this plan, engineers are taking a leading part in municipal administration. The author of this paper is practically the city manager of Philadelphia and holds the most important position in municipal service of any engineer in the United States.

Robert S. Woodward[1] (written). I am interested to observe that many of the ideas which Mr. Cooke has brought forward are similar in their import to ideas I have long held. To some of these ideas expression was given in an address read by myself at Wood's Hole in July 1914 on the occasion of the dedication of a new laboratory of the Marine Biological Association.

I am especially interested in what the author says in regard to the necessity on the part of the engineer of going somewhat into politics, not in the bad sense of the word but in its better sense. I expressed the same idea in the address referred to, and I feel very strongly that before the reforms essential to further progress in society can be brought about, the engineer must take a hand at the problems presented. His points of view and his methods must be availed of more and more by society if it expects to make evidently needed progress.

The Author. The reception of this paper is proof that the members of our Society individually and collectively are deeply interested in the problem of American municipalities. As the question of expert advice in utility matters has been so vigorously discussed—especially by those directly employed by the utility companies themselves—I have taken occasion to discuss it further and at greater

[1]President, Carnegie Institution of Washington, Washington, D. C.

length in two lectures, delivered at several eastern universities, under the title Snapping Cords—Comments on the Changing Attitude of American Cities Toward the Utility Problem. The valuation of utilities is of course the real question which is being debated. The position of the engineering profession toward the expert in valuation cases must inevitably be defined with more and more charity. For the theory and practice of valuations must within a few years become a national issue comparable in importance only with the tariff and the liquor questions.

No. 1455

ɩAINING FOR CITY EMPLOYES IN THE MUNICIPAL COLLEGES OF GERMANY

By Clyde Lyndon King,[1] Philadelphia, Pa.

Non-Member

Five factors may be singled out as being responsible for the .ency toward sustained and thorough, yet specialized and practical, ›aration for municipal service in Germany.[2]

2 The first of these is the rapid rise in urban populations. In years the population of cities of over 100,000 increased 50 per :. Half of the German population are now urban residents. This ·mous increase in urban populations means an increase in public :tions assumed by city governments many times greater than the ease in population. This increase in public functions requires ency and training of public employes.

Preparation for governmental positions in the state has been ided for in the state universities. These institutions are under lomination of practically the same group of officials that control tate administration. Thus, while state positions are amply pre- l for, at least in certain of the universities (though German uni- ties, like many American universities, have been all too slow in ɑg courses in the political, social and economic sciences, adequate ·eparation for the highest public positions) these state institutions ɔt tend to give the specialization and the emphasis upon municipal ıce.demanded by urban needs. This inadequate training of mu- ɔal officials and employes, with its accompanying lack of proper ialization and proper adaptation, caused a demand for local .tutions that would offer the training necessary and adequate for

'harton School of Finance and Commerce, Univ. of Pa.

ocational Education in Europe, Cooley. The author has drawn ex- vely on this work for facts as to the general educational system. The ıssion of particular institutions is based on an intensive study of recent ogues and announcements.

ıbstract of paper presented at the Annual Meeting, December 1914, of American Society of Mechanical Engineers.

municipal employes. This is the second factor tending toward the creation of municipal colleges for the preparation for municipal service in Germany.

4 The burgomaster and the paid expert advisers in the magistrat were, as a rule, well trained at the state institutions. But no special training was provided for the great rank and file of city employes, the efficiency of whom, after all, decides the skill and utility with which the taxpayer's money is spent. The need for training well every municipal employe, so that there will be no lost motion through inadequate preparation for positions, is the third factor leading toward adequate public training for public service in Germany. The qualifications for the higher paid positions are stipulated in state law. Both theoretical training and practical experience are required. These requirements apply in fact, though not in form, to burgomeisters for which, under the Prussian law at least, no specific qualifications are laid down. For the higher positions, less and less importance is being attached to a purely legal training and preparation. "It is felt that for an official who has to administer finance, commercial enterprises, education, poor relief, and above all to manage men, other qualifications are more necessary, such as a thorough grasp" of the economic and social sciences. This trend is especially to be noted in the curriculum at the Düsseldorf institution later to be described.

5 The fourth factor lies in the fact that public service is a recognized profession of dignity and permanence in tenure. The oft-repeated assertion that there are *no* politics in German city positions is far from accurate, for in many cities an avowed member of the social democratic party could never be ratified for a leading city position no matter what his worth, while a conservative of the landed gentry point of view would be ratified no matter how incomplete his preparation. But in Germany the provincialism characteristic of so many American cities, which brands experts from other cities or states as "outsiders" or "aliens," finds no place. The result is that a public employe with adequate qualifications, who finds himself blocked in one city because of his party affiliations, can look toward employment in other cities. A position once secured, a tenure for life or for a term of 12 or 24 years is assured, followed by a pension at the end of service. Over 40 per cent of the officials in general administration and under 30 per cent of those in the technical departments are appointed for life. Moreover, promotion is made from city to city so that there is no limit to the economic returns and social prestige of

public official of competence and skill. Even the burgomaster and the leading expert advisers in the magistrat are chosen at will n other cities. The salary, moreover, is adequate to attract the talent, and increases in remuneration follow at specific intervals. national laws frequently provide that appointees to certain tions shall have stated professional qualifications, but all examina- s are qualifying and not competitive. The state examinations ely determine eligibility and within the large list of eligibles, the istrat has full discretion in choosing officials.[1] Probationary ods of service without salary or for a nominal payment, promotion he recommendation of superior officers, with due regard to merit experience, security of tenure, protection against arbitrary dis- al, exclusion of civic employes and officials from all participation ection campaigns, all these features of American civil service find ace in the German system. But the arbitrary provisions char- :istic of American civil service, such as that the appointing official mited in his choice to the three highest, finds no place in the nan régime. The result is freedom of choice by an employing al who must have the best talent and get the best results within expenditures, for pressure of the tax is as keenly felt in German s as in American cities.

The fifth factor making for the inculcation of efficiency prin- s in the German municipal service is the fact that the great public ies such as the street railways, gas, rail and waterways, are publicly ed and operated. This means that not only the best paying posi- s but also the positions carrying with them social prestige and r, are within the gift of the state rather than in the power of ate corporations. The youth of capacity and training turns, efore, by preference to the public service. Then too, as is es- lly pointed out in the Prospect of the Training School for Public ice at Aschersleben, "the numerous obligations which self- rnment and the new social and political legislation put on the inistration show obviously the absolute necessity for the profes- l education of public officers."

The technical training required for the municipal expert in nany is usually afforded by some branch of the regular educational m.[2]

[1] vernment of European Cities, W. B. Munro, p. 178.

[2] rman schools can be divided into the following two classes: (*a*) State in- ions: (1) Those which are supported entirely by the State, and (2) for which private corporations furnish a share of the cost; and (*b*)

8 In the first place, there are the great technical universities everywhere maintained by the individual states, in which technical training of the most definite and specific kind can be obtained for either public or private expert work. At the present time there are 11 great scientific universities, the organization of which is under the control of several states of the German Empire.[1]

9 Below the highest technical institutions are two grades of machine trade or mechanical engineering schools,[2] those providing for the training of engineers, constructors, foremen, machine draftsmen, etc., and those of a lower grade which train machinists, mechanical draftsmen and technical officials of middle rank and others preparing for positions that require a less highly developed technical ability. To both these classes of schools are often added Sunday and evening courses, open to workmen who cannot afford to give up work entirely and attend school.

10 Technical preparation for expert work in building trades can be secured in the fifty odd building-trades schools in Germany, most of them with two departments: architectural (Hochbau) and civil engineering (Tiefbau).[3]

11 Technical preparation for the industrial arts can be secured in either one of the following groups of art trade schools: industrial continuation schools for the art classes; schools for hand-crafts; schools for industrial art and hand-crafts, and industrial art schools.

Local community institutions, either pure community institutions or those to which either the State or local organizations contribute.

There is a third class of institution, supported by associations and unions, which is not carried on for gain, but which requires considerable financial assistance from both the State and the city.

[1]Brunswick, Berlin, Karlsruhe, Munich, Dresden, Stuttgart, Darmstadt, Aix-la-Chapelle, Hannover, Danzig, Breslau. (Vocational Education in Europe, Cooley, p. 172.)

[2]The higher of these requires greater academic preparation and a longer course of study. Into the second will be admitted those without a complete secondary education but who have, at least, one year of practical training. The *Höhere Maschinenbauschulen* is a real secondary technical school, the condition for admission being the completion of the six years' course in the academic secondary school, together with practical work in shop or factory for a period of two to three years.

[3]In this latter department are included courses for civil engineering, road, street and railway building, hydraulic engineering and bridge construction, and sometimes irrigation and drainage. (Vocational Education in Europe, Cooley, p. 144-145.)

These prepare thoroughly skilled laborers. Every endeavor is made to adapt the study to the particular industrial conditions of the locality.

12 Preparation for other special positions requiring technical preparation can be found in the continuation schools, in the textile schools, in the technical schools for woodworkers, in the commercial schools, many of which are also supported by the leading commercial and labor organizations of the country, in the modest classes conducted in winter evening hours by the light of the oil lamp in the low school room of the villages. By the end of 1912 there were in Germany 4400 industrial and trade continuation schools of a more or less urban character (attendance 630,000), 5200 rural continuation schools (attendance 84,000) and 17,000 general continuation schools.

13 One characteristic of the preparation often required in Germany is that some practical experience is required for admission. Practical work means shop or factory work under actual conditions. In the foundry it means driving and attending to machinery. The student must put in the full number of hours of work and submit to the rules and regulations of the work like any other workman.

14 But general school training can not make the efficient employe. There are at least two other prerequisites. The first is specific preparation of a kind that could not be expected in a general university, and the second is particular training for those who are employes and officials in municipal service. To meet these two needs, a number of strictly municipal institutions have sprung up in Germany. These schools include the special training schools for employes of certain departments, such as the training school for policemen and the college of town planning in Berlin, and the school for the training of police officials at Ludwigshafen.

15 A definite movement for local municipal colleges is on foot in Hamburg, Frankfort-on-Main, Cologne, Dresden and Posen, and the small towns of Altdorf, Willenberg and Helmstedt, all three of which had their own universities in the past and want them renewed.

16 Other schools in Prussia are those at Düsseldorf, Hagum and Bochum. In Berlin instruction is given in some of the continuation schools to young people who wish to prepare for the lower grades of the municipal service. In Saxony there are schools for communal officials at Cottbus, Nerchau (the latter with 145 pupils in training in 1911), and Aschersleben. Similar schools are the Munich (Bavaria) Trade College and, for the Thuringian States, a two-years course at Eisenach "on such courses as local finance and taxation,

education, poor relief, town planning, police functions and social legislation."[1] Dortmund in Westphalia has recently established a college for the administrative and social sciences.

17 The work and functions of these new universities can best be expressed by a special study of two of them rather than generalized comment on all of them. For this purpose are chosen the Akademie für kommunale Verwaltung zu Düsseldorf and the Erste Preussische Verwaltungs-Seminar zu Aschersleben.

18 The purpose of the academy for municipal administration in Düsseldorf, opened for work in the autumn of 1911, is to strengthen and broaden the knowledge of, and to offer a scientific and practical training to municipal officials, and to give business-like, scientific and practical education to persons intending to enter the municipal service. A survey of the courses offered and the methods employed indicates that the academy is primarily an institution for the further training of the higher municipal officials.

19 The academy is not an independent legal entity but a municipal institution of the city of Düsseldorf, established by the city council thereof. The Kuratorium or board of directors comprises the chief mayor, six members of the city council, representatives from other local governmental units and representatives from the Academy faculties. The first budget comprised about 50,000 M. inclusive of the cost of fitting up a municipal building for the purpose. The teaching staff is composed of (*a*) official expert teachers, heads of departments, appointed with the sanction of the Kuratorium, (*b*) expert teachers who offer lectures for each academic year, and (*c*) honorary experts, who offer lectures for a specified time on selected subjects, thus giving to the college the assistance of the best scientists and specialists, and (*d*) leading state and municipal officials, (*e*) scholars and (*f*) former professional men who are procured for certain discourses.[2] While the academy is thus under municipal control and supported by municipal grants, it is subject to state supervision by the minister of ecclesiastical and educational affairs.

[1]W. H. Dawson, Municipal Life and Government in Germany, p. 115.

[2]The chief mayor appoints the director of studies, after confirmation by the college faculty and the city council and appoints, with the approval of the faculty, all the other classes of teachers. (Satzung der Akademie für kommunale Verwaltung in Düsseldorf). As a rule, instruction is offered by men who are lecturers in universities and by experts in particular fields of municipal administration. Purely administrative matters pertaining to courses, attendance thereon, the ratification and approval of all the teaching staff, save only the director, rests upon the faculty of the school.

20 The course of study is so arranged that advanced students can complete requirements for the examination in two semesters of about 25 weeks of study each. Students are advised, however, to take two years of two semesters each, before attempting the examination.[1]

21 The courses offered include the following subjects: Constitutional rights; governmental rights; the police power; social questions; school and sanitary administration and legislation; insurance law; road law; economics; agricultural economy; political science; sociology; resources of the country; national economy; lawful rights of government; organization of city, state and nation; efficiency in government; science of finance; taxation law; money and banking; public works; the city's utilities; statistics; building regulations and administration; cultivation of prosperity and of refinement; defense of the country; the labor question; relief of the poor; business law; practical work in administrative law; municipal finance and constitutional law "with special reference to the work of present and future city officials"; criminal law and procedure; the poor law; administrative law; labor union laws and their interpretation; criminology, hygiene and commercial and financial bookkeeping.[2]

22 The analytical, practical and thorough character of the courses offered may be gleaned from the content of selected courses. Thus the course in the science of law includes the foundation principles as to the rights of citizens and the rights of officials; purchases, leases, deeds and their characteristics; indemnity obligations of the community; earnings and laws of properties; real estate law, rights of mortgages, the authority of parents and the power of the respective governments as guardians; the rights of associations and of business; commercial law; the foundation principles as to state, rural and city administrative law; the constitution of the state of Prussia, the Imperial constitution, the rights of administrative organs of government, the police power and the general position of the police including the safety and sanitary police. The course in taxation law includes discussions of the various kinds of taxes, such as professional and occupation taxes; concessions; beer, dog, amusement and other indirect general taxes; double taxation; the increase in taxes and the value

[1] Of these two semesters, one extends from the end of October to the end of February and the other from the middle of April to the middle of July in each year. The period of study can begin with the winter or summer semester. (Satzung der Akademie für kommunale Verwaltung in Düsseldorf.)

[2] "Akademie für kommunale Verwaltung zu Düsseldorf."

thereof; the relation between city, district and provincial taxes. Insurance law includes a history of public insurance, the details as to sick, accident and invalid insurance, the relation of the insured to each other. The course in statistics includes discussions as to the nature of statistics, statistical methods, technique in presenting statistics, the principal province of governmental statistics, etc. Thorough-going courses are offered in political economy with special application to the protection of properties and the development of new industrial opportunities. Efficiency in governmental administration is likewise taught as is "the cultivation of prosperity" in the different communities and the inculcation of the proper doctrines as to a national program for industrial supremacy. In the course germain to pure water for the city are given complete geological data. In short, the courses include minute, reliable, thorough-going investigations into the legal, social, economic, political, industrial and even geological ramifications of the municipal official's duties and responsibilities.

23 Of a significance equally as great as the practical and far-reaching content of the courses is the practical work required of the students before graduation. Following each lecture, and presented in a way leading from the less to the more complex, certain important, practical questions are taken up in a very intensive manner. These reports, on practical questions, prepared by every student, are in form partly written and in part a compilation of material. They may be presented in loose form or perhaps in the form of a bound work. These assigned reports on practical questions are prepared under the supervision of the expert in charge of the course and are so chosen and conducted as to bring the student very close to the local administrative machinery and to the definite problems in his own field, and, more than this, inculcate methods of research on daily practical questions of incalculable value in later public service.[1]

24 After careful and conscientious attendance, and upon the completion of the lectures and the required practical work, candidates may be admitted to an examination.[2] This examination in-

[1]Ratschläge für die Einrichtung des Studiums an der Akademie für kommunale Verwaltung zu Düsseldorf.

[2]The announcement of one's intention to take the examination must be made at least fourteen days before the end of the second semester, and the announcement must contain, with other things, the following: (*a*) A sketch of the life of the candidate; (*b*) school records and evidences of practical activity; (*c*) a statement of the subjects that have been most interesting to the student at the Academy, and the subject of his written work; (*d*) a statement as to when his required written work will be completed or a request for

a "task" to be written at home. This written work must be ed within four weeks after the assignment of the task. In ion to the home work, some special work will be given which iot take more than four hours. In doing this work, the candidate have one-half hour for preparing himself without help. More-there is required a theme in the field of economics, social politics public finance or a theme in the general field of economics and ce. Then follows an oral examination of 20 to 25 minutes in h. This examination covers: (*a*) state, communal, national iization including the rights of officers; (*b*) administration in-ng school, industry, the poor, transportation, buildings, insur-questions of eligibilty of holding office; (*c*) science of economics; political economics, agricultural industry, trade; (*e*) political e and social politics; (*f*) finance. At the completion of the nation, the candidate receives a diploma from the chairman of uratorium and from the director of studies.[1]

In the academy's first year, there was a total attendance of gular students and 49 matriculated students. During the winter ter of 1913-14 more than 18 different courses of lectures were by a force of 16 instructors.

Quite in contrast to the Düsseldorf academy, which trains rily the higher officials, is the Professional Training School for Service at Aschersleben which offers courses preparing primarily e one year probationary service, the middle and lower classes of employes, and for promotion from a lower to a higher grade of e.

The stated purpose of this institution is "To give to young is the general and professional education necessary to enter the service career as a minor or middle officer." The course gives same time an opportunity to prepare for higher municipal ad-trative positions such as mayors in smaller towns and the higher in the larger towns. Preparation for the highest posts usually es a degree of training equal to that for the degree of Ph.D., h one reason for the establishment of the practical school was to lief from the theoretically trained Ph.D.

The duration of the general course is three years. The school ffers a one-year special course for the training of minor civil

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service employes under governmental, provincial and administrative boards, as well as a one-year continuation training course for the career of minor municipal officials. The school also provides a three-months' continuation course for those in military service who may desire to prepare during compulsory army service for minor governmental positions. To take this course the student must get leave of absence from the military authorities. He receives his regular pay and in addition 13 pfennigs (3¼ cents) per day for expenses.

29 The curriculum includes three general classes of subjects: (*a*) scientific courses such as German, mathematics, history, geography, French, English, chemistry and physics, (*b*) professional courses such as jurisprudence or general legal knowledge, constitutional and administrative law, social administration, political economy, public finances, the science of taxation, the budget, and the treasury, and (*c*) applied courses such as typewriting, stenography, drawing, accounting, bookkeeping, arithmetic and German. Definite practical work is required in all courses. On the whole, therefore, this course is at once narrow enough to prepare for definite positions and general enough to be of life-long stimulating value. All young persons over 14 years of age, who have a "public school education and possess some knowledge of the French and English languages" are eligible to the entrance examination into the general three-year course. Those long from school must present a police "certificate of conduct." On every pupil is imposed the duties of showing himself worthy of public service by attention, zeal, high morals, clean conduct and good habits.

30 Graduates of the institution are assured in the school's announcements that they will be prepared as well for "private service such as factory clerks, cashiers, correspondents, office clerks and similar positions." Special emphasis is placed, however, on positions in the "imperial administration, railway management, coöperative and insurance associations, street railways and other utilities, taxation boards, administrative courts, and similar city and governmental bodies." Aschersleben is urged to be just the place for training for the public service because "it is provided with all such modern accommodations as aqueducts, canals, municipal baths, gas and electric works, hospitals, slaughter houses, etc.," which serve as laboratories for practical training.

31 The student is drilled so that he can hunt up and understand the decisions of the civil and administrative courts. The instructors are employed teachers and the public officials of the city of Aschersle-

ben. At the end of the one year, the tuition for which is 150 M., there is a final examination in the presence of a state examiner, the chief burgomaster of Aschersleben and invited members of the Central Alliance of Prussian officials on the basis of which a final graduation certificate is given. With the institution is connected an employment bureau.

32 On the whole therefore both these institutions provide training both for the initiate and for the official or employe already in service. The Academy at Düsseldorf gives preference and special attention to burgomasters and other of the higher city officials. The seminary at Aschersleben is especially adapted to the lower civil service positions. Both offer what may be called "continuation" courses.

33 The "prospect" of the school at Aschersleben points out that municipal administrative boards are already requiring a certain degree of preparation in the very courses offered in the institution, and the Central Alliance of the Public Officers of Prussia has passed a resolution requesting the Royal Government "to come out strongly for an elementary, intermediate and advanced (continuation) training of all public officers corresponding to the conditions of the times. . . . The central association greets all professional institutions which, in the spirit aforesaid, will be strenuous in raising the efficiency of public employes. From those pupils who do not possess already the scientific qualifications necessary for the one year voluntary military service will be required general scientific preparation requisite to the passing of the one year probationary examination, and the municipalities should uniformly require for entrance to the middle posts in the public service a certificate showing these educational qualifications."

34 Both schools assure such educational qualifications, and their pupils are given preference in appointments. Indeed the catalogues of the institution at Aschersleben state that the constant demand in public employment for the well educated assures "even the youngest students" that they can "early get into good positions in which they can create for themselves a secure future."

35 The need for further specialized training in America is to be measured by the extent to which existing educational institutions are meeting the rapidly rising demand for well-trained public officials who can look to permanency in the public service.

36 The universities of our country are already doing a splendid

work in providing for the public service. Through the activities of the Committee on Practical Training appointed by the American Economic and Political Science Associations, our universities are beginning to make an extended use of the agencies for practical training available on every hand, such as the practical work by graduate and well-equipped undergraduate students in tax, railroad and industrial commissions, investigating boards, state boards of public affairs, city departments, boards of health, finance commissions, bureaus of municipal research and the different federal agencies in Washington. All the various universities now offer courses in constitutional law, in municipal government and allied subjects. University faculties are being called on extensively for practical work.

37 In America, as in Germany, however, there is a distinct movement toward local institutions for specialized training. There are now, as in Germany, a few strictly municipal universities. Leading among these are the University of Cincinnati and The College of the City of New York. The city council of Akron, Ohio, has recently taken over Buchtel College, and established a municipal college under the name of the University of Akron. Cleveland, Ohio, is looking toward a municipal university made up of the local institutions including the Western Reserve University. In Philadelphia a municipal educational committee was appointed by Mayor Blankenburg, at the suggestion of Morris Llewellyn Cooke, Director of the Department of Public Works, for the purpose of furnishing expert educational guidance and assistance to municipal employes; nothing more definite came from this commission than evidence of the need for thorough practical training of public employes in the city's educational institutions.

38 This survey of what certain German institutions are doing and what American universities are offering leads to these definite conclusions: (*a*) While American universities are doing much, they are not offering the practical, definite preparation for public service that is being offered by certain German institutions; (*b*) that the courses of study offered and the plans for municipal colleges in Germany point to endless possibilities for adaptation in the courses and work being offered in American colleges and universities; (*c*) to the end that the public employe may be more adequately and efficiently trained, our colleges and universities can extend with profit to themselves and to the public, the number of definite, practical courses offered in their institutions; and (*d*) particular attention can and

should be given to the preparation for special types of public service in certain of our educational institutions. One or two of the universities in the larger cities can prepare definitely for municipal service, others for the consular and diplomatic service, others for state service, others for service in departments of health and sanitation, while others can prepare experts in engineering, social, financial and accounting fields; and (*e*) there is a need in America for a few institutions offering specialized training for the public employe who has had his technical preparation, such as is given in the Academy for Public Administration at Düsseldorf and the Professional Training School for Civil Service at Aschersleben. This last class of schools is particularly necessary for the enhanced efficiency of large numbers of our public employes.

DISCUSSION

JAMES J. YOUNG[1] (written). Are our courses to be offered chiefly for the young college student who thinks that he may enter the public service, or for the city employe who is already busy at his work? Much depends on which of these two classes we choose as our chief clientele. Heretofore we have taken for granted that the young college man was to be the source of our future supply of city experts. Most of our plans have been based on this supposition. I feel strongly that we should work chiefly in the opposite direction, and should so arrange our courses that they will appeal to and help the man who is already active in city employment or the practising engineer who, after having seen the problem from a point nearer its center, has decided that he wishes to devote himself to city work. Both of these types of men are far more valuable for our purposes, that is, the purpose of providing and training an adequate supply of scientific technical city administrators and experts, than is the young college student.

We need a sharper distinction between the general course on city government and the technical highly-specialized course on sanitation, housing conditions and methods, city transit, labor, accounting, finance, etc. Thus far we have tried to cover all these fields and have therefore presented in a single course a group of studies which are too general for the technical student and too technical for the general student.

With the new attention to the subject which is now arising, we must have a clearer notion of the class of men and women who are

[1]Univ. of Penna., Philadelphia, Pa.

to be trained, a relegation of the general courses to the field of general education of college undergraduates, and a more extensive development of the highly specialized technical subjects for small classes of professional men and women. This means a change in the cost of instruction, in its location, and in the time at which it is given. It involves the raising of funds, which would be by no means difficult, for special courses to be given at the large city university, or in the city hall under university auspices. There are numerous philanthropic persons in every city who would regard an appropriation for this purpose as a pleasing variety from the money which is now spent in political reform. This plan also involves a complete transfer of the technical work to the evening, in order that it may be pursued by those who are already engaged in engineering municipal employment or other vocations.

Such a sharp distinction between courses based on a clearer view of the clientele to which they are to appeal would lead to a different development from that which has taken place in Germany, but would I believe answer more fully the distinctively American needs for that training of municipal servants which the paper so admirably describes.

JOHN A. FAIRLIE[1] (written). I would like to call attention to one or two matters noted in Dr. King's interesting and valuable paper. The professional schools in the state and private universities in this county are giving professional training in engineering, law and medicine, offering special preparation for the municipal service; and the University of Michigan has announced a graduate course in municipal administration, made up of courses in several of the schools of that university. In several states, there are associations of municipal officials which hold their meetings and carry on their work in coöperation with the state universities (as in Wisconsin and Illinois). Special mention may be made of the Illinois State Water Survey, which is located at the University of Illinois and works in active coöperation with water supply officials, both of cities and water companies, and with the Illinois Water Supply Association which meets annually at the University. The Illinois Municipal League met at the State University this year, and voted to meet here again next year; and it has been suggested that the University should offer for city officials a series of one or two-week courses in municipal subjects similar to its short courses in agriculture.

[1]Univ. of Illinois, Urbana, Ill.

There is undoubtedly need for further development of special aining for municipal officials, and this will require the active co-eration of our educational institutions, public officials and the embers of the several technical professions.

H. S. GILBERTSON[1] (written). There are both an academic and so a practical reason why a profession of public service has not been veloped in this country long before this. The academic reason is at there has been a fear on the part of a large number of political aders that democracy would be endangered by a permanent and ghly-trained civil service; that we should drift gradually into ureaucracy and all it entails. The practical reason is that another, d a very large element in political leadership has desired for party asons to control appointments to public office.

So long as this latter condition prevails, it is perfectly obvious at efficiency and fitness are minor considerations and public serv- will be repellant to men of high qualifications, but happily present nditions afford much hope that both the academic and the practical jections to a trained civil service will gradually disappear.

Civil service reform also obviously favors the trained man. The erit system in the civil service as now administered was primarily vised as a method of eliminating politics and the most unfit ap-icants for public office from the lower grades of the service. But vil service reform is now developing in new directions and is cor-cting some of its mistakes, and there is a tendency to make records efficiency the basis of promotion. This undoubtedly will favor t only a higher degree of preparation on the individual's entry to public service, but a certain standard of performance will be ade the price of remaining in the service. This should so dignify vil service that a higher type of men will be attracted to it.

Still another movement which I think will greatly favor a trained dy of public servants is the application of the principle of the hort Ballot, which, when carried to its logical limits, will produce much sharper distinction in the public mind between politics on e one hand and administration on the other.

There is coming to be a general recognition on the part of all telligent people of the need for better trained public officials. Peo-e are beginning to see that, when everything else is being subjected high efficiency tests, government cannot much longer be run on e haphazard plan which has obtained in the past.

[1]Exec. Secy., The National Short Ballot Association.

No. 1456

[THE DESIGN AND OPERATION OF THE CLEVELAND MUNICIPAL ELECTRIC LIGHT PLANT

By Frederick W. Ballard, Cleveland, Ohio

Member of the Society

The new municipal lighting and power station in Cleveland, which recently been completed and has been in operation since July 20, .4, is the largest central station in this country to be built by a nicipality. The design and operation of this plant will be of conerable interest to engineers, as well as to the public generally, both reason of the magnitude of the undertaking, and because of the ny new features to secure maximum economy.

2 The higher efficiency and greatly decreased unit cost in the pro-tion of power in large central stations, compared with small plants, oming to be a well recognized factor in power plant engineering. the same time, the item of power costs in manufacturing is one of largest and most important, and any material reduction in this item alone will make a vast difference in the cost of production a large variety of goods. In any city which can, by the operation a large central power station, furnish power to a large portion of factories at a cost of from one-half to one-third of what their costs l been when they made their own power, a wonderful advantage l be afforded to manufacturing.

3 It does not seem to be generally realized how much the cost of ducing power in central stations depends upon the load factor, nor v much the unit cost can be reduced by making proper use of the ersity factor between lighting and power loads, as well as between erent classes of power loads. Nor does there seem to have been ch attention given to the important fact that with power rates m central stations sufficiently low, a more desirable class of power tomers can readily be secured, whose long hours' use produces a st desirable effect upon the load factor with a cumulative effect

Presented at the Annual Meeting, December 1914, of The American So-ry of Mechanical Engineers.

toward lowering the unit cost of producing power in the central station. Central power stations, whether privately or publicly owned, are to a certain extent coöperative institutions. Both the central station and the customer should be mutually benefitted by every advantage which the station can secure tending toward the lowering of unit costs. The fact that lower rates to power users aids in securing a better load and a better load factor, which of course lowers unit costs, seems to have been overlooked. In this way a policy of altruism

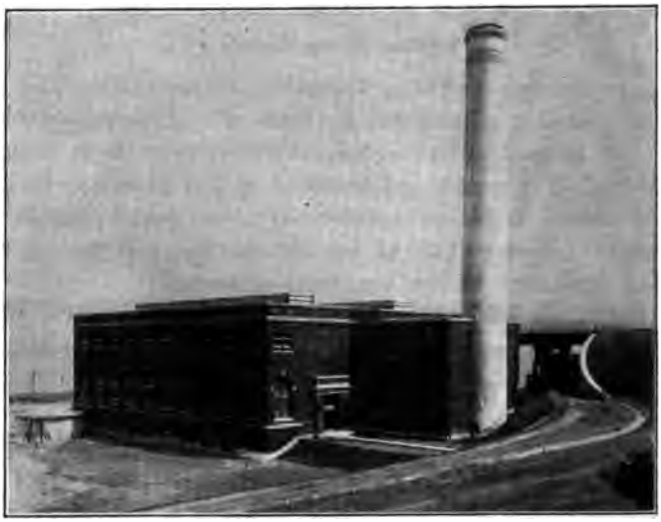


FIG. 1 EXTERIOR VIEW OF THE CLEVELAND MUNICIPAL LIGHTING PLANT

effects not only a great benefit to the community, but reacts with its compensation of lower unit costs to benefit the central station itself.

THE CLEVELAND MUNICIPAL LIGHT PLANTS

4 The city of Cleveland now has three electric light plants under municipal ownership and operation. There is a small plant in the extreme eastern section of the city, known as the Collinwood Station, which was acquired in 1910 by the annexation of the village of Collinwood to the city of Cleveland. This plant has a capacity of 750 kw., and its equipment consists of five horizontal return tubular hand-fired boilers, and two simple non-condensing Corliss engines. This station is now supplying 1787 customers, who are scattered over 4½ sq. mi. of territory.

5 The second plant, known as the Brooklyn Station, is located in : extreme southwestern section of the city, and was acquired by the y in 1906 by the annexation of the village of South Brooklyn. This nt now has a capacity of 1500 kw., and its equipment consists of) steam turbines of 1000 and 500-kw. capacity, running with jet idensors in connection with a cooling pond, the vacuum averaging out 25 to 26 in. This station is equipped with water tube boilers, l operates at 150-lb. steam pressure without superheat. It is supply- ; current to 4881 customers, and its distribution lines cover a terri- y of 10 sq. mi.

6 The new plant (Fig. 1), which has recently been completed by : city, is known as the East 53rd Street Station. It has a maximum acity of 25,000 kw., and is intended to supply current for lighting l power purposes throughout the entire territory covered by the city Cleveland. A floor plan of the plant is shown in Fig. 2. This plant s built from the proceeds of a bond issue by the city of Cleveland ounting to $2,000,000, about one-half of this amount being invested the station itself, which is now completed. The other half is to be ested in the distribution system, including overhead and under- und lines, and the substations. In addition to the $2,000,000 ived from this bond issue, there is also available the proceeds of a id issue of $500,000 voted by the city council to supplement the ginal bond issue of $2,000,000, making a total amount of 500,000, to be invested in the distribution system. The value of : present distribution systems connected with the Brooklyn and llinwood Stations is about $500,000. This then will make the total ue of the East 53rd Street Station, together with its distribution tem, equal to about $3,000,000. The operation of the Brooklyn ation is to be discontinued. The machinery which is installed there- will be removed, part to the main station at East 53rd Street, and rt to the substations. The operation of the Collinwood Station is be continued for the present.

HISTORY OF THE BROOKLYN STATION

7 The record of the Brooklyn Station has been one of continuous owth. From the small plant built by bonds issued in 1902 of 0,000, until in 1914, when it was taken into the general distribution tem connected with the large central station recently built, it had otal investment value of over $500,000. The largest part of this restment had been made from earnings of the plant, which had

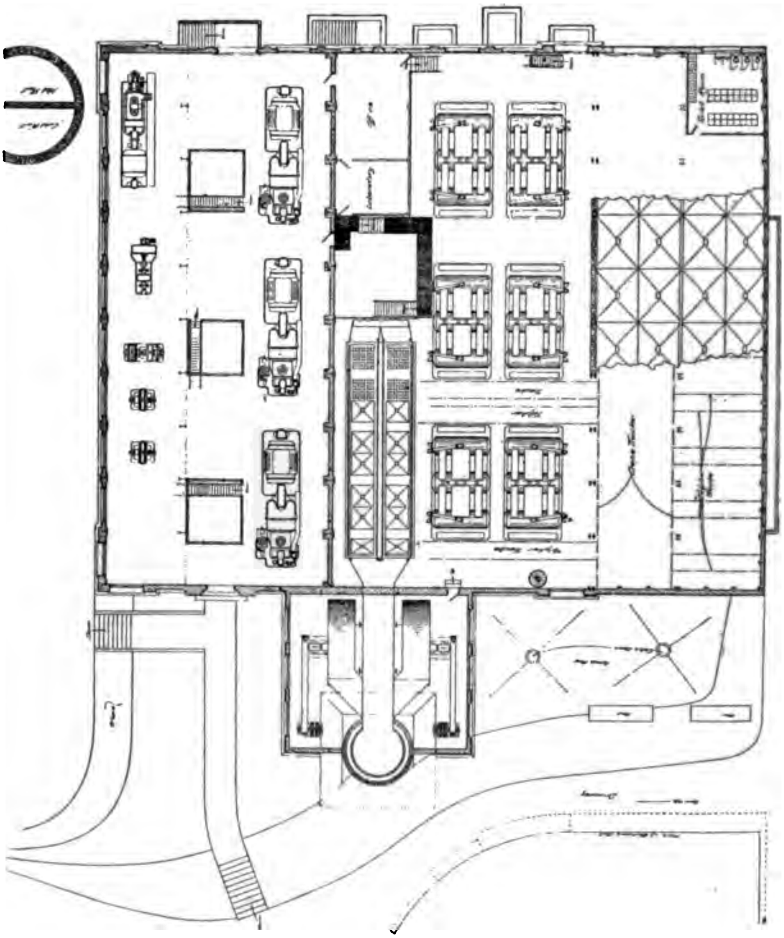


FIG. 2 FLOOR PLAN OF THE CLEVELAND MUNICIPAL LIGHTING PLANT

een turned back into new equipment for the station, and extensions f its distribution system. Table 1 shows in a condensed statement he financial record of this plant. The records of the village of South

TABLE 1 ANALYSIS OF PLANT VALUE OF BROOKLYN LIGHTING STATION AND DISTRIBUTION SYSTEM

Bond issue 1902			$30,000.00
From taxes 1906–1909	$101,129.75		
From general fund 1906–1909	219,666.49		
		$320,796.24	
Value of street lighting 1906–1909		109,147.02	
Amount added to plant value from taxes and general fund 1906–1909			211,649.22
Added to plant value from earnings:			
Prior to year 1910		$97,528.69	
Year 1910		23,856.78	
Year 1911		41,223.36	
Year 1912		77,302.08	
Year 1913		66,622.30	
			306,533.21
INVESTMENT IN PLANT DECEMBER 31, 1913			548,182.43
Depreciation written off to December 31, 1913			113,244.19
DEPRECIATED VALUE OF BROOKLYN STATION, December 31, 1913			434,938.24

Brooklyn from 1902 to 1906, show very little extension to the plant, but from 1906, when the plant was acquired by the city of Cleveland, to 1909, the city's records show $320,796.24, appropriated from taxes and general fund for electric light purposes, of which $109,147.02, are classed as earnings by the plant for street lighting service furnished to the city of Cleveland, leaving an amount of $211,649.22, as added to plant value from taxes and general fund during this period. Prior to 1910 there had been a total of $97,528.69 added to plant value from earnings. From that time on, there has been a steady increase in the amount which the plant has been able to turn back into new equipment from earnings, making a total amount which this plant has added to its plant value direct of $306,533.21, giving a total investment value of $548,182.43, more than half of which was acquired by its own earnings. Depreciation which had been written off up to December 31, 1913, is $113,244.19, leaving an actual value of this station and its distribution system of $434,938.24.

8 The record of this station has been such as to inspire confidence in the proposition which the city of Cleveland is now working out, and in order to set forth more complete the data which has led to the

TABLE 2 REVENUE AND EXPENSE STATEMENT FOR YEAR 1913

Total revenue from sale of current for year 1913	$185,698.81
Kw-hr. generated. 7,797,661 Average sale price..$0.0238	
Kw-hr. sold...... 5,656,668 Average sale price..$0.0328	
Total operation and maintenance expense for year 1913	$116,719.55
Kw-hr. generated. 7,797,661 Average cost price..$0.0149	
Kw-hr. sold...... 5,656,668 Average cost price..$0.0206	
Net earnings	68,979.26
Fixed charges—depreciation and interest	19,079.50
Kw-hr. generated. 7,797,661 Average cost price..$0.0024	
Kw-hr. sold...... 5,656,668 Average cost price..$0.0033	
Profit for year of 1913	$49,899.76

TABLE 3 POWER STATION REPORT FOR YEAR 1913

Operation		Unit Cost
Labor	$23,050.25	$0.0029
Oil, packing and waste	1,538.52	
Water	3,110.00	
Sundry expense	743.32	0.0007
Coal	39,275.42	0.005
Maintenance		
Buildings	$105.85	
Boilers	3,515.98	
Engines and generators	3,449.72	
Condensors and piping	606.91	
Switchboard	153.48	
Tools	223.81	
Arc light equipment	661.88	
Sundry repairs	246.21	0.0011
Total operation and maintenance	$76,681.35	0.0097
Total kw-hr. generated	7,797,661	

undertaking of the city of Cleveland to install a large central station, and to sell current for lighting and power purposes at a price never before attempted, the Tables 2, 3 and 4 showing revenue and expense from this station are given.

TABLE 4 DISTRIBUTION SYSTEM—OPERATION AND MAINTENANCE FOR YEARS 1912–1913

	1912	1913
Poles and lines	$7,342.53	$8,203.32
Arc lamps	2,241.68	4,845.53
Meters	334.12	486.68
Tools	197.25	213.69
Wagons, harness, etc	582.16	760.28
Stable expense, feed, etc	1,134.86	1,935.57
Carbons and globes	2,219.08	2,735.80
Trimming labor	2,811.25	2,437.48
Services, transformers, etc	3,224.87	6,166.62
Miscellaneous expense	573.40	1,084.94
Auto truck	....	923.61
Substation maintenance	....	2,054.98
	20,661.20	31,846.50
Kw-hr. generated	4,611,853	7,797,661
Cost per kw-hr. generated	$0.00448	$0.00408

9 The figures from these tables show an average cost price of the total kw-hr. generated in the station, and including everything for which money was paid during the year 1913 of $0.0149, and an average cost price for the current actually sold and delivered to customers of $0.0206. It will be noted that the total operating costs of $0.0097 and the distribution costs of $0.00408 leaves an item of $0.00112 per kw-hr. as administration charges. A close analysis of the figures in the tables shows that in many cases these costs could be greatly reduced by the operation of a system on a large scale, and by the efficiencies which will be obtained in the new power station. The item of cost in central station work which has usually been considered the most uncertain and problematical, and therefore most likely to stand in the way of success for municipalities, is the cost of distribution. The costs for operation and maintenance of the distribution system connected with the Brooklyn Lighting Station in Cleveland, becomes, therefore, of particular interest, and the itemized costs set forth in Table 4, establishes a certain definite value for this feature.

BASIS FOR ESTIMATING RESULTS IN EAST 53RD STREET STATION

10 In building a large central station, like the one at East 53rd Street, and in announcing in advance the results to be secured therefrom, as well as the rates at which current is to be sold at a profit, it was of course necessary to make certain definite assumptions in regard

to the costs of the various items of expense similar to those set forth in the tables representing costs of Brooklyn Station, and at the same time to take carefully into consideration the lower costs which could be secured by the efficiencies which could evidently be obtained. Where any element of uncertainty existed, as to just how much these costs could be lowered, then the figures secured in connection with the operation of the Brooklyn Station have been used, this tending to place the estimates upon a very conservative basis. It was first necessary to make an estimate of what should be allowed for fixed charges, and these to consist of the interest on the investment, allowance for depreciation, or amortization, and also a due allowance for taxes, which of course the city does not have to pay, but which should be properly allowed for because the city's tax income is by that amount reduced.

11 The bonds which have already been sold to secure funds for the construction of this station, and its distribution system, bear interest as follows: the original $30,000 issued in 1902 by the village of South Brooklyn bear interest at the rate of 5 per cent. Of the other bonds sold recently, $700,000 bear interest at 4 per cent, $500,000 at 4¼ per cent, and $800,000 at 4½ per cent, making an average rate on the bonds outstanding of 4.27 per cent. There are still $500,000 worth of bonds to be sold, and in addition to this, there is a plant value which has been secured by investments from taxes and earnings of approximately $470,000 more, making a total bonded debt of $2,530,000 which, with the original plant value of the old stations, will give an investment of $3,000,000. It would certainly be very conservative to allow for an average interest rate on the whole investment value of 4½ per cent. The tax rate can be conservatively estimated at 1½ per cent, and the rate to be allowed for a reserve fund for depreciation, or what really would better be known as an amortization fund, since depreciation, obsolescence, etc., will be taken care of from the maintenance fund. The amortization fund should be taken care of by a rate of 3 per cent, this rate for use as a conservative allowance, because 2.92 per cent of the original cost invested annually at 4 per cent compound interest will equal the original investment in 22 years. These rates for interest, taxes and depreciation call for an annual allowance to cover fixed charges of 9 per cent of the original investment.

12 In order to arrive at the estimated unit cost for the fixed charges, it was necessary to assume a certain total output for the station for a year. A 40 per cent load factor is generally considered very good in central station work. There is no question, however, but

that under good conditions a load factor much better than this can be secured. Assuming a 40 per cent load factor in a peak load of 18,000 kw. would give a total output a year of approximately 60,000,000 kw-hr. Fixed charges for the entire plant investment of $3,000,000 rated at 9 per cent would amount to $270,000 per year, and on the basis of a 60,000,000 kw-hr. output, the cost per kw-hr. to cover fixed charges would be $0.0045 or $0.0015 for the station cost and $0.003 for the distribution cost.

13 In regard to the proper estimate on unit cost for coal, sufficient data are available from the known efficiencies of stations of this kind to warrant an estimate of $0.002 per kw-hr. being used, the price of coal ranging from $1.60 to $1.70 per ton, with a thermal efficiency of from 13,000 to 13,500 B.t.u. per lb. of coal.

14 Many data are also available in regard to unit costs for labor, maintenance and sundries in a station of this character. In a paper on Power Costs by Rhodes in the Proceedings of the American Institute of Electrical Engineers for February 1912, he gives a total value for this item of $0.001191 per kw-hr. This figure corresponds closely to an estimate made in regard to these items from figures secured from Brooklyn Station and others, compared with conditions which will obtain in the East 53rd Street Station. However, the value of $0.0015 is included in the estimate of costs for this item for the purpose of being conservative. Under the heading of distribution costs, the estimate includes but two items; one for operation and maintenance at $0.004 per kw-hr., which is the figure already obtained in practice in connection with the operation of the Brooklyn Lighting Station, as explained above in Par. No. 9. In addition to this the item for fixed charges is valued at $0.003 per kw-hr., while under administration charges, the value of $0.0005 is used as being a conservative estimate for this expense, taking into consideration the known amount of cost in connection with the operation of the Brooklyn Lighting Station when setting up the additions which would be required to operate the business on such increased magnitude as would be necessary for the larger station operating the full capacity, and also taking into consideration the increased output from the larger station. These items thus described cover the entire cost of operation and maintenance including the fixed charges of interest, taxes and depreciation, but in order to be perfectly fair in making a comparison with privately owned and operated plants, an allowance should be made for profit of 8 per cent, as this is the amount generally allowed by public utility

commissions in the various states as that necessary to give a market value to the securities of this class of public utility property. 8 per cent on the investment value of $3,000,000 would require a profit of $240,000 per year, and this would be equal to an additional cost of $0.004 per kw-hr., making a total average price necessary to secure for the total kw-hr. generated at the station of $0.0165.

TABLE 5 ESTIMATE ON UNIT COSTS FOR EAST 53RD STREET STATION

Station Costs	Cost per kw-hr.
Coal	$0.002
Labor, maintenance and sundries	0.0015
Fixed charges	0.0015
Total station costs	0.005
Distribution Costs	
Operation and maintenance	0.004
Fixed charges	0.003
Total distribution costs	0.007
Administration Charges	
Administration charges	0.0005
Total amount cost	0.0125
Profit required	0.004
Average sale price required per kw-hr. generated	0.0165
Estimated kw-hr. to be generated	60,000,000

RESULTS OBTAINED WHICH SUBSTANTIATE ORIGINAL ESTIMATES

15 The results which have already been obtained in the operation of the Brooklyn Lighting Station and the East 53rd Street Station during the first eight months of the year 1914, tend to substantiate the original estimates of what will eventually be secured in connection with the operation of the East 53rd Street Station. Following is the statement of revenue and expense connected with the operation of these two stations for the first eight months of this year:

REVENUE AND EXPENSE STATEMENT FOR FIRST EIGHT MONTHS, 1914

Revenue from sale of current for first 8 months of 1914		$153,363.65
Kw-hr. generated. 7,863,610	Average sale price. . $0,0195	
Kw-hr. sold 6,270,726	Average sale price. . $0.0244	
Operating and maintenance for first 8 months		$97,044.60
Kw-hr. generated. 7,863,610	Average cost price. . $0.0123	
Kw-hr. sold 6,270,726	Average cost price. . $0.0154	
Net earnings for 8 months		$56,319.05

The total kw-hr. generated for eight months is greater than the output for the entire year of 1913. The average cost price per kw-hr. generated is $0.0123 as compared with $0.0149 for the previous year.

16 The East 53rd Street Power Station has been in operation since July 20, 1914. The results secured in the way of operation and maintenance costs in the power station itself for the month of August and September are shown in Table 6.

TABLE 6 EAST 53RD STREET POWER STATION REPORT, AUGUST AND SEPTEMBER, 1914

Operation	August	Unit Cost	September	Unit Cost
Labor	$1,498.48	$0.0018	$1,573.00	$0.0017
Switchboard attendance	352.80	0.0004	380.00	0.00042
Oil, packing and waste	....	....	66.89	0.00008
Sundry expense	....	....	10.46	
Coal	2,686.50	0.0033	2,415.69	0.0026
Maintenance				
Condensors, piping, etc	5.48	....	....	....
Total operation and maintenance	$4,543.26	$0.0056	$4,446.04	$0.0048
Total kw-hr. generated	809,120	....	914,850	....

The East 53rd Street Station during these two months has been operating at less than one-fifth of its total capacity. The figures representing unit costs for the various items of labor, maintenance, fuel, etc., are, of course, considerably higher than can be obtained when the station is running up to its capacity, when it will be operating at a much higher efficiency in regard to coal consumption per kw-hr, and also the labor and other charges will be less per unit cost by reason of the larger output. During the month of August, the output of the Brooklyn and East 53rd Street Stations amounted to 1,117,920 kw-hr., of which 936,467 kw-hr. were actually sold to customers, giving a loss in transmission of only 16¼ per cent, the average sale price for the kw-hr., generated being $0.0174 while the average sale price of what was actually sold was $0.0207; the revenue for the month being $19,405.38.

17 That an average load factor of 40 per cent will be secured on this station when the load is built up to its ultimate capacity seems to be assured, and in fact indications are that a better load factor than this will actually be obtained. Prices charged for current for power purposes, ranging from $0.03 down to a minimum of $0.01 become particularly attractive to factories, who are able to supply those con-

ditions necessary for a good load factor, as is attested by the load factor which has already been secured on this station. A typical load curve is shown in Fig. 3. In this curve the peak load is shown to be only 2700 kw., but with a load factor of 80 per cent based on the peak load, there is a total output on the generating station of 51,925 kw-hr. If these conditions can be maintained, or even approximated, when the load on the station has been built up to its ultimate capacity, the load factor will be considerably greater than 40 per cent.

DESIGN OF THE EAST 53RD STREET STATION

18 The location of the East 53rd Street Station was determined not so much by proximity of a desirable load for the station, as by the

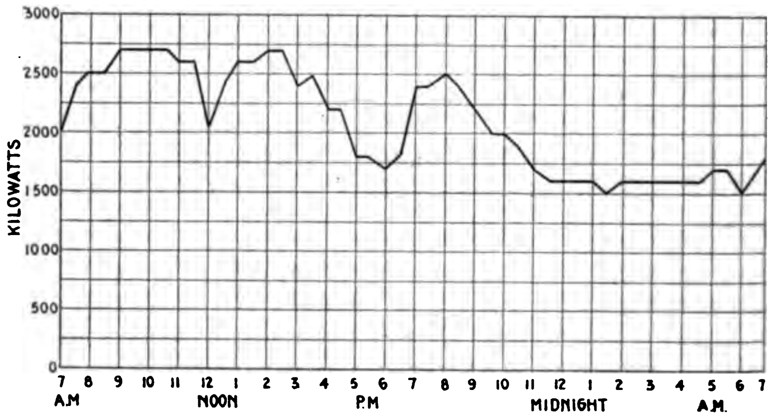


Fig. 3 Typical Load Curve, East 53rd Street Station

question of the most convenient and economical situation for delivering coal, and also by the possibility of securing in the cheapest manner the very best water for condensing purposes. The plan which was worked out for securing condensing water illustrates some of the advantages which can be secured through the coöperation of different departments in a municipality. In this particular instance, the Water Works Department have a 9-ft. tunnel extending 5 miles into Lake Erie, and draw their water at this point from 125 ft. below the surface. When the Municipal Lighting Plant decided to use water from the City Water Works aqueduct, and then after passing this water through the brass tubes in their surface condensors, to allow it to pass on to the suction chambers of the pumping engines supplying the city with water, they were only extending the plan which is generally followed n waterworks engineering of using the cold water for condensing the team in their engines before passing it on to supply the city's needs. The only objection which could possibly be raised to such a plan would be the increased temperature of the water, but in this case it is estimated that the increase in temperature of the water going into the city mains will not exceed 1 deg. fahr., and in this way the Municipal Lighting Plant has not only secured the cleanest and coldest water for their condensing purposes which it could be possible to obtain, but has also made use of a plan calculated to obviate any possibility of interruption by clogging of the inlet with ice or débris floating in the lake.

19 The coal question was considered as of next, if not of equal importance to the water question. In the particular site selected for the Municipal Lighting Plant, where it is located in close proximity to the Water Works Pumping Station, the fortunate condition exists of the L.S. & M.S. Railway tracks running along the southern line of the property with an elevation of about 60 ft. above lake level, and a method of handling the coal has been worked out wherein gravity is used almost entirely. In Fig. 4 is shown a cross-section of the station in detail, wherein the coal is delivered overhead by the railway cars, and is discharged by gravity into bunkers which have a capacity of 3400 tons. From these bunkers it is drawn through gates under pneumatic control into an electric telpher, which moves back and forth from under the bunkers on the track leading out over the stoker hoppers. The coal hopper on this telpher is carried on scale beams, and the weight of the coal, and the time of delivery is carefully recorded. In Figs. 5 and 6 are given views respectively under the coal bunkers and of the method of delivering coal into the stoker hoppers.

20 The special features in connection with the design of this station which are different from standard practice, are as follows: The use of motor-driven auxiliaries exclusively throughout the plant; the use of large boiler units with high steam pressure; the use of economizers of much greater capacity than ordinarily installed; a new arrangement of coal handling apparatus; the use of both forced and induced draft with practically atmospheric pressure in the combustion chamber; the automatic control of furnace conditions; the simplicity of the piping layout, due to motor-driven auxiliaries; and the use of an auxiliary steam turbine for driving the auxiliary motors. This turbine is supplied with a jet condensor, whose cooling water is the boiler feedwater before going to the economizers.

21 The practice of using motor-driven auxiliaries has not been adopted in this country principally for two reasons: (*a*) the use of exhaust steam from the steam-driven auxiliaries for feedwater heaters has been considered advisable as giving sufficient economy to warrant the use of steam, rather than motor-driven auxiliaries; and (*b*) the operation of the auxiliary equipment in the station by current from the

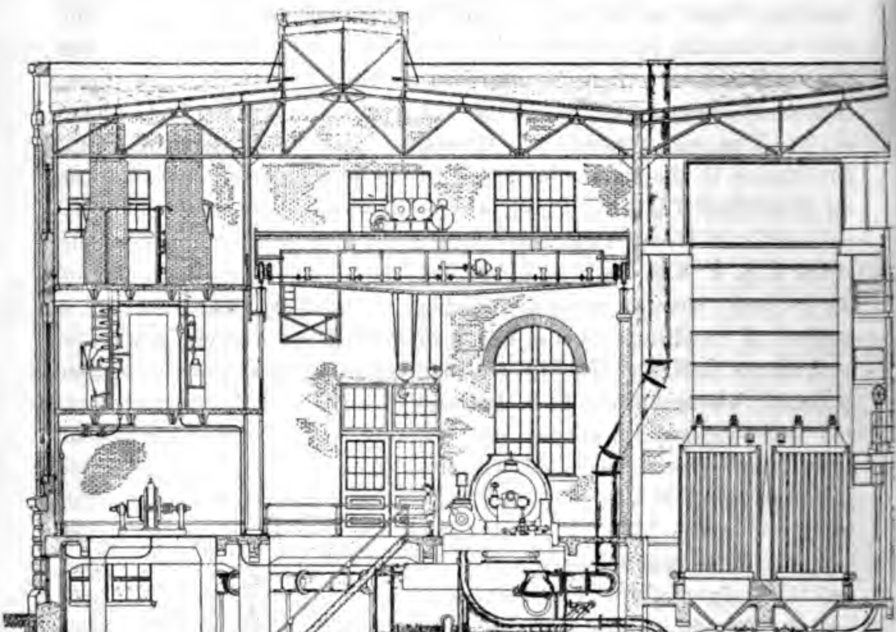
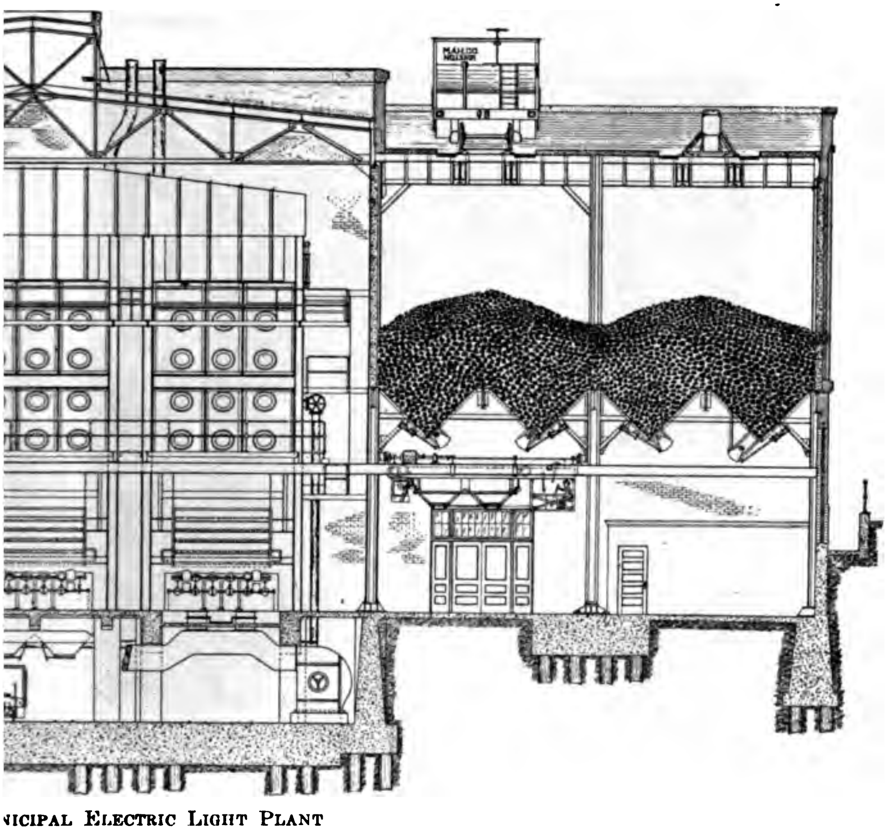


Fig. 4 Cross-Section of Cleveland

main generators has been considered to introduce an element of uncertainty and unreliability into the service which it would be better to avoid. In answer to the first objection it can be stated that the thermal efficiency of the station can be shown to be much higher when the auxiliaries are motor driven, and the heat for the boiler feedwater is secured by the use of economizers from the flue gases. No arrangement of steam-driven auxiliaries would give just the proper amount of exhaust steam for heating the feedwater properly at all loads on the station. There would always be periods when there would either be not enough, or there would be too much steam, and some would go to waste. There is also the complexity of steam piping necessary for supplying the auxiliary engines with the incident losses from radiation and leakage. The second objection is answered by the installation in this



NICIPAL ELECTRIC LIGHT PLANT

station of the auxiliary steam turbine. A 1000-kw. turbine with an overload capacity of 1500 kw. has been in operation in the Brooklyn Station for years, and is now in very good condition. This machine will be removed from the Brooklyn Station, and will be installed in the East 53rd Street Station.

22 This machine will be operated in connection with a LeBlanc jet condensor, the cooling water for which will be drawn from a cistern,

which is used for the storage of the boiler feedwater for the station. This cistern is divided into two compartments, by a wall, the top of which is about two feet below the surface of the water. On one side of this wall will be the cold well, and on the other side the hot well. The condensate from the three main turbines will be discharged into the cold well, and carried to a point near the bottom, where is located the suction end of a pipe, carrying the circulating water to the jet condensor. The discharge from the jet condensor will be carried to the

FIG. 5 VIEW UNDER COAL BUNKERS

other side of the cistern, known as the hot well, and delivered at a point near the suction end of the pipe delivering feedwater to the boilers. The make-up water for the system will be delivered into the cold well at the same point as the discharge of the condensate from the main turbines. The make-up water will be under control of a float valve designed to maintain the level of the water in the cistern at the required height. As can be seen from this arrangement it is not the intention that the quantity of water flowing through the feed piping stem to the boilers shall determine the volume passing through the condensor. In order to secure the proper conditions in the jet consor, the volume of circulating water will be several times greater n the quantity of feed required by the boilers. The water in the ern will therefore pass through the jet condensor several times be- it goes as feedwater to the boilers, and in order to prevent a uni- m temperature throughout the cistern and a consequent lower um in the jet condensor the arrangement of hot and cold well was

FIG. 6 VIEW IN AISLE BETWEEN BOILERS

ovided, and the piping connected in such a manner as would supply e coldest water to the condensor and the hottest water to the boiler ed system. The auxiliary motors in the station will all be connected rough a double bus system, so that each motor can be operated either current, from the auxiliary turbine, or from the main generator. this way the load on the auxiliary turbine can be adjusted, so that e temperature of the feedwater will be that best suited for delivery the economizers. This temperature should be approximately 120 g. fahr. If much less than this amount, the economizer tubes will scale with soot, and cause trouble. If a greater temperature than that necessary to avoid this trouble is secured, then there will be a sacrifice of economizer efficiency.

23 The use of large boiler units with high steam pressure was decided upon, and the boilers ultimately installed were quite similar to those in the Delray Station of the Detroit Edison Company. A front view of a boiler unit is shown in Fig. 7. These boilers have been described in great detail by D. S. Jacobus, in the Transactions of this

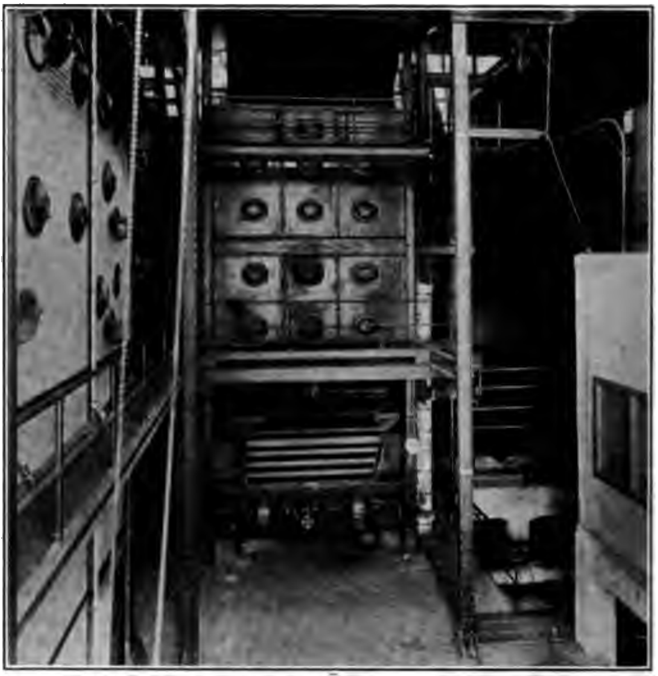


Fig. 7 Front View of Boiler

Society.[1] The dimensions are identical with those of the Detroit boilers, except the length of the drums. These boilers are installed with 10,000 sq. ft. of heating surface each, and are designed to carry 275-lb. working pressure with a superheat ranging from 125 to 150 deg. fahr. They are equipped with Taylor underfeed stokers, and are intended to be capable of operating up to 300 per cent of rating (Fig. 8).

24 The operation of the boilers at a high percentage of rating

[1]Trans. A.S.M.E., vol. 33, p. 565.

ans a higher temperature of flue gases. This, with the low temature of feedwater, gives a temperature head between flue gases l feedwater which will be practically double that ordinarily obied in economizer practice. This alone would be sufficient to wart the installation of a larger amount of economizer heating surface, n would ordinarily be deemed advisable. However, there is another

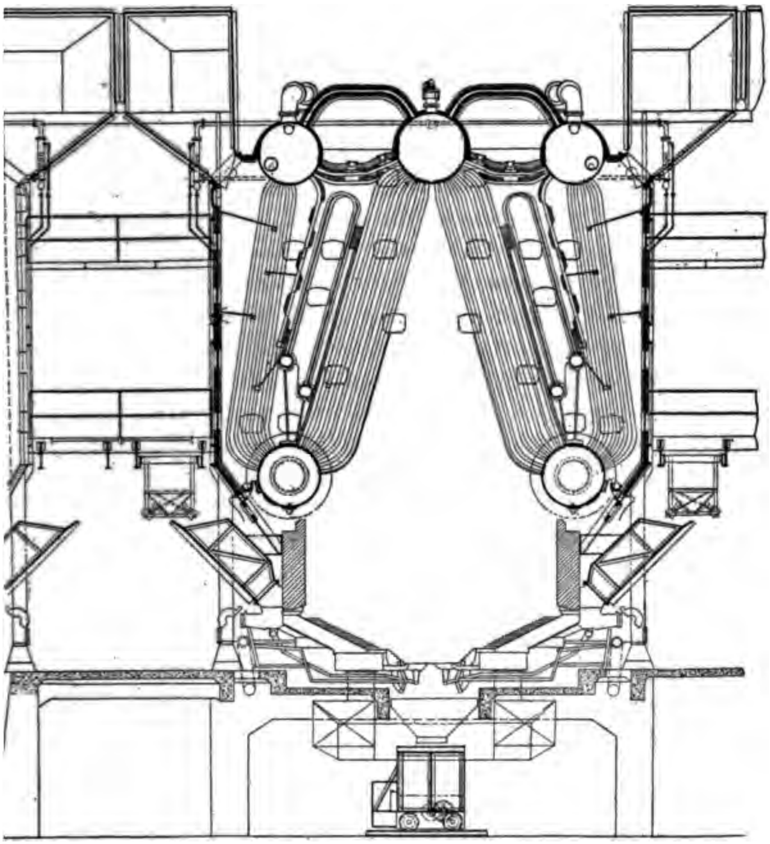


FIG. 8. SECTION OF STIRLING BOILER, SHOWING FURNACE AND STOKER

tor in the Cleveland situation which also warrants an increase in economizer capacity installed. In economizer practice the interest the investment generally figured at 6 per cent is balanced against saving which will be produced in the economizers, but in munial engineering it is found that interest on the investment can be ured at 4½ per cent instead of 6 per cent. This fact alone would warrant an increased capacity in the economizer. Taking these factors into consideration, it was thought that a very conservative estimate on economizer requirements would be 27,000 sq. ft. of heating surface. The economizers which were installed were made by the Green Fuel Economizer Company, and are arranged in two parallel sections, entirely independent, so that either can be cut out by means of dampers for cleaning and repairing, leaving the other section in operation.

25 The use of both forced and induced draught contributes greatly to the flexibility of the installation, and makes it possible to carry practically a balanced pressure in the combustion chamber, thus avoiding one of the greatest sources of loss in boiler practice, namely, the leakage of air through the boiler settings. Two induced draft fans were installed, either of which has a capacity of taking care of the peak load requirements of the station. A separate forced draft fan with an individual motor drive was installed in the boiler room basement for each furnace. The motors on the forced draft fans are under automatic control, and their speed is governed by means of Cutler-Hammer rheostats, controlled by the boiler pressure. The motors for operating the stoker feed are also controlled by Cutler-Hammer rheostats, governed from the pressure in the air ducts underneath the boilers. The induced draft fans are under manual control, and their speed is intended to be regulated by the man operating the boilers. This speed is to be such as to give the proper draft for holding practically an atmospheric pressure in the furnaces.

26 The steam piping in the plant is quite simple because outside of the auxiliary turbine, and the emergency equipment consisting of a steam turbine exciter and a turbine-driven feed pump, steam will be used only in the main generators. The plant is so arranged that each battery of two boilers is opposite one turbine generator, the steam lines from the boiler going directly to the header from which a short branch is taken to the turbine. The header is capable of being cut into three sections by means of Hopkinson-Ferranti valves, with operative working parts of half the diameter of the steam main. The interior of these valves is shaped like venturi nozzles; they will pass an amount of steam equal to the full carrying capacity of the pipe with practically no reduction in pressure. The main steam header is located in the boiler room basement near the floor, and the piping arranged in such a manner as to drain to this header from all directions. This header is 135 ft. long, and designed for a minimum of expansion which would affect a lateral movement in the branch pipes.

; is divided in the middle by a loop for taking up expansion, which ›nsists of two short headers, carrying four small U-shaped pipes of ıly one-half the diameter of the main. Two halves of the main ›ader are then anchored securely at their central points, and carried ı rollers from this point in both directions. This then divides the ain header in such a way that at no place would the movement ıused by expansion be more than that due to the expansion in one- ›urth of its length. The main steam header is only 14 in. in diameter, nd is composed of ⅝-in. thick steel pipe with welded necks and anges. The branch pipes contain no fittings, except the valves which re of heavy cast steel. All turns are of long bends, and all sections ave welded flanges.

27 The feedwater pumps are all centrifugal pumps. Two are onstant speed and motor driven. One is steam turbine driven, and ; designed for emergency purposes, and for operation where no elec- ric current is available. This pump is arranged with governor con- rol for constant pressure, and is therefore capable of being used in onnection with either of the motor-driven pumps and to supply water o the boilers only when the demands are in excess of the capacity of he other pump.

28 In the chief engineer's office are located indicating and re- ›ording instruments for practically every operation in the station. There is a graphic recording totalizing watt-meter which gives a con- inuous record of the combined output of the entire station. The ımount of feedwater going to the boilers is shown by the indicating lial of a Lea V-notch recorder, which also gives a continuous graphic record and the total quantity by means of integrating dials. The CO_2 in the flue gases is recorded here by a Simmance-Abady machine; while recording thermometers keep record of the temperature of feed- water entering and leaving the economizer, the temperature of the flue gases in the boiler breechings as well as at the discharge end of the economizer. The steam pressure and also the temperature of the steam in the main header is also recorded here, thus giving a record of the superheat. This information, together with the record of the weight of coal going to each boiler, which is turned in to the chief engineer at the end of each 8-hour shift enables him to have a com- plete log of the performance of the station made up every day.

29 Perhaps the most important innovation in connection with the operation of this station is not in the station itself. In central sta- tion practice in large cities it seems to have become a fixed rule to

supply the congested districts with direct current through 220-volt 3-wire Edison systems. This is undoubtedly an inheritance from the days before the development of a successful distribution system with alternating currents, and the prevailing practice has resulted in an enormous investment in copper, the fixed charges on which, such as interest, depreciation and taxes, adds vastly to the cost for service. In addition to this is the much greater loss in transmission at the low voltages and also the loss of from 15 per cent to 20 per cent in transformation from alternating to direct current in the substations. And with the additional necessity of a greater number of substations than would be required for alternating current distribution.

FIG. 9 SWITCHBOARD AND 11,000-VOLT COMPARTMENT FOR SUPPLYING BUSINESS DISTRICT

30 It is a fact that nearly all lighting and power requirements can be met in the congested districts with alternating current as well as with direct current. There are, however, a few cases where the requirements can be met better with direct current but these constitute a very small percentage of the total. In power work there are places where finer gradations of speed control than can be secured with alternating current are desirable, and in lighting work there are places where storage batteries are necessary to provide an absolute security against interruption of service. But in such cases it would be much more economical to take care of the requirements on the premises of

customer and install there the necessary converters, accumulators, . The cost of this would be represented by thousands, whereas the estment necessary for the transmission of low voltage direct current m substations runs into millions of dollars.

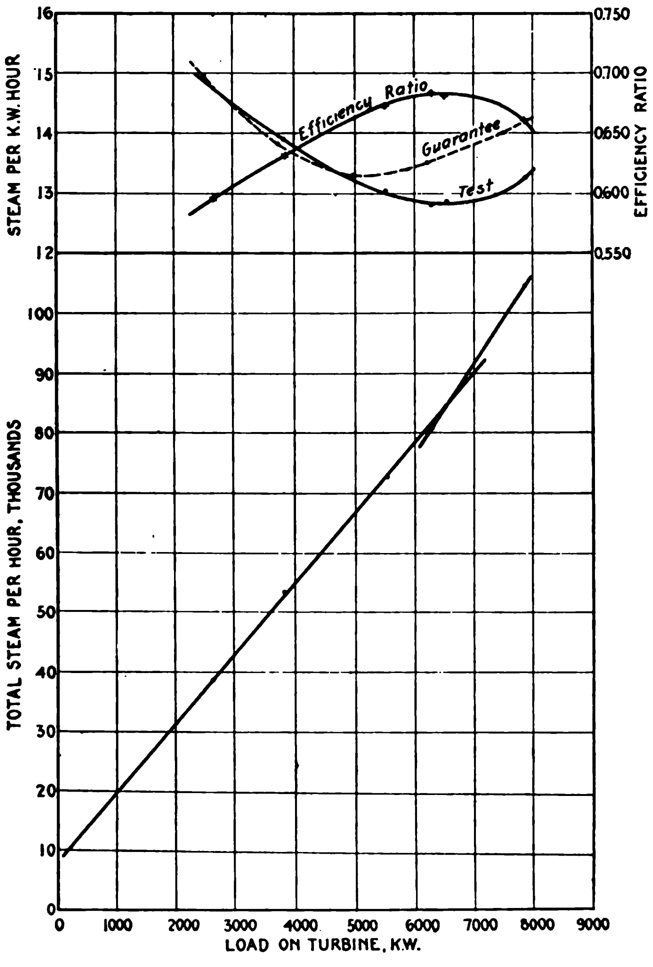


FIG. 10 RESULTS OF TESTS ON 5000-KW. STEAM TURBINES, 1800 R.P.M.

31 In Fig. 9 is shown the arrangement of the 11,000-volt comrtments and switchboard of the East 11th Street Station, which pplies the "down town," or the business district of Cleveland with ernating electric current from the Municipal Lighting Plant. The

simplicity of the station and the absence of rotary converters is particularly notable when compared with the prevailing practice of supplying the congested districts of large cities from numerous substations in which are installed large numbers of rotary converters for changing alternating into direct current.

TESTS ON EAST 53RD STREET STATION

32 Tests were made on the East 53rd Street Station during the months of September and October under the direction of Prof. Carl C. Thomas of Johns Hopkins University, to determine the steam consumption, efficiency and operation characteristics of the steam turbine generators installed in this station and to compare the results with those guaranteed by the manufacturers. The tests on the turbines were made simultaneously with tests to determine the efficiency of the condensers, and the power required to operate the condenser pumps. Tests were also made under the direction of Professor Thomas to determine the efficiency and capacity of the boilers and stokers installed in this station. The results of these tests are shown in the abstract from Professor Thomas's report which follows:

33 *Turbine Tests.* The turbine guarantees were based upon given steam pressure, vacuum, and superheat, and the results were corrected to these standard conditions. The three turbines are of the Allis-Chalmers-Parsons type, rated at 5000 kw. each, 1800 r.p.m., 11,000 volts, A.C., steam to be supplied at 225 lb. per sq. in. gage pressure, and 125 deg. fahr. superheat. The equipment of surface condensers was furnished by the C. H. Wheeler Company of Philadelphia. Before the turbine tests, the condenser to be used was tested for tightness by maintaining about 16-lb. water pressure by gage on the circulating pump outlet for 26 hours. The amount of leakage was about eight gallons. After the tests the condenser was put under vacuum of 28½-in. mercury, by means of the dry air pump, and with steam shut off the turbine and with the generator operating as a motor, the gland water (measured in barrels on the station roof) and the condenser leakage were weighed together. The leakage was found to be a negligible quantity. The bottom of the suction pipe from the condenser to the dry air pump was drained and it was found that no water was drawn out of the condenser by the dry air pump with the exception of the water vapor carried with the air.

34 Eight turbine and generator tests were made at 90 per cent power factor, of which eight were reported, and two tests were made at

a 100 per cent power factor and the results corrected to 90 per cent power factor. The first six of these tests were made on No. 1 turbine and two on No. 3. The governor adjustment on the No. 1 turbine had not been completed before the tests were begun and at full load it was found to open in such a way as to cause the use of more steam than was required by the load. During the shut-down for adjustment of the governor, the 20-in. outlet pipe from the condenser burst and as turbine No. 3 had been adjusted, the tests were continued on it. General results of the tests are shown in Fig. 10.

35 The load was applied by means of a water rheostat in the lake, and electrical readings were made by a corps of skilled observers under the direction of Prof. F. C. Caldwell of Ohio State University. As all guarantees were based on 90 per cent power factor, a second 5000-kw. turbo-generator was operated in parallel with the one under test, and by means of under excitation of its fields it was caused to give the necessary lagging component and bring the resultment of the test load to 90 per cent power factor.

36 The turbines operated satisfactorily in every respect and the results as to economy of steam, governing and temperature rise of generators were well within the limits of the guarantee. At times the superheat was run up to 175 deg. during boiler tests and turbines were operated under this condition. The amount of water supplied to the condenser by the circulating pump was computed from measurements made in the 20-in. inlet pipe between the pump and the condenser with a pitot tube of special construction designed by Professor Thomas.

37 *Boiler and Stoker Tests* (Table 7). The boilers are of the Stirling type with 10,134 sq. ft. of heating surface each, and equipped with superheaters for supplying steam at 125 deg. fahr. The working pressure of the boilers is 250-lb. gage pressure per sq. in. Each boiler is equipped with two Taylor Stokers of six retorts, or a total of 12 retorts per boiler.

38 Before the tests a special feed line was run from an improvised hot well which received water directly from the weighing tanks. A special blow-off pipe was arranged for the boiler under test, and all necessary precautions were taken to insure against leakage and water unaccounted for. The steam from this boiler was used for running one or more turbines. The economizer was not used during these tests, and the water fed to the boiler was the condensate from the turbines, with make-up from the city water supply.

39 The coal was taken from the overhead hoppers in the travelling

larry which is fitted with weighing scales. A special ash hopper was built of brick under the boiler to serve as an air lock and to facilitate dumping quickly, especially during high capacity tests, the ash and clinker being taken in a steel car without quenching and weighed, after which the whole car load was quenched and crushed in a special crusher in order to obtain representative samples for analyzing the ash. The fires were dumped once in three or four hours.

40 About 300 lb. of coal were taken as samples during each of the long tests. The loss of weight due to drying over the boilers was used for the preliminary determination of moisture. The entire sample then was crushed and quartered, and the small sample taken and sealed up for delivery to the chemist selected for the analysis.

41 There were about 300 lb. of ashes taken during each 24-hour test. These were taken in small amounts at regular intervals during crushing. They were crushed to a fine size, and portions sealed in jars for delivery to the chemist.

42 Gas was drawn from the upper part of the boiler just underneath the damper. The sampling pipe entered the uptake at two points and was led to an Orsat on the boiler room floor at the end of the boiler from which the sample was being taken. Two Orsats were thus used, one at each end of the boiler. Observations were taken on each of these Orsats every twenty minutes. In order to check this work, a professional chemist was employed during some of the tests, analyzing the flue gas with a Hempel apparatus, his samples being taken simultaneously with those going to the Orsats.

43 The boiler under tests was new and in order to arrive at satisfactory test conditions and to train the staff of observers, preliminary tests were run during a period of about three weeks. Satisfactory conditions having been attained, the tests were conducted in the following manner: The condition of fire was noted from both side doors by at least two observers, and as the time for ending a given test approached, the fire was watched and the test continued until the starting conditions were again closely attained. The coal hoppers were leveled to the top at the start of the tests, and were leveled at the end of each hour during the test. Delivery of fresh coal was continued with practical regularity during the test. The water level in the special hot well used in the test was noted by a hook gage at the end of each hour, and it was found possible by manipulation of the water valves to bring the water very closely to the starting level at the end of each test. The high capacity test, at about 275 per cent of rating was continued

Steam pressure, lb.					
Boiler	227.52	225.55	224.35	237.48	237.29
Superheater	214.78	222.98	226.87	241.72	238.50
Temperature, deg. fahr.					
Superheated steam	552.11	529.31	551.39	586.40	608.00
Deg. superheat	153.84	131.81	154.28	184.62	206.28
Feed water	70.32	71.26	70.11	69.10	70.00
Boiler room	78.00	72.30	71.33	72.84	72.10
Factor of evaporation	1.2896	1.2769	1.2897	1.3080	1.3182
Water					
Total water	1,062,820	699,817	975,138	634,393	108,896
Water per hour	42,513	29,159	40,631	52,866	72,598
Total water, f. and a.	1,370,613	893,596	1,257,635	829,786	143,547
Total water, f. and a. per hr.	54,825	37,233	52,401	69,149	95,698
Total water, f. and a. per sq. ft. H.S.	5.41	3.68	5.17	6.83	9.45
Coal					
Total coal as fired	140,085	82,393	126,702	86,853	16,609
Coal per hr. as fired	5,603	3,433	5,279	7,238	11,073
Coal per hr. per retort	467	286	440	603	923
Per cent moisture	3.65	2.94	4.00	3.16	2.66
Total dry coal	134,972	79,971	121,634	84,108	16,167
Dry coal per hr	5,399	3,332	5,068	7,009	10,778
Dry coal per hr. per retort	450	278	422	584	898
Combustible					
Total combustible	116,577	70,191	106,084	71,993	13,432
Combustible per hr	4,663	2,925	4,420	5,999	8,955
Combustible per hr. per retort	389	244	368	500	746
Evaporation coal as fired	7.59	8.49	7.70	7.30	6.56
Evaporation f. and a. dry coal	10.15	11.17	10.34	9.87	8.88
Evaporation f. and a. combustible	11.76	12.73	11.86	11.53	10.69
Horse power developed	1589.1	1079.2	1518.9	2004.3	2773.9
Per cent rating	156.87	106.53	149.94	197.86	273.83
Temperature flue gases	600.57	510.70	597.82	731.87	832.50
Gas analysis					
Carbon dioxide	15.15	16.13	16.58	15.05	15.93
Oxygen	3.30	2.28	1.66	3.21	2.66
Carbon monoxide	0.05	0.03	0.26	0.51	0.02
Nitrogen	81.50	81.56	81.50	81.23	81.39

Drafts					
Furnace	−0.09	−0.06	−0.05	−0.09	−0.08
Top first pass	+0.19	+0.16	+0.22	+0.16	+0.15
Bottom last pass	+0.02	+0.06	+0.04	−0.07	−0.15
Under damper	−0.10	+0.07	−0.03	−0.43	−0.95
Stoker data					
Rev. per hour	28.44	17.13	30.90	43.50	71.40
Air pressure	2.01	1.28	2.10	3.39	5.40
H.p. stoker motor	....	7.13	8.51	10.91	14.20
H.p. fan motor	....	25.09	28.34	41.04	71.60
Coal analysis					
Moisture	3.65	2.94	4.00	3.16	2.66
Volatile matter	32.42	32.78	32.58	32.48	32.59
Fixed carbon	55.98	55.57	55.55	55.06	55.69
Ash	11.61	11.65	11.87	12.47	11.72
Total carbon	71.33	72.63	72.38	72.01	72.65
Sulphur	1.50	1.77	1.92	2.21	2.10
Hydrogen	5.14	4.89	4.89	5.00	4.99
B.t.u. (dry basis)	13,452	13,369	13,386	13,247	13,353
B.t.u. combustible	15,219	15,132	15,189	15,134	15,126
Per cent carbon in ash and refuse	22.70	17.28	20.47	33.44	33.35
Combined boiler and grate eff.	73.22	81.08	74.93	72.30	64.53
Eff. combustible basis	74.98	81.64	75.77	73.93	68.58
Total dry ash and refuse	18,395	9,780	15,550	12,115	2,735
Per cent ash by test	13.63	12.23	12.78	14.40	16.92
Heat balance (dry basis)	Per cent	Per cent	Per cent	Per cent	Per cent
Heat absorbed by boiler	73.22	81.08	74.93	72.30	64.53
Heat loss due to temp. flue gases	11.14	9.04	10.38	14.05	15.91
Heat loss due to comb. in ash	3.35	2.31	2.86	5.31	6.17
Heat loss due to moist. in coal	0.35	0.28	0.39	0.32	0.28
Heat loss due to burning hydrogen	4.43	4.12	4.25	4.60	4.71
Heat loss due to carbon monoxide	0.18	0.10	0.86	1.81	0.07
Heat unaccounted for	7.33	3.07	6.33	1.61	8.33

Boiler pressures have been corrected due to water leg by —12.56 lb. for all tests. Boiler pressures on tests 1 and 2 have been corrected for 2 lb. for error in gage. Superheater pressures on tests 1 and 2 have been corrected by —18.5 lb. for error in gages.

for only one and one-half hours, and cannot be considered to be an accurate economy test. The purpose of this test was to ascertain whether or not this load could be carried by the stokers and this having been demonstrated, it was thought unnecessary to continue running under these very severe conditions. The boilers and stokers operated satisfactorily and showed that they were capable of maintaining the conditions for which they were designed. The results of the tests as a whole are shown in the accompanying table.

44 There is no doubt but that every new installation in power plant work should be made the subject of careful test. It has come to be the generally accepted practice to exact guarantees from manufacturers of apparatus in the way of capacity, efficiency, etc., and to capitalize these factors when comparing bids for placing contract, yet when installations are completed it is too often the case that either tests to determine whether these guarantees have been met are not made at all, or they are made in a careless or perfunctory sort of manner, all of which has the effect of producing a certain amount of indifference on the part of manufacturers in regard to guarantees. However, there is an equal, if not greater benefit to be derived from careful and thorough tests, such as have been made on the Cleveland Municipal Lighting Station, and that is the training of the operators in the proper method of handling the equipment for securing the best results and highest efficiency.

DISCUSSION

Robert L. Brunet[1] (written). Mr. Ballard's paper is decidedly interesting, not solely because this plant is the largest municipal central station in this country, but also on account of the diligent forethought shown in its design and the arrangement of its equipment.

The operation of auxiliaries in the Cleveland plant, while an innovation in a certain sense, is a move in the right direction, and, by the use of motor-driven apparatus, there is no question whatever but that the conditions of operation can be more evenly gauged and better economies effected than otherwise. In the use of motor-driven equipment, the main point which engineers have discussed formerly has been the uncertainty of the operation of auxiliaries, provided trouble occurs in the main station, and the result has been that where continuity of service must be fostered motor-driven auxiliaries have not been looked upon with favor. The Cleveland plant has over-

[1]Public Service Engr., Providence, R. I.

come this objection by the use of an auxiliary steam-driven unit, and no possible objection can be raised, other than those of a minor nature which need not be discussed.

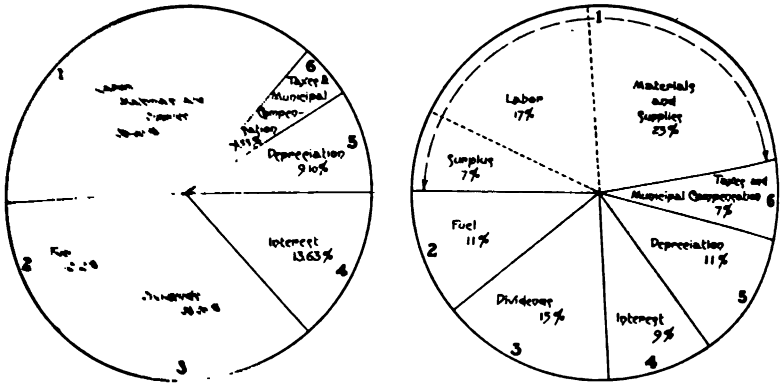
Great emphasis should be laid on the arrangement of the coal-handling apparatus and the facilities provided at all times for a complete cognizance of the actual conditions of boiler service.

In connection with the use of both forced and induced draught in this plant, it can be stated that boiler-plant engineers at times fail to remember that it is of a decidedly beneficial nature to carry a balanced pressure in the furnace, by which latter means losses may be either eliminated or reduced to negligible quantities.

The location and general arrangement of the chief engineer's office, together with the instruments erected therein, cannot but help assist in the economical and efficient operation of the plant. No one thing in the operation of a central station is of such vital importance as the fact that the chief engineer should be in close touch with the plant, and be advised, from time to time, of the actual conditions of operation. It is my belief that the design and arrangement of the chief engineer's office is one well worth the study of all central station engineers, particularly those who are now operating their plants by the "hit and miss" methods.

As the author states, the most important change in connection with the operation of this station is the use of alterating current for the congested business districts, instead of the Edison three-wire system which has been in general vogue throughout the country. From experience, I know of engineers in charge of large central stations who are trying their best to devise ways and means of getting away, as far as is practicable, from the use of this D. C. three-wire system. As they explain, except in a few minor instances there are practically no customers who cannot be properly and adequately served with A. C. as well as with D. C.; and where D. C. is absolutely essential, the transformation from A. C. to D. C. can be more economically effected on the customer's premises than otherwise. No prolonged discussion of this point is necessary, for anyone familiar with the operation of a central station knows full well that the investment in a large amount of copper incidental to the use of D. C., together with the transformation losses, are very important arguments against the use of such current, if high voltage A. C. can be supplied instead.

With low rates for current, both for lighting and power, it seems may fair to state that the load factor of 40 per cent will possibly be realized, based on a peak of 18,000 kw., but when the peak of 18,000 kw. is reached, the generating equipment will undoubtedly have to be increased in order to insure reliability and continuity of service. In general, it is true that as the load factor of a plant increases, the cost per kw-hr. decreases and the resultant effect will be that, as in practically all stations operating along economical lines, the rates for service will be proportionately reduced. As is well known, the load factor itself is dependent upon the diversity factor, i. e, the ratio of the sum of the separate maxima to the total co-incident maximum. In some stations where the load factor is in the neighborhood of from 30 to 40 per cent the diversity factor will be from 2 to 3 per



CLEVELAND MUNICIPAL STATION LARGE PRIVATE STATION, 1913

FIG. 12 PERCENTAGE OF INCOME

cent dependent, primarily, upon the means employed by the central station to obtain additional load.

Many people have an idea that the ratio of kilowatt-hours sold for power to the total kilowatt-hours generated is rather insignificant, but the reverse is the case in all plants which have sought after power business. As a matter of fact, in modern central stations the ratio of the current sold for power varies from 50 to 75 per cent, and without this power business the lighting rates would be decidedly increased to the small consumer. In other words, the relatively high ratio as indicated above has been the ultimate means of furnishing current to lighting customers at rates which are much lower than would be afforded under dissimilar conditions.

Engineers should not forget that a diversity factor in a station is the basis of profit, and this question is one which should receive the utmost consideration at their hands.

In making a study of the income of various central stations, I have found that the income per dollar of investment varies in most private plants from 20 to 25 per cent. In Mr. Ballard's paper, he has estimated an income of 33 per cent per dollar of investment. This figure in itself seems to me relatively high, and it is my belief that it will be somewhat reduced by the fact that when his peak reaches the estimated maximum of 18,000 kw., his distribution system will be so extended that the actual investment will be greater than the figure he has used at this time.

As a matter of information, I have compared in Fig. 12 the disposition of each dollar of income for a large private station, and the estimated disposition for the Cleveland municipal station. The private station has a capacity of approximately 350,000 h.p., with a total output of 840,000,000 kw-hr. per annum. The Cleveland plant has a total capacity of 33,500 h.p., with an estimated output of 60,000,000 kw-hr. per annum.

In order to supply a close comparison, these itemized figures are given below:

	Large Private Central Station per Cent		Cleveland Municipal Station per Cent
Labor	17	47	36.40
Materials, etc.	23		
Surplus	7		
Dividends	15		24.20
Interest	9		13.63
Depreciation	11		9.10
Taxes and municipal compensation	7		4.55
Fuel	11		12.12
Total	100		100.00

James R. Cravath[1] (written). The plant described in this paper presents such an unusual array of cost figures that appear at first sight to those who have not followed closely the central station situation almost impossible of attainment. In the light of recent development the proposition assumes a more reasonable aspect and limits questions as to the attainment of some of the low costs to certain features.

[1]140 S. Dearborn St., Chicago, Ill.

One of the features brought out, regarding which little has been published, is the low cost of modern steam turbine plants as compared with turbine or engine plants of like capacity a few years ago. A cost of $100 to $150 per kw. of maximum capacity was common in large city stations until very recently. The decreasing cost of steam turbine units per kilowatt and the increasing steam output to which boilers of a given capacity are being forced in common practice, together with the small ground space taken up by large turbine units per kw., have combined to lower power station costs. But a short time ago costs of $70 per kw. of station capacity were common for large steam turbine stations. According to the author's figures, the cost of the station is about $1,000,000, which for a maximum capacity of 25,000 kw. corresponds to $40 per kw. of maximum capacity. On the basis of an 18,000 kw. peak load as assumed by Mr. Ballard in his estimates of earnings, the cost is $56 per kw. of peak.

The figures given as to investment and operating costs correspond with estimates made by the writer on a station of similar capacity intended to operate under conditions of rather high load factor. The thermal efficiency from coal pile to bus bars, assumed by the author as about 11 per cent, corresponds to modern good practice in actual working conditions with the station fairly loaded. This efficiency in the best and largest modern turbine stations ranges from 10 to 13 per cent.

The economical supply of good condensing water is unusual for a plant of this kind and the method used is in part responsible for the low cost of the plant per kw.

Whether the estimated maximum load of 18,000 kw. can be brought to the station under conditions existing in Cleveland with a distribution system cost sufficiently low to bring the total investment in power plant and distribution systems to only $3,000,000 remains to be demonstrated. The cost of a central station distribution system depends very much upon the character and distribution of the load. If the station can be fully loaded with a distribution system covering a small area and serving mainly large power consumers, the cost may even be under that given. If the distribution system is to cover a large city where the load density is necessarily low because of dividing the business with a competing central station existing experience indicates that it is very doubtful whether the station can be loaded to 18,000 kw. with a total investment

$3,000,000. The value of the power station being $1,000,000 leaves $2,000,000 for distribution systems. With 18,000 kw. maximum load, this corresponds to a cost of $111 per kw. for distribution system. On a similar basis, the cost of the entire plant would be $167 per kw. of maximum load for station and distribution system. It is probably not correct to take the cost of the South Brooklyn system as a criterion of the cost of the 53d St. Plant with its distribution system when completed, but it is interesting to note that the South Brooklyn system complete, on a basis of 1500 kw. capacity, cost $365 per kw. of station capacity. If the station is not fully loaded the cost per kw. of maximum load will be higher than this. If we assume that the South Brooklyn station alone cost $100 per kw., we would have $265 per kw. maximum load for distribution system investment. Distribution system costs run in general from $100 to $300 per kw. As before explained, their cost will depend very much on the density of the load and upon the size of the consumers. A large number of small consumers greatly increases the investment per kw. in distribution systems.

As the author points out, the economy of production is much dependent upon the attainment of a high load factor. A number of years ago a load factor of 20 to 25 per cent (annual) was common on the central station systems of our large cities. This has gradually been brought up by the acquisition of additional power loads and in some cases by taking on street railway loads. A load factor of 35 per cent (annual) is high for a station supplying electric light and power alone, and stations obtaining 40 per cent have done so usually at the expense of many years of strenuous work. It is possible that, by cultivating the large power business and ignoring the low load factor lighting business, a 40 per cent load factor might be maintained from the start in an enterprise like that at Cleveland. It must not be thought however that such a load factor represents an easy attainment. The low load factor business comes of itself, especially where rates as low as those given in the paper are charged. The natural tendency of such a rate would be to load up the plant with low load factor business unless great care were exercised to prevent it.

Further information concerning the market for light and power it is proposed to supply and the methods to secure as high a load factor as 40 per cent (annual) would be of much interest to those engaged in central station commercial development. It should be kept clearly in mind in discussions of this kind that the average cost per kw-hr. is not by any means the actual cost of serving different classes of consumers. Some consumers with very high load factor cost the central station much less than the average to serve, while other consumers with low load factor and with high investment in distribution systems cost much more. If the average, or anywhere near the average price is charged to the small consumer with low load factor, this class of consumers will flock to the service in great numbers and the central station will serve them at a loss which can only be made up by exacting unjust profits from high load factor business. We thus see the importance of the fundamental principle that the rates charged must bear some proportion to the actual cost of serving these classes of consumers.

Such a low average interest rate on the whole investment as 4.5 per cent. is due to the fact that this is a municipal rather than a private corporation security. In allowing 8 per cent profit in addition to 4.5 per cent interest, however, the author has apparently inadvertantly allowed considerably more annual return on the investment than would be necessary to clear him of a possible charge of unfairness to private corporations. As far as I know, where commissions have passed on the question of reasonable return upon the investment in a plant of this character, the total annual returns including both interest and profit allowed have been in the neighborhood of 8 per cent on the entire investment rather than 8 per cent in addition to interest. Mr. Ballard's fixed charges should therefore be reduced 4.5 per cent.

Fixed charges, depreciation and interest on the Brooklyn plant with an investment of $548,182 is given as $19,079. This is only 3.6 per cent on the investment and appears to be an error. From the information given in the discussion, the depreciation on the South Brooklyn plant would be considerably higher than for the 53d St. plant inasmuch as a part of the Brooklyn plant investment would be written off as it is replaced by the 53d St. station.

Depreciation on the complete new plant is assumed at 3 per cent, calling for an average life of plant of 22 years. It is doubtful whether this is a sufficient allowance, even though it may be in accord with the customs of some private corporations. In the Madison Gas & Electric Co. case before the Wisconsin Railroad & Public Service Commission in 1910 the commission decided that the average life of the electric plant was about 17 years.

One element of first cost which can only be determined after the undertaking has reached the state of development anticipated in the preliminary estimates is that classified by the Wisconsin Commission as "going value." Under this head is included whatever loss in operation is incurred in the early years before the load has been built up to a point to yield a proper interest and profit on the investment. This amount must needs be added to the tangible physical investment to determine the total money put into the property. Such an item is just as truly a cost of a going plant as the cost of the physical property necessary to get it going on a profitable basis.

Walter C. Allen wrote that the paper omits a description of one of the features most interesting to electrical men, viz.: the distribution system. Apparently the new 53d St. station is delivering its energy to the existing distribution system through the East 11th Street sub-station, without the use of rotary converters.

The loss in distribution from the Brooklyn station for the year 1913 as given is 27.4 per cent, while the loss for the first eight months of the present year, with the 53d Street station operating with it during the last six weeks of that period, is 20.2 per cent. The loss during the month of August with both stations operating, is given as 16.25 per cent. In the absence of any further information regarding improvements in the distribution system, the reader must assume that this increased efficiency is brought about by the use of alternating current in the low tension system, instead of direct current through rotary converters.

It will be interesting to see what further efficiencies are obtained from the new distribution system, for which it appears $1,500,000 is available.

Alex. Dow said that he had followed the construction of the Cleveland plant with a great deal of interest. It is in a neighboring town, the consulting engineer is an old friend, the plant is a good one and a credit to the author. There is, however, much in the paper that is speculative. He hoped that at a later time when the proof of the performance of the plant was completed, the results, whatever they might be, would again be placed before the Society. At present, there is lacking a distributing system for the plant, there is lacking a load and accounts kept in a manner which would be acceptable to a Public Service Commission. When these are realized we shall know the answer to the question of what the plant is accomplishing.

kept clearly in mind in discussions of this kind that the average cost per kw-hr. is not by any means the actual cost of serving different classes of consumers. Some consumers with very high load factor cost the central station much less than the average to serve, while other consumers with low load factor and with high investment in distribution systems cost much more. If the average, or anywhere near the average price is charged to the small consumer with low load factor, this class of consumers will flock to the service in great numbers and the central station will serve them at a loss which can only be made up by exacting unjust profits from high load factor business. We thus see the importance of the fundamental principle that the rates charged must bear some proportion to the actual cost of serving these classes of consumers.

Such a low average interest rate on the whole investment as 4.5 per cent. is due to the fact that this is a municipal rather than a private corporation security. In allowing 8 per cent profit in addition to 4.5 per cent interest, however, the author has apparently inadvertantly allowed considerably more annual return on the investment than would be necessary to clear him of a possible charge of unfairness to private corporations. As far as I know, where commissions have passed on the question of reasonable return upon the investment in a plant of this character, the total annual returns including both interest and profit allowed have been in the neighborhood of 8 per cent on the entire investment rather than 8 per cent in addition to interest. Mr. Ballard's fixed charges should therefore be reduced 4.5 per cent.

Fixed charges, depreciation and interest on the Brooklyn plant with an investment of $548,182 is given as $19,079. This is only 3.6 per cent on the investment and appears to be an error. From the information given in the discussion, the depreciation on the South Brooklyn plant would be considerably higher than for the 53d St. plant inasmuch as a part of the Brooklyn plant investment would be written off as it is replaced by the 53d St. station.

Depreciation on the complete new plant is assumed at 3 per cent calling for an average life of plant of 22 years. It is doubtful whether this is a sufficient allowance, even though it may be in accord with the customs of some private corporations. In the Madison Gas & Electric Co. case before the Wisconsin Railroad & Public Service Commission in 1910 the commission [illegible] that the [illegible] life of the electric plant was about 17 years.

One element of first cost which can only be determined after the undertaking has reached the state of development anticipated in the preliminary estimates is that classified by the Wisconsin Commission as "going value." Under this head is included whatever loss in operation is incurred in the early years before the load has been built up to a point to yield a proper interest and profit on the investment. This amount must needs be added to the tangible physical investment to determine the total money put into the property. Such an item is just as truly a cost of a going plant as the cost of the physical property necessary to get it going on a profitable basis.

Walter C. Allen wrote that the paper omits a description of one of the features most interesting to electrical men, viz.: the distribution system. Apparently the new 53d St. station is delivering its energy to the existing distribution system through the East 11th Street sub-station, without the use of rotary converters.

The loss in distribution from the Brooklyn station for the year 1913 as given is 27.4 per cent, while the loss for the first eight months of the present year, with the 53d Street station operating with it during the last six weeks of that period, is 20.2 per cent. The loss during the month of August with both stations operating, is given as 16.25 per cent. In the absence of any further information regarding improvements in the distribution system, the reader must assume that this increased efficiency is brought about by the use of alternating current in the low tension system, instead of direct current through rotary converters.

It will be interesting to see what further efficiencies are obtained from the new distribution system, for which it appears $1,500,000 is available.

Alex. Dow said that he had followed the construction of the Cleveland plant with a great deal of interest. It is in a neighboring town, the consulting engineer is an old friend, the plant is a good one and a credit to the author. There is, however, much in the paper that is speculative. He hoped that at a later time when the proof of the performance of the plant was completed, the results, whatever they might be, would again be placed before the Society. At present, there is lacking a distributing system for the plant, there is lacking a load and accounts kept in a manner which would be acceptable to a Public Service Commission. When these are realized we shall know the answer to the question of what the plant is accomplishing.

He further called attention to the author's statement of engineering matters, with no implication of lack of truth, but because of slackness of expression which could not be overlooked when made by an engineer before an audience of engineers. An examination of the figures given shows the continuous duty of the station to be 18,000 kw. with good luck. He questioned the claims made for new and radical features. The record plant with which every engineer is familiar is at Dunstans, with the auxiliaries motor-driven throughout. The boilers of the Cleveland plant are rather less than half the size of those of the same type at Delray which have been in service five years and there is nothing radical in the increase of steam pressure from 225 to 275 lb. The balanced draft he remembered to have seen in use in torpedo boat practice when he was a "cub" on the Clyde.

Another inaccuracy is in reference to the figures upon the kilowatt hours generated. A note should be inserted that something like 10 to 15 per cent of this power is used in the station itself.

EDWARD W. BEMIS[1] (written). The Cleveland experiment in municipal ownership of this plant follows closely upon a somewhat similar experiment in street railways. In the case of its street railways certainly, and until now, at least, in the case of the private electric light plant there, the city has not deprived the private company of a fair return on its actual investment in the property, using investment to cover moneys furnished by the stock and bond holders in addition to good dividends from the start.

At the November Conference of Mayors in Philadelphia, Mayor Hocken, of Toronto, declared similar results were being secured by similar methods there. If these experiments continue to succeed, it is evident that state regulation will have to cease allowing companies returns on unearned increments, donation and surplus earnings invested in their properties, or existing laws in the various states will be changed where necessary to permit direct municipal competition under proper safeguards of publicity and uniform accounting, referendum on bond issues, etc.

It will be recalled that this method of potential municipal competition was endorsed in 1907 by the National Civic Federation Commission on municipal versus private management as the most effective method of control.

[1]4500 Beacon St., Chicago, Ill.

When the efficiency of public operation approaches that of private operation, the handicaps upon the latter, through its demand for returns which public operation never makes, such as going value, and the increased cost of replacement as compared with actual cost, etc., to say nothing of differences in the demanded rate of return, will prove serious. Whether that time has yet arrived, and how far private companies will awake to the situation, as they have been doing in England, will vary with every community and with changing conditions.

REGINALD P. BOLTON. This paper may be divided broadly into two divisions for the purpose of discussion, as it comprises, firstly a description of a carefully-planned and modernized electrical generating plant of moderate capacity, and secondly a statement of certain estimates and assumptions of an economic character, largely based on deductions from the past operation of a smaller installation; these appear as the warrant for the proportions of the plant described, and upon them the hopes and expectations of its propriety and of its efficient operation depend. As the design of the plant does not include any very new or original departure from accepted up-to-date practice, we are more concerned with the aspects of the economical side of the subject, the data presented and the conclusions founded thereon.

The engineering of a plant may be faultless, but if its conception should be based on faulty foundation, the purpose of its construction and the value of its economical features must be to a large extent discounted. Our first inquiry therefore should be directed into the facts and figures of the operation of the South Brooklyn electrical plant and system, and here it is regrettable to find that all the ascertainable facts are not presented, nor are the accounting figures either complete or reliable.

The very large investment in the new municipal electrical system is represented as justified by the record of the smaller plant of the village of South Brooklyn, which is asserted to have made the remarkable record of having acquired more than one-half of its total value in eight years from the earnings of the plant itself. So far as the details of these earnings are made available in the paper under discussion, the diversion of such earnings was not warranted. The career of this South Brooklyn plant has been rather short and has been beclouded by a good deal of mis-statement of figures. From an examination of the files of the Electrical World and other papers, one can learn the following:

The issue of bonds of $30,000 is still extant, and no provision has been made for their retirement; $18,000 of the issue are due in January 1915 and an ordinance is pending for their renewal. Earnings therefore should have first provided for this necessary retirement. The figures of capital investment show that the total investment of public money in the system has been, to end of 1913, $320,796; and from the operating income of the system prior to providing for necessary fixed charges, there has been sunk $306,533; giving a total of $627,329.

Now this account is credited with a sum of $109,147 which was given by the author in the Cleveland Plain Dealer of February 3, 1914, as $89,909, for the value at the same rate that could or would have been paid to a local company for street lighting. The real value of the amount in question must be regarded as dubious, especially as it represents lighting done more than five years ago, bills for which were never rendered. Such as it is, however, it almost exactly offsets a book charge for depreciation of $113,244, so that the effect is that any money for the latter necessary purpose has been burnt up and the value only exists as a book debit. The character of part of the earnings may be readily seen by comparing the figures of operating income with the item for 1913. The net earnings for 1913 were $68,979; the earnings put back in the plant were $66,622; leaving for fixed charges of $19,079, only $2,357.

It would have been of special interest to know what proportion of the gross income was contributed by city payments for light and power. I find in the official audit of this plant by the State of Ohio the figures for the first three years' operation:

Sales to private consumers	$41,086
Sales to city departments	59,035

These do not include, of course, the $109,000 for street lighting, which was not billed to the city.

The income of the South Brooklyn plant was secured in 1913 by an average sale price at the rate of 3.28 cents per kw-hr. We are informed by the author that during the first eight months of this year the operation of the new rates has reduced the average income to 2.44 cents per kw-hr. The direct loss on the South Brooklyn system is therefore 84/100 of a cent, and allowing for the economy in production cost due to the new plant's operation, the net loss is $31,100.

Turning to the figures of operation of the new plant we find:

The earnings for August were, at the average rate of 2.07	$19,405
Average of 8 months monthly operating cost	12,130
Leaving for administration and fixed charges	7,275
The fixed charges are stated in par. 14 to be per month	22,500
Resulting in a deficiency, for the month, of	15,225

and it is upon this somewhat ricketty foundation that the basis for estimating results in the 53d St. station has been predicated.

The assumption of an annual output of 60 millions of kilowatt hours with a load factor of 40 per cent is taken as the basis for predetermination of a unit cost. It must be evident that such assumptions are little better than guesswork. The present operation and that of at least several succeeding years will result in a loss on fixed charges which may largely increase the liabilities. The assumption of so large a business depends upon two features:

1 The superior desirability of the service from the point of view not only of price but of character and continuity.

2 On the character of service attracted by the inducements of the rates.

First, the service, however, is only to be alternating current, in face of the conceded extent of direct current service in the best business part of the city. We are not told if the distribution system is underground or exposed. For much of the business of Cleveland. therefore, the service offered will be of unattractive character, and much direct current machinery would have to be altered or discarded for its adoption.

Second, the rates which I find in the records of the Municipal Council are such as to offer little inducement to those consumers whose usage is the most desirable in producing a high load factor. The rates do not include any service charge and are drawn merely on the relation of connected capacity and monthly consumption. The following examples have been worked out therefrom:

he actual cost of the service connection, upkeep, meter installation, lamps, accounting and bills, as per consumer, per annum, $8.41. This is over and above the cost of producing and delivering the energy used. On such small installations, the use of energy at the three cent rate would not bring in a return covering the cost.

The propriety of the construction, in advance of a determination of business to be secured, of this large station, in its completed form, must be regarded as dubious from a financial and business standpoint. The anticipations of financial success of the system, so far as they are based upon the facts and figures of past operation, are of doubtful probability.

C. F. LACOMBE[1] (written). The problem of the operation of municipal lighting plants under favorable load and operating conditions depends not only on proper engineering conducting of the work but on the political scheme of administration governing the engineering control. It is obvious that, by employing engineers of ability and experience under proper incentives, a municipal corporation can have a plant built of the best type and in the same way it can also operate it.

Unfortunately, the laws governing municipal administration do not place the chief operating engineer in control of the manufacture of his product and accountable to the political body only for the proper costs of production and good service. In consequence, the conduct of the plant and the service rendered by it suffers, as well as the engineer in charge. To my mind the secret of successful municipal operation of utilities requiring experience in engineering work is an assured engineering control, given proper support by an advisory board of engineers, and responsible for results only without reference to political interests or changes.

THE AUTHOR. I have been told so often that we were radicals up at Cleveland, that I was glad to learn that Mr. Dow does not consider anything in this station to be at all radical and that we have built a plant so nearly like the Delray station. There is then no reason why the latter should not sell current at the same price as we are selling ours, and I hope to see this done.

In regard to the capacity of the Cleveland station, there is at the present time some degree of uncertainty in the method of rating power stations and power station machinery. My understanding is that

[1]30 Broad St., New York City.

Load Factor per Cent	Monthly Consumption kw. hr.	Connected Load kw.	Rate Cents	Bill Dollars
64	2,000	5	3	60
16	2,000	25	3	60
8	2,000	50	3	60
100	3,120	5	3	93.60
33	3,120	15	2.1	65.52
50	67,400	200	1	
75	100,600	200	1	

The accompanying diagram, Fig. 13, indicates that the inducements of the rates are towards high connected capacity which is of course

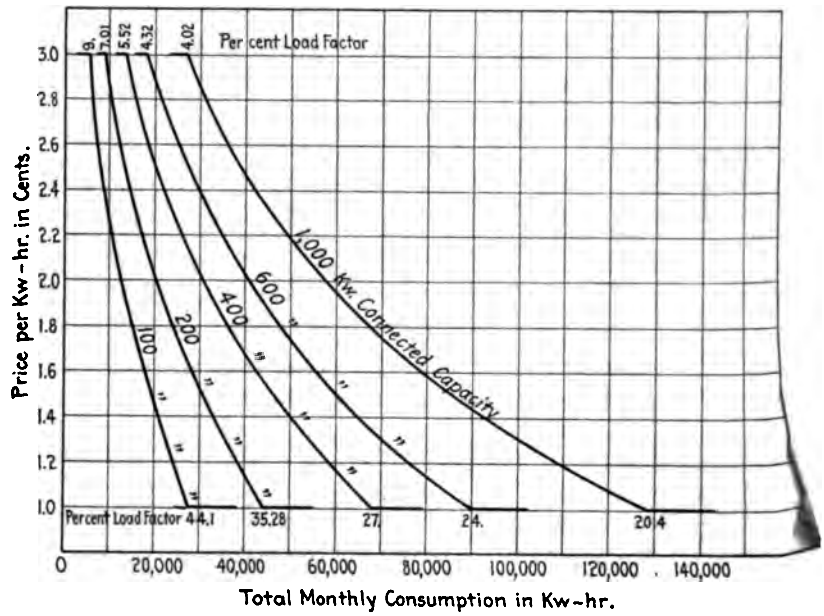


FIG. 13 RATE PER KW-HR. WITH VARYING CONNECTED CAPACITY, CLEVELAND MUNICIPAL ELECTRIC LIGHT PLANT

a source of production of high peak and low load factor. We are led to enquire, when we read that the maximum rate is to be 3 c., upon what determinate data such a limit was reached. The total costs of the 936,000 kw-hrs. sold in August were, without administration, $34,630, or, per kilowatt hour 3 7/10 c. The cost of the service of small household consumers is known to be high. The Detroit Edison Company, which serves 73,000 of such consumers, has made public e actual cost of the service connection, upkeep, meter installation, nps, accounting and bills, as per consumer, per annum, $8.41. This over and above the cost of producing and delivering the energy ed. On such small installations, the use of energy at the three nt rate would not bring in a return covering the cost.

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[1]30 Broad St., New York City.

stations at the present time are generally rated upon their maximum continuous capacity. Tests show that our turbines are capable of 7500 kw. continuous capacity; three of them would give 22,500 kw., and the auxiliary machine would add 1500, making 24,000 kw. maximum continuous capacity. That is the basis on which I have made all my statements in regard to capacity.

Mr. Dow questions the accuracy of the figures based upon the kilowatt-hours generated. He evidently is misinformed as the "kilowatt-hours generated" in our reports refers to the kilowatt-hours on the switchboard leaving the station and does not include the power used by the auxiliaries in the station.

I was interested in Mr. Cravath's discussion. I noticed that his estimate of the cost of the distribution system of the Brooklyn station was $365 per kw. As near as our appraisal will show, the value of the Brooklyn distribution system is about $200 per kw. and of the station itself from $160 to $175 per kw.

As to whether it will be possible to get a 40 per cent load factor, we are now running every day with between 60 and 80 per cent load factor. I realize, however, that, as we build up the load on our station, we will probably secure a much poorer load factor, and may get down to 40, but I hope not below that.

Mr. Cravath also raised the question in regard to cost per kilowatt-hour being so much different for the different classes of customers. That is very true and we are radical in the respect that we are selling current to some customers at a loss. The waterworks department in Cleveland is selling water at 40 c. per 1000 cu. ft. to the smallest household user as well as to the factory. That is probably the other extreme, but the department is subject to no competition, and can make its rates uniform if it wishes. Of course, that cannot be done in an electric light proposition. Apart from the question of competition, if there was only one station in the city and every customer had to take current from it, a uniform rate and load could not be maintained. Current could not be sold to all small residence lighting customers at as low a rate as it would be necessary to sell it to power customers. On the other hand, if the power customers were charged higher rate than the residence customers, business could not be obtained.

Mr. Bolton raised a question in regard to $49,000 being shown in our report as profit, and $66,000 being put back into the plant from earnings. That is correct, although the latter amount was set up ıe books as depreciation. A great many companies are mistaken at ıe present time in setting up 10 or 15 per cent for depreciation year :ter year, with the result that the book value of their plants will soon : much less than the physical value of the material. I remember ap- raising the factories of a large company I was associated with for a umber of years, and finding that the value of the company's property as thousands of dollars more than their books showed, simply be- ıuse they had been writing off too much depreciation.

The actual expense should be carried and the plant should be kept p to its physical value as a maintenance expense, which should be ritten off year after year at actual cost; then a reserve fund should ɜ set up for depreciation. In the Brooklyn plant between 10 and 20 er cent has been written off and that is where the difference between ıe $49,000 and the $66,000 comes in.

Mr. Bolton has, unconsciously perhaps, allowed a fallacy to creep ıto his argument when he attempts to balance the $109,000 due to ıe Municipal Light Plant for service rendered to the City, against the ıtal depreciation of $113,000 which has been set up on the books. He so assumes that any money which has been set up on the books as epreciation should not be turned back into additions or extensions : the plant, but evidently believes that this money should be held in a ınd, and I can only say that the practice as outlined in our report is ıat followed by a great number of large private corporations and is ndoubtedly the most effective means for using the depreciation fund ır maintaining the plant value, and that of course is what the de- reciation fund is supposed to be for.

The results which have been secured since the preparation of the ıper have been such as to still further justify our original estimates, ıd since considerable interest seems to have been aroused in regard ı the possibilities of this station, the author will bear in mind that it ıight be advisable to prepare another paper for the Society after the ɜsults of a year or two of operation have been secured.

No. 1457

A STUDY OF CLEANING FILTER SANDS WITH NO OPPORTUNITY FOR BONUS PAYMENTS

By Sanford E. Thompson, Newton Highlands, Mass.

Member of the Society

Efficiency in municipal government will only come about as the ɔrk in the various departments is put on a basis which gives each an, from the common laborer up to the skilled artisan and clerk, well-defined task to do in a given time, with a definite reward for accomplishment. Under the ordinary methods of handling city ɔrk it is cheaper where there is fair competition to let work by con- ıct than to handle it by day labor. With an effective system that minates not merely favoritism but also presents a definite incentive r each man to do a fair day's work, a city may save the contractor's ofit, employ its own force of city men, and avoid one of the largest urces for mulching a city treasury through collusion between the ;y officials and contractors.

2 The construction and maintenance work in the department public works is a field that offers the largest opportunities from an ıgineering standpoint. It includes such operations as trenching, pe-laying, sewer construction, aqueduct construction, filter clean- g, street cleaning, road building, grading, concrete work, and build- g construction.

3 No doubt the readers of this paper will raise the question as ı the advisability of a city handling such work as this on a day .bor basis, and the possibility of reducing costs below those which ın be obtained by competitive contracting. Under ordinary ıunicipal management, as I have indicated, it is out of the question ɔ handle work of this kind economically. However, practically very one of the classes of work mentioned has been handled at arge reduction of cost by means of systematic planning of the work n advance and layout of tasks or establishment of piece rates; not

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all in city work, but enough work has been done in municipalities to show conclusively that the same system which has proved so efficient in private construction can be extended to cover practically all classes of city labor. This can be done as soon as citizens realize that such work can be divorced from politics and handled through an organized routine method which will provide automatic checks and definite permanent records.

4 In the present paper it is proposed to describe one of the accomplishments of the City of Philadelphia along the line of improved methods. The particular operation studied is the cleaning of filter sand, one of the operations in the Bureau of Water of the Department of Public Works, which is in charge of Mr. Carleton E. Davis, Chief of the Bureau, and under the supervision of Mr. Morris L. Cooke, Director of Public Works, and a Member of this Society.

5 The City of Philadelphia has five large filtration plants consisting of covered reservoirs operated by slow sand filtration. The water pumped into the reservoir from the Schuylkill and the Delaware Rivers after passing through the pre-filters percolates through about four feet of sand and gravel and is thus purified. The impurities are caught largely in the upper few inches of sand, so that if this upper portion is washed the filtration area is practically renewed. Several methods of cleaning filter sands are in use, all of them involving considerable manual labor. Further details of the methods followed in the case under observation are referred to below.

RESULTS

6 The object of the plan has been to lay out the work of each gang of men so as to increase the effectiveness of the plant and provide a definite task to be accomplished in a day.

7 The results of the plan which is being put into operation are as follows:

Rotation of cleaning the filters is planned in advance by well defined rule.

A definite area of sand to clean is assigned to each gang, this area depending upon the depth of cleaning necessary.

This setting of tasks has increased output of each gang 15 per cent and this should be further increased to at least 25 per cent.

Accurate records are kept, showing the time consumed by each gang.

Cost accounts, as well as pay-roll, are made up from the time tickets furnished to the men.

Gang leaders are required to pay closer attention to their duties.

Improved apparatus and machinery are under consideration.
Methods of determining depths of sand to clean are being standardized.

OBSTACLES

8 The greatest obstacle encountered has been the City Ordinance fixing the rate of pay of unskilled laborers on a level wage per day regardless of the quality of the workman or the amount of work he is able to accomplish. While in city government strict regulation is necessary, a plan such as is followed in Chicago, where the employes in each department are definitely graded, with different wages for each grade, provides a means for rewarding a man according to his ability and giving a city good value for money expended. The Philadelphia ordinances prevent the payment of a bonus and thus make it difficult to encourage the men to accomplish the tasks assigned them.

9 Another hindrance to efficient management that is found ordinarily in city laws is the fact that civil service regulation, while preventing the discharge of a man for political reasons, at the same time limits the power of discharge for inefficiency. The municipality thus pays inferior men not only the same rate as first-class men but prevents the good man who is out of a job which he really deserves from obtaining a situation which the loafer holds. Although the fear of discharge or reduction in wage is a crude and unsatisfactory way of obtaining a fair day's work, its elimination with no means of providing a corresponding substitute increases the difficulties in the way of giving a city fair return for its money.

10 In the case under consideration, for example, the handling of the work would have been much simplified and made substantially automatic if it had been possible to provide, for a man well fitted to his work, a reward for accomplishing a good day's task. As this was impossible, and as it is unfair in any case to expect a man to do an exceptional day's work without an exceptional day's pay, the tasks laid out were lower than would be set under a proper system of task and bonus, and their maintenance was more difficult to enforce.

11 At the beginning, the general attitude of the men and the foremen was antagonistic, as is almost always the case where new methods are being introduced. This is gradually overcome as the results become evident.

METHOD OF CLEANING

12 In the filtration plant first handled by the new method

there are 65 filters, employing about 128 men for cleaning. Each filter is about 140 ft. wide by 250 ft. long, and is built with groined arch bottom and roof, having columns about 16 ft. on centers.

13 The Nichols method of washing is used in this plant. In this method the dirty sand from the surface of the bed to a depth specified is shoveled to an ejector, furnishing water under about 85 to 100 lb. pressure, which forces it through a large hose into the separator, which is a cylindrical iron tank provided with a concentric baffle about 6 or 8 inches from the outside shell. The water and sand swirl around this, the clean sand settling in the conical bottom and passing out through a 2-in. hose below. The dirty water passes under the baffle and out of the top of the tank, whence it passes out of the bed through a hose and pipe to sewer.

14 From the separator the sand is returned by the hose to the bed, where it is properly distributed and levelled. Sometimes, according to conditions, the dirty sand is shoveled direct to the hopper of the ejector, and in other.cases is scraped and piled from the first and one-half the third bay into the second line of bays; from the other half of the third and one-half the fifth line of bays into the fourth line of bays; and so on, to include the ninth bay. This scraping and piling is done usually as an independent operation by old men unfit for harder work.

15 Four washing gangs are required for each filter bed, the outside gangs having 2½ bays each and the inside gangs having 2 bays to clean. In each gang there are 3 shovellers to a hopper, two men shoveling at a time while one rests. Each man shovels 40 minutes and then rests 20 minutes. The fourth man takes care of the hose from the separator, distributing the clean sand to the bed. A fifth man, recently introduced, working with 2 gangs, spades up the hard sand that has been uncovered before replacing the washed sand.

METHOD OF ATTACK

16 The method of attacking any problem in order to place it on a scientific basis varies with the character of the work. In certain cases, such as intricate factory operations, it is necessary, before any tasks are set or even before time studies are made, to establish a complete system of routing the materials and the employes. In other cases the first necessity is to establish standards, making minute investigation of the processes. In still other cases time studies can be made at the start.

17 In the sand cleaning proposition all of these methods were

carried on in a measure simultaneously. Studies were made of the men and the methods employed to see where the manner of handling the work could be improved. Time studies were made to determine the unit times for each individual operation, so that the tasks could be figured accurately in advance. From records already on file, giving the approximate time for cleaning, it was possible to begin the organization of the routing system.

OPERATION ORDER

RETURNED ISSUED		CHARGE TO DFT
OPERATION OR SYMBOL DFT		FILTER STATION

WORK TO BE FINISHED	HOURS TO DATE

RATE	AM'T EARNED	TOTAL HOURS	REGULAR HOURS	O. TIME HOURS
	(DO NOT	FILL OUT HERE FOR	GANG WORK)	

MAN'S NAME

IF JOB IS NOT FINISHED SCRATCH OUT THIS ☞			F.
IF JOB IS FINISHED SCRATCH OUT THIS ☞			N. F.
ROUTE SHEET	PAY ROLL	COST DIV.	

FOREMAN

SUPERINTENDENT

Fig. 1 Time Ticket

18 Besides the studies in this particular plant, time studies were also made on various operations in the other plants and methods in various places compared. The general laws of the variation of the filters as regards loss of head, rate, and turbidity, were sought by means of graphical tabulations and curves. Unit costs of labor in the past were investigated.

ROUTING

19 As soon as the preliminary studies were far enough advanced a bulletin board of the type used in the Taylor system was set up in the office at the plant, provided with suitable hooks for the tickets which designated the work of each man. One of the lines of hooks held tickets indicating "Work to be done NOT READY"; a second line above it, "Work to be done READY"; and the third line, above this "WORK IN PROGRESS." On these tickets, which are 4¼ by 4¼ in., there is space for all the information required. The ticket is shown in Fig. 1.

20 The order in which the filters were to be cleaned was designated by the Superintendent. The time each task is begun is recorded on the ticket and also the time of completion. From these tickets records are kept at the plant in terms of labor hours on every class of operation for each individual bed, and the payroll is made up from them. From the pay roll division the tickets go to the cost division, where they are filed under the various charges, so that a monthly cost of operation sheet can be made.

21 A definite system of cross-checking is provided. Previously the time was charged against the various cost items by the gang leader on a daily report sheet and the pay roll and the cost sheet made out from these were sent to the cost division. The results were inaccurate, as the charging of the time was kept by the gang leader.

22 The initial stages of the introduction of the new methods were under the personal direction of my associate, Mr. Lichtner. The system of routing was handled by Mr. Albert Tolson, and the studies and tabulations made by Mr. Lyle L. Jenne. As soon as the routine was established, it was taken over by Mr. Siddons, the superintendent.

23 Eventually, the central planning office will be established at City Hall, with auxiliary bulletin boards at the various plants and operated by telephone from the central office. This plan was started at the beginning, but it was found that further standardization of the method of determining the order in which the filters are to be cleaned was necessary before the centralized planning office would work satisfactorily. New record forms have been developed and the system is working smoothly.

UNIT TIMES

24 Time studies were made by the aid of the stop watch on the

labor operations in the beds, such as shoveling dirty sand to hopper, cleaning up around hopper, moving hopper, moving separator, and moving track. These times for individual operations were then converted for direct use into the time per cubic yard for 1 in. of depth.

25 Studies were also made on the rate of delivery of sand from separator and the effect of opening and closing the separator on the rate of shoveling. Different methods of handling the ejectors were also included in the investigation.

26 The object of the time studies was to find the time of each individual operation, so that unnecessary operations could be eliminated and the unit times of the necessary operations could be combined to apply to all conditions. Over-all time records are of no use whatever, because, for example, with each change in depth of shoveling, the number of moves of the hopper and of the separator vary.

27 The unit times for the individual operations were determined by the taking of a large number of time studies in such a way as to eliminate all unnecessary delays, but with a sufficient allowance for resting and delays which were unavoidable. The unit times obtained are given in Table 1.

TABLE 1 UNIT TIMES

Operation	Unit Time per Operation, Min.	Time per Cu.-Yd. per 1-In. Depth, Min.
Moving hopper	0.20	0.34
Moving separator	0.50	0.45
Moving hopper hose	0.25	0.11
Moving track	0 83	0.44
Waiting for hopper to empty	0.42	0.38
Moving pressure hose	1.80	0.36
Additional necessary rest	....	0.12
Shoveling to hopper	....	6.32

28 The time given in each case is that for the gang, since it was necessary on this work to set a task for the entire gang instead of starting the individual men, as it is always best to do when possible. The time of shoveling into the hopper is in each case based on the rate of output that the ejectors will take care of. It was found that one man, instead of two, could very nearly produce the required output, but this would have lengthened the time of cleaning so as to be inadvisable. For example, with one man shoveling, the shoveling time per cu. yd. is 8.8 minutes with a 1-in. depth, and 6.75 minutes per cu. yd. when the depth is 18 in. These studies indicate therefore that further change is necessary in the method of operation so as to

increase the output of the ejector and separator in order to obtain the full value of the labor of the gang.

29 In addition to the time studies on the work of the laborers in the filters, time studies were also made on the clerical work, such as making out tickets, operating bulletin board, extending time on tickets, entering time on various records, and checking up the pay roll in order to distribute the work equally among the force employed to carry it on.

SETTING TASKS

30 Having determined the unit times and established the system of routing and giving out of tickets, the area of surface that should be shoveled by each gang was figured and the point to which they were supposed to go in a day's work was marked with a flag. In order to fix this, it is necessary to determine in advance by test holes the depth which should be cleaned, figuring the area from the volume at the required depth. Curves have been plotted, giving areas or rather distances to clean for the outside and inside gangs for various depths. These distances are converted into pier locations, so many feet in front or back of pier number so and so. The actual point reached each day is reported at the office and the mark for the following day calculated therefrom.

31 On the first two days, after everything was ready, no instructions were given the gang leader or the men as to how much they were expected to do. The total area shoveled by each gang, however, was noted, and compared with the area they should have accomplished. Every gang shoveled less than the figured area, the amount running from 10½ per cent less to 31½ per cent less. After this second day's work we concentrated on E-1 gang, since it is always necessary in order to avoid friction to work with a single man or a single gang, and laid out in advance the amount this gang should accomplish in a day by setting a flag at the point which marked the end of the day's work. As a result, they readily accomplished the task and reached the mark. The task setting was then extended to other gangs.

32 One rather interesting point came up in connection with the handling of the work at first. The men in the outside bays had to shovel about 7 per cent more sand than those in the inside bays because the areas were wider; nevertheless, all gangs had been accustomed to keep abreast, the men who had the narrower width to handle slowing up to accommodate their speed to the outside men.

When the men began working by the task, the operation was somewhat similar, except in the other direction, until the men realized he difference. The inside men, because of the narrower width, were given the longer area to cover and gaged their speed to accomplish their task. The outside men, although shoveling a greater width kept abreast with them without special trouble, thus exceeding their task.

ACCOMPLISHMENTS

33 The rates were set on the basis of a fair day's work which should be accomplished with a first-class foreman and with no incentive to the laborers. Because of this absence of incentive the work actually done averages considerably less than the actual tasks.

34 To compare the amount of work accomplished before and after setting tasks the records were averaged of 27 cleanings taken at random from a period of 1½ years previous to the introduction of the new methods. These showed an average rate of 6.3 cu. yd. shoveled per day per gang. An average of 55 cleanings after task work was started gave 7.2 cu. yd. per day, an increase of nearly 15 per cent. This increase, however, was less than half of what it should have been, the figured rate being 8.4 cu. yd. per day. Although the 15 per cent increase was well worth accomplishing, our tests showed positively that the larger increase of over 30 per cent should readily be accomplished with first-class supervision. One plan considered as a partial incentive is a record card for each man showing his output and thus indicating his relative rank as a workman. The rank of a man would influence the laying off if work is slack, or, on the other hand, if a man is required for a higher position, his ranking would be taken into account. If it had been possible to pay an actual money bonus, the task would have been set still higher and the output would have been increased about 50 per cent.

35 As the work on the filter management was getting under way, circumstances called the men in charge to other locations in the city temporarily. Going back to the job and making further studies, it was found that time had been lost: (*a*) by not throttling down the separator so as to make it run continuously and thus deliver its full output; (*b*) by unnecessary throttling of the hopper and cleaning up ahead before moving hopper to next portion of pile; (*c*) by not keeping spray open to fullest capacity. It was noticed whenever the gang was watched closely that they accomplished their task without any difficulty.

APPARATUS

36 The studies, as is always the case where thorough investigations are made, indicated a number of changes advisable in the apparatus and methods of handling it. It was found that the lines of piping for the water used under pressure were poorly arranged, so as to require in certain cases long lengths of hose and a consequent deduction in pressure which largely increased labor costs. In other cases certain pipe lines had to be moved from bed to bed during the operation of cleaning. The studies have shown that a mechanical washing device probably can be devised which will greatly reduce the cost of cleaning.

37 Even with the present apparatus the method of handling the separators and ejectors can be considerably improved and the cost of this quickly made up by labor saved.

38 The design of the hoppers and separators, as already stated, could be improved so that they would handle just the right amount of material that a gang can readily shovel. The present output is limited by the design of the hopper and ejector.

39 These various matters are under consideration and improvements are being made from time to time.

CONCLUSIONS

40 It is evident from the results obtained here and also from similar experience in other work that output on city work can be appreciably increased simply by careful planning of the work in advance, systematizing its handling, and following it up in routine fashion. To obtain the full value of organization, however, it is necessary to provide some definite incentive to the men to accomplish their tasks. This makes the handling of the work automatic and eliminates friction, and, especially, gives the men the extra money which they actually deserve whenever the tasks are set high enough to require a good day's work.

DISCUSSION

Carleton E. Davis[1] (written). The author's studies were concentrated upon the physical operation of cleaning filters, the primary object of his efforts being to put this work on a better basis. The influence of the studies upon the sanitary functions of the filters was incidental only, and the paper should be read with this understanding.

[1]Chief, Bureau of Water, Philadelphia, Pa.

The labor cost of operating the filters of the Philadelphia water upply is about $175,000 per year. The result of Mr. Thompon's work as maintained up to the present time is to increase by about 5 per cent the output of the force employed upon cleaning sand in he final filters. This phase of the filter operation represents perhaps 0 per cent of the total labor cost of running the plants. This imrovement is very gratifying to all concerned and the author may rell feel pleased that he has accomplished so much in the face of aderse circumstances.

Mr. Thompson's studies have developed a marked advance in the rganization of the force and the handling of problems connected herewith. They have not, however, changed the fundamental charcteristics of the filtration factors of the plant, nor have any new nderlying principles been discovered. This should be clearly undertood in view of the statement that rotation of cleaning filters is lanned in advance by a well-defined rule. The planning is done in dvance as far as possible, as is the case in all well-organized filter lants, but no new rule has been discovered or developed whereby ach filter can be assiged to a fixed position in a prearranged cleaning chedule.

Variation in the quality of the raw material and fluctuation in raft or demand are well-known factors affecting the length of run f filters. The Delaware River from which the Torresdale filters take heir water is affected by storms and other weather conditions, by easonal changes, by temperature variations, by tides, and even by avigation in the stream. A sudden or unexpected storm or any one f a number of other phenomena may upset any prediction as to the xact day when a particular filter should be cleaned. Fluctuations the draft or demand made upon these filters are constantly ocurring in accordance with the needs of the city. Such variations ust be met by altering the rates under which the several filters re working, and these alterations in turn affect the length of the uns and the time when the filters need cleaning.

Filtration engineers will be alert for any definite suggestions that may help to materialize the intimation that a mechanical washing pparatus can probably be devised which will greatly reduce the cost f cleaning. This matter has received earnest attention both in this ountry and abroad. Thousands of dollars have been expended in xperiments and the inventor of a successful apparatus will receive he gratitude of many communities, if not high financial reward.

The advisability of changes in lines of piping and other details is mentioned in the paper. Perhaps it should be stated that the desirability of making such changes had been recognized and that only lack of money for such an item prevented the work from being done. This is an instance of inflexibility in available funds and may be included as one of the features constituting a drawback to the economical carrying on of city work.

The sand cleaning gangs are now working at increased speed and with less time lost by errors or false motions on the part of the foremen. Certain factors stand out more prominently than others in having produced these results. Defining in advance what shall constitute a day's work, clear and easily understood general orders, and the toning up of the organization whereby each man is more or less on his mettle appear to be the features productive of the most good.

Time studies were instrumental in determining what is a fair day's work. Experience showed that better results were obtained by clearly making the limits of each hour's work rather than depending upon a single mark defining the end of a whole day's work. The more frequent goals aid the judgment of the foremen and stimulate the efforts of the men. Individual time tickets assist in keeping the force on its toes, so to speak. Knowledge that his name and a record of his personal work pass under the inspection of his supervisors is an incentive to greater effort by the workman. General standing orders containing explicit and readily interpreted instructions about each feature of the work are issued to all foremen. These orders place before each man an outline of his duties and take away the excuse of ignorance or misunderstanding.

Many features of the work at the filters were apparently found by Mr. Thompson to be as satisfactory as prevailing limitations permitted. The type of shovel used in handling sand was not changed. The motions of the laborers were not corrected. The work and rest periods were not altered, and other features were left without constructive suggestions.

The intimation of the existence of antagonism on the part of the men and foremen borders on the psychological. It may be fairly asked, however, that if this state of mind is found as a usual thing, why a system for anticipating and disarming it in advance has not been developed. Might not an advance campaign of enlightenment and education, leading up to the desired issue, be undertaken in ch a way that the men would feel that the new methods were their 'n suggestion?

The author's studies represent one phase of the work undertaken Mr. Cooke, towards the improvement of the filtered water supply Philadelphia. The Torresdale filters, furnishing 65 per cent of the ater of the city, were manifestly not fully adapted to the work im- ›sed upon them by the conditions existing at times in the Delaware iver. The turbidity in this river varies from 4 to 5 parts per illion to 1000 or 1200 parts per million. Even with the assistance ndered by the preliminary filters, the water delivered to the final ind filters has at times a turbidity of 500 or 600, or twenty times excess of what this type of filter is designed to handle successfully. uch overtaxing produces an unsatisfactory effluent as well as a erangement of operating conditions.

In the general problem, therefore, two lines of attack presented iemselves, both of which were sound and practical, alike from the ltration and management standpoint. The raw material upon which ie plant worked, or the water delivered to the final filters, should e kept as much as possible within certain limits; the mechanical ork of the operation should be standardized. This latter feature ould be undertaken at once, and it is along these lines that Mr. 'hompson has worked. To secure greater uniformity in the raw ater, certain additional preliminary treatment was necessary in- olving large construction and the accompanying delay and uncer- inty in securing funds. Improvement in this direction is now also sight, as Mr. Cooke has recently secured an appropriation for a reliminary sedimentation basin, work upon which will probably be gun in the Spring.

While this sedimentation will not overcome all the difficulties tending changes in the quality of the Delaware River water, the ak loads from which the plant now suffers will be materially reduced. here is every reasonable assurance that Mr. Cooke will accomplish is desire to make this plant one of the best in the country.

THE AUTHOR. As Mr. Davis indicates in his discussion, many iings are yet to be accomplished in the attainment of more definite andards of handling the plant. Because of the limited time given to , it has been impossible as yet to proceed nearly as far as the work hould be carried. The planning of the rotation of cleaning has re- ulted in much more systematic arrangement than formerly. Contrary to Mr. Davis's opinion, from the studies thus far made, taken in connection with other problems with at least as many indefinite factors, it is unquestionable that means can be provided for allowing for the contingencies indicated so as to still more thoroughly route the cleaning. The special conditions are no more extraordinary than are provided for by routine means in construction and manufacturing plants.

In regard to the attitude often met with among men who have handled work all their lives in a rule-of-thumb manner and who cannot, therefore, see any possible chance of change for the better, the best argument to convert them is results. In many cases, this appears to be the only way to convince them. At the same time, educational methods should be introduced through a reading of up-to-date books on management, and personal contact, and above all, the influence of the higher officials indicating their thorough sympathy with the improvements suggested and the necessity for thorough coöperation of all concerned.

In some cases, education can be effected before any changes whatever are made in the organization. In one plant, for example, the beginning of the introduction of scientific methods was delayed for a period of six months so that the head of the concern should have an opportunity to talk with his department chiefs and bring them into thorough sympathy with the modern spirit of management. In this case, the delay in beginning the work was well made up by the enthusiasm with which it was undertaken by all hands when it once started.

No. 1458

A RATE-FLOW METER

By H. C. Hayes,[1] Swarthmore, Pa.

Non-Member

The velocity with which a fluid flows through a conduit can be determined by finding either its kinetic energy or its change in potential energy with respect to the direction of flow.

2 The kinetic energy of unit mass is the same as its potential energy would be if all its energy of motion were expended in raising itself against the force of gravity. Calling the height through which it would be raised H, we have the relation:

$$H = \frac{V^2}{2g}$$

where V is the velocity of the fluid and g is the acceleration due to gravity

3 The value of H is determined experimentally as the height the fluid is raised by the impact pressure. The pitot tube operates in accordance with this formula, and an application of the formula leads to Thompson's formula

$$Q = K.H^{\frac{5}{2}} \text{ or } Q = K\sqrt{H^5}$$

where Q is the quantity which flows in one second through a V-shaped weir, K is a factor of proportionality, and H is the height of the water level above the bottom of the notch.

4 The relation between the velocity of the moving fluid and the change of pressure with respect to the direction of flow is obtained through Newton's Law of Motion, mass times acceleration equals the accelerating force.

5 In Fig. 1 consider the small element of volume ds^3 of the moving fluid having the front and rear faces perpendicular to the

[1]Prof. of Physics, Swarthmore College. The experiments were conducted at Harvard University where Dr. Hayes was formerly connected with the Jefferson Physical Laboratory.

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direction of flow. Let ρ be the density of the fluid supposed to be incompressible. Then from Newton's Law we have:

$$\rho \cdot ds^2 . a = dp \cdot ds^2$$

where dp is the pressure difference at the front and rear faces. This simplifies to:

$$\rho a = \frac{dp}{ds}$$

Putting for a its equal $\frac{dV}{dt}$, and for ds its equal $V \cdot dt$, we get the following relation

$$V \cdot dV = \frac{1}{\rho} dp$$

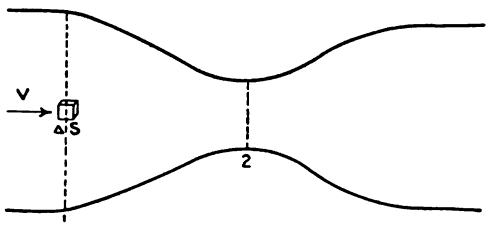

FIG. 1 SECTION OF CONDUIT OF NON-UNIFORM CROSS-SECTION

Integrating this equation between the points 1 and 2 gives

$$\frac{\rho}{2} (V_1^2 - V_2^2) = P_1 - P_2$$

which states that the gain in kinetic energy is equal to the loss of potential energy.

6 Calling A_1 and A_2 the cross-section of the conduit at the points 1 and 2 respectively, we get through the law of continuity the relation

$$A_1 V_1 = A_2 V_2$$

This enables us to express V_2 in terms of V_1 and the equation becomes

$$\frac{\rho}{2} \left(\frac{A_1^2}{A_2^2} V_1^2 - V_1^2 \right) = P_1 - P_2$$

By expressing the pressure difference in terms of head and the cross-sections in terms of diameter the equation simplifies to

$$H = \frac{V_1^2}{2g}\left(\frac{D_1^4}{D_2^4} - 1\right)$$

The venturi meter operates in accordance with this equation.

7 Of the several rate-flow meters on the market, excepting those with movable parts such as the disk and plunger types, each operates through one or the other of the principles stated, and each type, under proper conditions, gives good service. But under

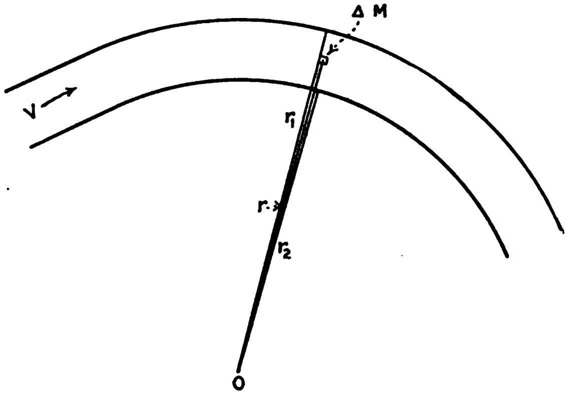

Fig. 2 Conduit Bent in Arc of a Circle

conditions such as attend boiler-feed and return water of condensation, where there are sudden fluctuations in velocity head and large changes in temperature, the venturi meter and those based on the principle of the pitot tube have not proven dependable. Besides, these meters are unreliable at the lower rates of flow under any conditions.

8 Those meters employing the principle of the weir come nearest to meeting boiler-room needs and conditions, but their bulk and price prohibits their use in all but the largest plants. Moreover, these meters do not give a true record of the flow because of their large stori[illegible]acity.

9 [illegible]thy feedwater record is now looked upon as a neces[illegible]p-to-date steam plants, for it gives important inf[illegible] the efficiency of the system. Such a record [illegible] of water are evaporated per pound of coal,

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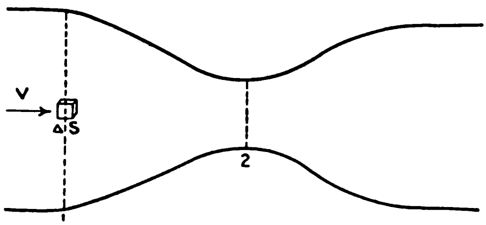

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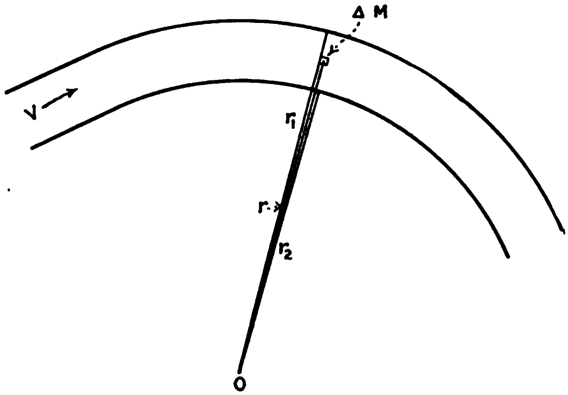

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Those meters employing the principle of the weir come near- o meeting boiler-room needs and conditions, but their bulk and prohibits their use in all but the largest plants. Moreover, meters do not give a true record of the flow because of their storing capacity.

A trustworthy feedwater record is now looked upon as a ssity in all up-to-date steam plants, for it gives important mation concerning the efficiency of the system. Such a record 's how many pounds of water are evaporated per pound of coal, discloses irregularities in boiler feed due to inattention, makes known line leaks and slipping losses due to faulty valves and plungers in the feedwater pumps, and thus serves as a valuable check on the whole system. The meter to be described was designed especially for giving such records.

10 This meter operates through the relation which exists between the velocity of a moving fluid and the change of pressure in a direction perpendicular to the direction of flow. The pressure gradient in this direction is, of course, zero unless the flow lines are distorted. When these lines are made to describe the arc of a circle the relation is simple.

11 Suppose, in accordance with Fig. 2, the conduit is bent in a circular arc of outside radius r_1 and inside radius r_2. A difference in pressure will exist between points 1 and 2 due to the centrifugal force. A small mass dM at a distance r will give an increment of pressure dP outward along the radius such that:

$$dP = \frac{dM \, . \, V^2}{g \, . \, r}$$

The difference in pressure at the points 1 and 2 is given by integrating this expression from r_2 to r_1,

$$P_1 - P_2 = \int_{r_2}^{r_1} \frac{dM \, . \, V^2}{gr}$$

12 If the fluid is incompressible,

$$dM = \rho \, . \, ds^2 . \, dr$$

and if we neglect the effect of viscosity, as has been done in obtaining all the formulæ, V will be independent of r and our expression becomes:

$$P_1 - P_2 = \frac{\rho \, . \, ds^2 . \, V^2}{g} \int_{r_2}^{r_1} \frac{dr}{r} = \frac{\rho \, . \, ds^2 . \, V^2}{g} \log . \frac{r_1}{r_2}$$

and in order that P_1 and P_2 shall be the pressure per unit area, ds must equal 1. Making this change and writing $P_1 - P_2$ in terms of head we get the relation

$$H = \frac{V^2}{g} \log \frac{r_1}{r_2} = KV^2$$

13 Some idea of the value of K is given by expanding $\log \frac{r_1}{r_2}$ in a series.

$$\log \frac{r_1}{r_2}=2\left\{\left(\frac{\frac{r_1}{r_2}-1}{\frac{r_1}{r_2}+1}\right)+\frac{1}{3}\left(\frac{\frac{r_1}{r_2}-1}{\frac{r_1}{r_2}+1}\right)^3+\frac{1}{5}\left(\frac{\frac{r_1}{r_2}-1}{\frac{r_1}{r_2}+1}\right)^5\right\}$$

$$=2\left\{\left(\frac{D}{r_1+r_2}\right)+\frac{1}{3}\left(\frac{D}{r_1+r_2}\right)^3+\frac{1}{5}\left(\frac{D}{r_1+r_2}\right)^5\right\}$$

$$=\frac{D}{r}+\frac{1}{3}\left(\frac{D}{r}\right)^3+\frac{1}{5}\left(\frac{D}{r}\right)^5$$

where D = diameter of conduit and $r=\frac{1}{2}(r_1+r_2)$.

14 If $\frac{D}{r}$ is less than 0.67 all but the first term of the series can be neglected and still leave the formula accurate to within 1 per cent. Giving $\frac{D}{r}$ this value we find that

$$K=0.021$$

wherefore

$$H=0.021\ V^2$$

15 A meter of this form works well for measuring large values of V, but is not sensitive enough for feedwater purposes. The factor of proportionality increases as r_2 is made smaller, but the higher terms can no longer be neglected, and when r_2 approaches zero the flow approaches more and more nearly to vortex conditions.

16 Suppose the conduit is so shaped that a vortex is formed, as shown in Fig. 3. The pressure difference between points 1 and 2 will approximate the value given by a circular vortex of the same cross-section and the value of the circulation corresponding to the velocity, V. The difference in pressure between the center and outside of a circular vortex of radius a is:

$$P_1-P_2=\frac{\rho K^2 a^2}{8\pi^2 a^4}$$

where K is the value of the circulation and is here equal to $2\pi a V$.

Substituting this value and expressing the pressure difference in terms of head we have:

$$H = 0.5\ V^2$$

17 This result is but a rough approximation for the stream lines are spirals instead of circles, but the formula suggests that a sensitive meter might be constructed along these lines. Such a meter should not be greatly affected by fluctuations in pressure such as are always produced by feedwater pumps, for the inertia of the vortical mass

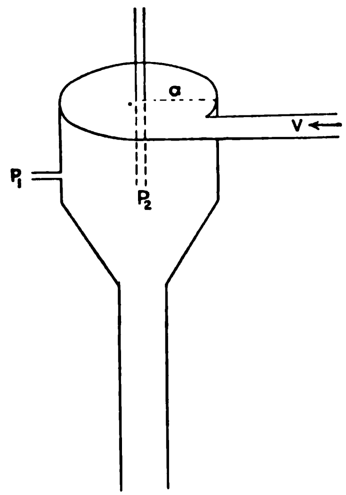

FIG. 3 CONDUIT SO SHAPED THAT A VORTEX IS FORMED IN THE MOVING FLUID

will serve to steady the gage readings much as the flywheel does the motion of an engine.

18 Distortion of the entering stream lines through faulty connections or elbows placed too near the meter will affect the readings but little as these distortions will become straightened in the vortex before the pressure terminals are reached. Finally, the sensitiveness of the meter can be changed by moving the low-pressure vent along a radius of the vortex and as a result the meter could possibly be made to give correct results for any particular temperature by setting the low-pressure vent properly.

19 This will be possible if the percentage correction in H caused by moving the low-pressure vent is independent of the flow; and if

ne correction so introduced is proportional to the distance the ent is moved, and the correction which is made necessary through hange of temperature is proportional to the temperature change, nen it follows that the meter can be made self-compensating by ausing the low-pressure vent to be moved by an unequal expansion rrangement, providing the required motion is small.

20 Whether or not these conditions will be fulfilled can be redicted if the vortex is regarded as circular. We have for such a ortex

$$p-P=\frac{\rho K^2 r^2}{8\pi^2 a^4}$$

where p is the pressure in the vortex at distance r from the center and P is the pressure at the center. It follows that

$$p''-P=\frac{\rho K^2 a^2}{8\pi^2 a^4}$$

where p'' is the pressure at the outside. The value of H is

$$H=\frac{p''-P}{\rho}=\frac{K^2 a^2}{8\pi^2 a^4}$$

nd the change in H caused by moving the low-pressure vent a istance r out from the center is

$$\Delta H=\frac{p-P}{\rho}=\frac{K^2 r^2}{8\pi^2 a^4}$$

The percentage change in H is

$$\frac{\Delta H}{H}=\frac{r^2}{a^2}$$

result which is independent of K and therefore independent of V.

21 Calling $\mathbf{H}$ the change in H caused by moving the low-pressure vent a distance r from the center, we have for the relation between $\mathbf{H}$ and r

$$r^2=\frac{8\pi^2 a^4}{K^2}\mathbf{H}$$

a parabolic and not a linear relation. Plotting this equation for different values of V, i.e., for different values of K, we have a family of parabolas, five of which are shown in Fig. 4. The change in H, caused by shifting the central vent a distance Δr, will be

$$\Delta H = \frac{d\mathbf{H}}{dr} \cdot \Delta r = \frac{K^2}{4\pi^2 a^4} \cdot r \cdot \Delta r$$

and if r is large with respect to Δr the percentage change in r will be small and the change in H will be nearly proportional to the change in r, for $\frac{\Delta H}{\Delta r} = \frac{K^2 r}{4\pi^2 a^4}$, a constant practically.

22 The change in r necessary to correct for temperature will

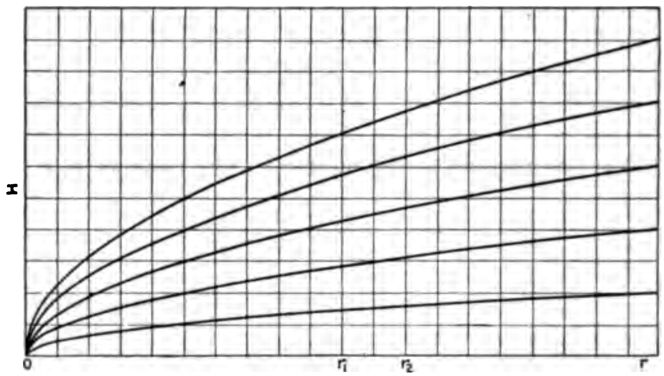

Fig. 4 Five Curves of the Family $\mathbf{H} = K^2 . r^2/8\pi^2 a^4$

probably be small, comparable to r_1 minus r_2 in the figure, and if the normal position of the low-pressure vent is a distance from the center r_1, then, as shown in the figure, the relation between r and H for values of r between r_1 and r_2 is nearly linear. Under these conditions we may assume that the correction introduced by changing r is proportional to the change.

23 It remains to consider whether the error caused by change of temperature is proportional to the temperature change. The error introduced by change of temperature arises from two sources: first, from the resulting change in the density of the liquid and the second, from the change in viscosity. These errors may or may not tend to neutralize each other depending on whether the meter is calibrated to give the flow in terms of weight or volume.

24 The calibration curve for the meter is

$$H=K\,V^a$$

nd if H is expressed as pressure the equation becomes

$$p=\rho H=\rho K\,V^a$$

Calling p_c and ρ_c the pressure and density respectively at the calibration temperature, and p_t and ρ_t the corresponding values at some higher temperature t, we have the two equations

$$p_c=\rho_c K\,V^a$$
$$p_t=\rho_t K\,V^a$$

and if V, supposed here to be in terms of volume, is the same in each equation we have for the percentage error caused by the change of temperature:

$$\frac{p_t-p_c}{p_c}=\frac{\rho_t-\rho_c}{\rho_c}$$

And if we assume a linear relation between the density and the temperature, which is very nearly true, the error will be proportional to the change in temperature. This error will be negative since ρ_t is less than ρ_c, and must be corrected by moving the low-pressure vent toward the center.

25 If the meter is calibrated for flow in terms of weight we have for the relation between V and W

$$W=k\rho V$$

where k is a factor of proportionality and W is the weight of flow per second. The calibration equation becomes

$$p=\rho\,K\left(\frac{W}{k\rho}\right)^a$$

and, as above, we have

$$p_c=\rho_c K\left(\frac{W}{k\,\rho_c}\right)^a=\frac{1}{\rho_c^{a-1}}\cdot\frac{K}{k^a}\cdot W^a$$

$$p_t=\frac{1}{\rho_t^{a-1}}\cdot\frac{K}{k^{a-1}}\cdot W^a$$

and the percentage error is

$$\frac{p_t-p_c}{p_c}=\frac{\rho_c^{a-1}-\rho_t^{a-1}}{\rho_t^{a-1}}$$

26 If a has the value 2 as has been predicted, then the error here will also be about proportional to the temperature change, but the error is positive for ρ_t is less than ρ_o, and the error must be compensated for by moving the low-pressure vent from the center. In either case the error will be about 0.02 per cent per deg. fahr.

27 The error introduced by change of viscosity can be predicted as follows: It can be shown that H is proportional to the kinetic

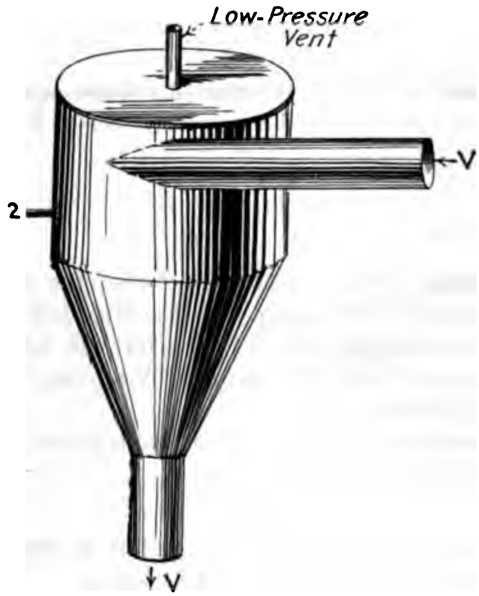

FIG. 5 MODEL 1 OF THE VORTEX FORM OF METER

energy of the vortical mass and we therefore have the relation

$$H = k\ (E - D)$$

where E is the kinetic energy, this mass would have if the liquid were nonviscous and D is the energy dissipated, changed to heat, as the water passes through the meter. The value of D can be shown to be proportional to μ, the coefficient of viscosity of the liquid. The relation between H and μ is therefore

$$H = A - B\mu$$

and H varies inversely as μ.

28 The relation between the coefficient of viscosity and the

mperature is nearly linear if the temperature does not approach o near to freezing, so in case of feedwater we may assume the near relation. The error introduced by change of viscosity will be ositive and must be compensated for by moving the low-pressure ent away from the center of the vortex. This error will amount about 0.026 per cent per deg. fahr.

29 It results that the errors introduced by change of temperature nearly cancel each other if the meter is calibrated to

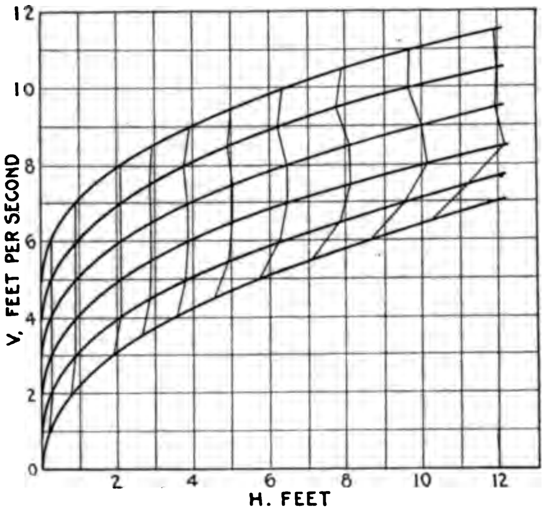

FIG. 6 CALIBRATION CURVES FOR MODEL 1 FOR DIFFERENT POSITIONS OF HIGH-PRESSURE VENT

ive the flow in terms of volume, becoming —0.02 per cent + 0.026 per ent, or 0.006 per cent per deg. fahr.; but if the flow is given in terms f weight, as is usually desired in feedwater measurements, the rrors will add giving a resulting error of 0.046 per cent per deg. fahr. These expectations have been very nearly met in the operation of wo models of somewhat different form.

EXPERIMENTAL RESULTS

30 The first model was fashioned in accordance with Fig. 5. The inlet and outlet were each an inch and a half inside diameter. The vortex chamber consisted of a hollow cylinder 4 in. in height nd 3 in. in diameter, terminating in a 30 deg. cone. Six vents were equally spaced along an element of the chamber; one could be

used for the high pressure terminal, the other five being plugged. The low pressure vent was taken out through a small tube which entered the chamber through a packing-box in the center of the top cap, and could be lowered to any point along the axis of the vortex. This model was constructed for the purpose of determining the variation in pressure along an element of surface of the vortex and also along the axis. This knowledge was obtained as follows:

31 With the central vent fixed, the meter was calibrated for each of the six high-pressure vents, and then with this vent fixed it

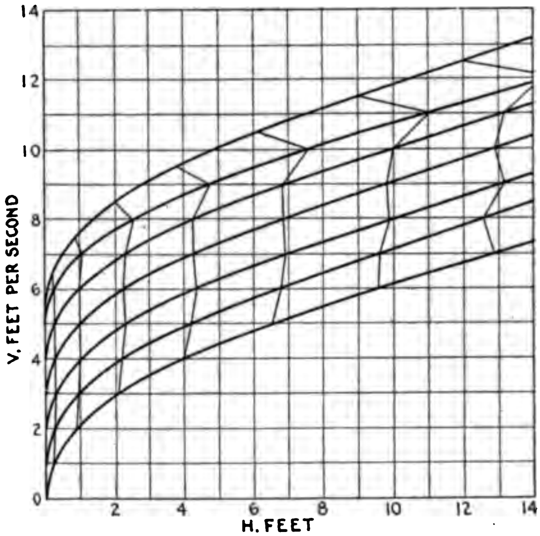

Fig. 7 Calibration Curves for Model 1 for Various Positions of Low-Pressure Vent

was calibrated for several positions of the low-pressure vent. These data are plotted in Figs. 6 and 7 respectively. The ordinates are in terms of velocity, V, (ft/sec.), and the abscissæ in terms of meter head, H, (ft.). The curves in Fig. 6 are displaced along the V axis in accordance with the position on the meter of the high-pressure vent to which the curve refers, and in Fig. 7 a similar displacement has been made with respect to the position of the low-pressure vent.

32 If points corresponding to a certain velocity are taken on each of the six curves in Fig. 6 and a curve passed through these points, this curve will give the variation in pressure along the surface of the vortex for that particular velocity of flow. A similar

urve drawn in Fig. 7 will give the pressure along the axis of the ortex. In both figures such curves are drawn for various values f V.

33 An inspection of these curves shows that the pressure along n element of surface is practically constant until the outlet of the hamber is nearly reached, and the pressure along the axis is about onstant until the top is closely approached. About a centimeter rom the top the pressure reaches a minimum and increases rapidly rom this point until the top is reached.

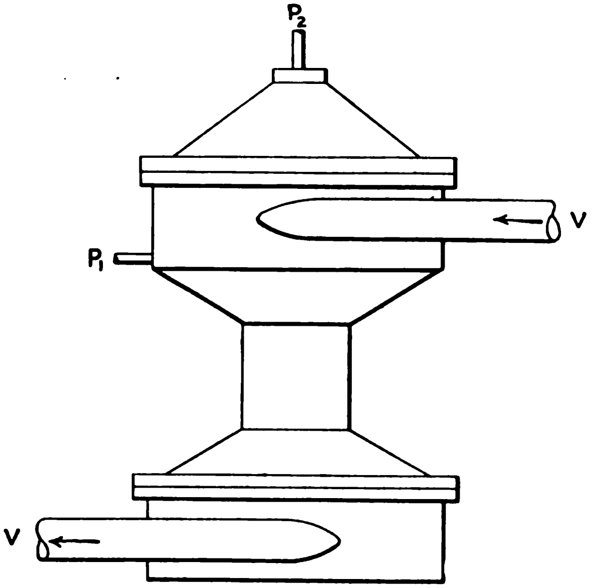

Fig. 8 Model 2, Showing Tangential Inlet and Outlet

34 These results are very favorable. They show that the meter s sensitive, that the vents do not need to be placed with great ıccuracy if they are located about half way down the chamber, and inally that the meter readings will not be greatly influenced by a light distortion of the entering stream lines, such as may be caused ɔy a faulty connection or by an elbow joint placed too near the neter. Such distortions will be eliminated in the vortical whirl ɔefore the pressure terminals are reached.

35 An attempt to determine the loss in head through the meter ɔy taking the difference in pressure between two vents located

one foot each side of the vortex chamber resulted in giving the loss of head in the wrong direction. This result is easily accounted for by the fact that the water is whirling rapidly when it enters the outlet and must continue in this condition for considerable distance. The pressure exerted through a vent in the outlet will be equal to the normal pressure plus the centrifugal force due to the spiral motion. The sum of these two is greater than the pressure in the inlet.

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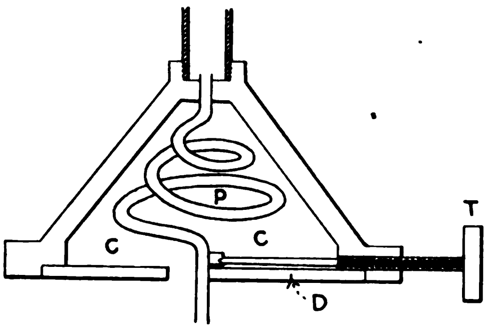

Fig. 9 Arrangement for Moving Low-Pressure Vent Radially

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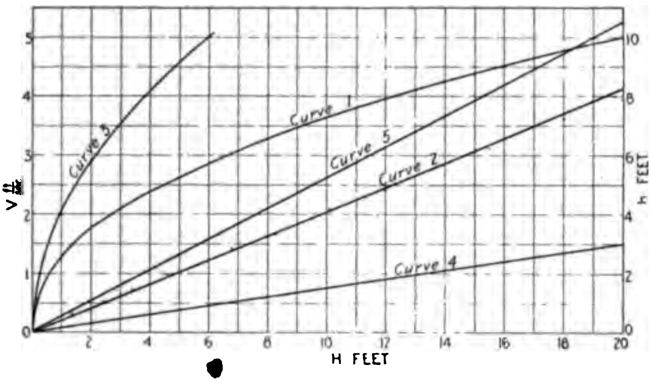

FIG. 10 CALIBRATION CURVES FOR MODEL NO. 2

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$$h = 0.312\ V^2$$

41 The form of the calibration curve suggests that it can be xpressed mathematically by an equation of the form

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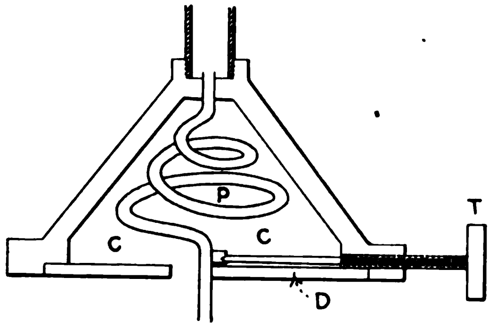

FIG. 9 ARRANGEMENT FOR MOVING LOW-PRESSURE VENT RADIALLY

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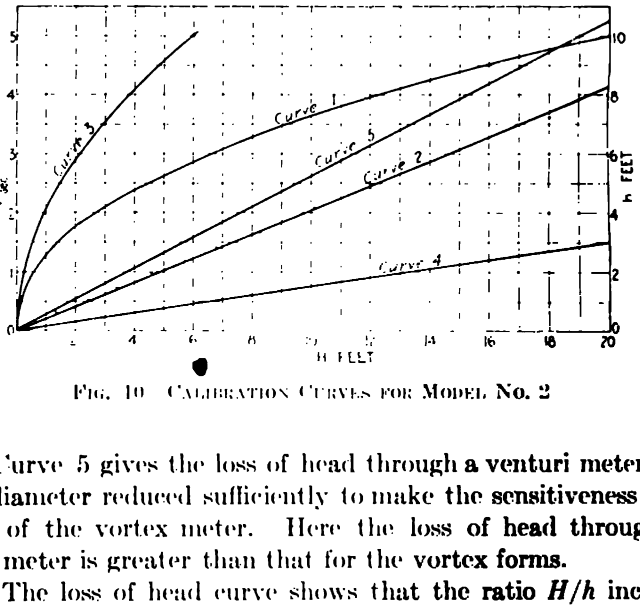

FIG. 10 CALIBRATION CURVES FOR MODEL No. 2

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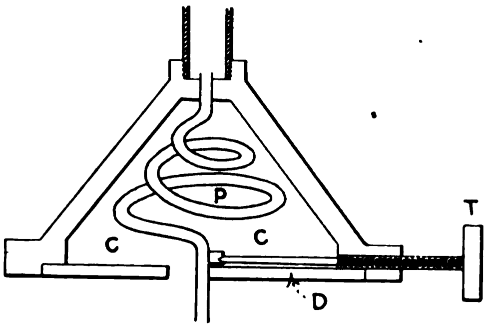

FIG. 9 ARRANGEMENT FOR MOVING LOW-PRESSURE VENT RADIALLY

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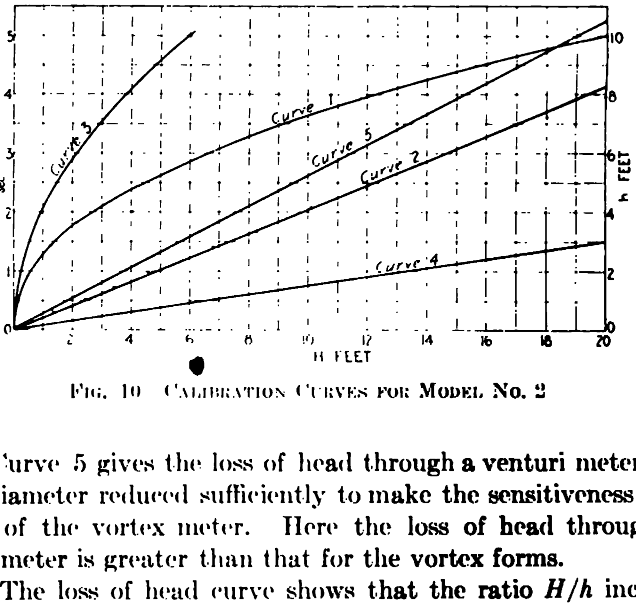

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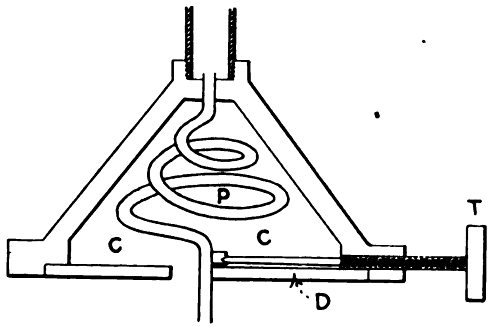

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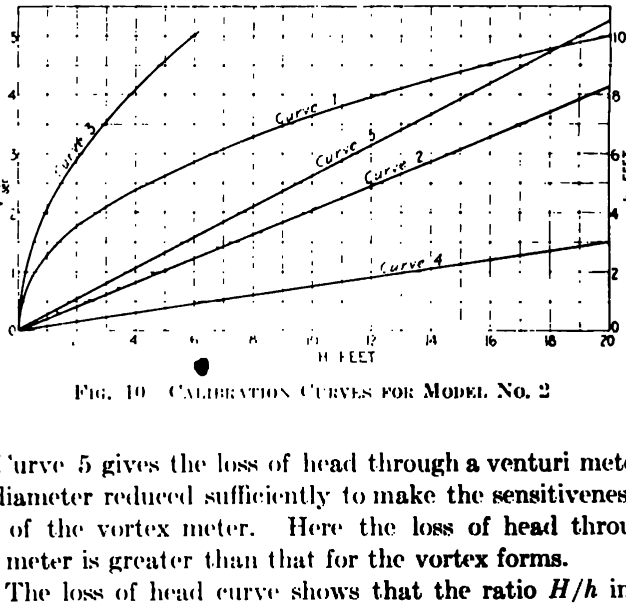

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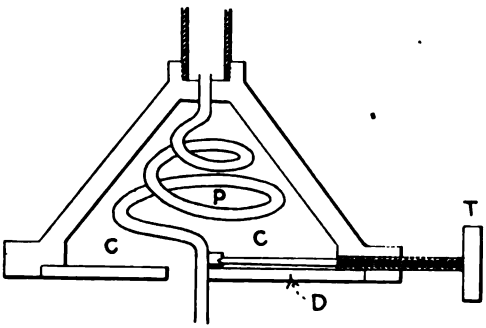

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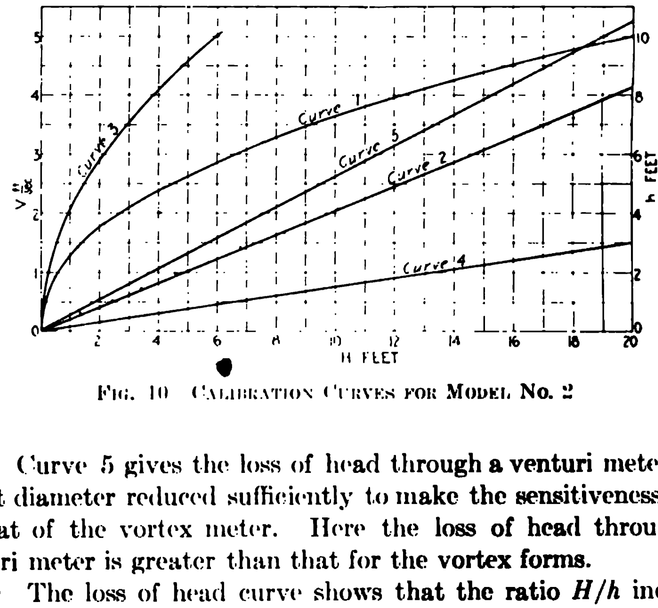

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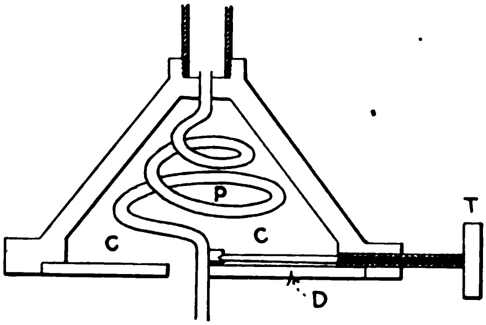

Fig. 9 Arrangement for Moving Low-Pressure Vent Radially

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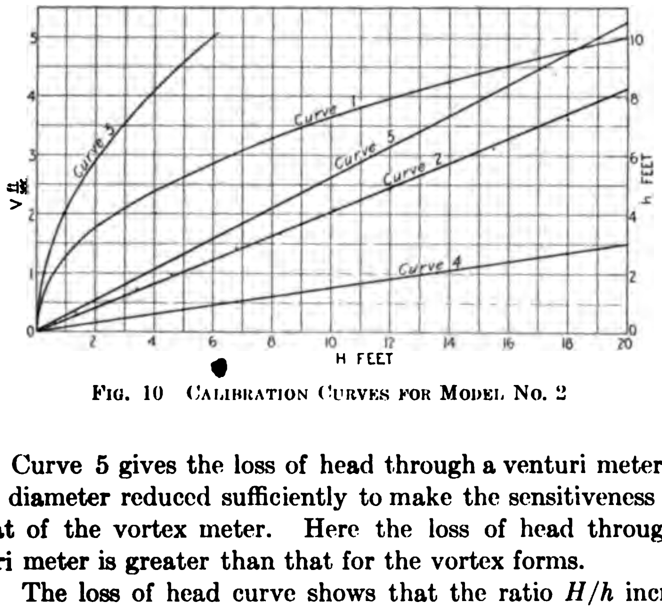

FIG. 10 CALIBRATION CURVES FOR MODEL NO. 2

'at. Curve 5 gives the loss of head through a venturi meter with 'oat diameter reduced sufficiently to make the sensitiveness equal that of the vortex meter. Here the loss of head through the ıturi meter is greater than that for the vortex forms.

40 The loss of head curve shows that the ratio H/h increases V increases. This suggests that H is proportional to some higher wer of V than the square, for the loss of head should be very arly proportional to V^2. Curve 2, Fig. 11 was obtained by plotting ıgainst V^2. The points fall on a straight line to within the limits experimental error. The slope of this line is 0.312 and the re- ,ion between V and h is given by the equation

$$h=0.312\ V^2$$

41 The form of the calibration curve suggests that it can be pressed mathematically by an equation of the form

$$H = K.V^a$$

where H is the meter head, K a factor of proportionality, V th velocity, and a some constant. By taking the logarithm of eac side of this equation we have the linear relation

$$\log H = \log K + a \log V$$

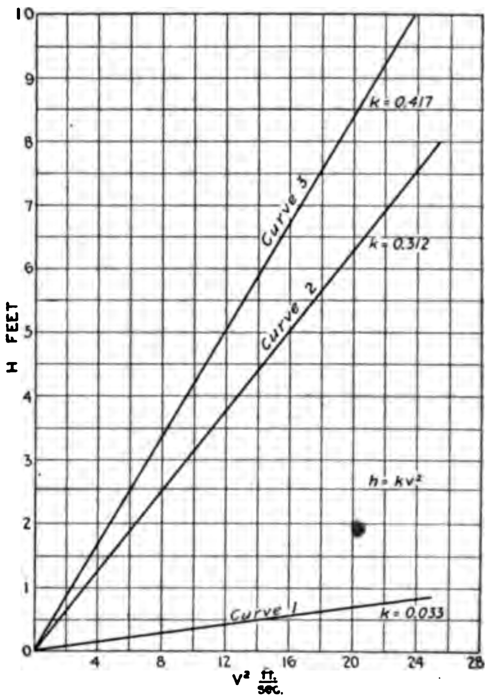

Fig. 11 Relation between Loss of Head and Square of Velocity

42 This curve is plotted in Fig. 12. A straight line pass through the points to within the limits of experimental error, therel proving that the calibration curve can be expressed by such equation. The values for K and a as determined from the logarit metic curve are $K = 0.584$ and $a = 2.20$, so the calibration curve given by the equation

$$H = 0.584\ V^{2.2}$$

It will be remembered that the predicted curve was

$$H = 0.5\ V^2$$

The ratio for $\frac{H}{h}$ can now be completely expressed in terms of V

$$\frac{H}{h}=\frac{0.584}{0.321}V^{0.2}=1.87\times\sqrt[5]{V}$$

For a velocity of 5 ft. per sec. the value of $\frac{H}{h}$ equals 2.58.

43 The loss of head through the ordinary form of venturi meter, where the ratio of the two diameters is ½, is about 2.5 times less

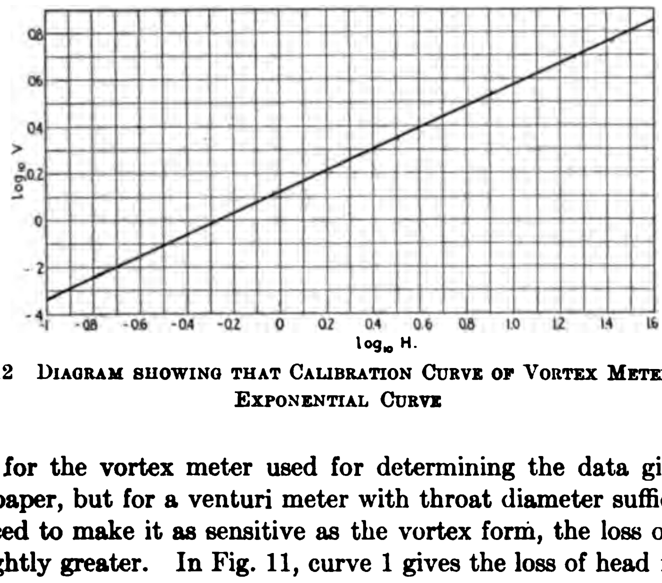

FIG. 12 DIAGRAM SHOWING THAT CALIBRATION CURVE OF VORTEX METER IS AN EXPONENTIAL CURVE

than for the vortex meter used for determining the data given in this paper, but for a venturi meter with throat diameter sufficiently reduced to make it as sensitive as the vortex form, the loss of head is slightly greater. In Fig. 11, curve 1 gives the loss of head for the ordinary venturi and curve 3 the loss of head for a venturi of the same sensitiveness that the vortex meter has.

44 The loss of head through the vortex meter can be made much less than that given by model 2 without lessening the sensitiveness of the meter. The meter apparently works as well with a much larger passageway between the two chambers and the loss of head is lessened by this means. There is little doubt that the meter can be bettered in many respects through change of form and this work will be undertaken later. The loss of head, however, is not a serious matter at the low velocities for which the meter is designed.

45 Fig. 13 gives the change in H caused by moving the low-pressure vent out along the radius for five different values of V.

The ordinates give the change in H in centimeters of mercury, and the abscissæ are given in turns of the thumbscrew. The curves show that the change in H is nearly proportional to the displacement of the low-pressure vent.

46 Dividing the slope of these curves by the value of H corresponding to the velocity of flow at which the data for the curve

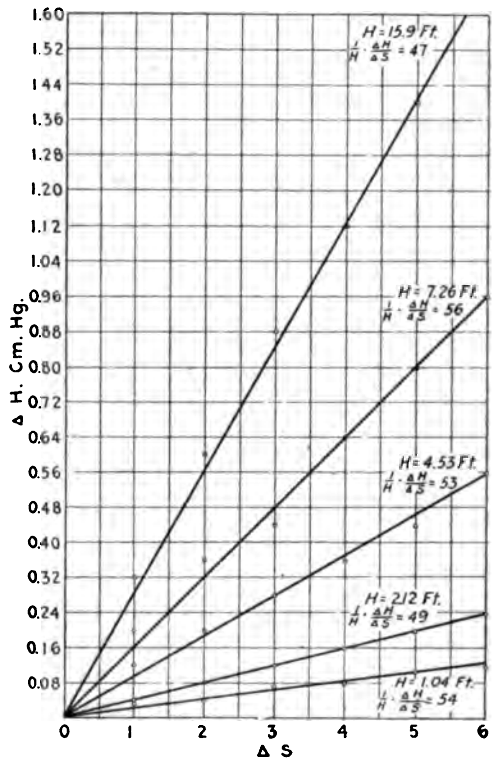

FIG. 13 CURVES SHOWING THAT CHANGE IN METER READING CAUSED BY MOVING LOW-PRESSURE VENT IS INDEPENDENT OF RATE OF FLOW

were obtained gives a value proportional to the percentage change in H caused by moving the low-pressure vent a distance equal to one turn of the thumbscrew. These values are given under the separate curves, and prove to be nearly the same for each. This shows that any correction made by shifting the position of the low-pressure vent will be independent of the flow. As a result the meter can be made to give correct readings at any temperature by turning the thumbscrew to the proper position.

47 Four tests were made at different temperatures to determine the error for which the meter must be corrected. These results are given in Fig. 14. The meter was calibrated at temperature 46 deg. fahr. The percentage correction was determined in each case by dividing the actual flow, as given by weighing the discharge, into the difference between this and the value given by the meter. The curve has these values for the ordinates and temperature fahrenheit for abscissæ.

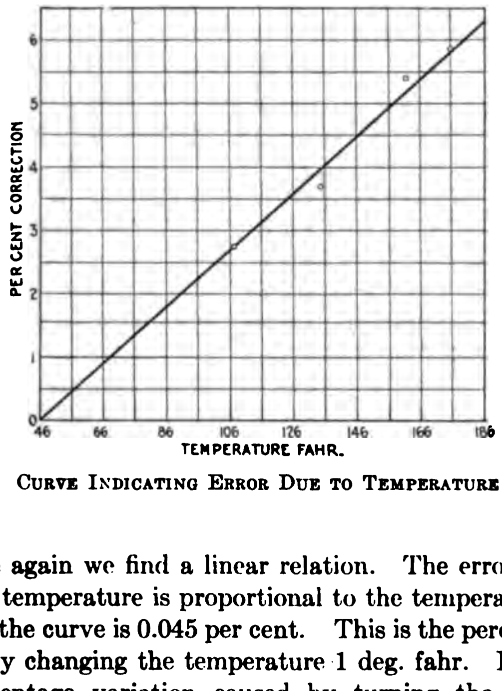

FIG. 14 CURVE INDICATING ERROR DUE TO TEMPERATURE CHANGE

48 Here again we find a linear relation. The error introduced by changing temperature is proportional to the temperature change. The slope of the curve is 0.045 per cent. This is the percentage error introduced by changing the temperature 1 deg. fahr. Dividing this by the percentage variation caused by turning the thumbscrew once gives the number of turns required to correct the meter for a change of one degree temperature.

49 It results from this division that 0.0572 of a turn of the thumbscrew will correct for one degree change of temperature, and since the pitch of the thread is 0.025 in., the distance that the vent moves is 0.00143 in. This motion can easily be given by an unequal expansion arrangement and then the meter will give correct results at all temperatures. The design of this compensating device is shown in Fig. 15. The unequal expansion elements, I and Z, are made of invar steel and zinc respectively. The ratio of their coeffi-

of the movable arm B. The bottom of the two arms, A and B, are connected through the small tube t. Both the connections to arm B are made through flexible steel tubing and thus allow the arm B to spring up and down. When the meter is in operation mercury is forced from A to B until the difference in level is equal to the meter head H, and if the shape of tube A is such that the quantity of mercury forced into B is proportional to the rate of flow through the meter, then the depression of the arm B, due to this weight will be proportional to V. This motion can easily be transferred to pen or pointer.

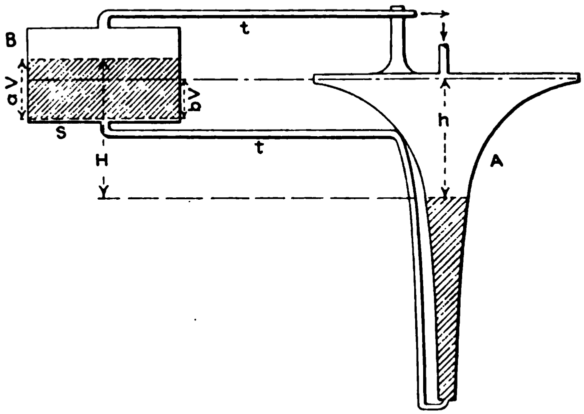

FIG. 16 DIAGRAM SHOWING PRINCIPLE OF RECORDING DEVICE

55 The form of tube A depends, of course, on the shape of the calibration curve of the meter and can be found as follows. Let this calibration curve be

$$H = K.V^a \quad \text{[1]}$$

and let h be the depression of mercury in tube A when a given velocity of flow V is taking place through the meter. Then if the cross-section of B is uniform and we assume that the weight of mercury forced into this arm is proportional to V, the depth of the mercury will also be proportional to V. Call this factor of proportionality a. At the same time the arm B has been depressed a distance proportional to V. Call this factor of proportionality b. Then the meter head H is related to these displacements as follows:

$$H = h + aV - bV = h + (a - b)\,V \quad \text{[2]}$$

56 Since the weight of mercury forced into B is proportional to V, we have

$$\pi\rho \int_0^h r^2 dh = aS\rho \int_0^v dV$$

where ρ is the density, r the radius of tube A at height h, and S is the cross-section of B. Differentiating the equation gives

$$\pi\rho r^2 dh = aS\rho . dV \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots [3]$$

From equation [2] we have

$$dH = dh + (a-b)\, dV$$

and from equation [1] we get

$$dH = aKV^{a-1}.dV$$

whence

$$dh = [aKV^{a-1} - (a-b)]dV$$

Substituting this value for dh in equation [3] gives

$$\pi r^2 \, [aKV^{a-1} - (a-b)] = aS$$

or

$$V^{a-1} = \frac{1}{a\,K} \left\{ \frac{aS}{\pi r^2} + (a-b) \right\}$$

From [1]

$$V^{a-1} = \left(\frac{H}{K}\right)^{\frac{a-1}{a}}$$

And since

$$H = h + (a-b)\, V$$

we get for the relation between h and r

$$\frac{h + (a-b)\, V}{K} = \left[\frac{1}{Ka} \left\{ \frac{aS}{\pi r^2} + (a-b) \right\} \right]^{\frac{a}{a-1}} = \ldots\ldots\ldots [4]$$

57 By adjusting the restoring force on B properly we can make $a = b$ and the equation then simplifies to

$$\frac{h}{K} = \left[\frac{aS}{\pi a\, K} \cdot \frac{1}{r^2} \right]^{a-1}$$

It is to be noticed that when $a=b$ then $h=H$, and if we take for a the value for the vortex meter 2.2 our equation becomes

$$H=\frac{C}{r^{\frac{11}{3}}} \qquad [5]$$

where C is a constant depending on the value of r as chosen for any value of H except zero or infinity.

58 In the computations which follow the radius r has been replaced by the diameter D. The equation, of course, will remain the same in form.

59 Equation [1] shows that as V approaches zero H also approaches zero, and equation [5] shows that as H approaches zero r approaches infinity. It follows that for extremely low values of V the radius of the tube A must be very large if we are to have a linear relation between the depression of arm B and the velocity of flow V; but, as will be shown, the value of r does not become abnormally large until velocities lower than it is customary to measure are reached.

60 The value of D, in the present model, was taken as 1.5 cm. corresponding to the value 48.5 cm. for H, and the equation for an element of the tube A is

$$H=\frac{214}{D^{\frac{11}{3}}}$$

If the largest value of D is taken as 10 cm. the corresponding value of H will be 0.0462 cm., and the device will give a linear deflection for all values of V greater than that which corresponds to this value for H. By substituting this value of H in the calibration curve,

$$H=1.31\ V^{2.2}$$

this value for V proves to be 0.216 ft. per sec. For

$$O<V<0.216$$

the deflection will not be proportional to V, and as a result the pen will not register zero on our linear scale when the flow is zero.

61 The position at which the pen will come on our linear scale for zero flow can be found as follows:

62 First suppose tube A is properly shaped to give a linear deflection for all values of V. The volume of mercury displaced when the value of V is 0.216 will be

$$\text{vol.} = \frac{\pi}{4}\int_0^{0.0462} D^2 dh$$

Now

$$H = \frac{214}{D^{\frac{11}{3}}}$$

Therefore

$$D^2 = (214)^{\frac{6}{11}} \times H^{-\frac{6}{11}}$$

Then

$$\text{vol.} = \frac{\pi}{4}\int_0^{0.0462} 214^{\frac{6}{11}} \times H^{-\frac{6}{11}} dH = \frac{\pi}{4} \times 214^{\frac{6}{11}} \times \frac{11}{5} \times (0.0462)^{\frac{5}{11}} = 8.0 \text{ cu. cm.}$$

63 Secondly, suppose the diameter of A for values of h between 0 and 0.0462 is constant and of value 10 cm. The volume of mercury contained will be

$$\text{vol.} = \frac{\pi}{4} \times (10)^2 \times 0.0462 = 3.64 \text{ cu. cm.}$$

The position, on the linear scale, which the pen will take for zero flow will be equal to the deflection which the 4.36 cu. cm. difference in the two cases would deflect the arm B.

64 The meter gives a value of 48.5 cm. for H when the velocity is 5 ft. per second. The quantity of mercury forced into B by such a velocity will be

$$\text{vol.} = \frac{\pi}{4}\int_0^{48.5} D^2 dH = 188.3 \text{ cu. cm.}$$

Therefore the deflection for a velocity of 1 ft. per second will be due to the weight of 37.7 cu. cm. of mercury, and the deflection caused by 4.36 cu. cm. will be equivalent to that given by $\frac{4.36}{37.7}$ or 0.11 ft. per second. The deflection for velocities of flow between zero and 0.26 are readily calculated.

65 By extending the funnel to a radius of 20 cm. the deflection will be linear for flows as low as 0.19 ft. per sec., but velocities below 0.3 ft. per sec. are seldom met if the feedwater is at all well regulated, so this extension seems unnecessary.

66 The quantity of water that has passed the meter during any interval of time will be accurately given by the area underneath that portion of the rate curve corresponding to the interval in question providing the velocity has not, during this interval, fallen below 0.216 ft. per sec. This seldom happens, and if it does, it is for only a short interval, so the quantity of flow will be given to within a small percentage error in all cases, and the fact that the deflection is not uniform through the whole range makes very little difference.

67 It will be noticed that the quantity of mercury required is comparatively small, being about 200 cu. cm. The restoring force for a small displacement of the pen is great because all the displaced mercury tends to restore equilibrium and not the portion displaced by a float. Moreover, the friction of movable parts is reduced to practically that of pen friction.

68 The restoring force on the pen for a displacement of 0.01 ft. per sec. can be readily found. In the present model the pen moves 4.24 times as far as the arm B. The recorder gives a displacement of 2.54 cm. for a velocity of 1 ft. per sec. and therefore the displacement of the pen will be about 0.025 cm. The corresponding displacement of B is 0.0060 cm. This multiplied by the cross-section of B, 62.8 sq. cm., gives a displacement of 0.378 cu. cm. and therefore a restoring force on B of 5.14 gr. The restoring force on the pen will be $\frac{5.24}{4.24}$ or 1.2 gr. Pen friction is less than this unless the changes in velocity are very rapid indeed, so the apparatus would give satisfactory results if the tube A had been made somewhat smaller in cross-section thus requiring even less mercury.

DISCUSSION

F. zur Nedden, after expressing his admiration for the very able way by which the author had reached and amplified his conclusions, referred to the loss of head caused by the meter. He thought that the dilatation of the lower part of the experimental meter as shown in Fig. 8 was rather sudden and that if the venturi meter should be designed in the same way, with the dilatation as sudden as in this vortex chamber, probably the loss of head would be about the same as in the Hayes' meter. He suggested that after the lower part was stretched out and shaped more toward the form of the diffusive part of the venturi meter the result would be better.

He also pointed out that the author, in his enumeration of devices for the recording of flow, had apparently overlooked one design which is, in a way, similar to his own. This is the design of the late Dr. Amsler of Schaffhausen in Switzerland, the inventor of the planimeter bearing his name. Amsler's recorder is very little known, but one was tried out in connection with a venturi meter in 1909 by the Shawinigan Water and Power Company, Montreal, Que. It consists of two vessels which are connected by a U-shaped flexible tube and filled with mercury, fixed to a weighing level.

Mr. Nedden described Dr. Amsler's device and pointed out the features which render the recorder more sensitive as the zero rate of flow is approached, suggesting that the application of this principle might further intensify the accuracy of the vortex meter described by the author. He mentioned that, as Amsler's recorder did show up very satisfactorily in Montreal, the Washington Water and Power Company, Spokane, Wash., ordered a set of four such recorders in 1912.

He expressed doubt as to whether the Hayes' meter will in itself record accurately in the neighborhood of zero, as he had noted in checking the curves in the paper that in the vicinity of the zero point the meter does not seem to work exactly proportional to the rate of flow. He pointed out also an objection that may be encountered when the meter is arranged for practical use, namely, the question of sediment; he suggested that sediment is liable to accumulate from boiler feed water and that this would alter the real radius of the vortex chamber and thus permit a certain inaccuracy in the meter.

He considered that this form of meter is at a disadvantage in that it is considerably larger in diameter than a venturi tube for the same rate of flow. Therefore if for use in connection with high pressure, it might be necessary to make this form of meter a great deal stronger than the venturi tube of the same rated capacity.

A. R. Dodge referred to a point of interest in connection with the formula of the calibration curve [1], Fig. 10, which indicates that the loss of head varies as the square of the velocity in accordance with the same formula on other meters, the pitot tube meter and the venturi meter. He questioned, if this is so, if the Hayes' meter is not of the same sensitiveness at low flows as the venturi meter or the pitot tube meter; that is, if the size of the instrument will not determine the constant.

Another point is the fact that the drop in pressure on a pitot tube meter is negligible, but that with the Hayes' meter the pressure drop is a considerable item.

CARL SMERLING asked if the author had attempted to measure gasoline with these meters. He pointed out the difficulty of the problem of measuring gasoline correctly in a meter and predicted a big field for a meter of this type if made available for gasoline.

THE AUTHOR pointed out the original meter, which is the first model he made, was more of the shape to which Mr. Nedden referred. He admitted that there was much less loss of head in that model, but he stated that the reason he made the second form was to measure the loss of head which he could not measure on the first one; he did not get enough to measure. He said his desire had been to obtain enough loss of head to be able to measure it and also to get the stream lines coming out straight. He told how he had changed the form of meters, since then including some changes in the neck, and that the loss of head had been materially reduced.

In reply to Mr. Dodge, he said that apparently the sensitiveness of the vortex meter is almost independent of the size of the chamber. While theoretically it would be absolutely independent, viscosity comes in and makes a little change, but a large vortex chamber or a small one could be used and the constant would be almost the same.

He replied to Mr. Smerling that the meter has not been used for gasoline.

No. 1459

ιBORATORY FOR INVESTIGATING AND TESTING LIQUID FLOW METERS OF LARGE CAPACITY

By W. S. Giele, Philadelphia, Pa.

Junior Member

'he laboratory which is the subject of this paper was designed built to facilitate the investigation and testing of liquid flow rs, in order that the construction of such meters might be lardised and a high degree of accuracy insured in commercial tice. While suitable for testing liquid flow meters of various s, its arrangement was in many respects determined by features liar to meters of the V-notch weir type which it was intended to

As is well known, the V-notch meter consists essentially of a ıngular chamber in which is a vertical dividing wall, to the ːr part of which is attached a V-notch weir plate. On one side e "approach" chamber provided with suitable baffles and on the r the "outflow" chamber which receives the discharge of the h and from which water passes to boiler feed pumps or other ɜs of delivery.

The V-notch weir is particularly adapted for measuring the of boiler feed water in that it has superior percentage accuracy nall flows, combined with good accuracy at all flows. As made he company at whose plant the testing laboratory was erected,[1] V-notch meter is combined for this purpose with a feed water er of the open type as illustrated in Fig. 1. In common with r flow meters, this meter is provided with an autographic re- ing device which gives a continuous record from which the ıntaneous rate of flow for any time may be read, while per- ing, also, a continuous integration of quantity.

The indicating, recording and integrating instruments will

[1] he Harrison Safety Boiler Works, Philadelphia.

'resented at the Annual Meeting, December 1914, of The American So- r of Mechanical Engineers.

be best understood by reference to the illustration, Fig. 2. A float resting upon the surface of the water, either in the approach chamber or in a chamber in communication therewith, bears a vertical stem, actuating (by means of a cable and drum) a revolvable cam, adapted to displace a pen carriage or integrating train equal distances for equal increments in the rate of flow. For convenience in manufacture and use, it is desired that one standard height of chart be employed for all capacities, and that this chart be subdivided decimally. With arbitrarily selected weir-notch angles this end might be

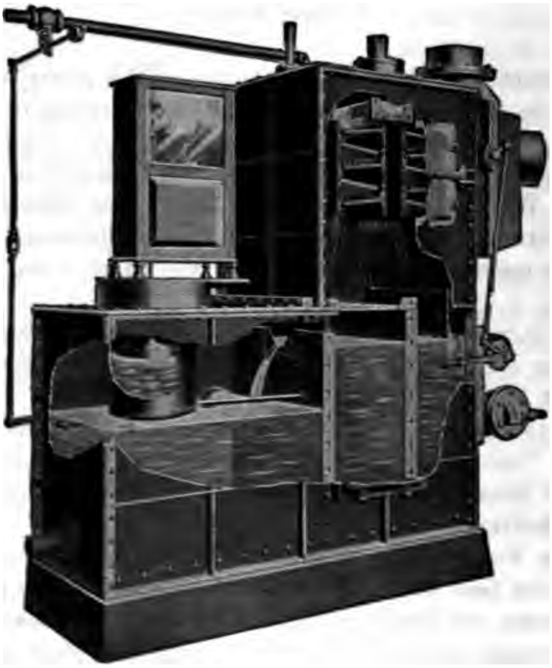

Fig. 1 V-Notch Meter Combined with Feedwater Heater

attained by cutting a different cam for each different capacity, but it is much easier, from a manufacturing point of view, to use one standard cam which embodies the relation between the rate of flow and the head of water on the notch, and to accomplish the adaptation to different rates of flow by varying the diameter of the drum upon which the cable winds and the angle of the notch itself, thus making it necessary to establish accurately the relation between the coefficient of the notch and the angle.

GENERAL METHOD OF INVESTIGATION

'he rate of flow through a flow meter may be determined uring, either gravimetrically or volumetrically, the quan-scharged during a known period and computing the rate of uch a method, however, involves the following difficulties:

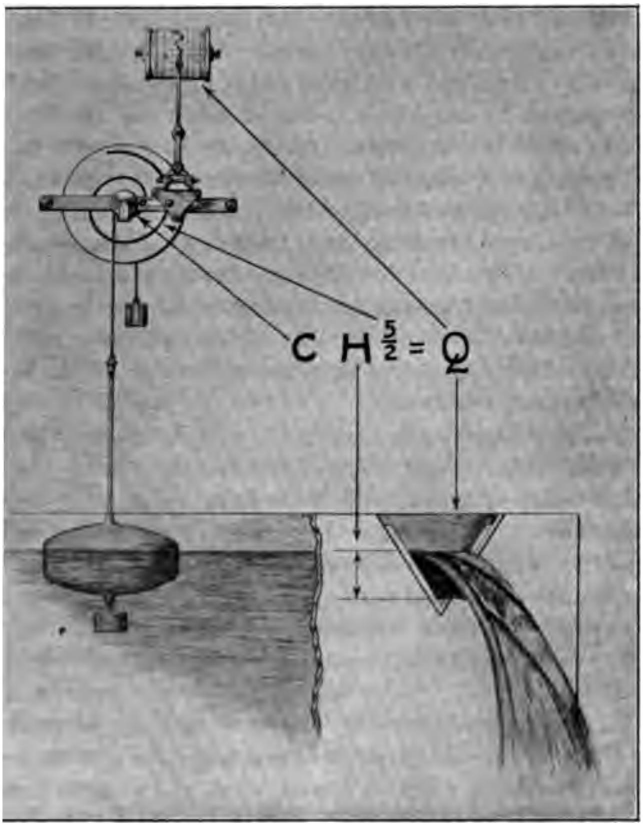

FIG. 2 DIAGRAM SHOWING PRINCIPLE OF RECORDING DEVICE

: Starting and stopping errors
Difficulties in maintaining the rate of flow constant for the whole period of test
Difficulty in keeping a record of the exact variations of head or pressure (these values cannot be averaged by

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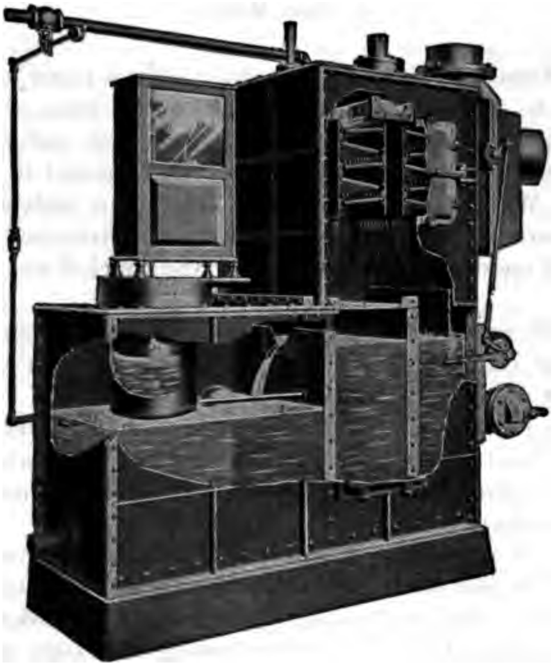

FIG. 1 V-NOTCH METER COMBINED WITH FEEDWATER HEATER

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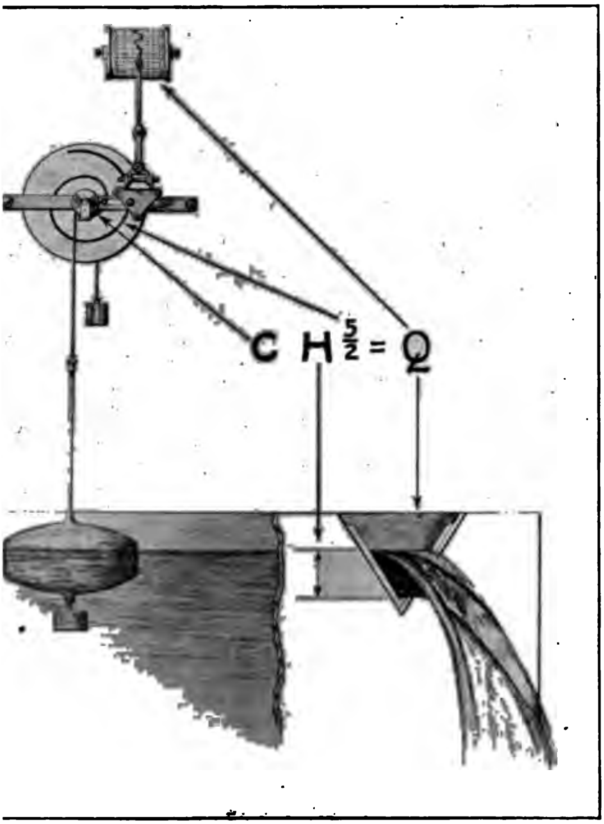

. 2 Diagram showing Principle of Recording Device

Starting and stopping errors
Difficulties in maintaining the rate of flow constant for e whole period of test
in keeping a record of the exact variations of essure (these values cannot be averaged by

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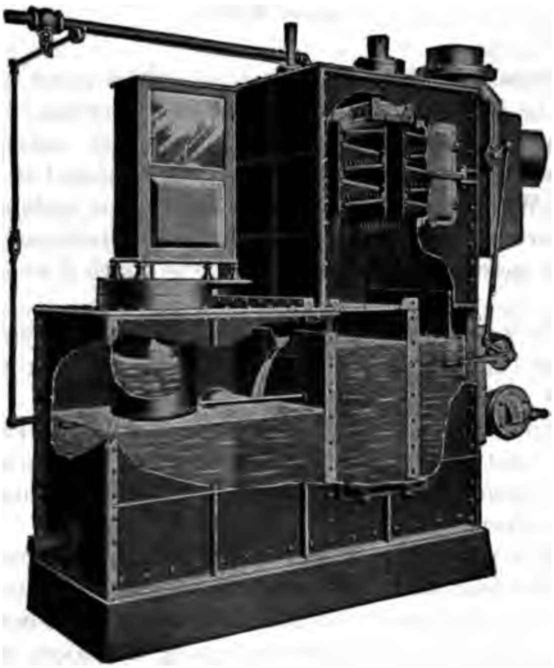

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GENERAL METHOD OF INVESTIGATION

5 The rate of flow through a flow meter may be determined measuring, either gravimetrically or volumetrically, the quan- es discharged during a known period and computing the rate of . Such a method, however, involves the following difficulties:

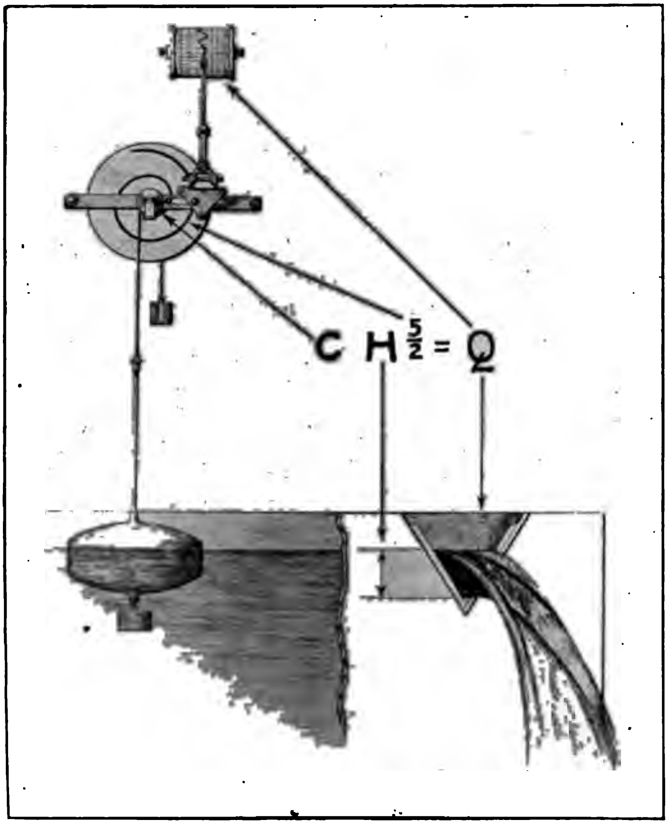

FIG. 2 DIAGRAM SHOWING PRINCIPLE OF RECORDING DEVICE

a Starting and stopping errors

b Difficulties in maintaining the rate of flow constant for e whole period of test

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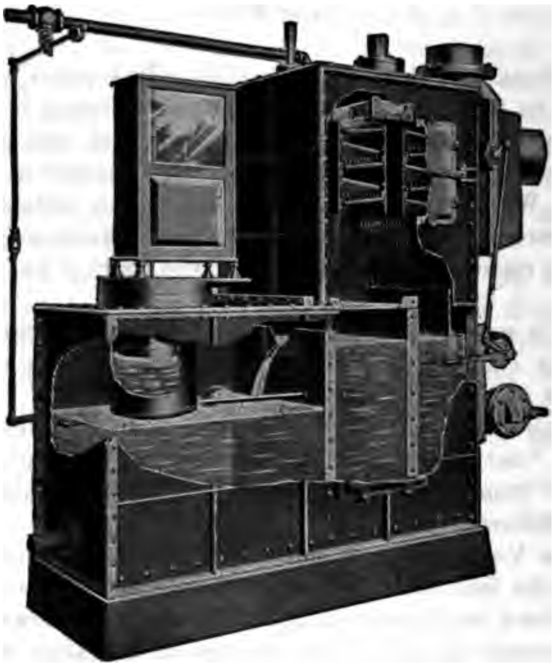

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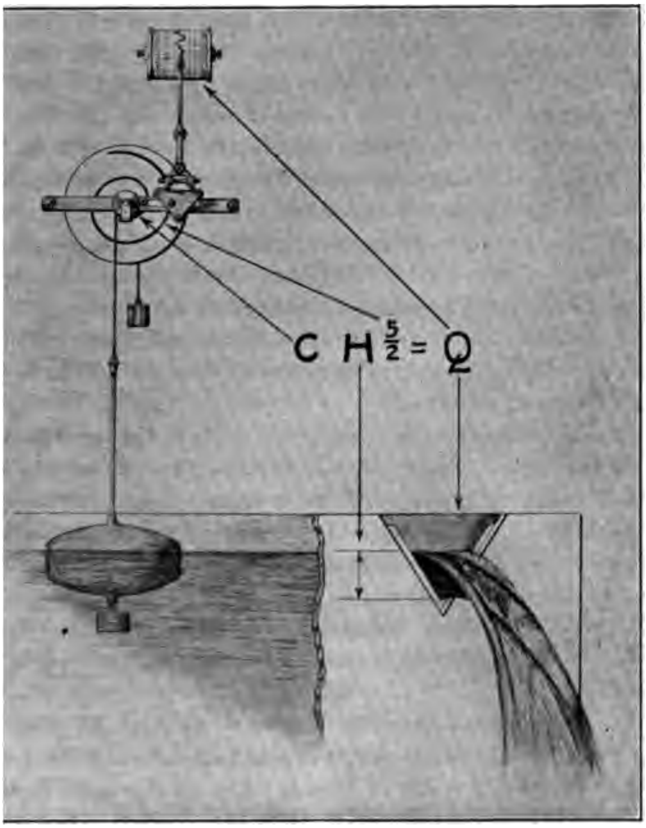

FIG. 2 DIAGRAM SHOWING PRINCIPLE OF RECORDING DEVICE

ι Starting and stopping errors

› Difficulties in maintaining the rate of flow constant for the whole period of test

: Difficulty in keeping a record of the exact variations of head or pressure (these values cannot be averaged by any simple method, since the flow varies, not directly as the head, but with the $\frac{5}{2}$ power of the head)

d Difficulties in obtaining exact time readings, particularly on runs of short duration

6 The method decided upon, therefore, was to construct and install a master flow meter so arranged that the rate of flow could be maintained accurately at any desired value for long periods; and after having determined with all possible precision the performance of this standard, to use it as a means of measuring the flow through the meters which it is desired to investigate.

7 By using this means of direct comparison, a degree of accuracy can be secured in the meter under test practically equal to that of the standard, without involving the liabilities of error enumerated above. Such a standard having once been accurately calibrated, disturbing influences arising from effect of proportions of channel of approach, conditions of surfaces, form and material of notch, directions and interference of currents of flow in the channel of approach, etc., can be ignored.

8 The time occupied in making the tests in this way is obviously much shorter than by any method of filling and emptying tanks or filling and weighing tanks, quite aside from the superior accuracy of the continuous flow method. Particularly, at the lower rates of flow the time required to accumulate a sufficient volume of water to be measured or weighed with a high degree of percentage accuracy would so extend the time required for a single continuous run that it would be nearly impossible to maintain constant conditions throughout the run.

9 It is estimated that by the flow method adopted greater accuracy can be obtained in a run of one-half hour at a low head than would be possible in a run of fifteen hours at the same head, using either volumetric or gravimetric methods. The relative difficulty of maintaining constant conditions for one-half hour and for fifteen hours hardly requires discussion.

10 A further advantage of the continuous flow method over any filling and emptying method is that the problem requires the measurement of head over the notch under test corresponding to a previously fixed rate of flow. Filling and emptying methods would require that the flow be approximated and test made. The rate [illegible] computed from the time interval and the total amount

of water passed and the process repeated by the trial and error method with comparatively little hope of arriving eventually at the exact desired rate of flow.

11 A calculation of the desired head, from data obtained in a run at the approximate head, would require a greater number of runs and probably result in a lower degree of accuracy. Thus not only is the accuracy of individual tests assured, but it is possible to conduct a very much larger number of tests and thus confirm the work done and take advantage of the law of averages.

DESCRIPTION OF PLANT AND APPARATUS

12 As shown in Figs. 3 and 4, the testing plant has a large storage tank from which the water is drawn by a pump and elevated to a supply tank at the highest level, which will be referred to as the constant-head tank, its purpose being to supply water to a discharge orifice at a constant head so that the rate of flow through the standard notch may be maintained invariable at any desired capacity.

13 From the constant-head tank the water passes to the standard-notch tank, thence flowing over the calibrated standard notch into the meter under test, whence it is discharged to the storage tank to circulate again.

14 During the preliminary work on the calibration of the standard notch, instead of passing from the standard notch to the meter under test, the water flowed alternately to either of two volumetric measuring tanks, from which latter it discharged into the storage tank to resume its course.

15 In view of the absolute necessity for permanent maintenance of conditions under all circumstances, the entire plant was constructed with the utmost regard to permanency and rigidity. The foundation consists of a concrete slab approximately 24 ft. long by 10 ft. wide carried to solid clay soil and reinforced in all directions by 1-in. rods.

16 *Storage Tank.* The storage tank rests directly on the concrete foundation and is 22 ft. long by 8 ft. wide by 6 ft. high, holding a little over 1000 cu. ft. of water. The supply to the pump is through an 8-in. opening located with its center about 8 in. above the bottom of the tank (to eliminate sludge which might accumulate on the bottom) and 12 in. from the vertical center line of the end of the tank.

17 The storage tank is also supplied with a 3-in. drain connection and washout at its lowest point and with a system of steam pipes whereby the water may be heated to the desired temperature.

18 *Pumping Unit.* The pumping unit is an 8-in. DeLaval single-stage centrifugal pump located about 4 ft. from the end of the storage tank. It is gear-driven by a single-stage DeLaval steam turbine. The capacity of the pump is about 120 cu. ft. per minute against the head of the highest tank, which corresponds to a flow of about 450,000 lb. per hour.

FIG. 3 METER TESTING PLANT

19 *Constant Head Tank.* The constant head tank is cylindrical, 9 ft. in diameter and 7 ft. deep. It is supported on a grill of structural steel carried by rigidly braced heavy columns resting on one of the volumetric measuring tanks.

20 The 8-in. pump discharge line enters the constant-head

tank in the center of the bottom with a 2-ft. length of pipe extending up into the tank.

21 The outlet from the constant head tank is a 6-in. line taken from the bottom of the tank as close to the side as possible. This arrangement was adopted after experiments looking toward the prevention of a swirling motion within the tank, resulting either from the inflowing or outflowing currents, since such a motion would interfere with the maintenance of steady flow conditions from the tank.

22 The maintenance of a practically constant head in this tank is essential to the maintenance of a constant flow through the system during the progress of an experiment and therefore vitally essential to the operation of the laboratory. This is accomplished by the installation of an overflow weir consisting of a rectangular trough 8 ft. 8 in. long, having inflow edges or weirs on both sides. These edges are constructed of metal and were carefully brought into a horizontal plane so that the discharge would be uniform throughout their length. An overflow over these edges is maintained throughout all experiments and is carried by a 4-in. pipe line back to the storage tank, this line being provided with a ½-in. bypass discharging into open funnels on both the standard notch level and the observation room level so that the observer may constantly watch the overflow and thereby judge of the constancy of the head. This overflow trough or weir and the pipe leading from it with its bypass are shown in Figs. 4 and 5.

23 Throughout the present paper an effort will be made to indicate the accuracy of the work by assuming conditions very much worse than could possibly occur in operation and calculating the resultant error.

24 For instance, suppose that the pump can be controlled only within a variation of discharge rate of 166.8 cu. ft. per hour, and that the head of water flowing over the overflow weir (approximately 17 ft. long) is 0.2 in., corresponding to an excess of overflow of 7.26 cu. ft. per minute. An increase in the delivery rate of the pump of 166.8 cu. ft. per hour would increase the head over the overflow weir to 0.245 in. or 0.045 in. greater than before.

25 The vertical distance or head to the valves through which water is admitted to the standard notch tank is 10 ft. The variation in head would therefore be from 10.0166 ft. to 10.0204 ft. The variation in flow, due to this variation in head will be as the square roots of these two heads or not more than 0.015 per cent.

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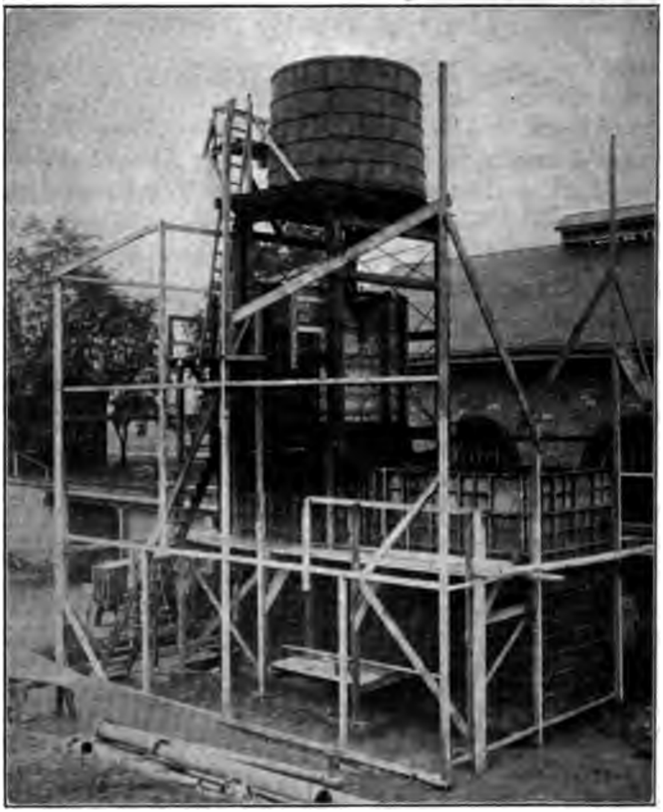

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26 The approximate amount of water in the constant-head tank is indicated by a float shown in Fig. 5 to which is attached a chain passing over sheaves and extending to the pump room with pointers at each level.

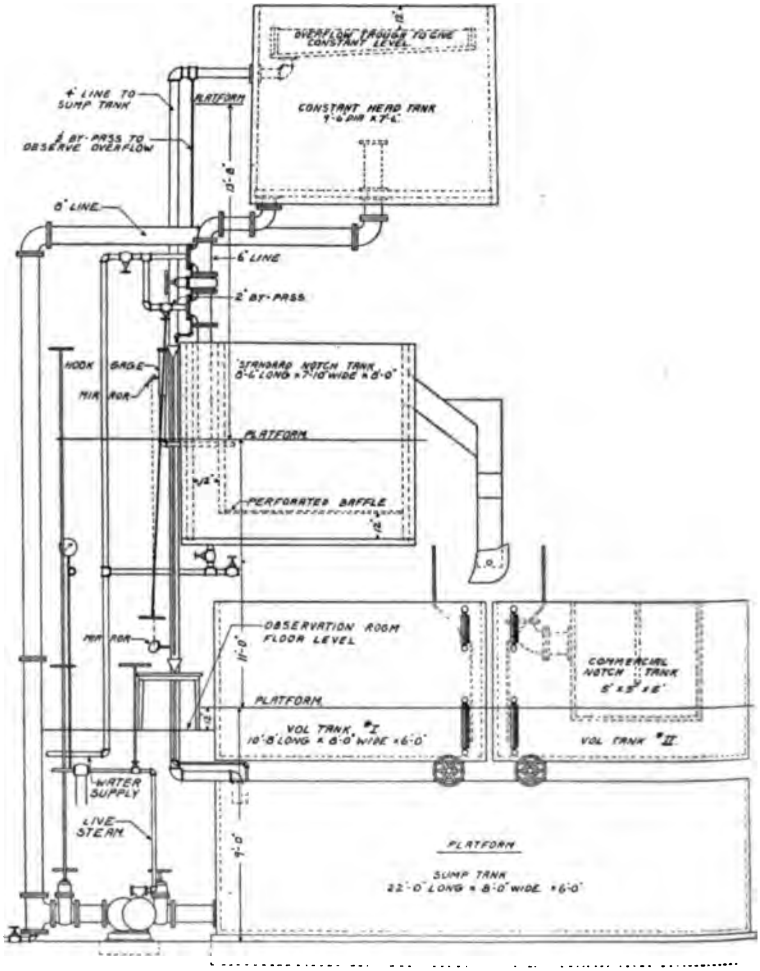

Fig. 4 Diagram of Meter Testing Plant

27 *Supply Line to Standard-Notch Tank.* This pipe line which has already been referred to as the outlet for the constant-head tank into the standard-notch tank, contains a 6-in. valve for roughly setting the larger flows and a 2-in. valve in a bypass carried around

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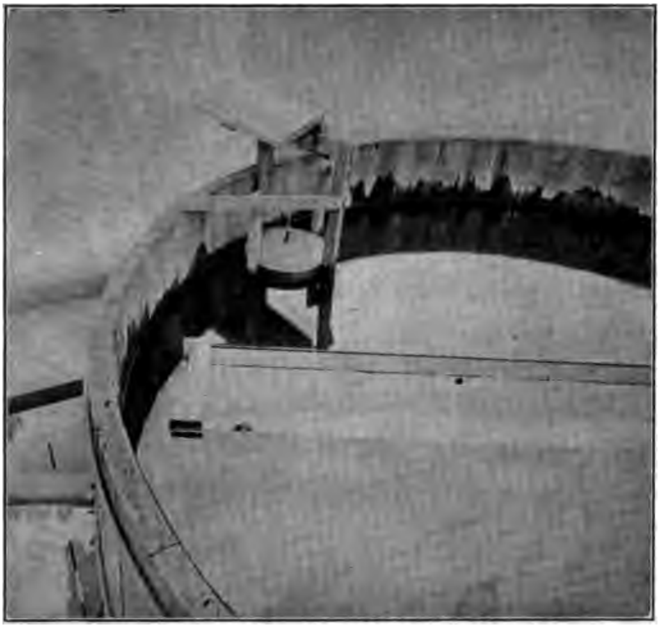

FIG. 5 CONSTANT HEAD TANK SHOWING WEIR AND FLOAT

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29 The standard V-notch, Fig. 6, is approximately 22½ in. gh by 11¼ in. wide at the top. Its full capacity at 18¼ in. head is ughly 110 cu. ft. per minute.

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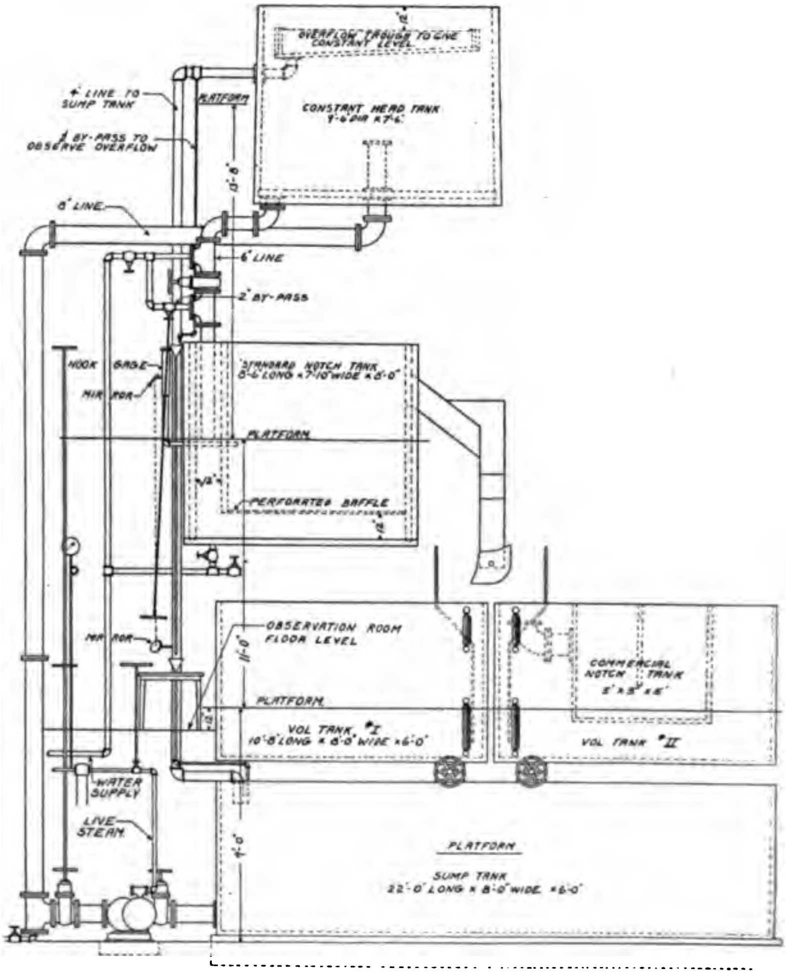

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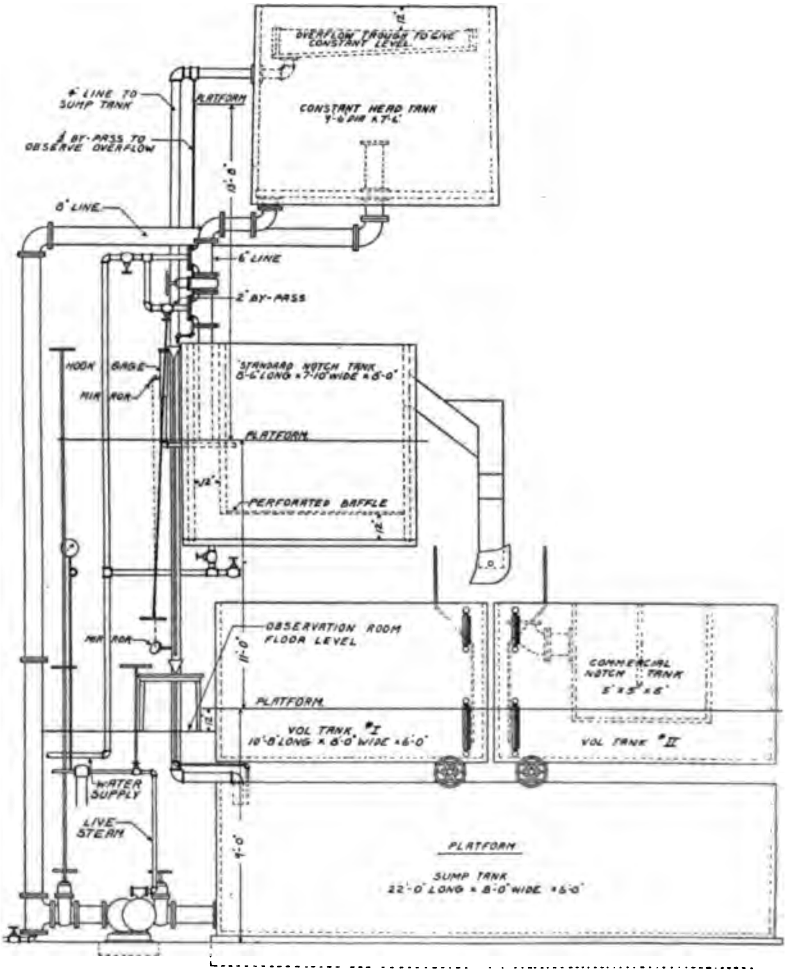

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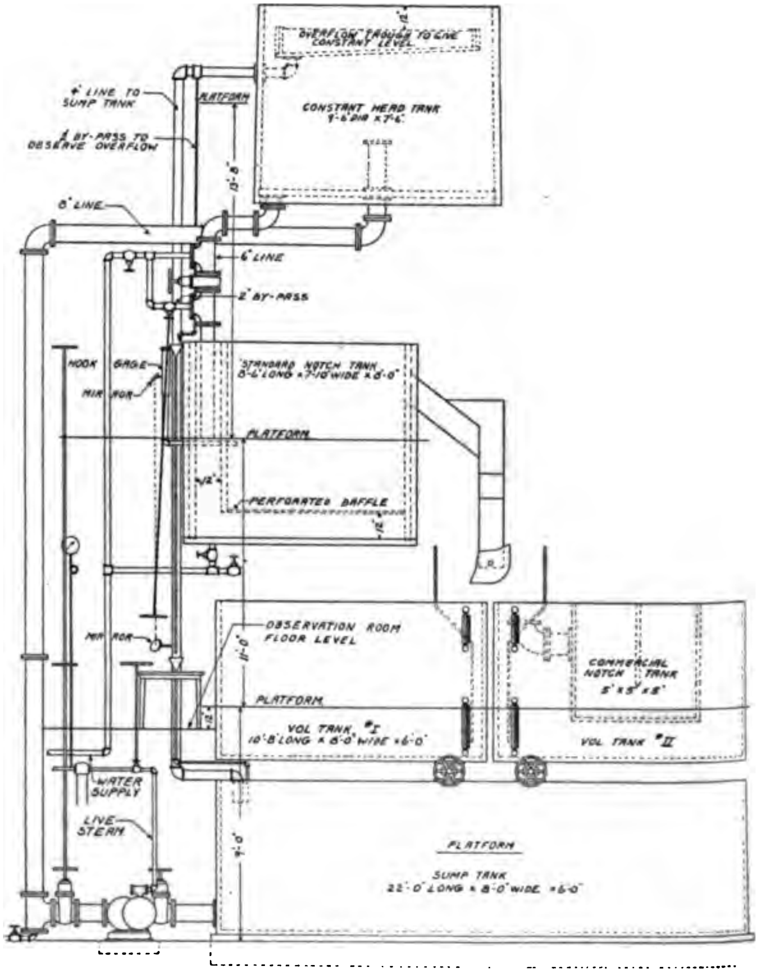

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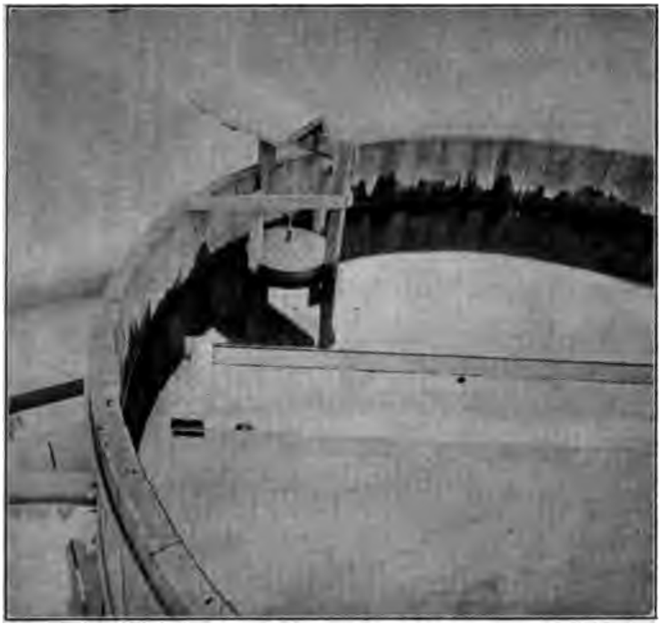

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this partition 2 ft. below the surface of the water. The water finds its way under the partition, spreads out over the bottom of the tank and rises through a perforated baffle having approximately 2000 holes ¾ in. square through which the water must pass. This arrangement has resulted in a very satisfactory quiet surface of approach,

FIG. 6 STANDARD V-NOTCH USED IN TESTING PLANT

for the standard notch, even at the highest rates of flow which are used.

31 Owing to the method of calibration and of future experiments it was not necessary to find the apex or zero level of the standard notch with extreme precision, it being necessary only to provide a reference point from which measurements could always be taken which would be immovable with respect to the notch itself. This

reference point consists of a hook gage securely soldered to the notch itself with its point in a plane normal to the plane of the notch through its vertical center line and ½ in. away from it.

32 The level of the water above the zero level is read by a second adjustable hook gage attached to the opposite end of the tank.

33 As any tilting of the tank in any direction would not only change the cross-section of the stream issuing from the notch but also the relation between the hook gage by which the level is read and the notch, the care in supporting the tank is further checked by means of special gages to indicate any deflection in the tank or supports, due to the increased weight of water carried in the tank between the zero setting and maximum flow.

34 These special gages consist of four glass tubes with three reference lines spaced 9 in. apart, etched entirely around each. The four gage glasses are firmly attached at the four corners of the standard notch tank by being cast in cement in special bracket castings bolted to the tank.

35 In order to insure that readings of these gages might not vary, owing to different conditions of velocity head at every point of connection with the water in the standard notch tank, the geometrical center of the four positions was located and exactly symmetrical pipe connections are carried from each gage to a common opening at this center.

36 Before being cast in the cement these gages were accurately adjusted by means of the water level so that the lowest graduation on each coincided with the zero reference point on the notch.

37 *Hook Gages.* The level of the water flowing through the notch in the standard-notch tank is obtained by means of a specially designed hook gage connecting with the still-water chamber.

38 The special and unusual construction of this hook gage arises chiefly from the extreme range of height which it must cover and the consequent possibilities of error resulting from differences in temperature between the various parts of the gage itself at various times, and also between the water column within the gage tube and the temperature of the water in the still-water chamber. To eliminate the effect of temperature changes in the parts of the gage itself, the elements were so constructed that expansions due to increased temperature would tend to compensate each other. To eliminate the effect of differences of temperature between the two water columns, the hook gage tube was jacketed by flowing water taken

from the same source of supply as that to the still-water chamber, and therefore at the same temperature.

39 The temperatures were regularly checked by calibrated thermometers, one in the still-water chamber and the other attached directly to the hook itself and completely immersed in the water column within the hook gage tube which is shown in Figs. 7 and 8. The hook gage tube is a 1-in. glass tube, joined by means of a rubber sleeve to a brass tube extending into the still-water chamber. Outside of this tube, with centering supports between, is a 1½-in. iron pipe extended as a 1¼-in. glass tube opposite the points from which observations must be taken. The whole is enclosed in a brass guard. From the lowest point of the jacket a goose-neck of ½-in. pipe is carried to the level nearly opposite the top of the tube. This acts as an overflow draining back into the storage tank, and maintains a constant flow through the jacket.

40 The hook itself has a 60-deg. point, and is constructed as shown in Fig. 8.

41 The whole system is aligned by gravity, and simply prevented from rotation by loosely fitting guides occasioning no redundancy of support. The hook rod is suspended on a phosphor bronze cable which passes over a very accurate sheave running on a hardened axle. From the sheave the cable passes over a drum on the same shaft with the graduated wheel by means of which the settings are made and the readings taken. This wheel is 18 in. in diameter, one complete revolution representing a rise of the hook of 2 ft. The circumference of the wheel is graduated in units, each representing 0.02 in. It has been entirely feasible with these graduations to estimate a movement of the hook of 0.0025 in. The brackets supporting these parts are made with welded joints so that there is no possibility of displacement.

42 The register of the point of the hook with the surface of the water is observed from below the water surface, in which position it is possible to see both the hook itself and the reflected image on the surface of the water. The hook is at the water surface when the point of the reflected image coincides with the point of the hook. Any deviation from this position is observed as double the distance between the point of the hook and the water surface, thus enabling extreme exactness in this observation, which is further promoted by the fact that the reading is taken through a magnifying lens and reflected downward and horizontally to the observation station, at which point a four-power binocular is rigidly supported

for observation of the image. Optical distortion is eliminated. Owing to the reduction of illumination incident to this magnification. the hook is illuminated by means of a frosted incandescent bulb.

43 *Volumetric Measuring Tanks.* After passing the standard notch the water is guided into a large funnel and conducted to a tipple

FIG. 7 HOOK-GAGE COLUMN, SHOWING MAGNIFYING GLASS AND MIRROR

by means of which it may be directed into either of two volumetric measuring tanks, or into a meter under test. The tipple is arranged with electrical contacts to ring a gong when it is thrown in either direction to facilitate the taking of time readings.

44 The volumetric measuring tanks were used only in the calibration of the standard notch, and afterwards served as catch basins

for the water discharged by the meters under test, and also as containers and supports for such meters.

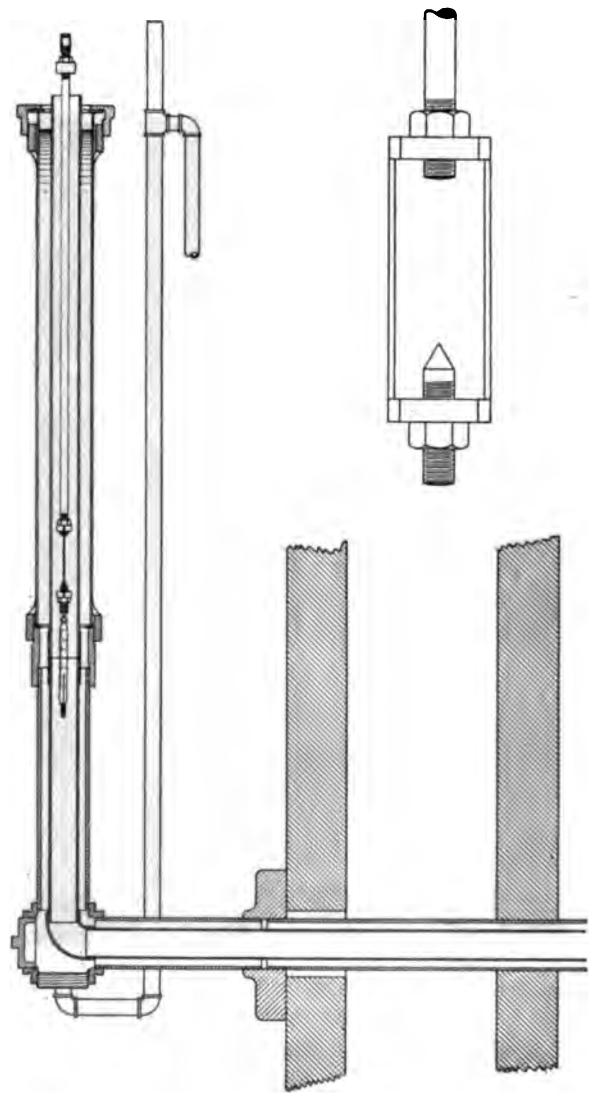

FIG. 8 DIAGRAM OF HOOK GAGE AND COLUMN

45 These tanks rest on the storage tank, supported by a series of 12-in. I-beams and have a capacity of approximately 525 cu. ft.

ach. They are indicated in the reports of the experiment by "I" and 'II", which are painted prominently on them.

46 Each of these tanks is provided with baffles to maintain a quiet water level. The volume of water is measured by glass gages graduated in cubic feet. It has been demonstrated that the bottom of the meniscus in the gage glasses can be read within 0.01 in. The tanks discharge through 12-in. and 2-in. valves into the storage tank beneath.

47 *Observation Room.* Owing to the number of readings to be taken and the amount of space both vertically and horizontally covered by the plant, special means are necessary to bring all observations and controls to a central observation station. Fig. 9 is an interior view of the observation room showing the desk from which observations are taken. This view indicates also the position of the binoculars and system of mirrors by which a magnified image of either the hook gage on the meter under test, or the hook gage on the standard-notch tank may be observed. It also indicates how the level of the water in the constant-head tank, the overflow from the constant-head tank, the steam pressures in the steam line to the turbine and in the turbine nozzle chamber, can be observed from the operator's station; and how the steam throttle of pump, discharge valve and by-pass valve controlling the rate of flow from the constant-head tank to the standard-notch tank are all within the reach of the operator.

48 Referring to the running of tests, it is necessary only to observe that the water level remains at the point of the hook and it is not necessary to read the height of the hook gage on the standard-notch tank during the progress of an experiment. A similar hook gage is applied to the meter under test with the addition of an extended shaft bringing the graduated scale to the observation room where the operator can read the height of water passing over the weir under test. This reading is taken immediately above the eye pieces of the binoculars through which is observed the coincidence of the water surface and the hook.

PRELIMINARY WORK AND CALIBRATION OF APPARATUS

49 The calibration of the 5-cu. ft. tank was carefully carried out and estimates made of the probable errors due to inaccuracies in weighing and in determining temperatures and to expansion or contraction of the tank itself.

... It is safe to assume that the weight was correct to within ... which is only 0.08 per cent of 312 lb., the total weight of the ... cu. ft. of water.

FIG. 9 OBSERVATION ROOM

... Assuming that the averaged temperature observed was in... by as much as 2 deg., which is not probable, the respective ... of 5 cu. ft. of water at 10 deg. cent. and at 12 deg. cent. are ... and 311.974, an error of but 0.02 per cent.

52 The difference in temperatures between the time when the tank was calibrated and the time when it was used for calibrating the volumetric measuring tanks is that between 52 deg. fahr. and 46 deg. fahr. This temperature difference has been calculated to result in a volumetric difference in the contents of the tank amounting to 1 cu. in. in 8640 cu. in. or about 0.011 per cent.

53 Starting with the 5-cu. ft. tank as a measuring unit, this was placed on a platform so that it would drain into either of the two volumetric measuring tanks, which were graduated by successive additions of the contents of the 5-cu. ft. tank. One cubic foot in either of the volumetric measuring tanks corresponds to about 0.14 in. in height on the gages. As a difference in level of 0.010 in. could be read on these gages the error of reading is probably not greater than 7 per cent of a single cu. ft. or 0.014 per cent of the 483 cu. ft. contained in the tank. If it be assumed that at the highest rates of flow the gages can be read to only within 0.03 in. or at intervals six times as great, the error is but 0.084 per cent.

54 As these volumetric measuring tanks had been on their supports and under the weight of their contained water nearly two years, it seems reasonable to assume that the only change of shape to be expected in them is that due to temperature variations. Assuming a temperature variation of 30 deg., the increase in contained volume will be only 0.053 per cent.

55 *Hook Gages.* It was determined after several experiments that the hook and hook rod must be relieved of all strains and left free to align itself by gravity. While with the jacketed arrangement described it was never possible to detect a difference in temperature between the water in the hook gage tube and in the still-water chamber exceeding ½ deg. fahr. during the course of a whole day, it is interesting to note the results which might be obtained from an unjacketed gage. Without the jacket water it was found that a difference of 20 deg. fahr. (from 50 deg. to 70 deg.) was entirely possible and affected a vertical head of 30 in. of water. The reading of the gage under such conditions would be 0.048 in. in error.

56 The various elements of the hook gage are analyzed as follows:

57 The weight supported by the phosphor bronze cable is about 4 lb. Under this stress no elongation of the cable was measurable.

58 It was assumed for the sake of illustration that the cable might wind on the drum at an inclination of 0.05 in. to a plane normal

50 It is safe to assume that the weight was correct to within ¼ lb., which is only 0.08 per cent of 312 lb., the total weight of the 5 cu. ft. of water.

FIG. 9 OBSERVATION ROOM

51 Assuming that the averaged temperature observed was [illegible] correct by as much as 2 deg., which is not probable, the res[illegible] weights of 5 cu. ft. of water at 10 deg. cent. and a[illegible] 312.039 and 311.974, an error of but 0.02 per ce[illegible]

52 The difference in temperatures between the time when the ınk was calibrated and the time when it was used for calibrating ıe volumetric measuring tanks is that between 52 deg. fahr. and 6 deg. fahr. This temperature difference has been calculated to esult in a volumetric difference in the contents of the tank amounting ɔ 1 cu. in. in 8640 cu. in. or about 0.011 per cent.

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Fig. 9 Observation Room

51 Assuming that the averaged temperature observed was incorrect by as much as 2 deg., which is not probable, the respective weights of 5 cu. ft. of water at 10 deg. cent. and at 12 deg. cent. are 312.039 and 311.974, an error of but 0.02 per cent.

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to the axis of the drum. Even this assumption results in a computed error of only 0.0015 in. in 12 in.

59 The flexure of the sheave support for the sake of illustration only was computed for displacement of 0.25 in. Even this extreme displacement results in a computed error of only 0.0013 in.

60 In investigating the effects of temperature changes on the parts of the gage it is to be noted that the vertical sheave support in its expansion will compensate for the elongation of the cable due to temperature and that the expansion of the drum will tend to compensate for the elongation of the hook rod between the point of the hook and the attachment of the cable. A computation of these changes indicates the resultant errors of about the same magnitude as the foregoing.

61 The absolute accuracy with which the zero reading of the hook gage could be checked day after day has established complete confidence in its accuracy.

62 *Standard Notch.* In preparing for the calibration of the standard notch, a curve was plotted, indicating the ideal conditions of flow which the experiments would approximate. This curve was then divided into sections so that these could be separately plotted from the empirical data obtained to a very much larger scale, 1 in. in the scale of ordinates on this plot equals 0.4 in. head and 1 in. in the scale of abscissae represents 1 cu. ft. per minute. The curve is in five sections, which assembled would constitute a plot 4½ ft. by 10 ft.

63 After having mapped out the points it was desired to plot on the curve it was only necessary to set the hook gage at heads corresponding to these points and start the circulation of water through the system.

64 After bringing the flow up to the desired head by manipulation of the control valves, readings were taken at regular and frequent intervals, until a sufficient number of readings had been obtained showing uniform conditions to furnish data for the necessary computation with assurance of reliability.

65 The time was taken by means of a special stop watch, reading to 0.01 minutes and the test conducted by alternate filling and emptying of the two volumetric measuring tanks.

66 Fig. 10 is the log of a typical run and will in itself indicate the nature of the observations and the computations. The accuracy of the calibration of the standard notch is indicated by percentage accuracy of the various steps leading up to it.

67 Fig. 11 is a curve indicating the percentage error in the flow

CALIBRATION OF STANDARD V-NOTCH
DATA SHEET (1)
HOOK GAGE ZERO - 11.230"

DATE - 3-12-14

SHEET NO. - 4
OBSERVERS 1 F.F.S. 2 3

NO.	HOOK GAGE READING	HOOK GAGE HEAD	TIME READING	TIME ELAPSED	TEMP. HOOK GAGE	TEMP. TANK	TANK NO. I LOWER GAGE	TANK NO. I UPPER GAGE	TANK NO. I NET VOL. CU. FT.	TANK NO. II LOWER GAGE	TANK NO. II UPPER GAGE	TANK NO. II NET VOL. CU. FT.	REMARKS
1	6.175	6.945	1:04.5	MINUTES	54.25	53.75	63.00						
2	6.175	6.945	1:41.5	37	53.75	53.75		448.50	385.50	80.25			
3	"	6.945	2:16.5	35	54	54	65.00				444.75	364.50	
4	"	6.945	2:53.5	37	54	54		450.00	385.00	64.50			
5	"	6.945	3:30.5	37	54	54	65.00				449.50	385.00	
6	"	6.945	4:07.5	37	54	54		450.00	385.00	64.75			
7	"	6.945	4:42.5	35	54	54.25					429.50	364.75	
			3:38.0										
TOTAL				218			193.00	1348.50	1155.50	209.50	1323.75	1114.35	
								193.00			209.50		
								1155.50			1114.25		
											1155.50		
											2269.75 ÷ 218 = 10.411 cu. ft. per min.		
												@ 6.945" net head	

FIG. 10 LOG OF A TYPICAL RUN

to the axis of the drum. Even this assumption results in a computed error of only 0.0015 in. in 12 in.

59 The flexure of the sheave support for the sake of illustration only was computed for displacement of 0.25 in. Even this extreme displacement results in a computed error of only 0.0013 in.

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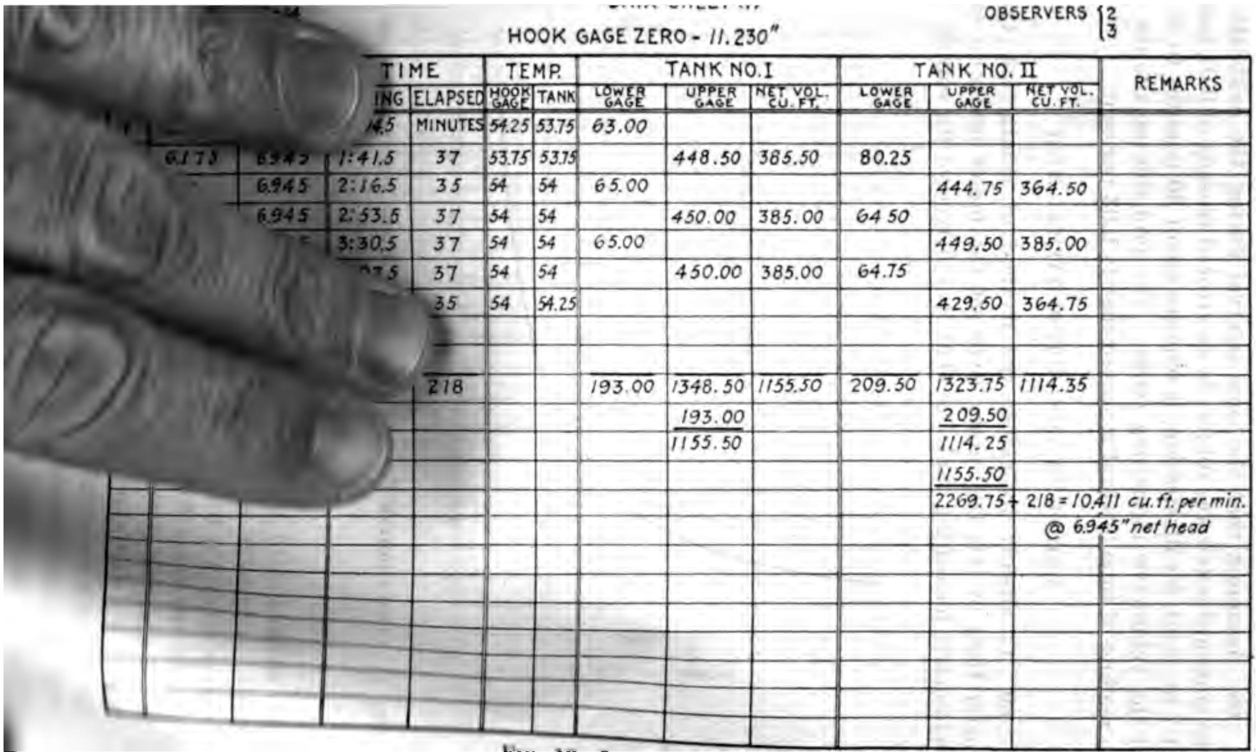
67 Fig. 11 is a curve indi



HOOK GAGE ZERO - 11.230"

OBSERVERS {2 3

		TIME		TEMP.		TANK NO. I			TANK NO. II			REMARKS
		ING	ELAPSED	HOOK GAGE	TANK	LOWER GAGE	UPPER GAGE	NET VOL. CU. FT.	LOWER GAGE	UPPER GAGE	NET VOL. CU. FT.	
		[illegible]4.5	MINUTES	54.25	53.75	63.00						
6.173	[illegible]	1:41.5	37	53.75	53.75		448.50	385.50	80.25			
	6.945	2:16.5	35	54	54	65.00				444.75	364.50	
	6.945	2:53.5	37	54	54		450.00	385.00	64 50			
	[illegible]	3:30.5	37	54	54	65.00				449.50	385.00	
		[illegible]7.5	37	54	54		450.00	385.00	64.75			
			35	54	54.25					429.50	364.75	
			218			193.00	1348.50	1155.50	209.50	1323.75	1114.35	
							193.00			209.50		
							1155.50			1114.25		
										1155.50		
										2269.75 ÷ 218 = 10.411 cu. ft. per min.		
										@ 6.945" net head		

FIG. 10 LOG OF A TYPICAL RUN

resulting from an error of 0.005 in. in reading the head in the hook gage.

68 Assuming that the time interval during the calibration of the standard notch was subject to an error of reading of 0.01 minute, at 7 in. head, for illustration, it requires about 30 minutes to fill one of the volumetric measuring tanks. The probable maximum error in reading of time interval is approximately 0.03 per cent.

METHOD OF CONDUCTING TYPICAL TEST

69 As already indicated, the method of conducting typical meter tests in this laboratory is to set the meter into one of the volumetric measuring tanks so that it will receive its supply from

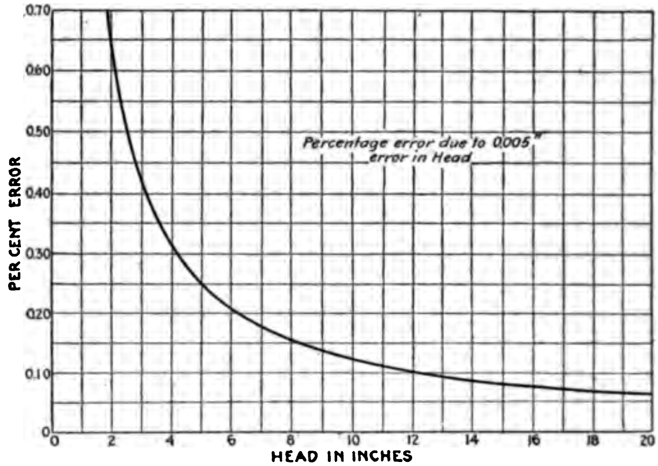


FIG. 11 CURVE SHOWING PERCENTAGE ERROR IN FLOW DUE TO ERROR OF 0.005 IN. IN HOOK GAGE READING

the standard notch and so that the volumetric measuring tank will catch its discharge simply as a catch basin and return it to the storage tank. The head on the standard notch corresponding to the desired rate of flow for which it is desired to find the head in the meter under test is read from the large scale curve and the hook gage on the standard-notch tank accordingly set. The flow through the system is then brought to the desired rate by controlling the water level in the standard-notch tank to the point of its hook gage. When conditions have become stable the head over the notch under test

Date	Flow		Standard Notch					Commercial Meter					Coefficient
			Hook Gage			Temp.		Hook Gage			Temp.		
	Lbs./hr. at 200 deg. F.	Cu. ft. per min.	Head from curve	Zero level	Setting on hook gage	Hook gage tube	Tank	Zero level	Reading	Head over notch	Hook gage tube	Tank	C.
	Lbs.	Cu. ft.	Inches	Inches	Inches	F. deg.	F. deg.	Inches	Inches	Inches	F. deg.	F. deg.	

FIG. 12 FORM TO BE USED IN LOG OF TESTS

is read by means of its hook gage. The log of such test is indicated by Fig. 12.

CONCLUSION

70 In conclusion the author not only desires to acknowledge the assistance obtained from various experimenters along these lines, but particularly to refer to the collaboration of Geo. H. Gibson, Member of the Society, in suggesting the general method of test, as well as co-operation in the development of many details of the laboratory.

71 Percy S. Lyon, student-member, deserves the highest credit for having superintended the construction and having operated the laboratory and assembled the data on which this paper is based.

72 Aside from the work on meters the laboratory has also been employed in investigating and testing means for proportional feeding of chemicals for water softening apparatus.

DISCUSSION

H. E. Ehlers asked whether any experiments were made to determine how much variation existed in the surface of the water in the V-notch tank. The quantity flowing over the notch is determined by the hydraulic head back of the notch, and while it might be entirely possible to measure the level in the hook gage to an accuracy of 5/1000 in., he would like to know how nearly uniform the water level in the tank itself remained.

Referring to the assumed error of measurement of the head in the two large standardization tanks of 3/100 per cent at the higher rates of flow, the maximum flow is about 110 cu. ft. per min., which allows about 5 min. only for the filling of one of these large tanks. Water flowing into tanks under such conditions causes disturbances and pulsations which take a considerable time to die out. The surface may become smooth, but it continues to rise and fall or pulsate, and he questioned how still the water in these tanks became.

Most of these meters are used for measuring hot water, and the statement is made that the storage tank is provided with a system of steam pipes for heating the water to any desired temperature. A meter of this type measures volume, which is converted to weight by a direct coefficient. The weir is calibrated at 70 deg., or ordinary temperatures, and a cam worked out which is intended to give a rating in pounds. If the temperature of the water is raised to say 210 deg., its density is changed and so is the depth of immersion of the flow used to indicate the head of the weir. The first change is constant, but the second change is a variable and also has a much greater effect at low heads than it does at high heads. He asked how these weirs are calibrated for temperatures as high as 210 deg.

GEORGE H. GIBSON (written). Two considerations favor the general adoption of the V-notch as a boiler feed meter. The first is its sensitiveness at small flows and the second its simplified construction when the rate of flow is assumed proportional to the 5/2 power of the head. This law is not strictly true even under ideal conditions, but its assumption facilitates the construction of float-actuated cams to move the recording pens.

The numerous combinations of different notches with weir chambers of various dimensions requires such a number of calibrations as to render volumetric and gravimetric methods tedious as well as expensive. To obviate this, the elaborate testing plant described was constructed, and by its means the manufacture of V-notch meter chambers has been standardized.

The sensitiveness of these meters at small flows is not a matter of the operation of the notch itself. Overcoming the friction of the translating cam consumes such a large fraction of the power available for operating the recorder as to render impossible the measurement of differences in head at these flows to great accuracy. This is particularly true in the case of the venturi meter in which reducing the flows to 1/4 reduces the velocity head to 1/16; below this flow great accuracy with this meter is out of the question.

J. H. NORRIS gave some personal experiences in a manufacturer's water meter testing plant, regarding the difference in level in the filling tanks. The weir in this plant is flat-crested and is 8 ft. in width. With approximately a foot head, the difference of level on the surface in the weir chamber is not more than 2/100 ft. provided the stream is properly baffled as it enters the chamber. The constant head is obtained by a centrifugal pump driven by an electric motor, and the head is changed by varying the speed of the motor. In the pressure chamber into which the pump delivers, the differences in head caused by the vibrations due to the action of the pump register from 1/10 ft. to 5/100 ft.

THE AUTHOR in replying to Professor Ehlers said that the relative error at various heads due to the same error in reading the head, or, what is the same thing, the error between float and cam in various positions, was shown in Fig. 11. The correct method to compensate for this error is believed to be by measuring the force required to move thé recorder and then to so proportion the water line area of the float that the latter will displace an amount of water proportional to this force. In this way it is possible to take full advantage of the greater relative accuracy of the V-notch at small rates of flow.

Considerable trouble was experienced in getting the surface of the water in the standardization tank and in the volumetric tank quiet, but disturbances in these tanks are now controlled even with the rapid passage of water. Variations in the surface of the water in these tanks were shown by the gages in their corners.

Referring to Professor Ehlers' question as to how still the water surface in the two large standardization tanks became, pulsations such as he refers to interfered considerably with readings, more particularly the bottom readings, when the tank held a large surface of shallow water, until the proper location of inlet ports and outlet ports as well as the correct size for these was determined.

A method has been devised whereby it is entirely feasible to calibrate not only the weirs but the entire meter including float and recorder with water at temperatures as high as 210 deg. fahr. without introducing errors due to evaporation.

Most of the other points raised by Professor Ehlers are covered by Mr. Gibson. In a V-notch meter there are so many variables, each affecting the other, that it seems best when making commercial meters of this type to build each meter as nearly correct as possible, test it under its working conditions, and make the results of this test standard for that meter.

No. 1460

A NEW VOLUME REGULATOR FOR AIR COMPRESSORS

BY RAGNAR WIKANDER,[1] PITTSBURGH, PA.

Non-Member

The ordinary reciprocating type of air compressors and blowing engines has a displacement proportional to its speed and the quantity of air pumped varies approximately in the same proportion.

2 In most cases, however, it is desired to regulate the amount of intake air so that it will correspond as nearly as possible to the amount of compressed air consumed, thereby keeping the pressure in the receiver practically constant. A number of regulators, governors or unloaders have been designed for this purpose and the object of this paper is to present a new method serving the same purpose as these devices in a simple and efficient manner and to demonstrate the principle upon which this method is based.

3 In order to realize fully all the limitations and shortcomings of the existing volume regulators, which have led to the development of this new device, we will first review briefly the various systems in common use at the present time.

VOLUME REGULATION BY MEANS OF SPEED VARIATION

4 A very simple method for regulating the volume of the intake air of a compressor is to vary the speed in proportion to the air consumption and this method has been resorted to in cases where it can be applied conveniently. For compressors driven by duplex or cross-compound steam ends it is used to great advantage. The speed can in such cases be varied from zero to its maximum value and the power required, as well as the amount of compressed air consumed, varies practically in the same proportion. The speed variation is, as a rule, obtained by means of a "speed and pressure governor," which acts upon a valve throttling the inlet steam.

[1]Hall Steam Pump Co., 918 St. James St.

Presented at the Annual Meeting, December 1914, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

5 For compressors, driven by single or tandem compound steam ends, this method proves less advantageous, because the speed cannot be reduced below a certain value without excessive reduction of the flywheel effect, which must be relied upon to turn the crankshaft over the dead centers. When the air consumption sinks below the amount corresponding to the minimum speed of the compressor, some other method must be resorted to in order to keep the receiver pressure constant.

6 A similar regulation of the air pressure between certain limits can be obtained by starting and stopping the compressor as soon as the air pressure in the receiver sinks below or rises above certain limits. The receiver stores the surplus air during the time the compressor is in operation and furnishes the quantity of compressed air required during the standstill of the compressor. This method is principally used for small motor-driven compressors. For larger motor-driven compressors it is, as a rule, not so advantageous, because the capacity of the storage tank must be very great, if it is desired to keep the air pressure within reasonable limits, without too frequent starts and stops of the motor. Frequent startings of an air compressor under load are very hard on the transmission organs, due to the extra work required for the acceleration of the revolving parts, and should be avoided if possible.

7 In cases of belt-driven compressors, a belt shifter in combination with a tight and loose pulley is sometimes used for the same purpose and automatically operated by air pressure.

CHOKING INTAKE UNLOADERS

8 This type of unloader is in very common use on account of its simplicity and in spite of its disadvantages. It consists of a choking or throttle valve, placed in the suction pipe of the compressor, and influenced by the receiver pressure so as to reduce the amount of intake air to correspond exactly with the amount of compressed air used.

9 The advantages of this unloader are its simplicity and its gradual operation.

10 Its disadvantages are:

a The waste of power on account of the increased amount of work required to compress each cubic foot of free air from its rarefied condition to the discharge pressure. If the consumption of compressed air decreases to 50 per cent of the full capacity of the compressor, the absolute pressure of the intake air will decrease to half an atmosphere and the work required to compress it to, say, 75 lb. gage pressure is 55 per cent more than for adiabatic compression of the same quantity of atmospheric air.

b The carbonization of the lubricant due to the great heat generated in the compressor cylinder, when working on partial load, and the resulting clogging up of valves and ports. In the above case the number of compressions increases from 6 at full load to 12 at half load and the corresponding final temperature for adiabatic compression and assuming 60 deg. fahr. intake temperature increases theoretically from 458 to 652 deg. fahr. For quarter load it would increase to 850 deg. fahr. and for a smaller fraction of the load the final temperature would be even higher.

c The danger of explosion which is always present when the vapors of the lubricant mingle with atmospheric air at such high temperatures.

11 If the gradual unloading is sacrificed and the unloader arranged so as to open or close the intake entirely, the loss of work mentioned under *a* is avoided.

12 In case the valves, stuffing boxes, piston and unloader are perfectly tight, the disadvantages mentioned under *b* and *c* are also avoided. In practice, this is not always the case and high temperatures are then produced when the compressor works at no load.

13 The fact that this unloader in spite of these great drawbacks, is in common use, shows, more than anything else, the need of a good and simple unloader or volume regulator for air compressors.

CLEARANCE UNLOADERS

14 The output of a compressor can be regulated by variation of the cylinder clearance without increasing the amount of work required for the compression of each cubic foot of free air to the discharge pressure and consequently without increased heating of the air or the lubricant. This method has been used for volume regulation and is distinctly superior to the choking inlet method of regulation.

15 In a well-known type of compressors two clearance pockets are provided in each end of each cylinder and automatically operated

valves are provided which put one, two, three or all four of these pockets in communication with the air cylinder, thereby reducing the intake volume of the compressor to 75, 50, 25 or 0 per cent of its full load capacity. The receiver pressure controls these various valves so as to regulate the volume of air pumped and maintain the receiver pressure within certain limits.

16 The drawbacks of this system are its high cost, the extra space required, the complication and the limited number of efficient capacities of the compressor.

OPEN VALVE UNLOADERS

17 It is possible to unload a compressor completely by keeping its suction or discharge valves open by force. In the first case the air drawn into the cylinder during the suction stroke, will return through it during the following discharge stroke and the discharge valves will remain closed.

18 In the second case the compressed air will reënter the discharge valves during each suction stroke and the discharge pressure will act on the suction valves, keeping them continually closed so that no air will enter the compressor. This latter arrangement has the disadvantage that if the discharge valves are allowed to seat when the piston is at the end of its stroke, the mean effective pressure on the first stroke will be equal to the full discharge pressure and produce a heavy overload on the driving motor.

19 The first method is in common use all over the world. By this method it is possible to reduce the capacity of the compressor to one-half by keeping the suction valves on one side open by force, while those at the other end of the cylinder are in normal operation.

20 The compressor operates then at full load on one stroke and at no load on the following. In order to even up the load and at the same time be able to run with 75, 50, 25 and 0 per cent of full load, compressors are built with two identical tandem-connected cylinders and the suction valves on the different sides of the two cylinders are held open (or special, automatically operated valves are arranged so as to connect the cylinder ends to the suction pipe), so as to render idle one-quarter, one-half, three-quarters, or the whole of the displacement of the compressor.

21 The objections to this system of unloading are again, high cost, complication of parts and the limited number of efficient capacities.

UNLOADERS ON COMPRESSORS WITH POSITIVELY MOVED VALVES

22 The best known type of unloaders on this type of compressors operates so as to hold the suction valves, which generally are of the Corliss type, completely open for a short time as soon as the air pressure exceeds the desired limit and permit them to operate normally as soon as the pressure sinks to a predetermined value. Several systems are, however, in use in which positively moved valves connect the cylinder with the suction pipe during a shorter or longer part of each discharge stroke, thereby regulating the amount

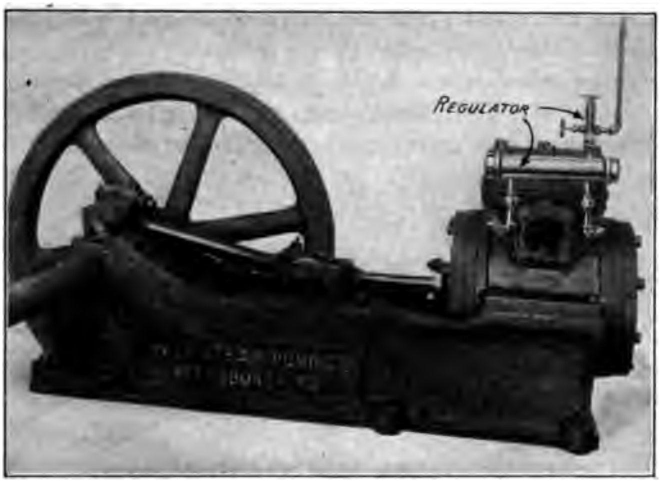


FIG. 1 HALL VOLUME REGULATOR MOUNTED ON AIR COMPRESSOR

of air compressed during each stroke, so as to correspond exactly to the consumption.

23 Both these systems operate satisfactorily and their only drawbacks are to be found in the high cost and rather complicated mechanisms required as compared with the ordinary air compressors with automatic valves.

THE NEW VOLUME REGULATOR

24 The preceding short synopsis of existing unloading systems shows that, with the exception of the one of speed regulation of duplex and cross-compound steam driven compressor, none of them combines simplicity of design with gradual and efficient regulation of all loads. These are the requirements which the new Hall volume regulator is designed to fill.

25 The operation of this regulator is based upon the following principle: The pressure acting upon and tending to close a suction valve held open by force during the discharge stroke of an air compressor, is proportional to the air pressure created in the cylinder and varies during said stroke, as shown in Fig. 2.

26 This diagram was taken on a 24 by 14-in. air compressor operating at 50 r.p.m. The valve area of the suction valve which was held open by force during the discharge stroke amounted to about 3.5 sq. in. and the average speed of flow of the air through this valve was therefore about 15,000 ft. per min. It is interesting to note how the cylinder pressure increased practically in proportion to the part of the stroke made by the piston.

27 From this diagram it can be assumed that a closing of the suction valves at an adjustable point of the discharge stroke would be obtained simply by a very gradual regulation of the force holding

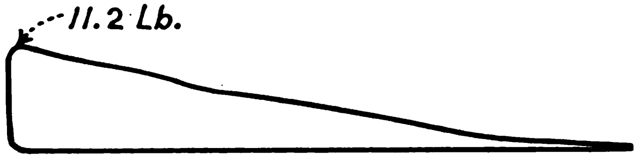


Fig. 2 Diagram showing Variation of Pressure during the Discharge Stroke of an Air Compressor

them open against the action of their springs, and experience corroborates this assumption.

28 In a similar manner a closing of the automatic discharge valves at an adjustable point of the suction stroke can be obtained by the gradual regulation of a force holding them open against the action of their springs.

29 In the first case the force is so regulated that the suction valves close when the amount of intake air remaining in the cylinder has decreased to correspond to the amount of compressed air desired at the time. In the second case the force is regulated in a way to keep the discharge valves open during such a part of the following suction stroke that the amount of compressed air returned into the cylinder, after expansion to the intake pressure, will leave sufficient room for the desired quantity of fresh air to enter the cylinder during the latter part of the suction stroke.

30 *Regulation by Action on the Suction Valves.* An application of this regulator to an ordinary poppet valve air compressor and

acting upon its suction valves so as to keep the receiver pressure constant, is shown in Fig. 3. *A* is the compressor cylinder. The suction valve *B* is provided with a spring which tends to close it,

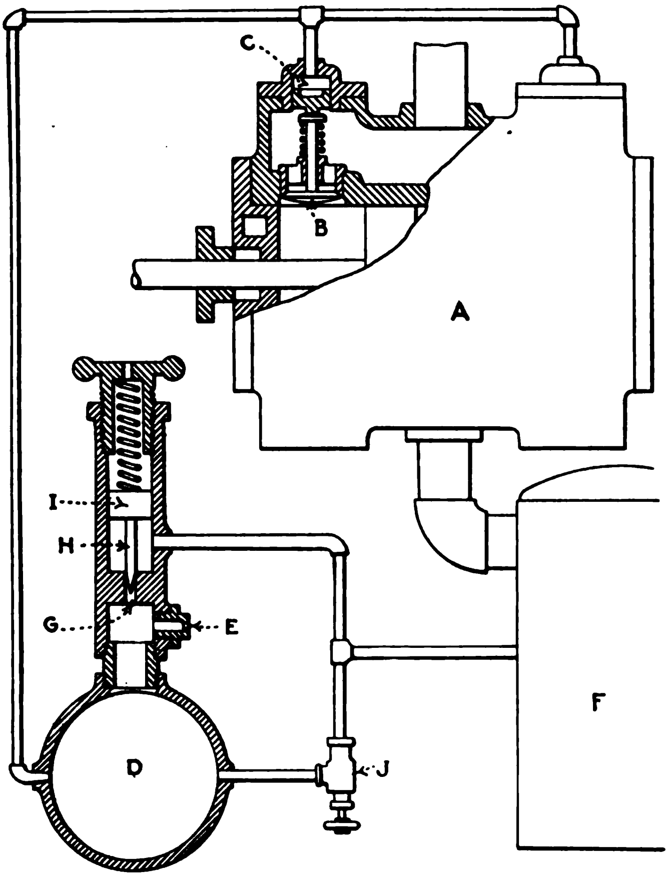


FIG. 3 APPLICATION OF REGULATOR TO AN ORDINARY POPPET VALVE AIR COMPRESSOR, SHOWING REGULATION BY ACTION ON THE SUCTION VALVES

and above it a piston *C* acted upon by pressure from the auxiliary tank *D*. This tank communicates with the atmosphere through the leak *E*. It is also connected with the main reservoir *F* through the port *G*. This port is closed by means of the pilot valve *H*, when the force of the adjustable spring overcomes the air pressure acting on the bottom of the valve piston *I*. An adjustable needle valve *J* can be arranged so as to obtain a constant leak from the main to the auxiliary reservoir, thereby preventing the pressure in the latter from decreasing below a certain value.

31 When the compressor is working at a constant partial load, the valve *H* will allow some air to enter the auxiliary tank *D*, and the same quantity of air will escape through the leak *E*, thereby keeping the pressure in the auxiliary tank acting upon the piston *C* constant. The suction valves will close at such a point of the discharge stroke as to compress exactly the quantity of air consumed, the pressure in the main tank remaining constant.

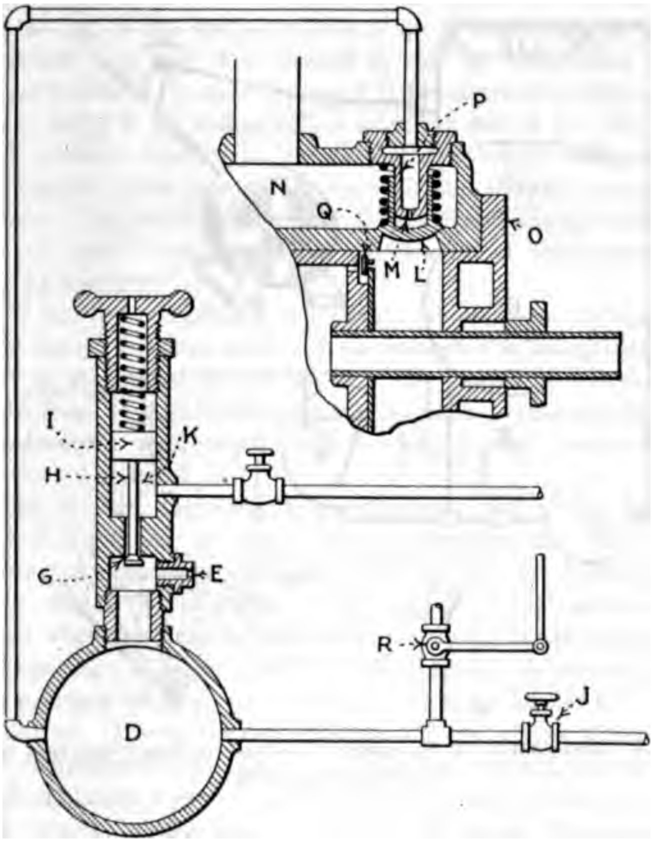
32 An increase (or decrease) in the consumption of air will cause a slight momentary decrease (or increase) of the pressure in the main tank, and the quantity of air entering the auxiliary tank, thereby decreasing or increasing the pressure in the auxiliary tank and changing the cut-off of the suction valves so as to increase or decrease the amount of intake air until new conditions of equal supply and consumption of compressed air at the same pressure as before are established.

33 For a certain pressure in the auxiliary tank, the air compressor will work at its maximum capacity, and the object of the adjustable needle valve is to admit constantly so much air as to produce this pressure. If more air be admitted the capacity of the compressor will be reduced and the volume of the intake air will vary with the consumption only as long as the latter remains below this reduced capacity.

34 *Regulation by Action of the Discharge Valves.* Fig. 4 shows the application of the same principle to the regulation of the discharge valves of a piston inlet type of air compressor. The action of the device is similar to the one represented in Fig. 3, and will easily be understood in referring to the drawing.

35 When the compressor is working at a constant partial load, the air under pressure from the main tank will enter the chamber *K*, and counteract the tendency of the spring to force down the piston *I*. This piston carries the needle valve *H* which closes to such an extent that the air enters the auxiliary tank *D* through the passage *G* at the same rate as it escapes through the leak *E*, thereby keeping the pressure in *D* constant. This pressure acts upon the cylinder valve *L* through the opening *M*. Under these conditions the pressure in the auxiliary chamber will be somewhat less than that in the main tank and in the passage *N* leading from the cylinder *O* to the main tank.

36 Owing to the low pressure thus created in the plunger *P*, discharge valves will be kept open during part of the following ke, and allow a certain amount of compressed air to reënter cylinder from the outlet passage *N* and expand in the cylinder ntake pressure. During the remaining part of the suction stroke,



'IG. 4 APPLICATION OF THE REGULATOR TO THE REGULATION OF THE DISCHARGE VALVES OF A PISTON INLET TYPE COMPRESSOR

amount of fresh air drawn into the cylinder will exactly correspond the consumption of compressed air at the time and the air pressure the main tank remain constant.

37 Assuming now that the consumption of compressed air is reased, a slight momentary drop of pressure in the main tank

will result. The spring will overcome the effect of the tank pressure on the piston *I* and will cause the valve *H* to open, thereby permitting a greater quantity of air from the main tank to enter the auxiliary chamber. The pressure in the auxiliary chamber will increase, and acting through the plunger *P* and the opening *M*, will cause the valve *L* to seat at an earlier point of the suction

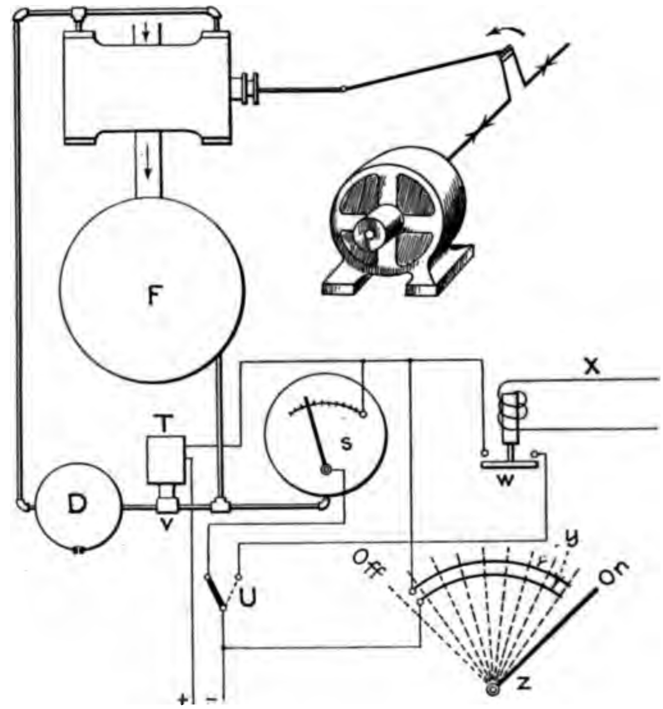


Fig. 5 Application of Electrical Control to the Operation of a Volume Regulator

stroke, thereby increasing the volume of fresh air drawn into the compressor through the intake valve *Q* until it equals the increased consumption of compressed air taken from the main tank, the pressure in the tank being kept therefore exactly the same as before.

38 In case of a decrease in the consumption, similar action will take place and a new equilibrium between supply and consumption will be established after a slight momentary increase of the tank pressure.

39 A needle valve J allows enough of the pressure air contained the auxiliary tank to escape to the atmosphere so as to unload the npressor by hand if desired. Valve R is opened by means of a ed regulator if the speed of the prime mover falls below a certain lue and it is desired to unload the compressor in that case.

40 *Electrical Control of the Volume Regulator*. Fig. 5 represents ne applications of electrical control to the operation of a volume gulator, acting on the suction valves of an ordinary poppet valve compressor. In case it is desired to run the compressor at a nstant air pressure, the gage contactor S is connected in series with e magnet valve T by means of the selecting switch U. As soon the air pressure reaches a predetermined value, the magnet T ll be energized, thus opening the valve V and thereby increasing e pressure in the auxiliary reservoir D and decreasing the amount intake air until it corresponds to the amount of compressed air nsumed at the time.

41 To run the compressor at constant power consumption and rying pressure, the limit switch W is connected in series with the agnet T by means of the switch U. The cut-off of the suction lves will then be regulated so as to maintain a constant current the conductor X, and consequently a constant power consumption the motor.

42 The contact segments Y are insulated when the starting ntroller Z is in "off" or "on" position, but are connected in all e intermediary starting positions. This insures the unloading of e motor during the starting period and a gradual assumption the load when the running position of the controller is reached.

43 *Regulation of Compound Air Compressors*. In case of com- und or multiple stage air compressors, each stage has, as a rule, its n regulation. Due to the fact that the different stages of multiple age air compressors may operate at different cut-offs, the present stem of regulation is exceedingly flexible and the generally intricate oblems arising in connection with the regulation of such com- essors are easily solved.

44 *Applications*. With the above noted exception of steam iven duplex and cross-compound air compressors, there are few ses where this new regulator could not be applied with advantage.

45 For single or tandem compound steam driven compressors can easily be operated in connection with the ordinary speed and essure governors, acting upon a throttle valve on the steam inlet, as to regulate the output of the compressor between full capacity

at its maximum speed and no volume at the lowest speed of the machine. On account of the perfect regulation which can be obtained by this combination it will in many cases be found advisable to use the cheaper single compressors instead of the duplex machines.

46 The new regulator is especially adapted to gas engine driven compressors. The feature of easy unloading of the machine, auto-

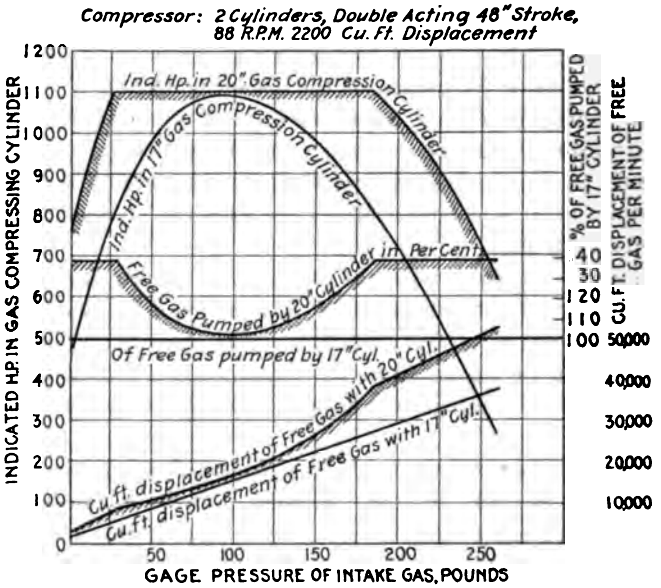


FIG. 6 COMPARATIVE POWER CONSUMPTION AND QUANTITY OF FREE GAS COMPRESSED PER MIN. BY 17-IN. CYLINDER WITHOUT AND 20-IN. COMPRESSING CYLINDER WITH HALL VOLUME REGULATOR AT 260-LB. CONSTANT DISCHARGE PRESSURE

matically or by hand, especially during the starting period is much appreciated in this case.

47 On account of the limited capacity of the gas engine for overload, it is advantageous to be able to build an amply large compressor and then regulate the volume of intake air so as to correspond exactly to the power exerted by the engine.

48 This feature is especially valuable in gas pumping plants where the gas pressure varies on account of field conditions. During the cold weather when great quantities of gas are needed, the field pressure is, as a rule, low and the gas engines are only partially

aded. With this regulator the compressor cylinder may be built rge enough to load the engine completely at the lowest occurring essure of the incoming gas without danger of overloading it at y intake pressure.

49 The curves in Fig. 6 represent the amounts of power conmed and the quantities of free gas, which can be pumped at various take pressures by

a An ordinary poppet valve compressor of 17 in. diameter of cylinders.

b A poppet valve gas compressor of 20 in. diameter of cylinders, provided with Hall volume regulator.

50 The curves show that the former loads the gas engine to its ill capacity only at the intake pressure, corresponding to the peak ad, while with the latter, the gas engine can be loaded to its maxiium capacity within a wide range of intake pressures. The amount f free gas pumped is thereby increased up to a maximum of 37 per ent more than can be obtained with the ordinary poppet valve ompressor.

51 The electric motor is essentially a constant speed machine nd economical volume regulation of electrically operated air comressors by variation of the speed of the motor can therefore not be btained, except within comparatively narrow limits or by the use f special and expensive motors and control apparatus.

52 The method in common use for this purpose is therefore, as reviously stated, the one consisting in running the compressor at ull speed and full load until the receiver pressure has reached a ertain maximum value and then stopping it until the air pressure n the same has decreased to a certain minimum value. This nethod is satisfactory for small compressors, operated from big power tations, but for reasons previously given and because of the iregular power consumption involved, it is, as a rule, not to be recomnended for big compressors, especially if the capacity of the elecrical power station is comparatively small.

53 The Hall volume regulator is of special advantage for large notor-driven compressors, because the power consumption can be educed so as to correspond to the air consumption at any time, or even to the average consumption of compressed air, without changng the speed of the motor, and because the compressor can easily e made to run idle so as to unload the motor during the starting eriod.

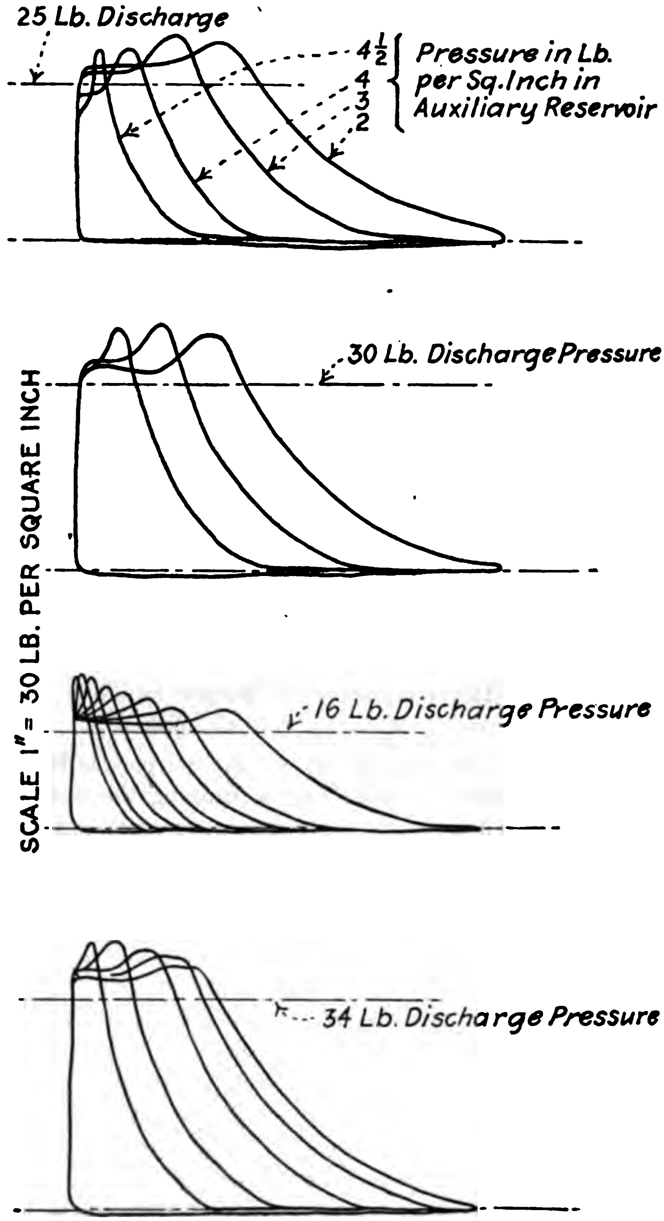


FIG. 7 INDICATOR DIAGRAMS FROM 12 BY 10-IN. BELT DRIVEN AIR COMPRES OPERATING WITH HALL VOLUME REGULATOR

54 The latter reason is in many cases sufficient to warrant the e of the new volume regulator even in cases where the above men- ›ned system of starting and stopping of the motor is applied.

55 *Results Shown in Test.* Fig. 7 shows a number of indicator rds taken on a standard Hall poppet valve air compressor with '-pass, equipped with the volume regulator shown in Fig. 3.

56 An important feature of this system of regulation is the cility with which it can be applied to almost any type of existing r compressor at a very low cost. Figs. 3 and 4 show that only a ght change of the suction or discharge valves is required in order apply it. The small auxiliary tank and a "trigger" or "pilot ılve" with needle point have, of course, to be added.

57 Every air compressor should have a spare set of suction and scharge valves and, as the above mentioned change can be made ı them, the application of the system will not require any inter- ıption in the service of the compressor.

DISCUSSION

W. L. Saunders, in a written discussion, stated that he regretted ıe author gives so little space to clearance unloaders or controllers, hich are not only extremely simple and inexpensive, but have been emonstrated to be highly efficient.

The cardinal requirements for the successful operation of a reg- lator for high speed compressors operating at constant speed are:

First, underload regulation must be obtained with such a degree f economy that the reduction in power required will be practically i direct proportion to the reduction in output capacity.

Second, all mechanisms for regulating the compressor must be in- ependent of the running gear, otherwise the timing of the regulator s the regulation varies is difficult to accomplish, and the delicate yet urable mechanism required, operating at the full speed of the com- ressor continuously, is extremely difficult to design and manufac- ıre. The difficulty and cost of maintenance and the shut-downs re- uisite for repair have proven excessive when the regulating me- hanism is part of or dependent upon the running gear of the com- ressor.

Third, the regulator should be of such design that, when the com- ressor is called upon for average operation at partial load capacity, ; can be so adjusted by hand as to limit the maximum capacity, and hus permit the compressor to operate at a higher average capacity or higher load factor than would otherwise be possible. This is a valuable feature under conditions where electric power service is furnished under a special maximum demand charge.

With the automatic clearance controller, the inlet capacity of the compressor is reduced without reducing the intake pressure. On a two-stage compressor, a constant ratio of compression throughout the entire load range and the highest compression efficiency are maintained throughout. The reduction in power secured with this method of control is practically in direct proportion to the reduction of load. The regulator is simple in construction and entirely automatic in operation.

On account of its under-load economy, the automatic clearance type is of value in the majority of conditions of constant speed power-driven compressor service requiring under-load regulation.

Joseph Esherick wrote congratulating the author upon his excellent paper and for his work in developing the Hall regulator.

In considering volume regulators, the author makes no mention of the Richards Pressure Unloader. This regulator permits the compressor to run unloaded until the desired speed is obtained, when it loads the compressor automatically. The device is placed in the discharge line between the compressor and receiver and is simple and inexpensive. It is used primarily on motor-driven compressors. Another type, called the Initial and Pressure Unloader, has been designed for continuous running steam and electric-driven compressors. This embodies means of adjustment for any degree of regulation, from 2 to 15 pounds.

One of the chief advantages of the Richards unloaders is that they permit, while the compressor is running unloaded, the passage of free air through the cylinder and passages, with its resultant cooling effect on these parts.

Paul Diserens wrote that the author's objection to the choking unloader were well taken as directed against its application by gradual throttling, but that this application was practically obsolete. It was not well taken in the case of the total closure unloader, which is both safe and efficient when properly protected by atmospheric relief valves. The only drawback to the total closure unloader is the sudden change from full load to no load it causes, but where this is not objectionable at the electrical end the device answers very perfectly.

Theoretically, the principle of varying the capacity of a compressor at constant speed by changing the clearance (clearance unloaders) ound. The chief objection to the practical application of this ıciple for volume control is in the obstruction to free communica- . between cylinder and clearance chambers occasioned by the re- :ted valve openings interposed between cylinder and valve pockets.

The author's comment on unloaders on compressors with positively- 'ed valves implies that unloaders operating the suction valves are best type, whereas one of the most widely-used devices of this ıre involves an auxiliary by-pass valve and connections.

The volume regulator which is the subject of the paper appears to end on the gradual increase, during the entire length of the com- ısion stroke, of the cylinder pressure as compared with the suction ıage pressure, but it does not seem clear why such gradual increase ıld occur.

It would also appear that on compressors of medium and larger s, operating at the relatively high speeds now generally employed, ıultiplicity of valves equipped with by-passing control would be led. This would appear to present some difficulty in synchron- g their action.

The application of the regulator described to a two-stage com- ısor necessitates the use of two independent governors, one to ılate the line pressure and the other the intercooler pressure. ›ugh this does not constitute a serious objection, it implies a com- ation to which the author takes exception in other forms of ıme control.

James Tribe expressed his written opinion that the form of 're to which this regulator was shown applied might operate with success under low-speed conditions such as formerly obtained, but nodern compressors, running at say 150 r.p.m., such a valve must e a very short life. Even the pressed steel cup valve, used for many rs by the best builders on account of its lightness, was proving massive to withstand the shock incident to valve action with high ›ds.

An air compressor invented by G. H. Reynolds in 1876 (U. S. ent 187,906) embodied the principle of by-passing air from the nder to the external air on the compression stroke when the re- 'er pressure was increased above a certain limit. This invention, ; since abandoned on account of the changing conditions of prac- , was similar to the Hall regulator in that the receiver pressure trolled valves in the cylinder for unloading the compressor auto- :ically.

Several large compressors recently built by the Allis-Chalmers Company have been equipped with unloaders on the Reynolds principle but reversed in application. These unloaders are independent of either the inlet or discharge valves and are not influenced by the speed of the machine.

JOHN GLASS[1] contributed a written discussion in which he stated the Hall regulator would not be applicable to compressors employed in large gas pumping plants where it is not practical to carry a constant discharge pressure at the various compressing stations. In such installations, the gas pressure is partly regulated at the compressing plant closest to the point of consumption, but the other plants back on the line are run at constant speed, that is, compressing all the gas possible. If more pressure is required in the line extra wells are turned in, and if the unloading device is affected by this, shortage of gas will occur at the consumption end.

Further, the changes of pressure in gas-pumping plants are too great to allow of the application of this regulator with advantage. When the field pressure drops, the discharge drops also, giving about the same number of compressions. A large diameter compressor would be a disadvantage, as the speed would have to be reduced so as not to exceed the economical number of compressions, about 4.5.

The regulator is well adapted to gas engine driven compressors, especially in starting and also on account of the limited capacity of the gas engine for overload. The facility with which it can be applied is also an important feature.

FRANK RICHARDS said that the device described could only be used in connection with obsolete or obsolescent types of inlet and discharge valves. He said we have learned that poppet valves are by no means the best for air compressors. The poppet valve has considerable inertia, and moreover the resistance of a spring has to be overcome in opening it; oil gums its guides and the valve requires frequent examination and cleaning; it gives a more or less restricted and tortuous passage for the air, and this feature is accentuated when the air has to play back and forth for regulation purposes. With this valve, too, the pressure of the air within the cylinder is necessarily lower at the beginning of the compression stroke than outside.

The Corliss inlet valve, wide open for nearly the entire stroke, and with large port area and a direct passage for the air into the cylinder,

[1]Chief Engineer, Carnegie Natural Gas Co., Pittsburgh, Pa.

gives a freer inrush to the air and a fuller pressure at the beginning of the compression stroke.

The Rogler valve, which has replaced the poppet valve, annihilates its objectionable features without entailing others. This valve consists of a very thin steel plate covering concentric annular openings in the valve seat, and with a minute, free lift it gives the largest and freest passage for the air that has ever been realized. The Hall regulator cannot be applied to either this or the Corliss valve.

The regulation of a compressor should be accomplished without interference with its ordinary operation, and so it might be well that neither the inlet nor the discharge valves should be interfered with for this purpose. This may be secured by controlled changes of the cylinder clearance, an almost ideal mode of regulating the output from nothing to full delivery. It is possible mechanically to have an automatically pressure-adjusted changeable clearance for the air cylinder so large that at one extreme of its capacity a whole cylinderful of free air will, when compressed up to receiver pressure, just fill this clearance space and none be expelled to the receiver. Then the compressor could run along continuously, and the air in the cylinder would be alternately compressed and re-expanded and no power expended.

A partial reduction of this clearance space would compel an expulsion or delivery of a portion of the air, and the remainder would re-expand upon the return stroke the same as with the clearance of full capacity, but in the latter case at the end of the stroke a portion of free air would be taken in sufficient to replace the volume delivered, and so on. With this adjustable clearance reduced to its minimum, the cylinder would be delivering its full charge of air, and its action would be entirely normal.

Such a clearance control is not yet fully realized, but the four stage clearance controller already in extensive use gives highly satisfactory results in practice. The only expense it involves is its initial cost, as it requires no constant operating expense.

THE AUTHOR. Concerning the remarks of Mr. Saunders, I wish to emphasize that all the "cardinal requirements for the successful operation of a regulator for high speed compressors, operating at constant speed" as enumerated in his discussion, are embodied in the new volume regulator described.

Replying to Mr. Esherick, I might have mentioned the Richards

Pressure Unloader, which, no doubt, is one of the best devices for regulation by means of total unloading of a compressor.

Mr. Diserens' remarks concerning the choking unloader are pertinent, and have induced me to modify par. 12. I think, however, that his opinion as to the practical obsolescence of the choking unloader by gradual throttling is rather advanced. The protection of the total closure unloader by means of atmospheric relief is a distinct improvement which, however, is far from being generally applied at the present time.

The volume regulator described in the paper depends in *one of its applications* on the gradual increase during the entire length of the compression stroke, or *very nearly so,* of the cylinder pressure as compared with the suction passage pressure. The reason such gradual increase occurs is that the air, being an elastic fluid, is compressed in the cylinder on account of the throttling when forced back through all or some of the suction valves. The compression increases the effect of the throttling and a cumulative action takes place which results in the point of the maximum pressure being displaced towards the end of the stroke as shown in Fig. 2. Later experiments have shown that the device, when pumping high-pressure gas which naturally is less elastic than air, requires a comparatively heavy throttling in order to obtain a satisfactory gradual regulation from full load to no load. Such heavy throttling has, however, the disadvantage of producing a comparatively big power loss. For this reason, it has in many cases been found preferable to apply the device to the discharge valves. In the latter application, a perfectly gradual regulation between full and no load is obtained in all cases without any strong throttling of the air flowing back into the cylinder.

Contrary to the apprehensions of Mr. Diserens, the application of the volume regulation to a multiplicity of valves has not presented any difficulty in synchronizing their action. This is probably due to the fact that the closure of one valve immediately increases the pressure tending to close all the others.

I agree with Messrs. Tribe and Richards in their opinion that the form of valve to which the regulator is shown applied does not lend itself to the application to high speed compressors, but there is no reason why this device cannot be equally applied to the modern plate or feather valves and, it has, in effect, been successfully tried on such valves. Regulators of this kind have, however, not yet been put in commercial operation.

In reference to the criticism by Mr. Tribe of the novelty of this ɘgulator, investigation has established the existence of only one prior ıvention of similar character. This was the subject of a patent to :. A. Rix in 1900 (U. S. Patent No. 602,170), and in the invention positively-moved system of levers, similar to the Corliss valve ear, operated to close the inlet valves of a compressor at some point f the compression stroke varying with and dependent upon the ressure in the outlet pipe or its connection.

In reply to Mr. Glass, who stated that a volume regulator operatng with constant pressure was not needed in large gas pumping lants, the regulator described is not limited to constant pressure, as t can also be operated to give any constant volume desired. In ordiary practice, a gas engine driven compressor is built so small that he engine can pull it under any conditions. With the regulator decribed, the gas engine can be built just large enough to take care of he ordinary conditions, and the amount of intake gas so regulated hat the work required for its compression corresponds to the capacity f the gas engine.

No. 1461

PHYSICAL LAWS OF METHANE GAS

By P. F. Walker, Lawrence, Kansas

Member of the Society

During recent years the development of the natural gas industry has been one of the marked features of the Middle West. In this development many problems of a technical nature have arisen, most of these having to do with the transmission and measurement of the gas as it is bought from producers and distributed to consumers throughout a large section of the country. Extension of pipe lines to greater distances than those common in earlier periods, together with a realization on the part of land owners and lease holders that the natural supply is not inexhaustable, has made necessary a greater degree of accuracy in many of the calculations involved, and the commercial prosperity of the large handling companies is becoming more and more dependent upon an exact knowledge of all of the conditions entering into the comparatively complex nature of the business.

2 The question of gas characteristics and its behavior under varying pressures enters in three important parts of the calculations. These are (*a*) the compression of the gas at various points in the transmission line in order to maintain pressures which will give economy in transmission; (*b*) the determination of conditions of flow by the various line-flow formulæ; (*c*) the measurement of the gas as purchased from producers and as sold to consumers. The discussion of methods of dealing with the various problems has developed a substantial literature on the subject, as is shown by articles which have appeared in The Journal during recent years. Several notable papers have been presented and through various channels much has been done to systematize the work and to establish formulæ for convenient calculation of the various quantities. Much remains to be done, however, especially along the line of the measurement of gas in large quantities and under the various pressures to which it is

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subjected. A great deal of attention is being given to this phase and much is being accomplished by the men employed regularly in the engineering departments of the large transmission companies.

3 In all of the work on which published matter is available, calculations have been based on the laws of perfect gases. It has been assumed that the laws of Boyle, establishing the proportionate relationship between pressure and volume at a fixed temperature, and of Gay Lussac, establishing the proportionality of volume to absolute temperature for gas under a constant pressure or the proportionality of the pressure to absolute temperature for a constant volume, hold for the gas which is being transmitted and measured. It is well known, however, that the gas does not follow these laws In the composite mixture called natural gas, there are many different elemental gases, including hydro-carbons of varying chemical composition. Most of these hydro-carbons are the lower units in the paraffin group, methane, CH_4, occurring in greatest abundance. Ethane, C_2H_6, occurs in definite quantities and is found to be increasing as the gas fields of Oklahoma are being drawn upon. Evidence of the presence of these compounds in a condition approximate to the saturated state is afforded by the occurrence of liquid during the compression process at many points in the territory. In some instances this occurs in such a degree that it becomes a nuisance. The fact that a light hydro-carbon oil, the lighter grade of gasolene, can be produced by a treatment of the gas is so well known that steps have been taken looking toward the establishment of plants for the manufacture of gasolene by the compression and cooling processes.

4 It is to be expected that in many of the calculations the assumption that the laws of gases will apply is hardly admissible when conditions are such that small liquid particles may be associated with the gas, much of which is already in a condition close to saturation. In attempting to determine laws which are practicable, it seems appropriate to start with that gas which forms the bulk of the mixture under consideration, but for a complete study of the subject new data will be required by first-hand experiments upon the gases themselves. The present paper represents an attempt to develop a few equations which relate quantities of real significance and to establish the values of a few coefficients which may be applicable when dealing with the gas mixture in computations where an especially high degree of accuracy is demanded.

5 The calculations in which these relationships occur and where the error involved in the use of the perfect gas laws are most pro-

nounced are in the line flow formulæ and in the measurement of volume. In all of the work it is necessary to convert volumes under high pressure to the equivalent volumes under standard pressure, this standard pressure being at or near the atmosphere according to the terms of the contract for purchase or sale of the gas. Density is always determined under atmospheric pressure, or a pressure but slightly above atmospheric, and it is then assumed that this factor will vary in a fixed proportion to the density of air under widely varying pressures. Since air is composed of gases and saturated vapors which do not conform to the laws of perfect gases it is conceivable that serious errors may be involved in this assumption. Even a small error of this character becomes a serious factor when the total transactions of a company amount to several millions of dollars annually. Since the temperature of the gas remains essentially constant, due to the influence of pipe line and the surrounding earth in which it is buried, this error is represented by the variance of the gas from the law of Boyle for constant temperatures. In many other calculations the equation expressing the relationship between pressure and volume during the adiabatic change of state becomes of great importance. In terms of the exponent applied to volume in the characteristic equation, $PV^n = \text{constant}$, the value ordinarily used on the assumption of constant ratio of specific heats is 1.26. It is to be expected that the true value of exponent n is different from this and the quantity is of considerable significance since it enters as an exponent on an item comparatively large. In an indirect way the value of this exponent is of importance in connection with compressor work, although it is not to be expected that it would have serious commercial significance in this connection. The variations from the laws of perfect gases in the case of changing temperature of the gas are of interest and will be developed as a step in the process of investigation, but this is not a question of great commercial importance since temperature changes are very slight and take place slowly and at infrequent intervals. The isothermal and adiabatic laws are the ones which are of greatest significance in this connection.

6 As stated above, methane is the element entering in the greatest amount in the composition of natural gas as it occurs in the mid-continental field. The composition of the gas may be noted by reference to the tabulation of analyses published in The Journal for May, 1912[1]. The average of all values shows that over 80 per

[1]Problems in Natural Gas Engineering, T. R. Weymouth.

cent of the gas is methane, while the amount of hydro-carbons closely associated with it bring the total gas of this general character to over 90 per cent of the total. It is probable that most of the mechanical difficulties incident to liquefation of gas during compression are due to the presence of the heavier hydro-carbons, but with the bulk of the volume in all cases in the form of methane it is evident that a study of this leading element is of prime importance. Because of the presence of the heavier gases, however, the natural gas under actual conditions is to be expected to vary from the laws of perfect gas by a still greater amount than does methane, so that the factors determined by an analytical study of the one element represents differences which are even smaller than those appropriate for adoption in practice. If the present discussion calls attention to the need which exists for more extended experimental study of the whole question of saturated vapors other than steam, the prime purpose will be realized.

7 It is found at the outset that information bearing upon the physical properties of methane is extremely limited. All that was found is given in the accompanying table of values of the product of pressure and volume under varying temperatures, according to the determinations by Amagat, and values for the specific heat by various authorities. In the tables of physical constants by Landolt, Börnstein and Meyerhoffer, specific heat under constant pressure is given as 0.5929 for temperatures varying from 18 deg. to 208 deg. cent. In the same reference, values of 0.5915 at a pressure of 1 atmosphere and of 0.6919 at a pressure of 30 atmospheres are authorized by Lussana. The same authorities, together with other physical chemists, unite in assigning an average value of 1.315 for the ratio of specific heats at constant pressure and constant volume. Another set of values is given by Kent in his Mechanical Engineer's Pocket Book, this being in the form given below and also treated at greater length in the appendix, in which the effect of varying temperatures is provided for. The value of the ratio as fixed by these specific heats is 1.235 to 1.24. Another value of the ratio commonly used by gas men and employed in the paper published in The Journal above mentioned is 1.266. Considerable uncertainty arises by reason of these discrepancies among authorities on this question, and final conclusions must of necessity be judged according to the values employed in the preliminary work. It has been decided to use the values given by Mr. Kent.

8 Fig. 1 is a graphical representation of the PV values given in

Table 1. A study of this sheet shows an appreciable variation from the perfect gas, since for the latter the PV values would lie on horizontal lines, this product being constant for constant temperature. Since the values are plotted on a base line representing pressure it is clear that with pressure increasing to a point far beyond those common in practice, the volume diminishes more rapidly than would the volume of the perfect gas. This indicates at once that in the more familiar process of expansion with lowered pressure the volume takes on values proportionately greater than would the perfect gas, thus giving an expansion curve on the usual pressure-volume co-ordinates which lies above the standard perfect gas isothermal, if

TABLE 1 PHYSICAL CONSTANTS FOR METHANE GAS[1]

Pressures		Temperatures					
Meters of Mercury	Lb. per Sq. In.	14.7 58.5 518.0	29.5 85.1 545.0	40.6 105.1 565.0	60.1 140.5 600.0	79.8 176.0 636.0	100.1° C. 212.2° F. 672° F. abs.
30	580	2580	2745	2880	3100	....	....
40	773.2	2515	2685	2830	3060	3290	3505
60	1160	2400	2590	2735	2995	3230	3460
80	1546.4	2315	2515	2675	2950	3195	3440
100	1933	2275	2480	2640	2935	3180	3435
120	2320	2245	2465	2635	2925	3180	3440
140	2706.2	2260	2480	2655	2940	3190	3460
160	3092.8	2300	2510	2685	2975	3220	3490
180	3479	2360	2560	2730	3015	3260	3525
200	3866	2425	2615	2780	3065	3305	3575
220	4253	2510	2690	2840	3125	3360	3625

[1] By Landolt, Börnstein and Meyerhoffer. Determinations by Amagat. Values of PV, volume relative.

a common initial high pressure point is taken for reference. This is shown to scale in Fig. 4.

9 The specific heat values are in the form $(a+bt)$. The specific heat values for constant pressure and constant volume are expressed in the same manner, the quantity a in the above expression differing by a fixed amount for the two cases. It is probable that the values thus given are slightly in error because of this constant difference, since this represents the work done during a constant pressure change accompanying one degree change in temperature, and the change of volume for such a constant pressure change is shown in Fig. 5 to be represented by a curve rather than by a straight line. The error involved is extremely small and it would not seem expedient to go back of the records in this connection at the present time. It should be said, however, that the uncertainty as to the values of

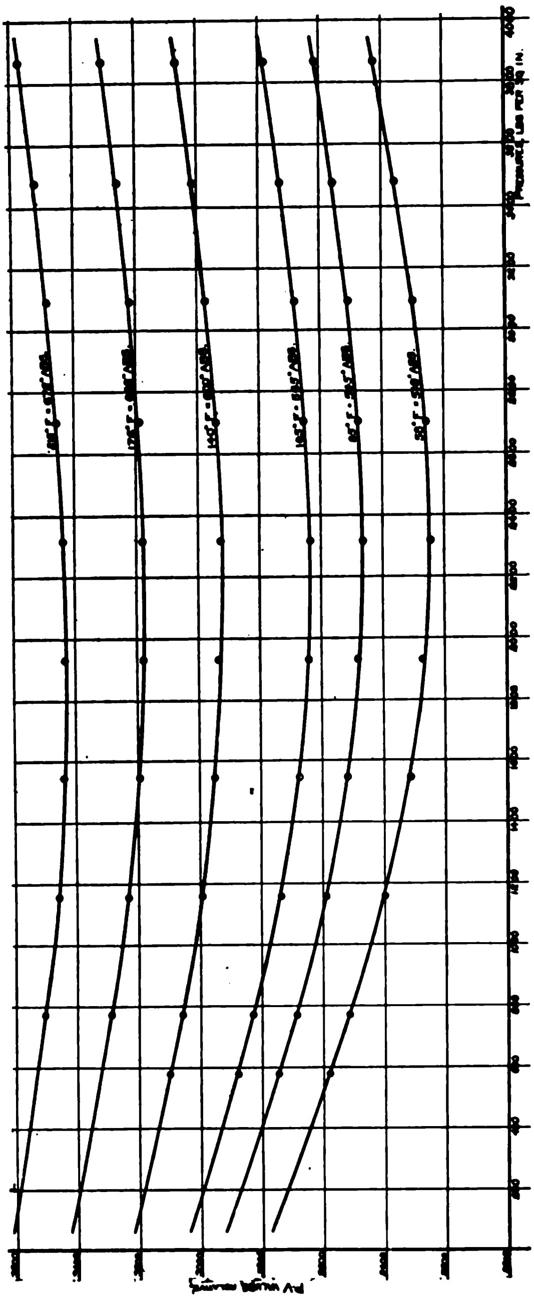


FIG. 1 *PV*-VALUES; *T*-CONSTANT CURVES ON PRESSURE, ORIGINAL DATA. VOLUMES OCCUR IN RELATIVE VALUES ONLY

specific heat is a matter of far greater importance in the actual handling of natural gas than it is in connection with a discussion of pure methane. Natural gas, as has been stated before, carries many other elements, these often being actual particles of liquid, and any attempt to use measuring devices which involve a knowledge of specific heat values is subject to serious and uncertain error.

10 The form in which the tabular data for values of PV occurs necessitates a somewhat complicated method for reducing the quantities to a standard basis. The volumes are given on a relative basis, making it necessary to deduce from the values given, the values of PV at standard atmospheric pressure and at the temperature of freezing water, in order to determine the mass of the gas dealt with and make it possible to express values on the basis of unit weight. In carrying out this process a difficulty was encountered because of the fact that the values given are for high pressures only. This made it necessary to extend the curves in Fig. 1 outside the limits of the observation values and take therefrom values pertaining to a lower pressure. The points indicated in Fig. 1 representing the regular observations are so well distributed, however, that no hesitation is felt in continuing the curves to a point where values for the pressure of 150 lb. are measured. Cross curves for constant pressure were then constructed as shown Fig. 2, values of PV being plotted on a basis of temperature. These curves develop in a very consistent manner so that, as before, no hesitation is felt in extending them the short distance necessary in order to establish a set of values at 32 deg. fahr.

11 With the set of values of PV established in Fig. 2 for pressures of 150 lb. to 2000 lb., the single constant temperature curve shown in Fig. 3 is drawn on a scale double that employed in Fig. 1. The points which established this curve are seen to conform perfectly to the law of change and the curve is extended to the standard pressure of 14.7 lb. per sq. in. Since the density of methane at this pressure and temperature is well established at 0.04464 lb. per cu. ft., the PV value of 2690 gives 0.05674 lb. of gas for the weight which was used by the experimenter in his work. Knowledge of this weight now makes it possible to express the volumes in absolute units, although the general accuracy of the various quantities which result from a comparative study of the data does not depend upon a knowledge of the absolute weight. While it is true that the extension of curves outside of the observed values taken in successive steps on these three preliminary diagrams is subject to some error,

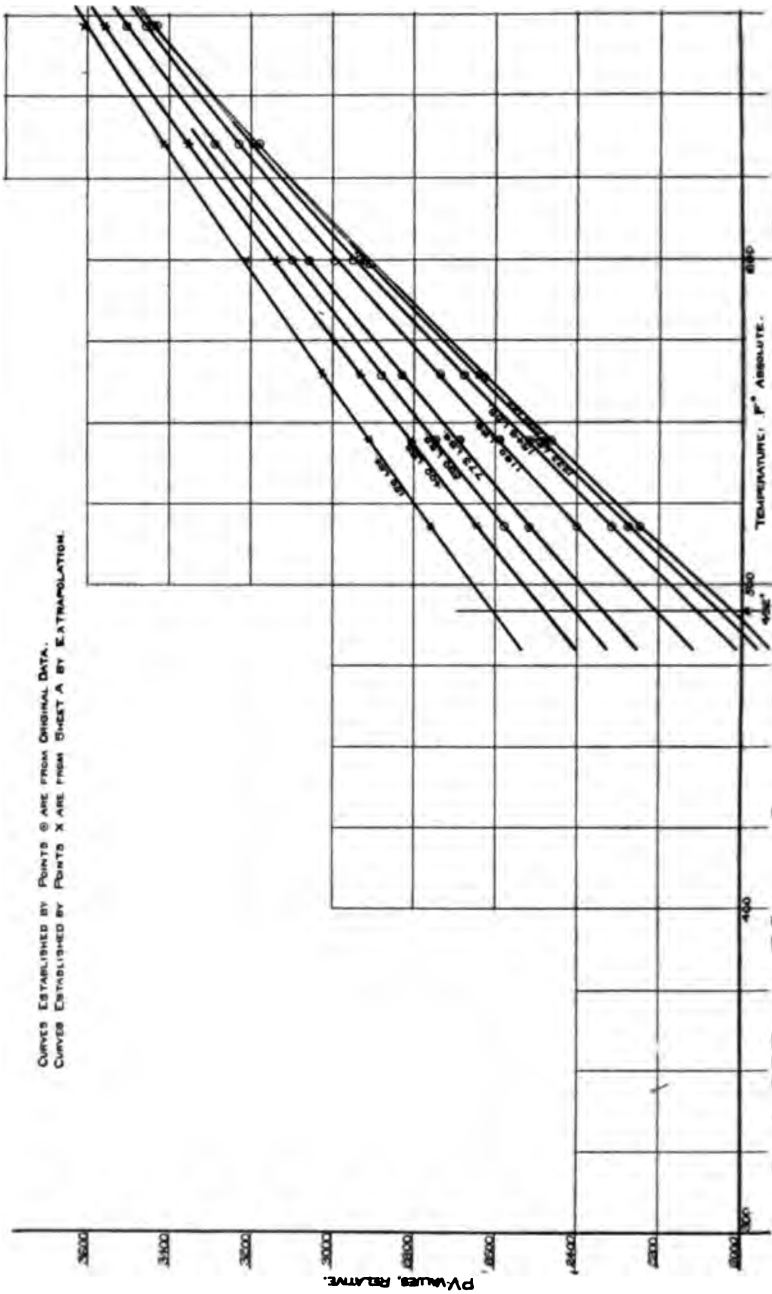


Fig. 2 *PV*-Values; *T*-Constant Curves on Temperature. Volumes occur in Relative Values only

it is true, nevertheless, that the curves thus extended are of slight curvature and of a character well established, both by the actual points fixed from the given data and by a general knowledge of the character of values under consideration, and it is not believed that sensible error results from this method of extrapolation.

12 The next step is the laying off of the isothermal curves in Fig. 4. Of these curves those for temperatures of 212 deg. fahr. and 105 deg. fahr. respectively are at the original temperatures of observation. The third one at 32 deg. fahr. is established by the extension of curves in previous diagrams already referred to. Comparison of the 212 deg. curve with an equilateral hyperbola drawn from the point of highest pressure on the curve shows that there is a noticeable variation. The gas fails to conform to Boyle's law by an amount which is of significance when a considerable range of pressures is involved. As shown by the calculations in the appendix, a calculation of the equivalent volume at atmospheric pressure, for a quantity of gas flowing in a line under 300 lb. absolute pressure, if made in accordance with Boyle's law, produces an error of 4 per cent. This is an item of considerable significance when large quantities of gas are being handled and it is much more than the observational error considered as permissible in engineering work. Expressed mathematically by an equation of the form $PV^n = \text{constant}$. These isothermal curves give a value of n of approximately 0.99.

13 Cross curves from the isothermals of Fig. 4 give the two series of constant pressure and constant volume lines of Fig. 5. Since all of the work with natural gas is carried on at temperatures between 32 deg. and 212 deg., it is not necessary to go outside of the limits set by the three points for each of the curves drawn on Fig. 5. These curves have been extended to their intersections with the temperature axis, but these extensions indicate simply the general behavior of the gas under the assumption that the laws of change within the indicated temperature limits would remain constant, and they are not employed for any subsequent calculations. It will be observed that these lines are slightly curved, with both pressure and volume diminishing more rapidly than would perfect gas under the diminishing temperature. A perfect gas would give straight lines passing through the zero of coordinates in all of these cases. As a matter of general interest the following equations of relationship between temperature and pressure at constant volume, and between temperature and volume under constant pressure have been determined. In doing this a right line has been drawn in place of the

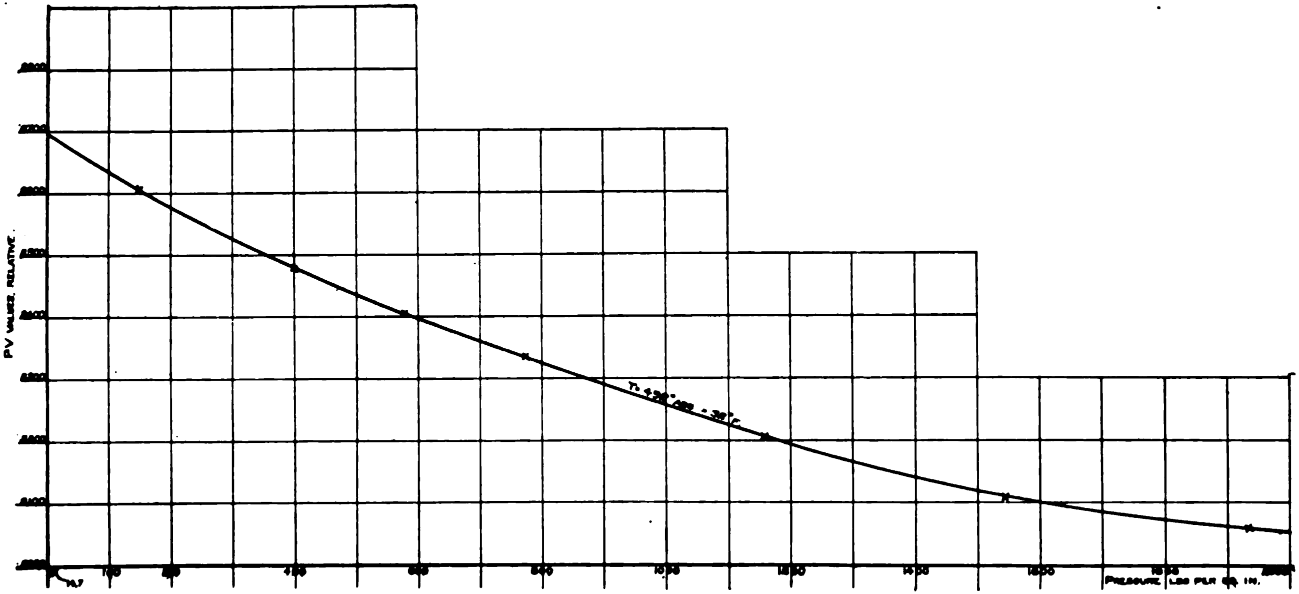
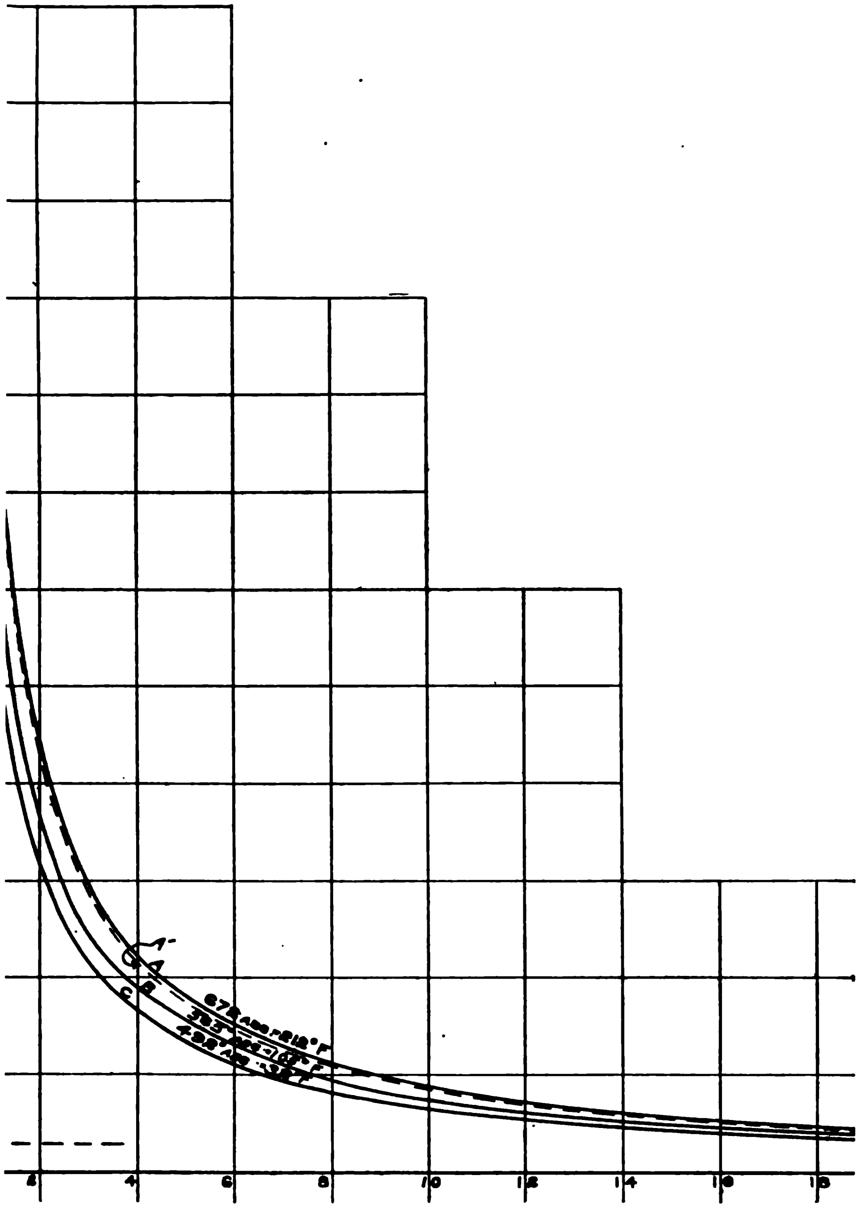


FIG. 3 *PV*-VALUES; *T*-CONSTANT CURVES DERIVED FROM FIG. 2. VOLUMES OCCUR IN RELATIVE VALUES ONLY. WEIGHT OF GAS DETERMINED AT 14.7 LB. PRESSURE FROM WHICH ABSOLUTE VOLUMES MAY BE FOUND. WEIGHT=0.05674



Cu. Ft.—Vol. per Lb.

G. 4 *T*-CONSTANT CURVES FOR 1 LB. OF GAS. CURVE *A'* IS A PERFECT GAS ISOTHERMAL. VOLUMES OCCUR IN TRUE SCALE curve in each case, this line being so placed as to pass through the points fixed for 32 deg. and 212 deg.

EQUATION FOR CONSTANT PRESSURE

$P = 50$ lb., $T = 75.4\ V$
$P = 100$ lb., $T = 152.5\ V$
$P = 200$ lb., $T = 280\ V+50$
$P = 300$ lb., $T = 427\ V+50$
$P = 400$ lb., $T = 539\ V+80$
$P = 500$ lb., $T = 584\ V+150$

EQUATION FOR CONSTANT VOLUME

$V = 2$, $T = 2.87\ P+40$
$V = 4$, $T = 6.51\ P-50$
$V = 6$, $T = 8.80\ P$
$V = 8$, $T = 12.0\ P$
$V = 10$, $T = 15.2\ P$

14 In the determination of the exponent in the equation representing an adiabatic expansion, the temperature-entropy method has been resorted to. It is assumed that one pound of the gas at a temperature of 32 deg. fahr. is heated at constant volume to some higher temperature, numerical calculations being made for 212 deg. and 105 deg. respectively. From this maximum temperature in each case the gas is assumed to expand adiabatically until its pressure has fallen to the original pressure. The temperature existing at the end of the expansion is found by assuming that the gas starts again from 32 deg., being heated under constant pressure until the entropy increment equals that found for the first calculation under constant volume. This combination of processes is shown in the left hand portion of Fig. 6, where the adiabatic expansions are represented by the vertical constant entropy lines A—B and C—D. At the initial 32 deg. point the volume may be assumed at any desired value, the pressure being found for any volume from data on density at 32 deg. or from Fig. 6, when a fixed weight of gas is under consideration. On the right hand portion of Fig. 6 four isothermal curves at the temperatures fixed by the entropy calculation have been drawn, and adiabatics drawn in accordance with the expansion between the two pairs of isothermals. The adiabatics A—B and C—D are thus established by assuming the initial volume of gas to be 2 cu. ft. per lb., and the adiabatics A'—B' and C'—D' are established by assuming the initial volume to be 4 cu. ft. per lb. As noted in the table of values on Fig. 6, the values of the exponent n are close to 1.17.

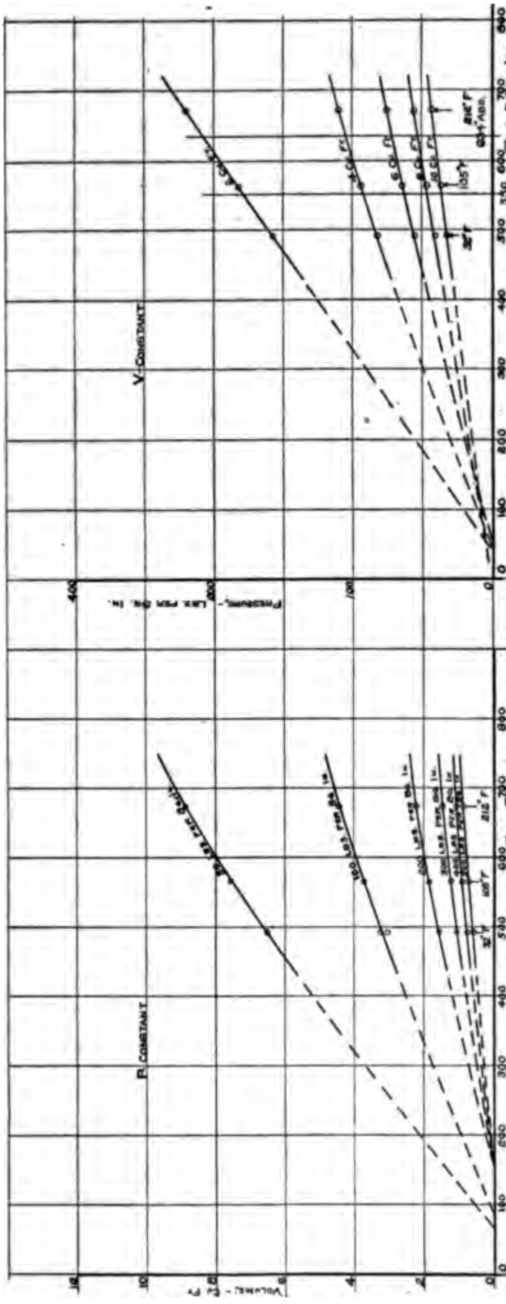


Fig. 5 P-Constant and V-Constant Curves for 1 Lb. of Gas. Volumes occur in True Scale. For Gas following Gay Lussac's Law the Curves would be Right Lines meeting at 0-0

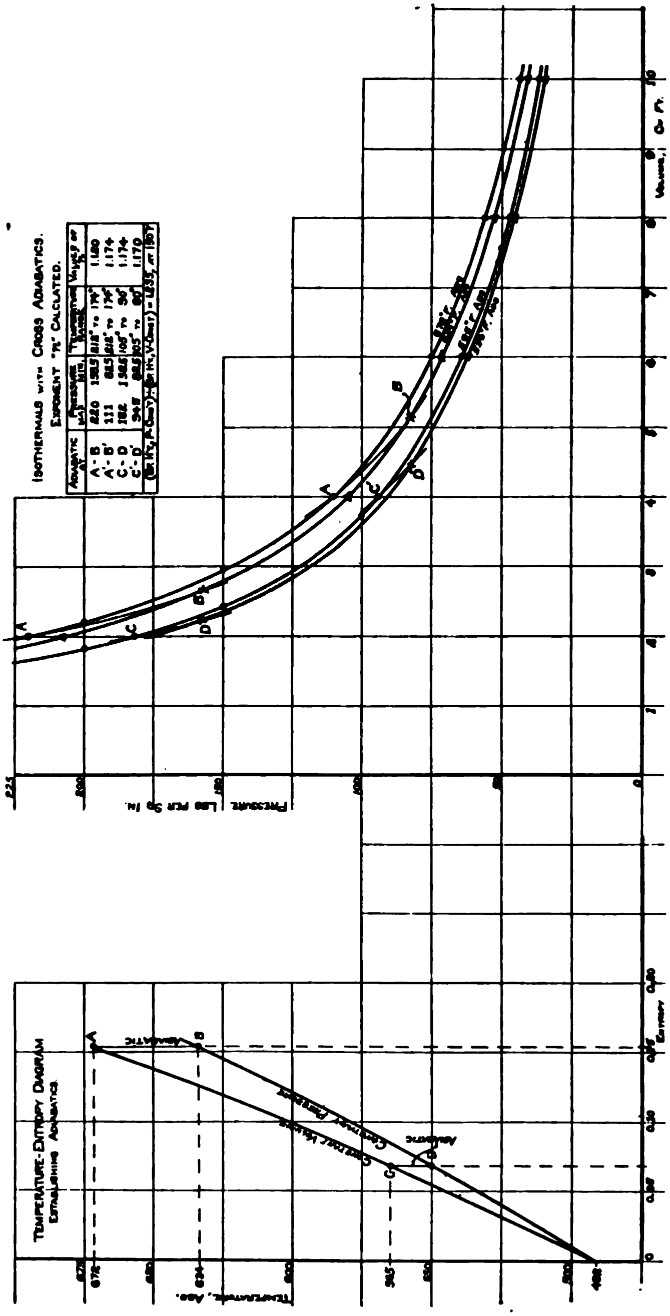


FIG. 6 DERIVATION OF ADIABATICS. ALL VALUES FOR 1 LB. OF GAS

Small variations from this value are of no significance, although the small value pertaining to the high pressure and temperature may indicate some variation in this direction. A complete investigation of this characteristic of the gas would include many more determinations than these which are recorded, but it is not the purpose of the writer at this time to fix numerical values for extreme conditions. Enough is given to establish the fact that the exponent has a value markedly below the ratio of specific heat. In much of the work in which this quantity enters it is in the form of $\frac{n-1}{n}$. Using a value of 1.17 in this combination the value becomes 0.145, while a value of 1.235 would give 0 19. A value of exponent 1.266, commonly employed in natural gas calculations, would give this combination form a value of 0.21. From this it is seen that in the form in which this quantity enters into much of the engineering work the use of specific heat ratios involves an error of 30 to 50 per cent.

15 These laws and coefficients pertaining to methane as a single gas indicate the necessity for more extended work upon this and other hydro-carbon gases which are of importance in the industries. Important experiments are already under way which are likely to throw additional light on the behavior of natural gas flowing through orifices, and many others should be undertaken in our laboratories for the determination of specific heat and other direct factors. Probably the most serious problem is that of measurement of volumes. Business men are no longer satisfied with results involving errors of 3 or 4 per cent. Tabulations of correction factors for the purpose of modifying results obtained by the use of the simple laws of Boyle and Gay Lussac should be compiled, but this should not be done on the basis of the incomplete data now existing, even if methane were the only gas involved. The work represented in this paper is but the beginning, and its prime function is to give emphasis to the need for scientific investigation of the actual gas employed in commerce.

APPENDIX

Calculation to Change from PV Relative Values to Specific Volumes

16 By the successive steps indicated in Figs. 1, 2 and 3 the value of PV at 14.7 lb. pei sq. in. and 32 deg. fahr. is found to be 2690. At this standard pressure and temperature the weight of methane per cu. ft. is 0.04464 lb. From the figures therefore

$$PV = 2690$$

$$V = \frac{2690}{14.7 \times 144} = 1.271 \text{ units}$$

If now we assume that the unit is the cubic foot,

Weight of gas = $1.271 \times 0.04464 = 0.05674$ lb.

17 It is clear that any other unit of volume, such as the liter, could be assumed and a different weight found, but the only purpose of deriving a weight is to express volume quantities on a specific basis.

18 With this base established the isothermal curve is derived as follows. At the temperature of 565 deg. absolute or 105 deg. fahr. from Figs. 1 and 2, the values of PV are read

At 20 lb. pressure, $PV = 3054$
At 100 lb. pressure, $PV = 3028$
At 200 lb. pressure, $PV = 2992$

19 It follows, then, that

$$V \text{ at 20 lb.,} = \frac{3054}{144 \times 20 \times 0.05674} = 19.06 \text{ cu. ft.}$$

for 1 lb. weight, and similarly for all desired pressures and temperatures.

Variations from Boyle's Law

20 The equation of the isothermal curves in Fig. 4 is found as follows: For the curve at 672 deg. abs.

When $P = 600$ lb., $V = 0.72$ cu. ft.
$P = 20$ lb., $V = 22.15$ cu. ft.

21 For an equation of the usual form, written for two points on a polytropic curve

$$P_1V_1^n = P_2V_2^n$$

From this

$$n = \frac{\log P_1 - \log P_2}{\log V_2 - \log V_1}$$

Using values on curve for 672 deg.,

$$n = \frac{\log 600 - \log 20}{\log 22.15 - \log 0.72} = 0.992$$

22 For different ranges of pressure and temperature the value varies from about 0.98 to 0.995. What the variations may mean to the practical gas man is shown in the following calculation: Suppose an amount of gas is sold by measurement in a pipe line under a static pressure of 300 lb. absolute, the amount being such that an actual volume of 1,000,000 cu. ft. passes the measuring mechanism. Under the usual contract the price is fixed per cubic foot at some stated pressure at or near atmospheric. We will assume this to be 14.7 lb., and that the temperature at the measuring point is the same as the standard. With the usual method of calculating equivalent volume we would have

$$\text{Volume at } 14.7 = 1{,}000{,}000 \times \frac{300}{14.7} = 20{,}410{,}000 \text{ cu. ft.}$$

With correct values taken from isothermal for 32 deg. fahr.,

$$\text{Volume at } 14.7 = 1{,}000{,}000 \times \frac{22.4}{1.053} = 21{,}270{,}000 \text{ cu. ft.}$$

$$\text{Error} = 100\left(1 - \frac{20410}{21270}\right) = 4.03 \text{ per cent.}$$

At rate of 18 cents per thousand cu. ft. this means a loss of

$$0.18 \times \frac{21{,}270{,}000}{1{,}000} \times 0.0403 = \$15.43$$

23 It may be noted in passing that in purchasing gas measured at high pressure, and selling it at a measurement made at low pressure, there is a gain in volume to the handling company, if Boyle's Law is applied in the calculation of equivalent volumes.

Specific Heat and Calculation of Entropy

24 Discrepancies among authorities as to values of specific heat and of the ratio of the two standard specific heats have been noted in the paper. The values given by Kent are:

For constant pressure, $0.608 + 0.0000748\ t$

and

For constant volume, $0.491 + 0.0000748\ t$,

these being in centigrade units. Changing to the fahrenheit scale, 0.0000748 becomes 0.00004155. At 150 deg. fahr. the values become 0.6142 and 0.4972 respectively, and the ratio 1.235.

25 In calculating entropy we have, designating entropy by E, and increase in entropy by ΔE:

$$\Delta E = \int \frac{dH}{T}$$

$$dH = (\text{Sp. Ht.})\ dt$$
$$= (0.491 + 0.00004155\ t)\ dt$$

But

$t = (T - 492)$, it being temperature above freezing.

Hence

$$dH = (0.491 + 0.00004155\ T - 0.00004155 \times 492)\ dt$$

and

$$\Delta E = (0.491 - 0.00004155 \times 492) \int_{T_0}^{T} \frac{dt}{T} + 0.00004155 \int_{T_0}^{T} \frac{Tdt}{T}$$

$$= 0.4706 \log_e \frac{T}{T_0} + 0.00004155\ (T - T_0)$$

Taking values for the gas being heated from 32 deg. to 212 deg. fahr. we have

$$\Delta E = 0.4706 \log_e \frac{672}{492} + 0.00004155\,(672-492)$$

$$= 0.1543$$

For the heating process at constant pressure, where ΔE must be the same,

$$0.1543 = 0.5876 \log_e \frac{T}{492} + 0.00004155\,(T-5492)$$

26 No direct solution for T is feasible, but by assuming successive values of T and solving for ΔE a series of points was found to establish a curve from which it is found that 634 deg. is the temperature which gives a value of 0.1543 for ΔE.

DISCUSSION

Carl Smerling called attention to an interesting point in connection with the heavier ends to the deposit in the pipe lines. He had been at work on a proposition of using those ends for the liquefying of gas, for gas production in town plants through the middle west and referred to one at Sibley, Ia., which uses liquefied gas at a Bonnet gravity of 86 per cent. His company had made a special distilling process for this gasoline which was a casing head or common gas process. In distilling this product, they have been able to reduce the precipitate or residue on a cold process to approximately 8 per cent., where with the old process of using casing head gasoline at 86 Bonnet, there would have been a residue of possibly 30 per cent; the latter would necessitate the emptying of the drip tanks weekly, whereas with the new process it had not been done inside of four months. He mentioned another plant in Pleasantville, Ia., where a similar plan has been used. The Sibley plant is a pipe line system of about ten miles.

The Author, in replying, said that the troubles from condensation referred to are not very serious so far as transmission is concerned. He stated that in the transmission of natural gas by compressors, it is not at all uncommon to have the liquid of condensation dripping out. By this it is not meant that methane gas changes to gasoline, but other gases, most of them of the paraffine group, which are present in the natural gas, will liquify under certain conditions. He stated that certain chemical changes are going on continually, it having been found in laboratory work that the chemical values are changing back and forth, either under heat treatment or under the varying pressure treatment.

Natural gas in the mid-continental field differs so widely in composition that certain wells are said to yield "casing-head" gas, and from this gas the production of gasoline has developed into a business of considerable magnitude. The element undergoing real change is C_2H_6, this being broken up so that a portion of it reappears as CH_4 in the gas remaining, while another portion is liquefied and so appears as a unit higher up in the series.

In the gas as it is transported in the lines, there are considerable quantities of C_2H_6 and possibly still heavier vapors, so that variations from perfect gas laws become noticeable. In certain trial determinations, a variation of 10 per cent from Boyle's law has been observed within pressure limits common in practice.

No. 1462

THE CLINKERING OF COAL

By Lionel S. Marks, Cambridge, Mass.

Member of the Society

The specifications for coal in general use at the present time are irrational because they include some items which are not of importance and do not include others which are of great importance.

2 The useful items in modern specifications are the heat of combustion of the coal and its water and ash content. A knowledge of the water and ash content is necessary to permit calculation of the cost of handling inert matter when firing the coal and when disposing of the ashpit refuse. In addition, the amount of moisture in the coal when fired must be known to permit calculation of the heat lost in vaporizing it. The volatile content of coal has an indirect interest in indicating its general nature but does not give any definite information about burning qualities. The sulphur content has generally been included in coal specifications with clinkering, spontaneous combustion or corrosion in view. The connection of sulphur with clinkering or with spontaneous combustion of the coal is not definitely substantiated by experience or by special experiment, while it is certain that the sulphur fumes do not attack metals under the conditions of boiler operation.

3 The important things about which specifications give no information are (*a*) as to the burning qualities of the coal (free burning or dead, caking or non-caking, etc.) and (*b*) the clinkering characteristics of the ash.

4 There is a growing feeling among large coal users that the very important matter of clinkering ought to be taken care of in some way when making contracts for coal, and it is frequently suggested that specifications ought to include the melting temperature of the ash as this has generally been assumed to determine the amount of clinker formed. A number of investigations have been made, or are being made on this subject, and much valuable information should now be

Presented at the Annual Meeting, December 1914, of The American Society of Mechanical Engineers.

available. It is in the hope of bringing out this information that this paper, embodying the results of certain tests by the writer, is presented.

5 Before the subject of clinkering can be put upon a satisfactory basis, two kinds of measurement are necessary; (*a*) the determination of the extent to which the clinkering of a given coal is objectionable in actual use, and (*b*) the determination by a laboratory test of some characteristic of the ash which indicates the objectionableness of the clinkering.

6 The important fact about clinkering is not so much the

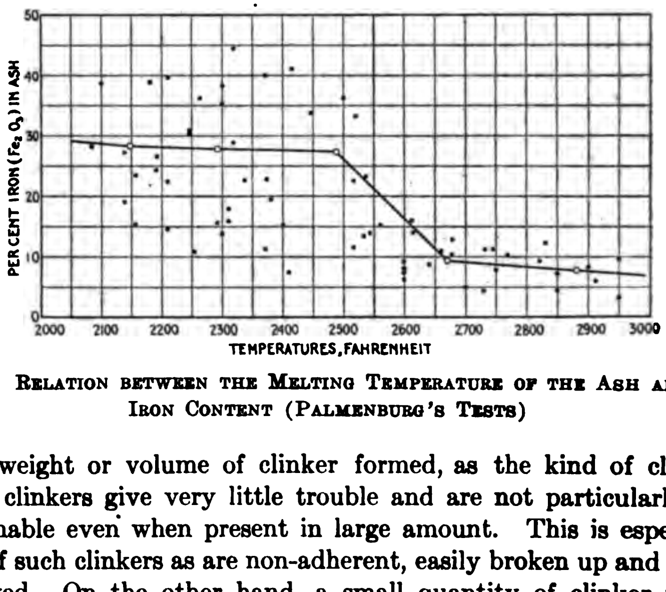


FIG. 1 RELATION BETWEEN THE MELTING TEMPERATURE OF THE ASH AND ITS IRON CONTENT (PALMENBURG'S TESTS)

total weight or volume of clinker formed, as the kind of clinker. Some clinkers give very little trouble and are not particularly objectionable even when present in large amount. This is especially true of such clinkers as are non-adherent, easily broken up and easily removed. On the other hand, a small quantity of clinker which forms a pasty mass with the surrounding coal, or which runs on to the grate and freezes there as a strongly adherent but thin sheet, gives a very great deal of trouble and diminishes both the capacity and efficiency of a boiler considerably.

7 It is probable that the only reliable basis at present for determining the "objectionableness" of the clinker, is the judgment of fireroom observers. The writer has attempted to get a quantitative measurement by sifting the ashpit refuse into a number of selected sizes. In tests made with a Murphy stoker equipped with the usual clinker-breaker, the coals which gave most trouble were found to have the lowest percentage of smallest size clinker (less than 1 in.),

and the highest percentage of the largest size clinker (greater than 2 in.). The differences between the percentages of the different sizes for good and poor coals is but small, so that the method cannot be relied on. These observations have, however, been used to confirm the judgment of the fireroom observers.

8 The only kind of laboratory test on coal ash which would seem to be of any real value in indicating the probable extent and character of the clinkering of a coal in actual use, is one in which the ash is subjected to such temperature as will cause it to melt either wholly or in part. A number of attempts have been made to determine the melting temperature of an ash from its chemical analysis, but none

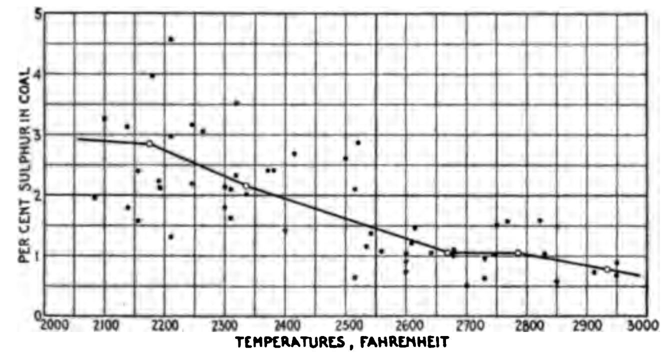


Fig. 2 Relation between Melting Temperature of the Ash and the Sulphur Content of the Coal (Palmenburg's Tests)

of these attempts has been satisfactory, nor does it seem probable (as pointed out earlier by the writer[1]) that this method will ever be available in view of the great complexity of the chemical constitution of coal ash.

9 That valuable indications may be obtained from a knowledge of the iron and sulphur content of the coal or of its ash, is suggested by some recent tests of Palmenburg[2] which, as pointed out by Bergwyn,[3] appear to show the following results:

a An ash containing less than 10 per cent of iron oxide (Fe_2O_3) does not fuse at a temperature below 2550 deg. fahr.; an ash containing more than 20 per cent does not fuse at a temperature above 2550 deg. fahr.; for an ash containing between 10 and 20 per cent the fusing temperature varies widely.

[1]Engineering News, Dec. 8, 1910.
[2]Journal of Industrial and Engineering Chemistry, April 1914.
[3]Journal of Industrial and Engineering Chemistry, August 1914.

b A coal containing less than 1 per cent of sulphur does not fuse at a temperature below 2550 deg. fahr.; a coal containing more than 2 per cent does not fuse at a temperature above 2550 deg. fahr.; for a coal containing between 1 and 2 per cent the fusing temperature varies widely.

c A coal containing less than 3 per cent of iron oxide plus sulphur does not fuse below 2550 deg. fahr., and a coal containing more than 3 per cent does not fuse above 2550 deg. fahr.

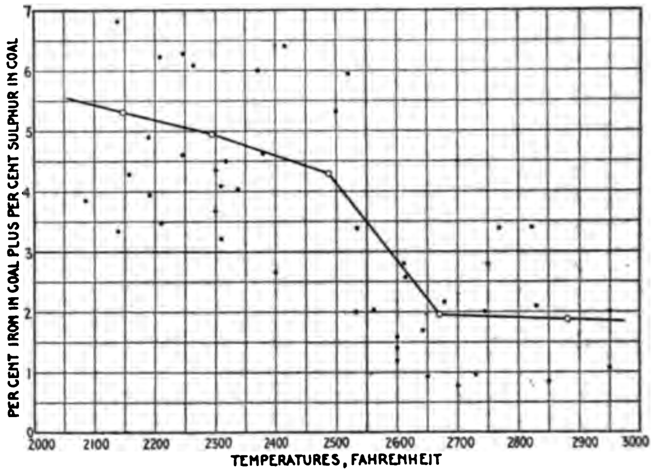


Fig. 3 Relation between the Melting Temperature of the Ash and the Combined Iron and Sulphur Content of the Coal (Palmenburg's Tests)

The observations on which these conclusions are based, are plotted in Figs. 1, 2 and 3.

10 The determination of melting temperatures of coal ash is attended with many difficulties, the most important of which is in the definition of the melting temperature. When a coal ash is heated slowly, that one of its constituents which is the most fusible will be the first to melt. Its effect upon the rest of the ash will depend upon three factors: (*a*) the amount of that constituent; (*b*) its viscosity when melted; and (*c*) its chemical reaction on the remaining constituents. If there is much of this constituent the ash will become fluid to an extent which depends upon its viscosity. If the molten part is small in amount but very fluid, it may separate from the rest. With certain constituents, a eutectic may be formed

whose melting temperature has but little relation to the melting temperatures of the constituents.

11 The best method of determining the extent to which melting has gone on at any given temperature, is probaby that which has been used so successfully by the Geophysical Laboratory at Washington. In this method a small mass of the ash is kept at the desired temperature for a time sufficient to insure that the melting corresponding to that temperature is complete. The melt is then quenched and a thin section of it is examined under the microscope. The following tests (Table 1) which were made for the writer through the kindness of Dr. Arthur L. Day, director of the laboratory, indicate the kind of information which is obtainable in this manner. The melting and quenching took place in contact with air.

TABLE 1 FUSION TESTS AT THE GEOPHYSICAL LABORATORY.

Ash No. 1, Feb. 3, 1914.

Temp. (deg. cent.)	Time, Hr.	Condition of Charge
1300	¼	Original not changed but for trace of glass
1300	1	Original not changed but for trace of glass
1400	¼	75 per cent (viscous)
1500	¼	90 per cent glass (quite fluid)

Ash No. 2, Feb. 10, 1914.

Temp. (deg. cent.)	Time, Hr.	Condition of Charge
1300	¼	Original not changed but for trace of glass
1300	1	Original not changed but for trace of glass
1400	¼	90 per cent glass (viscous)
1500	¼	All glass (quite fluid)

12 This method, while it is probably the best available for actual determination of the extent to which melting has occurred at any given temperature, may not be the most valuable for the determination of the clinkering characteristics of an ash.

13 There is another factor of great importance in connection with the behavior of molten coal ash, namely, its viscosity. A satisfactory laboratory test for clinkering should indicate viscosity as well as melting temperature. The only method which has been used to any extent for this purpose, is really an imperfect method of determining the temperature at which the material has a standard viscosity. This is accomplished by heating the material in the form of a Seger cone of standard dimensions, at a standard rate, until it has bent to some standardized final form. The cone has usually been set up vertically. The rate of rise of temperature is usually taken as 2 deg. cent. (or 4 deg. fahr.) per minute, and the melting temperature is taken as that at which the tip of the cone touches the

TABLE 2 COMPARISON OF FUSING TEMPERATURES AS OBTAINED IN DIFFERENT LABORATORIES, DEG. CENT. (FAHR.)

Laboratory	Coal Sample A	Coal Sample B	Coal Sample C	Coal Sample D	Coal Sample E	Coal Sample F	Coal Sample G
Harvard University	1350–1395 (2462–2543)	1360–1375 (2480–2507)	1400–1445 (2552–2633)	1470–1530 (2678–2786)	1420–1450 (2588–2642)		1450 (2642)
Boston, *A*	1270 (2318)	1270 (2318)		1560 (2840)		1410 (2570)	
Boston, *B*				1700 (3092)		1800 (3272)	
N. Y. Edison Co.	1245 (2272)	1239 (2262)	1290 (2354)		1350 (2280)		1490 (2714)
Geophysical Labatory	Temp. — % of Glass	Temp. — % of Glass					
	1300 (2372) — trace	1300 (2372) — trace					
	1400 (2552) — 75	1400 (2552) — 90					
	1500 (2732) — 90	1500 (2722) — 100					

A = Test coal of Feb. 3.
B = Test coal of Feb. 10.
C = Test coal of Mch. 24 (special sample).
D = Coal from Arthur D. Little, Inc.
E = Coal from N Y Edison Co.
F = Coal tested for E. E. I. Co. of Boston.
G = Pure nickel (fusing temperature 1450 deg. cent.).

Fusing temperatures for the Harvard University laboratory give the initial and final bending temperatures for horizontal cones; for the N. Y. Edison Co., the mean of these two temperatures; for the two Boston laboratories, the final bending temperature of vertical cones

The temperature in the Meker furnace was read by a Le Chatelier pyrometer which showed close agreement both with the Fery pyrometer and with the indications of Seger cones. Table 3 gives the melting temperatures observed in the two furnaces. The cones were in all cases vertical. The dates are those on which the coal (from which the ash sample was obtained) was burned under a boiler as described later. It will be seen that the temperature difference ranged from 120 deg. to 255 deg. cent. (260 deg. to 459 deg. fahr.). It should be noted also that even the order of fusibility was changed in some cases when the atmosphere is changed, and that the lower the fusing temperature in an oxidizing atmosphere the greater is the increase in fusing temperature when changing to a reducing atmosphere.

.E 3 INFLUENCE OF ATMOSPHERE ON THE MELTING TEMPERATURE OF ASH CONES

Date	Melting Temperature Deg. Cent.		
	Reducing Atmosphere	Oxidizing Atmosphere	Difference Deg. Cent.
Feb. 3	1560	1430	130
4	1580	1410	170
5	1580	1410	170
6	1605	1390	215
10	1620	1380	240
13	1635	1440	195
Mch. 3	1595	1440	155
5	1620	1365	255
11	1580	1400	180
13	1610	1445	165
17	1620	1500	120

There can be no question as to which of these two temperatures should be accepted since the atmosphere in a boiler furnace is always oxidizing. It is of prime importance that the cone should be surrounded by an oxidizing atmosphere. In Table 2 the results from the laboratory Boston *B* were obtained in a carbon tube resistance furnace and presumably, therefore, in a reducing atmosphere. This would account for the consistently high results from that laboratory.

b *Size of Cone.* The size of cone has an influence which is different for different materials. With Seger cones the difference is negligible. For example, a No. 16 Seger cone (17 mm. base, 70 mm. high) placed horizontally, has a melting temperature (initial and final bending) of 1355 to 1410 deg. cent.; when molded into the standard size of Seger cones of higher fusing temperature (8 mm. base, 30 mm. high), the result is 1355 to 1420 deg. cent. The size of cone adopted in the writer's tests was 11 mm. base and 52 mm. high. The ash of March 24 tested horizontally in a cone of this size gave melting temperature 1425–1450 deg. cent.; in a 13 mm. base, 57 mm. high cone, the temperature was 1400–1430 deg. cent. As is to be expected, the larger cones show a lower melting temperature but the difference is not great.

TABLE 4 INFLUENCE OF POSITION OF CONE ON MELTING TEMPERATURE

Date	Melting Temperature Deg. Cent.		Difference Deg. Cent.
	Vertical Cone	Horizontal Cone	
Feb. [illegible]	1430	1395	35
[illegible]	1410	1400	10
[illegible]	1410	1400	10
[illegible]	1390	1380	10
[illegible]	1380	1370	10
[illegible]	1440	1395	45
Mar. [illegible]	1440	1420	20
[illegible]	1365	1370	5
	1400	1380	20
[illegible]	1445	1395	50
[illegible]	1470	1450	20
Seger [illegible]	1350	1300	50
Seger [illegible]	1450	1420	30

Position of Cone. The melting temperature (complete bending) of a horizontal cone, is always less than for a vertical cone, as shown by Table 4. The difference varies considerably and is less with the more fluid melts. The cones of March 5 or February 10 showed a particularly fluid melt.

Nature of Binder. The ash is usually mixed with a 10 per cent solution of dextrin before molding into cones. It was found, however, that water alone was satisfactory if the cones are not dried much before putting in the furnace. The effect of adding dextrin is generally negligible, but sometimes it increases the apparent fusing temperature (complete bending) by as much as 10 deg. cent.

e *The Rate of Heating the Cones* has a marked effect on the apparent fusing temperature. Any increase in the rate results in increased lag of the pyrometer (Le Chatelier type with porcelain tube), and causes an apparent decrease in the melting temperature. Tests on the ash for February 4 and February 6 showed melting temperatures (complete bending) which were 40 deg. and 35 deg. cent. respectively lower, with 6 deg. cent. increase per minute, than with 2 deg. cent. increase per minute.

f *The Location of the Cone* in the furnace is important; it should be as close to the pyrometric element as possible.

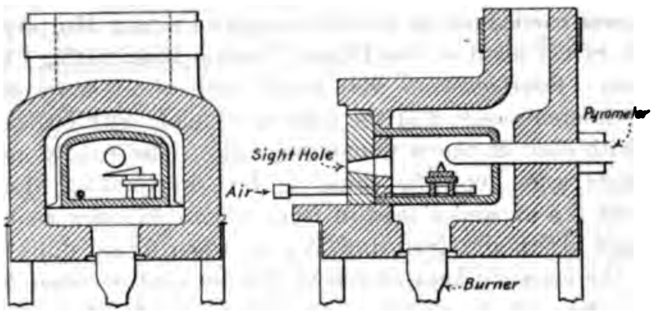


FIG. 5 ARRANGEMENT OF APPARATUS USED IN TESTS

The temperature at the front of a No. 29 Meker furnace was found to be about 20 deg. cent. lower than that in the middle of the muffle. An additional door plate reduced this difference.

g *The Cone must be Supported* on material which is unaffected by the highest temperature reached and which does not react chemically on the ash cones. Plates of fused quartz have proved very satisfactory in the writer's tests. They have to be supported in such a way as to permit circulation of the gases below them so that they shall have the same temperature as the rest of the muffle.

19 Another point of importance is the complete incineration of the ash before it is made into a cone. An appreciable amount of carbon remaining unburned tends to increase the apparent fusing temperature.

20 The arrangement of apparatus finally used in the writer's tests is shown in Fig. 5. Holes were made in the back of the furnace

for the insertion of the pyrometer, and in front for observation and for the insertion of a quartz tube through which a stream of air was introduced into the muffle to ensure an oxidizing atmosphere. The furnace was heated rapidly to within about 200 deg. cent. of the expected fusing temperature and the rate was then reduced to 2 deg. cent. per min., and was kept there. The observation hole was plugged up except when in use. Observations were made through very dark blue glass at 2½ min. intervals. The horizontal cones were supported only so far as was necessary, for balance.

21 In order to find out whether fusing temperatures as determined by the method outlined above, have any relation to the amount of clinker trouble experienced in burning the coal, a series of tests was carried out on a boiler equipped with a Murphy Stoker at the L Street plant of the Edison Electric Illuminating Company of Boston. Fourteen tests were made, each of 24 hours duration, with 10 different coals; 5 of the tests were made with one coal, and 1 test with each of the 9 remaining coals. The conditions of all these tests were kept the same as far as possible. Each test started at 7 a.m. and a load of from 150 to 175 per cent of the rated load was maintained until 5 p.m. when forced draft was put on and the capacity kept at 200 to 250 per cent of rated load for 2 hours; the capacity was then reduced to 150 to 175 per cent till 11 p.m. when the fire was banked until 7 a.m.

22 Table 5 gives the results of tests of the ash and a statement of the extent of the clinkering for each of these tests.

23 It will be seen that there is a general relation between the two but that it is not definite enough to be of much practical use. The coals giving the three lowest fusing temperatures (February 10. March 5, April 8) are also those giving the maximum clinker trouble. Those ashes with a final fusing temperature of 1400 deg. cent. (2552 deg. fahr.) or higher, gave little trouble, but the ash of February 6, which melted at 1380 deg. cent. (2516 deg. fahr.) gave little trouble, while those of February 13 and March 13 which melted at 1395 deg. cent. (2543 deg. fahr.) gave much trouble. The most troublesome clinkers (February 10, March 5 and April 8) had final melting temperatures of 1370 to 1375 deg. cent. (2498 to 2507 deg. fahr.) which is practically the same as the temperature for the good coal of February 6. It would appear then, that the final melting temperature cannot be taken as a criterion in the range from 1380 to 1400 deg. cent. (2516 to 2552 deg. fahr.) and the inference is that the uncertain region extends over a still wider temperature range. It is probably

ue that final fusing temperatures below 1350 deg. cent. (2462 deg. hr.) show a coal which would give clinker trouble under the con- itions of the L Street Station, and that temperatures above 1420 deg. ent. (2588 deg. fahr.) indicate a coal comparatively free from such ouble, but further investigation would be necessary to establish iat fact. The important thing, however, from the point of view of oal specifications, is that the tests of the ash of February 3, 4, 5 nd 6, when the regular station coal was used which gave a inimum of clinker trouble, yield results which fall in the doubtful

TABLE 5 MELTING TEMPERATURE OF ASH AND FIRE ROOM RECORD OF CLINKERING

Date	Melting Temperatures Deg. Cent. (Fahr.)		Amount and Character of Clinker
	Initial and Final Bending	Range	
b. 3	1350–1395 (2462–2543)	45 (81)	Light
4	1360–1400 (2480–2552)	40 (72)	Light
5	1360–1400 (2480–2552)	40 (72)	Light
6	1340–1380(2444–2516)	40 (72)	Light
10	1360–1375(2480–2507)	15 (27)	Hard, excessive; 50 per cent of grate
13	1350–1395 (2462–2543)	45 (81)	Excessive to moderate; large clinker
ar. 3	1370–1420 (2498–2588)	50 (90)	Not much but very hard and isolated
5	1350–1370 (2462–2498)	20 (36)	Excessive; 75 per cent of grate
11	1355–1380 (2471–2516)	25 (45)	Heavy
13	1340–1395(2444–2543)	55 (99)	Heavy
17	1430–1480 (2606–2696)	50 (90)	Light
24	1420–1450 (2588–2642)	30 (54)	Very little
26	>1500 (> 2732)		Light, hard
pr. 8	1335–1370 (2435–2498)	35 (63)	Excessive, very hard, 18 to 20 in. in V and thick

egion and would therefore be rejected in coal specifications based on ising temperatures alone. Tests made at the New York Edison ompany's laboratory on the ash of the coal of February 3 (see Table), gave a mean fusing temperature of 1245 deg. cent. (2272 deg. hr.) which Mr. J. P. Sparrow reports, from the experience of the ew York Edison Company, "would indicate serious trouble from inker in commercial service." This remark applies to combustion n a Taylor stoker. It may also be noted that the tests (Table 2) f Boston *A* laboratory, on the coals of February 3 and 10, gave the ame melting temperature although the former coal is found to ive negligible and the latter excessive clinkering in actual use.

24 Additional indications of the liability to clinker trouble may e obtained from the range of temperature during bending and from ie appearance of the bent cone. The cones of the ash which gave iost trouble had a very fluid constituent which ran down to the tip f the cone and also upon the supporting plate and gave the ap-

pearance shown in Fig. 6; those giving least trouble were as in Fig. 7. It would appear that the most fusible constituents will separate from the rest of the cone when it is very fluid, leaving a skeleton which does not bend until its own fusing temperature is reached; that is, with the kind of ash which gives most trouble, the Seger cone method fails as a result of the separation of the more fusible from the less fusible constituents.

25 It is possible to accept the appearance of the bent cone as a partial indication of the clinkering behavior, and it may be possible

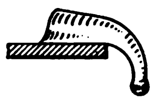


FIG. 6 FUSED CONE WITH VERY FLUID CONSTITUENT

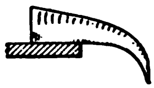


FIG. 7 NORMAL FUSED CONE

to predict the behavior of an ash from that indication combined with the fusing temperature. The range of temperature during bending may also possibly be used. The range varies from 15 deg. to 55 deg. cent. in the tests given in Table 4; in other tests by the writer it has amounted to as much as 140 deg. cent. There seems to be a very close relation between this range and the viscosity of the melted cone. The ash cones of February 10 and March 5 show the smallest range and they also show greater fluidity (Fig. 6) than any of the other cones. It should be noted, however, that there is a liability to error in observing the initial and final bending temperatures, which is not less than 10 deg. cent. so that an observed range of temperature of 30 deg. may actually be anywhere from 10 deg. to 50 deg. cent.; it is necessary to make several determinations in order to get the range with reasonable certainty. The appearance of the melted cone is consequently more valuable than the range of fusing temperature.

26 The investigations of the writer seem to show that under the conditions of combustion at the L Street plant of the Edison Electric Illuminating Company of Boston a coal with a fusing temperature (final bending) below about 1400 deg. cent. (2550 deg. fahr.) will probably give trouble if the ash has a fluid constituent; whereas, it will not give trouble above about 1380 deg. cent. (2516 deg. fahr.) if the ash is viscous. This conclusion would require further investigation with many other coals before it could be accepted even for this particular plant; naturally it cannot be applied to plants with different operating conditions.

27 It may be interesting to note here the conclusions reached by other investigators as to permissible fusing temperatures. Mr. J. P. Sparrow in a report to the Association of Edison Illuminating Companies, September, 1914, states as a result of boiler tests with a Taylor stoker, using 13 different coals:

> It will be seen that the critical point of ash fusion lies between 2400 deg. and 2500 deg. fahr. All coals where ash fusion temperatures are above 2500 deg. fahr. can be classed as non-clinkering, those below 2400 deg. fahr. as clinkering; using 2450 deg. therefore as a standard, there is an allowable margin of 50 deg. fahr. above and below standard to cover possible errors in testing.

28 Most of his boiler tests lasted 120 hours. The ash fusion tests were conducted under conditions very similar to those used by the writer. The fusing temperature is the middle of the range from initial to final bending of the cones. It should be pointed out that the fusing temperatures obtained in Mr. Sparrow's laboratory average about 260 deg. fahr. less than the temperatures obtained for the same ash in the writer's laboratory (see Table 2).

29 Mr. E. J. Constan[1] as a result of his investigations, finds that the melting point of coal ash varies from 1150 deg. cent. (2202 deg. fahr.) to 1700 deg. cent. (3092 deg. fahr.) and recommends the following ash melting temperatures; for boiler coals, above 1400 deg. cent. (2552 deg. fahr.); for locomotive and producer plants, above 1500 deg. cent. (2732 deg. fahr.).

DISCUSSION

F. C. Hubley[2] (written). The author states that a satisfactory laboratory test for clinkering should indicate viscosity as well as melting temperature. It would probably be well to go further and state that such a test should indicate viscosity at any temperature throughout the softening range, and should moreover, be of such a positive and definite nature that results from the same sample but from different laboratories will agree closely. If these requirements are not fulfilled and if the personal judgment of the experimenter enters into the determination of an arbitrary end point called the melting temperature, and a specification is based on this figure, this specification alone will not protect the buyer from clinkering trouble, nor will it be acceptable from the seller's standpoint.

[1]Jour. Gas Lighting, CXXIV, 572.

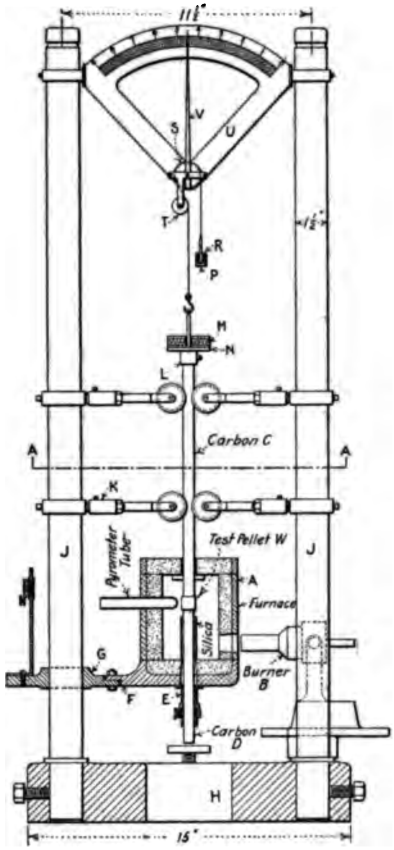
[2]P. O. Box 202, Cynwyd, Pa.

In searching for a form of test more definite than the various cone methods, the writer finally adopted a test in which the collapse, due to softening, of an ash cylinder, under a slight vertical pressure, is plotted against increasing temperature to form a curve, the shape and extent of which present a complete picture of the nature and position of the softening range of the ash under test. The ash cylinder is formed without the use of a binder, from the completely incinerated pulverized ash, in a press exerting 30,000 lb. per sq. in.

After experimentation in the construction of various designs of an instrument to carry out the proposed fusion tests, the form shown in Fig. 8 was adopted as the best suited mechanically to the purpose. A test pellet *W* is held centrally in the furnace *A* by carbon rods *C* and *D*, which are ordinary arc lamp carbons 1/2 in. in diameter. Rod *D* is held by clamp *E* to the bottom of the furnace body, while rod *C* and weights *L* and *N* are free to move vertically, the weights being designed in this particular instrument so that a pressure of 1.5 lb. per sq. in. is exerted on the pellet. The rod *C* is held on the center line of the instrument by four guide wheels as shown and a silk cord passing over the pulley *S* connects this rod with a counter weight *P*. Attached to this pulley is a pointer *V* which indicates on the scale on plate *U*. The pulleys are 1 in. in diameter and the pointer 6 in. long, so that any vertical movement of the road *C* due to softening of the test pellet is magnified twelve times on the scale, the total collapse of a pellet 5/8 in. in height being indicated by a movement of the pointer over 7 1/2 units on the scale. The several parts of the instrument are supported on two 1 1/2 in. diameter rods, fixed in a heavy cast iron base. This construction is considered necessary to obtain proper rigidity of the instrument.

In experiments carried out by the writer, a gas-heated furnace was used. Eight tests, including making of pellets, were performed in 3 1/2 hours, averaging 26 min. per test, which compares favorably with the time required to make a proximate analysis or a B.t.u. determination on fuel. During this performance the carbon rods were reduced from 1/2 in. in diameter to 3/8 in. in diameter at the pellet. Frequent replacement of these rods may be made since their cost is negligible.

In making a test, with the ash pellet and carbons in a central position vertically, and the pointer adjusted midway between zero and 1.00 on the scale, the furnace is gradually heated at the rate of from 50 to 100 deg. fahr. per minute and simultaneous temperature and



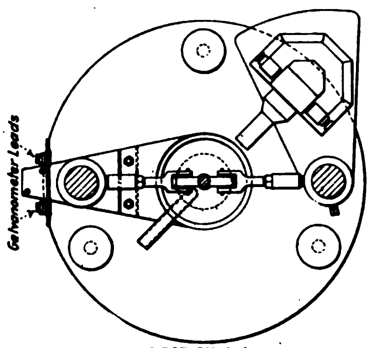


FIG. 8 ELEVATION AND PLAN OF FUSIOMETER

scale readings are made at 1/2 minute intervals. As the heat is increased, negative movement of the pointer will indicate carbon expansion up to a temperature where first softening of the ash pellet is indicated by a positive movement of the pointer. The experiment is continued till final collapse of the pellet is indicated on the scale. The results of readings if plotted, the temperatures as abscissae and the pointer movement as ordinates, produce a curve, an ordinate of which at any point is a measure of the relative rate of softening of the ash pellet at that temperature.

Length of the softening range, and its position on the temperature scale in relation to the working temperature range of a boiler fire, as well as the increasing rate of softening, whether gradual throughout the range (indicating high viscosity), or very slight for most of the range followed by a sudden collapse, are the factors in the fusiometer results which must be considered in predicting the probable clinkering action of a coal in a boiler fire.

A long range ash with a slow but steady increase in softness, indicated by a gently sloping curve, is productive of the close gummy clinker of high viscosity. Provided the softening range coincides approximately with the working temperature range of the boiler, this type of ash fusion produces the greatest losses from clinker formation in a boiler fire. This refers more particularly to stokers in which the fires are cleaned at regular intervals by a dropping of the back grates.

The other type of ash fusion is a short range spongy porous formation of low viscosity, which, if it does not occur too low on the temperature scale, can be handled with ease in the boiler fires. From a comparison of boiler-house results with a large number of tests made, the fusiometer curve for this type appears to be distinguished by a most decided downward dip in the curve just prior to final softening.

The "fusing point" of a substance is misleading and indeterminate, while the "fusing range" can be determined with exactitude. However, for purposes of comparison, an arbitrary point in the fusing range of an ash may be selected and called the "fusing point." For this point, in the case of the fusiometer results, the writer suggests the temperature at which the pellet has collapsed to one-half its original height. It must be noted, however, that, while this arbitrary temperature is of value in grading coals as to their probable clinkering tendency, the loss by clinker formation in the boiler fires can be predicted only by the shape, length and position of the fusion curve, which in turn indicates the nature of the fusion.

The following illustrations show curves developed from a number of ash tests, using this instrument, together with boiler-house reports in regard to the nature and extent of clinker formed under actual operating conditions. In Fig. 9 and 10, the coals represented were burned in Taylor Stokers with Rust boilers operating only slightly above rating.

Test 6983, Fig. 9: "This coal burned freely with a long flame, the only undesirable point being the formation of large clinkers which

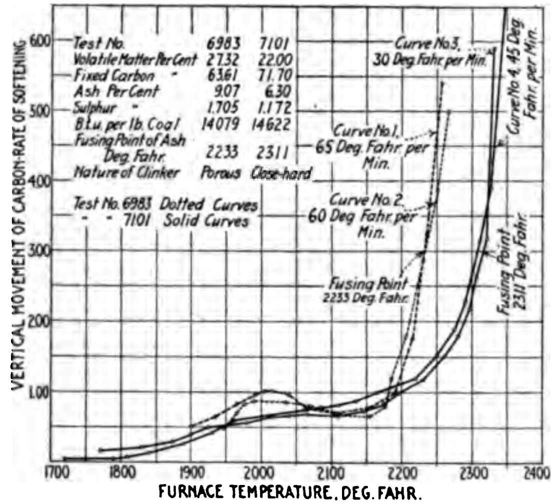


FIG. 9 ASH FUSION TESTS ON MIDDLE PENNSYLVANIA COALS WITH FUSIOMETER

did not, however, cause a serious amount of trouble." The dip in curves No. 1 and 2 appears to indicate low viscosity of the melt and the formation of a porous clinker easily broken up and removed from the firebox.

Test 7101, Fig. 9: "Proved so troublesome on account of clinker formation, that the remaining cars of this shipment were rejected. Required 45 min. to clean fires after six hours running." From the shape of curves No. 3 and No. 4 and the nature of the final pellet fusion, this ash has a long fusing range, a high viscosity throughout the range and finally forms a close gummy clinker, difficult to remove from the firebox.

These two samples illustrate the wide variation, in viscosity of melt, between ashes fusing at approximately the same temperature. and the futility of using only the relative ash "fusing points" to grade coals as to their probable freedom from clinkering trouble, without considering also, viscosity and length of softening range.

In Fig 10, the fuels represented were consumed at approximately 180 per cent of boiler rating.

Test 7891: "Clinkered severely when forced. One cleaning required 25 min. and another 45 min. to perform."

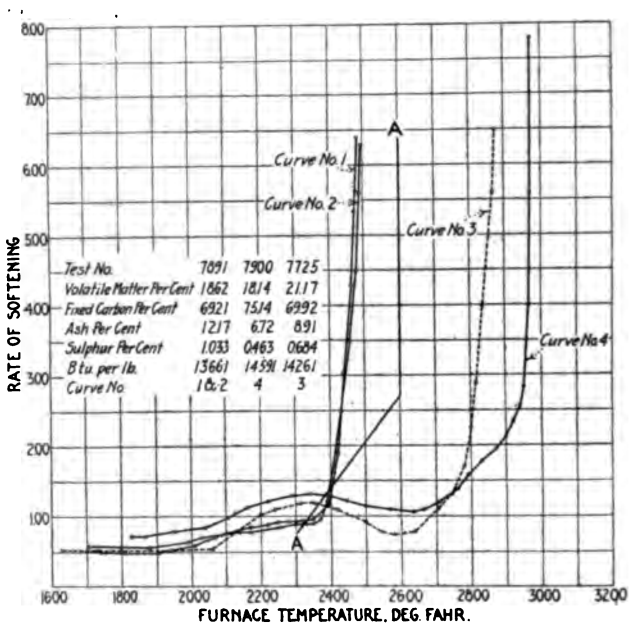


FIG. 10 ASH FUSION TESTS ON BITUMINOUS COALS WITH FUSIOMETER

Test 7900: "Burned free and fast and did not clinker. With coal of this quality we could reduce our present number of cleanings to four instead of six, and a possibility of three per twenty-four hours."

Test 7725: "Similar to Test 7900, requiring very little labor at fire cleaning periods, other than the dumping of the back grates."

The curves for calcium sulphate and red oxide of iron, Fig. 11, are interesting, since their shapes represent the two extremes of coal ash fusion. Of the total number of ash samples tested by this method, a large percentage of those melting between 2100 and 2500 deg. fahr.

show indications in varying degree of the dip in the calcium sulphate curve. Also, a coal ash producing a fusion curve similar to that of calcium sulphate fusion, shows a low viscosity of melt and will produce a porous brittle clinker easily broken up and removed from the firebox, while an ash producing a curve similar to ferric oxide, indicates high viscosity and the production of a tough gummy clinker difficult to break up and remove from the firebox.

The first type of fusion, while causing no excessive delay at cleaning periods, is productive of dirty fire and a high percentage loss of carbon in the ash pits. The second type not only causes delay at

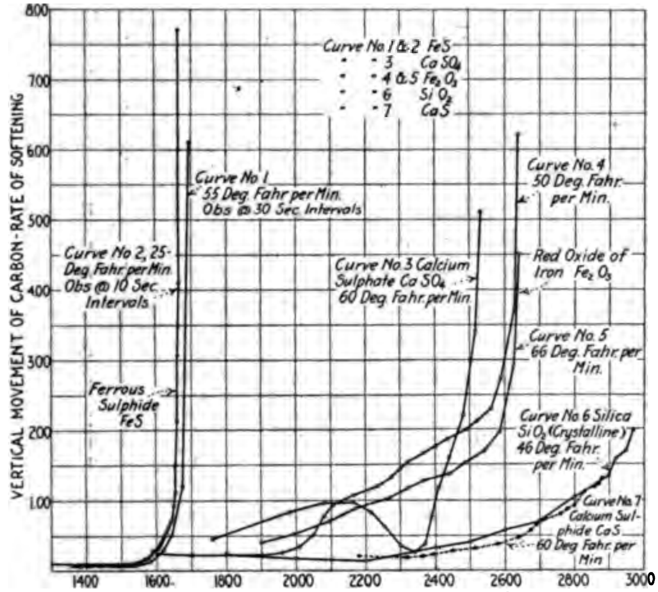


Fig. 11 Fusing Range of Ash Constituents with Fusiometer

cleaning periods, but increases the wear on the grate bars and brickwork, in addition to cutting down the capacity and efficiency of the boiler as a whole. One of the effects of this type of fusion is to arch over the back grates on a stoker, preventing the admission of air necessary to economically burn down a fire preparatory to cleaning.

The expansion of a pellet of calcium sulphate between 2100 and 2350 deg. fahr., or prior to the melting point, would indicate the evolution and release of a gas between these temperatures. The writer is still seeking an explanation of this occurrence, since this curve was reproduced a number of times both in shape and position on the temperature scale, first in the presence of reducing agents and later with the carbon rods covered with platinum ferrules and with an excess of air in the furnace gases.

Fig. 12, showing fusiometer tests on a 3-car shipment of coal from a certain mine, illustrates a number of important points bearing on the clinker problem. Curves 1 and 2 show the accuracy which may be obtained on duplicate samples from the same ash. The writer believes that if complete incineration and thorough pulverizing and mixing of the ash sample occurs previous to testing, the accuracy shown in these two curves and in some of the previous illustrations

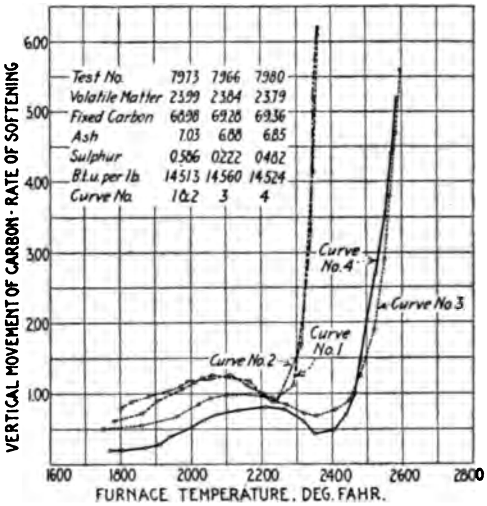


Fig. 12 Ash Fusion Tests on Bituminous Coal with Fusiometer

may be obtained in each case. It follows, therefore, that two different laboratories, both using this method, could be expected to show a correspondingly close agreement in results obtained, a circumstance which appears to be conspicuously lacking where modifications of the Seger cone method are used. This is an important point if the clinkering characteristic of fuel is to be regulated by a specification based on the method of determination of softening temperature.

Fig. 12 also illustrates that coal from three cars from the same mine, although showing the most remarkable uniformity as to proximate analysis, sulphur content and heating value, will vary considerably as to fusibility of ash. It has been found at times that the sh in the roof or large partings in a vein will vary considerably in usibility with the true ash of the coal, but in this case it would ppear, from the uniformly low ash obtained in each car, that in this ein or mine the true ash itself varied in fusibility.

As actually tested, these three cars were used in Taylor Stokers ith Rust boilers operating at 180 per cent of rated capacity. At his rate, fuel bed temperatures as high as 2800 deg. fahr., with an verage of over 2700 deg. fahr., have been observed with the Fery Radiation Pyrometer. The boiler room reported as follows: "This oal proved to be unsatisfactory inasmuch as it clinkered to a trouble-ome extent. Coal used in Test 7973 appeared to make a much arder clinker than that from either of the other cars." It would ppear therefore that, knowing the approximate fuel bed temperatures nder which this coal was to be consumed, the degree of probable linker trouble in using this fuel under these load conditions could ave been predicted from the curves in Fig. 12. The fact that a orous easily removed clinker was not formed (as would be ordinarily ndicated by the dip in the curves previous to melting) is probably ue to the high fuel bed temperature at which this fuel was con-umed, a temperature far above the final melting temperature of any ne of these ash samples. In other words, had fuels represented by urves 3 and 4 been consumed at fuel bed temperatures of 2500 deg. ahr. or under, a porous easily removed clinker would probably have een formed. The same can be said of fuel represented by curves and 2 for fuel bed temperatures of 2300 deg. fahr. or under. For Babcock & Wilcox boilers with Roney Stokers, 2500 deg. fahr. cor-esponds to a load of approximately 150 per cent of rating and 2300 eg. to 110 per cent of rating.

It has often been noted, in a boiler room, that in burning a fuel which produced a not too troublesome clinker, if for one reason or nother the fire is not thoroughly cleaned at one fire cleaning period, he clinker not removed at this period will give excessive trouble in emoval at the next succeeding period.

Basing an opinion on the form of test here described, the writer uggests the following specification: The pellet shall not have col-apsed, due to softening, to more than one-half of its original height t a temperature T, and, in addition, shall not show a collapse of nore than one-eighth of its original height due to softening at a emperature 300 deg. fahr. under temperature T. The first part of this specification will limit the final fusion, while the second part is intended to control viscosity and avoid a sloping curve.

Referring to Fig. 10, the position of the line *A-A* or the fixing of temperature *T* must vary for plant conditions. It is obvious that the buying field for steam coal will be restricted or broadened according as the temperature *T* is raised or lowered, so that the fixing of this temperature must be governed by the value which a plant management places on loss of boiler capacity, and risk of steam failure against the saving made in purchasing the cheaper fuel.

Oscar W. Palmenberg[1] (written). Taking into consideration the views of the author, I wish to call attention to a method which, although differing in certain details from his, has suggested itself to me from the satisfactory results obtained when comparing laboratory tests with results obtained in practice. I do not think all the tests conducted in a laboratory are absolute whether made by the method I will describe, or by others, for the reason that it is difficult to overcome some of the causes which influence pyrometric work of this nature. The tests give an approximation as to what may be expected of a coal ash when exposed to various degrees of heat.

I use a gas muffle furnace heated with a double blast Meker burner, and by this means can attain temperatures ranging as high as 3000 deg. fahr. The rate of heating is under good control and the temperatures required can be obtained conveniently. The muffle is uniformly heated, the flame passing around it, and has a door with a small opening for observation. The temperature readings are made with an optical pyrometer which is standardized in the usual way with an amyl acetate flame every time before making a fusing test, care being taken to have conditions as nearly constant as possible. The use of an optical pyrometer suggests itself under these conditions because observations are made into a hollow dark body heated from the outside, giving a true black body radiation.

The coal ash which has been burned free of carbon and heated to insure oxidation of the iron, is made into a round thin cone weighing one gram or less. This form is placed in a vertical position upon a thin piece of Battersea fireclay and set in the middle of the muffle. After heating the furnace, the blast is applied rapidly at first until the temperature is nearly that at which the form begins to bend. Then the heat is regulated carefully and readings made every 5 min. or

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oftener, depending upon the rate of heating. Care must be taken to have the heating carried on slowly. As soon as the cone shows signs of bending the temperature is noted and the operation continued until the cone has completely bent over and touched the plate, the temperature at which the point touches the plate being called the fusing temperature.

The writer has made a large number of fusing tests by this method which he carries out as part of the routine work in connection with coal analyses, and from the observations made by those using the coals tested the figures obtained bear out in most every case the action of the coal in service.

Fusing temperature tests on coal ash are of the greatest importance. It may be true that the fusing test does not at times agree with results as obtained in practice. This may be said of any other kind of laboratory test, but when a practical test is at variance with a laboratory test, the cause may usually be found and accounted for. The laboratory test gives an important clue of the value of a coal for certain furnace conditions which cannot otherwise be readily and conveniently ascertained.

In regard to the author's statement in par. 15 relative to the separation of the more fusible constituents, thereby leaving a skeleton which fuses at a higher temperature, this difficulty does not seem to present itself when the cones are made long and thin, at least not to the extent of interfering with the tests. If the ash is thoroughly ground and mixed, a complete fusion of the whole mass should take place. Furthermore, making the ash into a long and thin form tends to help it retain its shape during the whole time of heating and gives tests that can be duplicated to a fair degree of accuracy. With most coals the weight and height of the form does not make much difference, but it is good practice to have a standard size so that the results may be compared.

Whether a small amount of carbon left in the ash has any appreciable effect upon the fusing temperature will depend upon the conditions of the test and the nature of the coal ash. I have found that as much as 10 per cent carbon has no effect. If much iron is present the carbon may influence the test, but as a rule all the carbon will have burned off before fusion takes place. It is advisable to have no carbon present in the cone so that no reduction of the Fe_2O_3 can take place and raise the fusing temperature.

Mr. Hubley's findings regarding the relation of the fusing test to the iron oxide and sulphur bear out in a general way further investigations by the writer which showed that high iron and high sulphur coals give a low fusing ash, but low iron and low sulphur coals do not necessarily produce a high fusing ash. The tests referred to were made on Pennsylvania coals and as the coals all bear a certain relation to each other, there would naturally be a corresponding relation in the fusing tests. When coals from various sources are tested the findings are very different, so that the iron or sulphur content does not always give an indication of the fusing temperature of the ash. The writer has recently tested the ash of a Texas coal with an iron oxide (Fe_2O_3) content of 10.76 per cent and this coal had a fusing temperature of only 2138 deg. fahr.

As a further illustration of the variable influence of iron oxide and sulphur, Table 6 might be of interest:

TABLE 6 FUSING TEMPERATURES OF PENNSYLVANIA COALS

	Coal A		Fus. Temp. F.			Coal B		Fus. Temp. F.
	Fe_2O_3	S				Fe_2O_3	S	
1	33.97	2.80	2390 2408	2399	1	33.31	2.51	2280
2	21.23	1.74	2426 2480	2453	2	29.82	2.39	2282
3	42.68	2.96	2408 2300	2354	3	37.28	2.69	2262
4	38.48	2.69	2408 2426	2417	4	35.17	2.60	2228
5	37.76	2.15	2444 2426	2435	5	31.40	2.41	2246
6	41.40	2.44	2228 2300 2282	2270	6	35.09	2.67	2288
					7	42.95	2.40	2246
					8	35.41	2.37	2291
Mean	35.92	2.46		2388	Mean	35.05	2.51	2265

These determinations were made on two coals A and B both from Cambria County, Pa., mined from the *B Vein*, the mines being about 50 miles apart. The A coals represent samples taken from the face of the vein at various parts of the mine, while the B coals represent samples taken from deliveries. The samples represent a composite of 5 car shipments from consecutive weekly deliveries. This coal is prepared in a careful manner at the mine and is noted for its uniform quality. The coal is carried on a picking belt before being dumped into the railroad cars.

By comparing the results from these two coals, it may be seen that A has an ash fusing temperature more than 100 deg. higher than B although its Fe_2O_3 is somewhat higher and its sulphur about the same. The variations between the individual tests are interesting. There seems to be no strict relation of the iron and sulphur to the fusing test in either case. The results on A coal show plainly the variations obtained on samples taken from the face of the vein, whereas the average samples obtained of B coal shipments show few variations. The B coal samples, being obtained from a larger bulk, give a more uniform mixture of the ash constituents. These fusion tests cover a period of many months and therefore the various determinations were made under different conditions.

In Table 7 are a series of results of tests on ash samples before and after fusing.

TABLE 7 FUSING TEMPERATURES OF ASH SAMPLES

	Coal B (previous table)		
	Fe_2O_3 (ash)	Fe_2O_3 (cone)	Fus. Temp. F.
1	33.31	36.81	2280
2	29.82	30.81	2282
4	35.17	36.42	2228
6	35.09	36.85	2288
	Other coals.		
1	35.61	34.00	2273
2	17.02	19.75	2426
3	4.98	6.66	2732
4	15.63	19.02	2444
5	32.84	35.51	2300

From these results it will be seen that there is an increase of Fe_2O_3 in the fused cone. The probable explanation is that these coal ashes lose some of their constituents during heating and the proportion of the iron is thereby increased. The volatile constituents may be CO_2 from the carbonates and H_2O from water of combination in the silicates. The ash samples were subjected to heating with a blast flame in a flat silica dish, prior to being made into fusing cones, the object being to assure complete oxidation of the iron.

To show the accuracy with which fusing tests may be made, in Table 8 are given a few duplicate determinations and Seger cone tests from a number of tests made in routine work:

TABLE 8 SEGER CONE TESTS

Lab. No. 1012	a 2390	Run Sept. 30	
	b 2408	Run Oct. 1	
Lab. No. 4253	a 2408	Run Apr. 24	
	b 2408	Run May 6	
Lab. No. 4310	a 2372	Apr. 28	
	b 2378	May 6	
	s 2534	Seger cone No. 13	Should be 2516
Lab. No. 3445	a 2520	Sept. 15	
	b 2500	Sept. 16	
Lab. No. 3447	a 2530	Run Sept. 15	
	b 2535	Run Sept. 16	
Lab. No. 3448	a 2520	Run Sept. 15	
	b 2525	Run Sept. 16	
Lab. No. 4363	2444	Clay. Run May 14	(bent in 4 min., variation of temp. 18 deg. fahr.)
Lab. No. 4364	2246	Clay. Run May 14	
Seger cone No. 18	2732	Should be 2732	Run May 14

Mixture of coals

Coal A 2560 deg. fahr.
Coal B 2520 deg. fahr.

Mixture ¾ A and ¼ B	2520 deg. fahr.
Mixture ⅔ A and ⅓ B	2530 deg. fahr.
Mixture ½ A and ½ B	2520 deg. fahr.

Professor Marks deserves much praise for the splendid and convincing manner in which he has brought to our notice the variable conditions met with in the work of obtaining the fusing temperature of coal ash. Research of this nature is bound to lead in the near future to the selection of a standard method for this important and valuable work.

O. P. Hood[1] (written). The purchaser of coal desires a laboratory treatment of a small sample which will indicate the results that can be expected in actual practice, and laboratory methods should work towards this end, although there will always be lack of agreement with commercial results until furnaces and the treatment of fires are as carefully standardized as are the laboratory methods. Calorimetric determinations have been of great value, but the potential ability of the coal thus disclosed is not made available in the furnace because of numerous unfavorable factors. These factors each require careful

[1]Chief Mechanical Engineer, U. S. Bureau of Mines, Pittsburgh, Pa.

study and will some day find their place in coal specifications, the matter of clinkering being one of the most important. If the seriousness of the clinker difficulty holds some definite relation to the fusing temperature, then a laboratory determination of fusibility becomes desirable. It cannot as yet be said that such a relation is established although the assumption seems reasonable. Some coals with a low fusing temperature of the ash give no trouble with clinkering. Some coals with a high fusing temperature give trouble under certain methods of handling. There is practically no knowledge available as to the relation between laboratory results and clinker formation under furnace conditions.

The U. S. Bureau of Mines has consistently opposed the use of fusing-temperature tests in the purchase of coal under specifications by the Government until a thorough investigation of the subject should disclose the relation between these laboratory tests and actual furnace conditions and clinker troubles. It was realized that the results obtained for fusing temperature under different conditions of rate of heating, oxidation, and reduction would vary greatly, and that an extended investigation with a view to standardizing the laboratory test was necessary before a comparison with actual clinkering tests in commercial furnaces could be undertaken. Such an investigation has been conducted in the Pittsburgh Laboratory of the U. S. Bureau of Mines by A. F. Fieldner and A. E. Hall, whose conclusions from the work done before July 1, 1914, are stated as follows:

"The growing use of the fusing temperature of ash in coal specifications renders it necessary to so standardize the method of making the laboratory test that the results of various chemists may be directly comparable. A complex mixture of oxides and silicates like coal ash has no definite melting point. On heating a sample of coal ash it first cinters, then gradually softens into a more or less viscous slag. Hence in assigning a 'fusing' or softening temperature we can only take some point or temperature range where the material reaches a certain stage of softening or degree of fluidity. The temperature at which the visible softening takes place is affected by a number of factors:

1 Oxidizing or reducing atmosphere
2 Fineness of ash
3 Shape of test piece
4 Rate of heating.

The effect of these factors on the softening of ash molded into small pyramids similar to Segar cones, has been studied, and the results prepared for publication.

It is evident from the results obtained thus far that variations in the conditions under which laboratory tests are made may cause variations in the so-called fusing temperature of several hundred deg. cent.; and that the fusing temperature of the ignited ash of a coal is not the only factor in the clinkering properties of the coal."

Contrary to the author's results on the effect of oxidizing and reducing atmospheres, Fieldner and Hall do not conclude that the fusing temperature in reducing atmospheres is always higher than in oxidizing atmospheres. Their investigation, which covered over 50 different coals, showed in some cases higher results in reducing atmospheres and in other cases lower results. The difference varied with the composition of the ash and the extent of reduction that took place in the test furnace. Furthermore, they do not conclude that the test should necessarily be made in an oxidizing atmosphere. Conditions in the fuel bed are variable. There are local spots where ash forms in the presence of reducing agents. Incandescent carbon, CO, hydrogen and hydrocarbon gases are good reducing agents. The possibility of clinker formation under reducing conditions must therefore be considered. Keeping this in mind, the Bureau is making further investigations of the slagging of ash under the various possible fuel-bed conditions. The first step in this work is now being prepared for publication.

After a consistent laboratory method is devised whereby different laboratories can obtain comparable results there yet remains the correlation of these results with actual experience in the furnace to determine the value of their inclusion in coal specifications.

E. B. Ricketts (written). The value of coal clinkering and ash fusion data to the power plant manager lies in its effect on the efficiency and capacity of the boiler plant. To determine this effect a series of tests was made by the New York Edison Company in the spring of 1914 on a 650 h.p. Babcock & Wilcox boiler fired by a Taylor stoker. The boiler output was maintained at about 825 h.p. throughout the test, except for one hour when the boiler was forced to between 1250 and 1700 h.p. The boiler was cleaned before each test and the conditions were maintained as nearly constant as possible throughout the tests, most of which were of 120 hr. duration. Tests were made of 13 coals having ash fusion temperatures varying from

2225 to 2850 deg. fahr., and the results are indicated by the curve in Fig. 13. It will be seen that this curve consists of two discontinuous lines with a critical zone between 2375 and 2450 deg. fahr. Lowering the fusion point from 2375 deg. to 2225 deg. or raising it from 2450 to 2850 deg. has no effect on the efficiency, thus leaving a zone of uncertainty of about 75 deg. where the clinkering effect is doubtful. This critical zone covers the errors in testing and differences in fire conditions. The curve probably covers all ordinary operating conditions for Taylor stokers, but it is easily possible that the

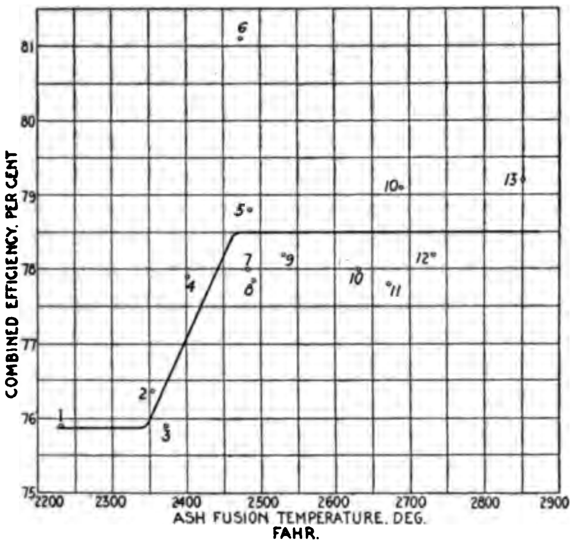

Fig. 13 Efficiency vs. Ash Fusion Temperature

critical zone for another type of stoker may be at a different part of the curve.

Applying the results of the above tests, the following method of determining coal values has been evolved: Taking any coal, the cost and analysis of which is known, as a standard, the relative value of any other coal of known composition can be determined by the following formula:

A = B.t.u. per lb. standard coal multiplied by efficiency from curve

B = B.t.u. per lb. other coal X multiplied by efficiency from curve

$C =$ Cost per ton of coal of transportation to the bunkers and disposal of refuse for each per cent of ash

$$D = \frac{(\text{per cent ash in coal } X - \text{per cent ash in standard coal}) \times C}{\text{Cost per ton of standard coal in bunkers}}$$

$$\text{Value of coal } X \text{ in per cent of standard coal} = \left\{ \frac{B}{A} \pm C \right\} \times 100$$

This method of coal valuation differs from those heretofore proposed in that the burning qualities of the coal are given proper weight and the detrimental effect of high ash is properly discounted.

The method used for determining ash fushion temperatures differs somewhat from that described by the author and is illustrated by Fig. 14. About 2 lb. of coal are coked in a crucible in a gas furnace for about an hour after which the lump of coke is broken up and a stream of compressed air is fed in near the bottom of the crucible for from 2 to 3 hr. until the coke is all reduced to ash. When burning the coke down, care is taken to keep the temperature below 1500 deg. fahr. to prevent premature fusion. The ash is then tested, a small amount at a time, with oxygen to make sure that all the carbon is consumed. It is of vital importance that no carbon be left in the ash, as a small trace may cause results several hundred degrees too high. The carbon-free ash is moistened with a little water and moulded in a paper cone 2 1/2 in. long and 1/2 in. base, which is dried for 5 or 6 hours. It is then fused in a muffle furnace without removing the paper in which it was moulded, being placed so that it overhangs the point of support about 1 1/2 in. The point of fusion is taken when the cone reaches a 45 deg. position and is read on a Wanner optical pyrometer.

The question of correct melting point is one of minor importance so long as the results obtained are consistent. With the above described method the same sample of coal can be checked within a few degrees and the behavior in the fire room of several hundred cargoes of coal from 25 different sources on which ash fusion tests have been made has consistently confirmed the results given in the test curve.

P. F. WALKER. I wish to call attention to conditions under which coal may give trouble, depending very largely upon the method of handling. I have in mind a situation where I had trouble in the use of a coal with a very large amount of ash, on both hand fired grates and with stokers. We found, however, that the firemen might be

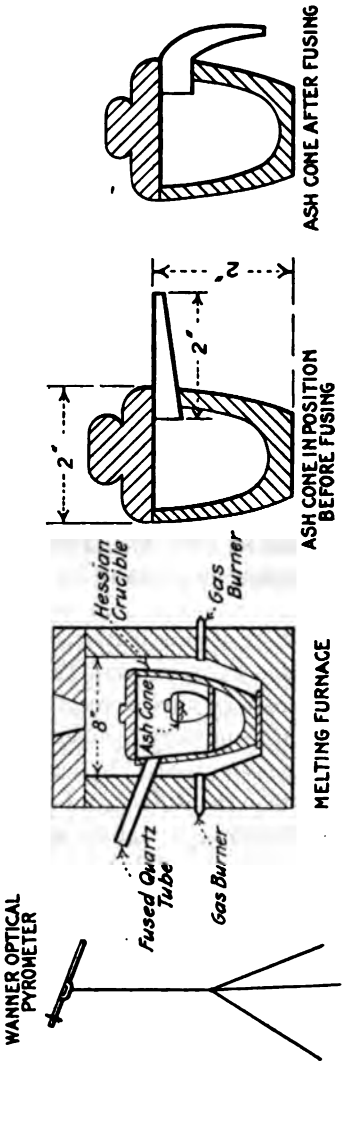

Fig. 14 Apparatus used in Determining the Fusibility of Coal Ash

taught to handle their fires so that the difficulties are vastly different in the one case from those in the other.

Roger DeWolf. In the early part of Professor Marks' paper a non-adhering clinker was referred to. If an ash does melt and form a non-adhering clinker, it gives very little trouble, as there is a very great difference between various coals in this regard. I would like to know if any work has been done that would indicate a method of determining the adherent qualities of the clinker.

The Author. Mr. Ricketts, in referring to the work of the New York Edison Company, showed a curve of fusing temperatures, and their relations to clinkering troubles. His own investigations would, apparently, give just about the same results, but with this difference: He had exchanged samples of ash with the New York Edison Laboratory, and his fusing temperatures came out consistently about 200 deg. higher than theirs. He had calibrated his pyrometer by the melting point of nickel and by the use of Seger cones, and he felt sure of his pyrometric work. The company also felt sure of its pyrometric work. Though the author and the New York Edison Co. had both come to the same conclusions, they are based on the indications of pyrometers which are strongly discordant.

F. C. Hubley. Speaking of this matter of discordant results between the New York Edison Company and Professor Marks, a rather interesting coincidence exists in this connection. The company has Taylor stokers, forced draft, and very troublesome peak loads, a mill-load in other words, and has specified 2700 deg. as the so-called fusing point of the ash. If you take the difference between Professor Marks' figures, I believe he stated 260 deg., and the average acceptable figure of 2450 specified by the New York Edison Company, you will obtain a figure of 2700 deg. fahr. I have personally measured the fuel bed temperature in Taylor stokers with a radiation pyrometer, with 200 per cent radiation, and for temperature of 2700 fahr. It would appear, therefore, as though the New York Edison Company have either misjudged the temperature of their fuel bed, or have been in error in the figures obtained in the laboratory.

No. 1463

DAMAGES FOR LOSS OF WATER POWER

By F. W. Dean, Boston, Mass.
Member of the Society

When the water of a stream or river is diverted for any purpose it usually happens that damages for loss of power must be paid to any mills having a water power plant located below the point of diversion. Such cases are frequently heard before a commission of three appointed by the court, one being an engineer, one a business man and one a lawyer. Counsel are employed by both sides, the hearings often cover long periods, and the legal expenses are great. Similarly much engineering talent is employed with a corresponding expense. Many questions of an engineering character are discussed, and the testimony of engineers on opposite sides is widely divergent, as is usually the case in the testimony of experts, and somewhat to their discredit. It is the purpose of this paper to discuss some of the questions about which such testimony differs.

THE DETERMINATION OF THE VALUE OF WATER POWER

2 It is now generally understood that the determination of the value of water power takes into consideration the cost of making power by steam which may be spoken of as the standard for comparison. This value is the capitalization of the annual saving by the use of water power. On the one hand the power required to operate the mill can be made by the best adapted steam plant, and on the other hand by the water power combined with a proper steam plant to produce uniform power throughout the year. In the first case the annual costs of operation are those of a steam plant, and in the second they are those of a combined water and steam plant. The costs may be tabulated in a general way as in Table 1.

3 If the amount of the first column exceeds that of the sum of the second and third, the water power has value, but if it is less, the water power has no value. It is a matter for careful consideration how much saving by the use of water will justify its use, for there are some inconveniences in the use of such power.

Presented at the Annual Meeting, December 1914, of The American Society of Mechanical Engineers.

RATE OF CAPITALIZATION

4 The theory in a water power damage case is that the award shall be such that the interest thereof shall be sufficient to equal fully the extra expense caused by the diversion. This rate is usually taken at 5 per cent, but is a subject of argument. As interest rates have a downward tendency it will be seen that there is ground for argument on this point. It is obvious that the rate has a great influence on the award. For instance, if an award was $200,000 on a 5 per cent basis, it would be $250,000 on a 4 per cent basis.

TABLE 1 GENERAL COSTS OF POWER BY STEAM AND BY WATER

Annual Costs of Power by a Steam Plant	Annual Costs of Power by Water Combined with Steam Sufficient for a Uniform Power	
	Water Power Plant	Auxiliary Steam Plant
Interest	Interest	Interest
Depreciation	Depreciation	Depreciation
Insurance	Insurance	Insurance
Taxes	Taxes	Taxes
Attendance	Attendance	Attendance
Fuel	....	Fuel
Supplies	Supplies	Supplies

5 In the case of an undeveloped power a higher rate of capitalization, say 12 per cent or more, may be used as a means of scaling down the value, when estimated in some detail, and as representing the necessary profit of an enterprise.

THE PROPER DEVELOPMENT OF A WATER POWER

6 Water powers are seldom developed to the power of the wet months, pulp grinding being the only case of full development that I know of. It is customary to develop to the average power of the eighth or ninth month of the year when the stream flows are arranged in the order of wetness.

7 A water power produced by the unassisted natural flow of the stream is of very little value when developed to the customary extent. This is shown by Table 2 which gives in the first column the average yield of the Sudbury River in Massachusetts for 37 years month by month in the order of wetness, in cu. ft. per second per sq. mi. of watershed. It will be seen that the largest yield is many times the smallest, and when it is considered that these are averages, that the smallest of any year is negative, and the largest of any year

much larger than the maximum here given, it is clear that such a stream is a poor power producer. Yet this is representative in a general way of all streams. Water sheds differ in precipitation and in other respects so that the yields differ in particular from those of the Sudbury as shown by the yields of two other Massachusetts rivers which are given in columns 3 and 4 of the table.

TABLE 2 AVERAGE YIELD OF WATERSHED

Months in Order of Wetness	Yields in Cubic Feet per Second per Sq. Mi. of Watershed		
	Sudbury River, Average of 37 Years	Nashua River, Average of 15 Years	Little Westfield River, Average of 6 Years
1	2	3	4
Dryest	0.137	0.330	0.22
2nd dryest	0.232	0.492	0.37
3rd dryest	0.386	0.633	0.47
4th dryest	0.546	0.802	0.81
5th dryest	0.707	0.939	1.00
6th dryest	0.929	1.106	1.37
7th dryest	1.156	1.319	1.64
8th dryest	1.574	1.718	2.59
9th dryest	2.188	2.283	3.24
10th dryest	2.746	2.764	4.32
11th dryest	3.518	3.542	5.42
Wettest	4.776	4.654	7.21

8 It frequently happens that areas are available in the water sheds that can be dammed, and overflowed in the wet months so as to be used to make up to some extent the deficiency in the dryer months. This is usually done and is a saving feature of water power development of great importance, but probably in no case results in a uniform power. In a certain case which I investigated the results for the average and dryest years were as given in Table 3.

9 In these cases, even in the smallest development, the installation of a steam plant is necessary. In such developments as those at Niagara and Keokuk, steam plants are not necessary because the power required for a long time will be below the minimum flow, and especially at Niagara which for scenic reasons, will probably never be developed to use the minimum flow.

METHOD OF ESTIMATING AVERAGE YIELDS

10 In treating a water power problem for almost any purpose it is necessary to have a systematic arrangement of the yields of the stream and the most convenient and effective one is that of monthly

yields in the order of wetness or dryness. The calendar order is without significance as the dryest month of a year may be, in Massachusetts at least, either January, February, July, August, September, or October. No matter when it occurs it produces the same effect on power, and therefore the proper method of obtaining a table of yields in the order of wetness or dryness from a table of monthly yields as they are reported from observations, is, first, to make a column

TABLE 3 RESULTS FOR AVERAGE AND DRYEST YEARS

Month	Horsepowers Based on the Natural Flow of the River		Horsepowers of 5000 h.p. Development Using Storage		Horsepowers of 7500 h.p. Development Using Storage		Horsepowers of 10,000 h. p. Development Using Storage	
	A	*B*	*A*	*B*	*A*	*B*	*A*	*B*
Dryest.....	1340	130	4400	130	1340	130	1340	130
2nd.......	2250	909	5000	909	2250	909	2250	909
3rd.......	3850	1904	5000	1904	3850	1904	3850	1904
4th.......	4590	2247	5000	4623	7500	2247	4590	2247
5th.......	5100	2465	5000	5000	7500	2465	5100	2465
6th.......	6000	2983	5000	5000	7500	5275	9900	2983
7th.......	7200	4455	5000	5000	7500	7500	10000	4455
8th.......	9350	5364	5000	5000	7500	7500	10000	8879
9th.......	11200	7699	5000	5000	7500	7500	10000	10000
10th.......	13500	9127	5000	5000	7500	7500	10000	10000
11th.......	16800	9213	5000	5000	7500	7500	10000	10000
Wettest....	27700	20457	5000	5000	7500	7500	10000	10000

A — Results for the average year.
B — Results for the dryest year.

composed of the yields of the dryest month of each year, the average of which is the average yield for the dryest month of the period covered by the observations. The average yield for the second dryest month of the period is the average of the second dryest months of all of the reported monthly yields, and similarly for all of the remaining months.

PROPER AUXILIARY ENGINE TO INSTALL

11 Investigation shows that the most economical engine to install depends upon the power to be made up to produce a steady power. Between certain limits of power the most economical engine is the simple non-condensing type. Beyond this and up to a certain other power the simple condensing engine should be used, and still further the compound condensing engine is necessary. Similar arguments apply to condensing and non-condensing steam turbines. The points to be considered in determining the economy are those

producing the greatest net economy as made up of fixed charges and costs of operation.

12 In any table containing the monthly deficiencies of a water power it will be seen that the make-up steam powers vary between wide limits. Here there is a chance to exercise judgment as to the best type of engine to install and also its size. In every such case an engine should be used that will be well overloaded in the dryest average month, and much underloaded in the wetter months, and the requirements of the months of the dryest year should also be considered. Here enter also the considerations of the preceding paragraph.

KIND OF COAL

13 The kind of coal to be considered in any case is not necessarily the kind that is used at the mill, but should be the normal coal of the district. This is nearly always a bituminous coal, but the coal actually used is often a mixture of bituminous and fine anthracite. The latter must be more or less temporary, and should not be considered normal to the district unless the location is near an anthracite field, or near a main line of transportation from such a field.

ECONOMY OF STEAM PLANTS

14 In damage cases a great deal of testimony is given concerning the economy of steam plants. It is well known that the economies of such plants are very variable and differ from each other. In some cases great care is taken to have good plants carefully operated, while in others they are neglected and incompetent men are employed, but such plants as the latter should not be taken as criteria for basing an award for damages. There is a great difference in the same boiler if fired by different men. Firemen can be, and many are, educated to fire properly, and if steam users realized what great savings in coal can be made by proper firing they would insist upon their firemen being taught. It is being recognized that greater skill is required in boiler rooms than in engine rooms. Devices are on the market for showing the firemen how the chemistry of combustion is proceeding, and how much steam the boilers are furnishing. Prizes are sometimes awarded for the best firing, and the economy is being watched in many places. Proper supervision should be given in all places. There are often waste steam and hot water, the heat of which can be, to some extent, returned to the boilers, causing a saving of as much as 15 per cent of coal in some cases. In addition

to this a saving of 5 to 10 per cent can be made by a Green's economizer which extracts heat from the gases which leave the boilers and gives it to the feedwater.

15 In the case of engines there are non-condensing and condensing engines and turbines, and they can be simple or compound. In addition there are steam engines that are being devised which are likely to surpass in economy any that are now on the market, and these improved engines are on the verge of being introduced. In addition superheated steam is being introduced and may be at any time installed in mills that are damaged by loss of water. By its use it is easy to save 10 per cent of coal without any accompanying disadvantages. The advantage of using better condensing apparatus is being realized and such apparatus is being introduced with improved economy.

16 The simple non-condensing engine, the exhaust steam of which is utilized for mill processes, forms the most economical steam plant, and this is generally understood.

17 These considerations bear upon the testimony that may be given in cases such as are under consideration. If a mill is using a wasteful plant it is obvious that the damages should not be based upon the performance of such a plant, and due consideration should be given to the possibility of improvement which might take place at any time. If an award is based upon a wasteful plant it would manifestly be too great for an economical one, and on general principles it is best always to keep in mind the possibilities of the future.

18 Another feature of damage cases is that of allowing for the variable loads that auxiliary engines carry, as already mentioned, but it should be borne in mind that recent engines are not as wasteful with such loads as were engines made 20 years ago. However this may be, there is considerable uncertainty in estimates of the coal used with variable loads.

THE USE OF EXISTING ENGINES AND BOILERS TO SUPPLY POWER LOST BY DIVERSION

19 It often happens in damage cases that the power to be made up month by month is sufficiently small to be assumed by the existing engine in the plant. It is beneficial to both sides of the controversy if this is so. The main engine is likely to be, or should be, of an economical type for the work and would in every way be more satisfactory to the damaged party by itself than in connection with an additional engine. If an additional engine is put in, the award

will be larger, but the recipient will have a more complicated, expensive and wasteful plant, and he will be likely to abandon it in a short time. If the existing engine cannot carry the additional load another should be added. If an expert seeks only to obtain the highest award for his client he will probably advocate an additional engine.

20 The same remarks apply to boilers. In many cases the existing boiler plant is ample to carry the additional load, and the same is true of the usual force of firemen, and, in fact, they seldom know that there is an additional load. In such cases it is surely better that the existing boiler plant should carry the additional load if it can properly, but if it cannot, the award should contemplate an addition.

THE EFFICIENCY OF WATERWHEELS

21 The maximum efficiency of waterwheels, which are new and clean, has been found to be nearly, if not quite, 85 per cent, and is quite certain to be 83 or 84 per cent. Wheels are generally so made that the maximum efficiency is at 70 to 85 per cent gate opening on account of the probability that the gate will not be wide open as a general thing. In practice it is impossible to keep wheels clean. They become rusty, coated with dirt, and more or less clogged with debris. As the supply of water in most cases is variable and small at times, the usual position of the gates is likely to be at such a point that the average efficiency will not be over 75 per cent. The gate opening which corresponds to this efficiency is from 45 per cent to 55 per cent.

22 Testimony is often given to the effect that the average efficiency of waterwheels is as much as 80 per cent, and this is used in estimating the power lost, while an examination of efficiency curves, and contemplation of the conditions to which wheels are subject, show that such an efficiency under the conditions is impossible. In my opinion the average efficiency used in water power damage cases should be taken at not more than 75 per cent.

23 It is evident that steam engines are more easily under observation than waterwheels, that it is easier to keep them in proper condition, to record their power and economy, and by more exact methods.

THE FRICTION OF WATERWHEEL GEARS AND SHAFTS

24 When waterwheels are tested the friction brake is applied directly to the wheel shafts. In the case of vertical wheels the power

is transmitted through bevel gears, the friction of which has been shown by Professor Allen's tests to be from 3 to 4 per cent. The shaft of a horizontal waterwheel, and the horizontal shaft driven through the gears of a vertical wheel, correspond with the shaft of an engine, and these considerations enable powers from the two types of wheels and from steam engines to be compared. The delivered power, from horizontal shafts for wheels and engines will compare about as follows, the power from the engine being referred to the indicated power:

Gross Water Power, Per Cent	Average Power Delivered by Shaft of Horizontal Wheel, Per Cent	Average Power Delivered by Horizontal Shaft of Vertical Wheel, Per Cent	I.h.p. of Steam Engine, Per Cent	Average Power Delivered by Engine Shaft, Per Cent
100	75	72	100	92

DEVELOPED AND UNDEVELOPED POWERS

25 In the case of a developed power the problem of determining a proper award is comparatively definite. The cost of the development and the power used are known, as well as many other particulars. In the case of an undeveloped power we are in the dark about most of the matters concerned. Supposititious cases can be assumed, but almost everything is guesswork, and the award is a guess. The price for which an undeveloped power will be sold depends upon "getting together" and little else. A man who has such a power to sell dislikes to let slip an opportunity for a sale, and for this reason good bargains for the purchaser are sometimes made. If, however, a would-be purchaser has a definite program ahead it is possible to determine what he can afford to pay.

26 A knowledge of the costs of such powers is, of course, very valuable, but such information is difficult to obtain.

THE VALUE OF WATER FOR NON-POWER PURPOSES

27 This is one of the most difficult matters to determine. The most obvious method is to ascertain the annual saving by the use of such water rather than to purchase it from a public supply and capitalize it. This method will give such a great value for lost water that it would always be strenuously objected to by the other side. Sometimes a plant can be moved to another source of supply, for it isn't always necessary for a plant to remain in the same place, although it usually is. Driven wells can sometimes be resorted to, but what-

ever is done the award must be sufficient to yield by interest the extra annual cost of providing a make-up supply equal to that lost by diversion.

28 The determination of the value of water for non-power purposes does not usually come from the diversion of water, for when this occurs it is common to give a manufacturer as much water as he needs for such purposes, as for boilers, paper washing, dye houses, etc. Sometimes the question arises as to how much shall be paid to the owner of a source of supply for a quantity of water, or how the price shall be readjusted.

DISCUSSION

JAY M. WHITMAN,[1] in a written discussion, commented on some of the statements in the paper, as follows:

Under par. 17, the author expects the condemning party to take advantage of the investment made by the mill owner. In par. 18 he treats of variable loads, and does not give to them the range of efficiency which I think is due them.

Under par. 19, the author fails to remember that the market value alone must control. Under par. 20, the condemning party should pay its pro rata of operating costs in the mill.

Finally, in all condemnation of water powers, local considerations must control and the loss in market value must determine the result.

[1] 607 Bullitt Bldg., Philadelphia, Pa.

[illegible]

No. 1464

FACTORS IN HARDENING TOOL STEEL

By John A. Mathews, Syracuse, N. Y.

Member of the Society

and

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Non-Member

The phenomena of carburizing iron and of hardening it by quenching have been known for many centuries, yet the explanation of hardening steel has not yet been given to the satisfaction of all. Many theories have been advanced and each has its adherents, but one can scarcely say that any generally accepted theory or explanation exists. As recently as this year, two very interesting new theories were advanced at the May meeting of the Iron and Steel Institute of Great Britain.

2 In what follows we are not so much interested in the theories as in the practice of the art of hardening and tempering tool steel and we shall confine our attentions to carbon steels, together with some consideration of so-called special steels containing various alloys, usually below 3 per cent. We shall not discuss high-speed steels, nor the many low-carbon alloy steels, primarily of value on account of their tensile qualities, but also, in many cases of limited value for tools, especially those used for hot work. In this way only can we hold either the paper or the discussion within reasonable limits. We shall consider the subject, also, from the basis of sound well-worked materials and shall not consider the influence of defects, such as pipes, seams, bursts, laps, burning, etc. The hardening operation itself will give sufficient scope for our thought and attention.

3 Tool steels are included within the range of 0.60 to 1.50 per cent carbon, but not less than 90 per cent of them fall within carbon

[1]Halcomb Steel Co.

Presented at the Annual Meeting, December 1914, of The American Society of Mechanical Engineers.

limits of 0.75 to 1.35 per cent. They are usually made by the very old crucible process or the very new electric processes, and just now there is considerable discussion as to the relative merits of these methods. As the writers are among the few men in the world who have had practical experience with both processes, we will refrain from discussing their respective merits at the present time to leave a free field for partisans. It is hardly necessary to remaık that no mere process is a guarantee of quality; it takes brains, plus a process, to succeed in almost any line of manufacture. This is particularly true of tool steel, which is subjected to so many operations between the melting and the selling stage.

4 Carbon forms at least one definite compound with iron, Fe_3C, known as cementite. This is the hardest constituent in steel. Cementite exists in annealed steel associated with a perfectly definite quantity of iron, or ferrite, as it is metallographically known. This definite relation between ferrite and cementite yields the constituent pearlite, in which the cementite and ferrite may exist in a laminated or a granular condition. This aggregate contains a definite percentage of carbon, 0.89 per cent, and steel containing 0.89 per cent carbon in its normal condition, is found to consist of nothing but pearlite when examined microscopically.

5 In steel containing less than 0.89 carbon the cementite associates with sufficient ferrite to form pearlite, and leaves the excess ferrite free in distinct microscopic grains or crystals. On the other hand, if the steel contains above 0.89 carbon, there is more cementite present than can become associated with ferrite, and the excess being unable to find a partner, so to speak, exists in separate particles, either granular or in a more or less perfect net work surrounding the pearlite.

6 The definite percentage of carbon which yields a full pearlitic structure in the annealed or natural condition is known as the eutectoid composition. Steels of lesser carbon are called hypo-eutectoid, and steels of higher carbon are called hyper-eutectoid steels. We are indebted to Professor Howe for these names.

7 When carbon steel is heated above a certain temperature, a change takes place in the constitution of the steel. This temperature is known as the carbon change point, critical temperature, or, preferably as the decalescence point. When this temperatuıe is reached the pearlite becomes austenite, a solid solution of iron carbide in iron. This change occurs at a nearly constant temperature, but in case of hypo-eutectoid steels, the austenite first formed above

the decalescence point acts as a solvent for the excess ferrite. In other words, at a somewhat higher temperature than the decalescence point, we obtain a homogeneous solid solution of all the cementite in all the ferrite. This is the best condition for hardening a low-carbon tool steel and accounts for the practice of heating low-carbon steels hotter than hyper-eutectoid steels for hardening.

8 The excess cementite of hyper-eutectoid steels is not readily soluble in the austenite first formed from the pearlite and it requires a high temperature to complete the solution of the excess cementite. Practically considered, nothing is gained by doing so.

9 Steels quenched quickly from above the decalescence temperature retain the carbon more or less perfectly in the condition of solid solution that existed above the decalescence point. The structural name for the quenched product is martensite. Hypo-eutectoid steels, hardened, may show either all martensite or martensite and ferrite. Hyper-eutectoid steel should show martensite and cementite. The martensite of eutectoid steels has been called hardenite by Professor Arnold.

10 Just as in the change of ice to water or of water to ice, there is an evolution or absorption of heat, so is there an absorption or evolution of heat in steel on passing through its critical range. There are several methods of determining this change point, but as these methods are so well known, we will omit detailed descriptions of the operations involved.

11 The position of this critical temperature is fairly constant in all straight carbon tool steels, but is affected to a variable degree by the addition of alloys. Just as the addition of salt to water lowers the temperature at which the solution freezes, so the addition of alloys lowers the freezing point of steel and frequently lowers the position of the critical temperatures. The addition of 10 per cent of nickel to a 1.00 per cent carbon steel, or of 4 per cent of manganese, for example, lowers the critical point to such an amount that steels of these types are martensitic at ordinary temperature, even after slow cooling.

12 The determination of critical temperatures has materially assisted in the solution of many metallurgical problems. So far as we are concerned in this paper, however, it is sufficient that for the practical hardening of tool steels this critical temperature must be exceeded by a fairly good margin, at least 25 deg. to 50 deg. fahr., depending on the size, shape, mass and composition.

13 On heating steel through its critical range changes occur

other than those noted. Steel is strongly magnetic below the critical range, but loses its magnetism within and above. The electrical resistance for hard steel increases with the temperature up to the critical point in a curve which is nearly a straight line. On passing through the resistance increases abruptly, and after having passed through, the increase per degree rise in temperature is very much less than in either of the other two cases. The specific volume of a hardened steel is approximately 0.01 greater than in its annealed condition. These marked changes in physical characteristics occurring at definite temperatures are indicative of the disturbances going on in the steel and occur at the temperature at which carbide carbon goes into solution on heating, or dissolved carbon is precipitated from solution on cooling.

14 Of great practical importance to the hardener, however, are the volume changes, both expansion and contraction, which occur during the critical ranges of temperature. The permanent changes in dimensions which steel undergoes in hardening are of the utmost interest to the hardener and associated with these changes is the problem of hardening cracks.

15 Le Chatelier[1] has studied the phenomena of expansion or dilatation by accurate scientific methods and has divided the changes into three zones of temperature: (*a*) changes at temperatures below that at which allotropic transformation begins; (*b*) changes at temperatures above that at which allotropic transformation occurs; and (*c*) changes occuring within the critical range itself. During the first of these periods from 0 deg. to 700 deg. cent., iron and steel expand nearly equally, the amount of carbon exerting little influence. For any iron or steel, however, the amount or rate of dilatation increases with the temperature. Below 100 deg. cent. the dilatation is about 0.000011 in., while between 600 deg. and 700 deg. cent. it increases to 0.0000165 in. per deg. cent. Above the critical range, however, the coefficient of dilatation varies directly with the carbon and is nearly twice as great for a 1.20 carbon steel as for a 0.05 carbon iron. The changes taking place at Ac_1 (decalescence point) and Ar_1, (recalescence point) Le Chatelier has not been able to study so satisfactorily. He has found, however, that the dilatation which increases directly with the temperature up to Ac_1, suddenly stops and that instead of an expansion, a *marked contraction* takes place.

16 On cooling steel from high temperatures, these changes in dimensions are reversed, although they are not quantitatively equal,

[1]Contribution à l'Etude des Alliages, p. 386.

nor do they occur at the same temperatures. It is an axiom that heat expands and that cold contracts; but with steel there is a certain critical temperature at which an abnormal behavior is noticed, namely a sudden shrinkage on heating and an expansion on cooling. The expansion of steel in heating to 750 deg. cent. is about ⅛ in. per ft., and when we recall that, in quenching, a corresponding contraction attempts to take place suddenly, it is little wonder that strains are set up that may exceed the ultimate strength of the steel.

RELATION OF ABOVE TO OVER-HEATING

17 What is the relation of the above to over-heating, i.e., heating above that temperature at which it is necessary to harden? After passing through the critical range, the expansion takes place at its maximum rate. When steel is heated in such a manner it assumes the shape corresponding to the maximum temperature and on cooling the whole piece tends to return to, or near, its original size. In so doing, the outer, or first cooled, portion is hardened first and forms a hard, brittle, unyielding shell, and the strains set up by the slower cooling interior may either (*a*) fracture the shell producing external cracks, especially if the shell be uneven in thickness, or (*b*) burst the piece at the center if the shell is of even thickness and strength. This latter occurrence is accompanied by a peculiar appearance of the fracture and frequently and wrongly called pipe.

TIME OF HEATING

18 Too much stress cannot be laid on the fact that there is a correct length of time for heating and that this time of heating is as important as the temperature to which heated. There are at least two dangers which must be avoided.

19 First, if the heating be too fast, a uniform temperature does not exist throughout the mass being heated. For example, a die block heated too quickly may exhibit the following conditions: The outer portions may be above Ac_1, and expanding at the maximum rate; the intermediate portions may be in the transformation range and contracting; while the inner portion, which is below Ac_1, is slowly expanding at the characteristic rate below Ac_1. What wonder that steel fractures under such conditions?

20 Second, grain size depends among other variables upon (*a*) temperature above Ac_1, and (*b*) time above Ac_1. If heating be of such a character that the piece is held above Ac_1, for an abnormally long time, the crystals may have grown to such an extent

that on quenching, abnormal grain size is retained and the result is a weak, if not cracked, piece.

21 Quick heating in a furnace which is considerably hotter than the correct hardening temperature is extremely bad practice. The difficulty is that the thin parts, corners, and edges are liable to attain an overheated temperature before the larger portions of the piece attain the correct hardening temperature, and this overheating of the thin parts produces large grain size, abnormal expansion and tends to produce cracks.

SPEED OF QUENCHING

22 If a sample of steel be cooled slowly from above Ac_1, the solid solution which has been formed breaks up and precipitates its cementite and ferrite and we have then an annealed steel. If the cooling on the contrary be rapid, the solid solution is not given the time necessary to permit the complete dissociation into cementite and pearlite and we find formed the intermediate breakdown of austenite, known as martensite. If the cooling be intermediate in its speed between extremely slow and extremely fast, we find intermediate microconstituents, troostite or sorbite. The correct constituent, however, in a hardened steel is martensite, and to form this martensite the material must be cooled quickly.

23 There are several degrees of "quickness" which at once suggest themselves. There is, however, a critical rate of cooling through the range which must be attained before the piece will be hardened.

24 On quenching it is clear that the surfaces of the section are cooled and hardened first. If the mass being cooled is of considerable size, different degrees of hardness are noticed from the outside to the middle. This can be illustrated by the following two examples, which, however, are not tool steels (Table 1).

25 Bars of the analysis shown, 3¼ in. sq. by 18 in. long, were quenched from indicated temperatures. A transverse section ½ in. thick was sawed from the middle and brinell hardness tests made at equidistant points on its surface. It will be noted that in each instance the corners, or thinnest portions were the hardest. Next in hardness were the edges and the decrease in hardness was quite uniform to the center of the bar.

26 The cooling medium used, its temperature, and condition also affect the rate of cooling. Benedicks[1] has investigated this

[1]Journal of the Iron and Steel Institute 1908, II, p. 208.

subject and arrived at conclusions of extreme interest. He found that in order that a liquid present in large bulk may exhibit a good quenching power it is necessary:

a That it should possess a high latent heat of vaporization

b That it be maintained at a temperature low enough to avoid too abundant formation of vapor

27 High specific heat, low viscosity and large heat conductivity all act, it is true, in the direction of quick cooling, but the influence of

TABLE 1 PENETRATION OF HARDNESS

	1	2	3	4	5	6	7	
1	411	359	321	314	321	359	411	3¼ in. sq. by 18 in.; water, 1500 deg. fahr. ½ in. transverse section from middle of length. C, 0.29, Si, 0.09, Mn. 0.65, P, 0.01, S, 0.01, Ni, 3.47
2	359	316	297	281	297	318	400	
3	337	283	283	280	283	295	340	
4	330	283	280	280	280	283	335	
5	337	278	283	280	285	298	340	
6	359	301	297	281	297	301	380	
7	411	359	337	317	337	380	420	
	1	2	3	4	5	6	7	
1	359	353	337	317	337	353	359	3¼ in. sq. by 18 in.; oil, 1675 deg. fahr. ½ in. transverse section from middle of length. C, 0.49, Si, 0.14, Mn, 0.74, P, 0.015, S, 0.014, Cr, 1.18, V, 0.17
2	350	335	325	320	323	327	350	
3	328	330	320	320	320	327	328	
4	325	320	316	314	316	320	325	
5	328	325	320	317	320	325	328	
6	350	327	323	319	323	327	359	
7	359	350	328	325	328	359	362	

the two factors last mentioned appears to be of a different and lesser grade than the heat of vapor formation.

28 The authors have devoted considerable time to investigating numerous commercial media which are in use in typical hardening plants of the country at the present time. The results given are only a small portion of those actually obtained, but they are typical.

29 In attacking the problem, the following method was adopted: A test piece of the dimensions shown in Fig. 1 was machined from a solid bar, and a hole drilled through the neck to within an equal distance from each side and bottom of the test piece. Into this hole a calibrated platinum-rhodium couple was inserted and the leads connected to a calibrated galvanometer. The test piece was then immersed in a lead pot, also containing a thermo-couple, to the point *A*, and the lead pot was maintained at a temperature of 1200 deg. fahr. When the couple inside the test piece was at 1200 deg. fahr., and the couple in the lead pot read 1200 deg. fahr., the test piece was removed and quenched to the point *B* in 25 gal. of the quenching medium under

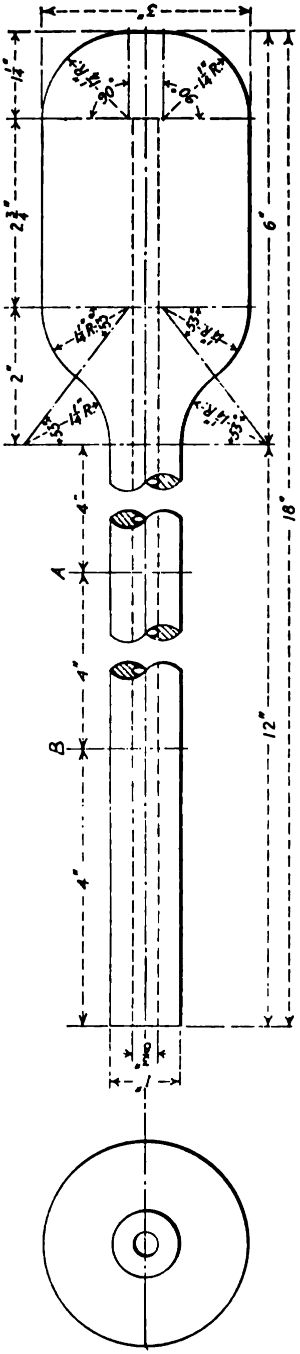
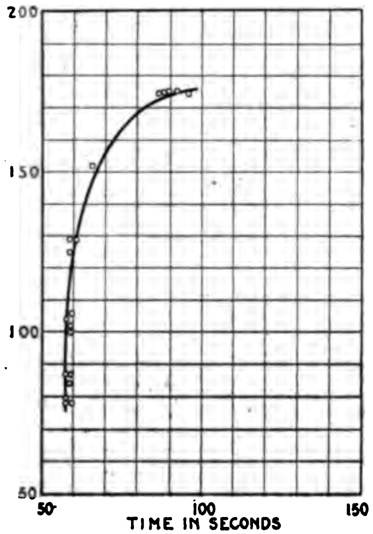
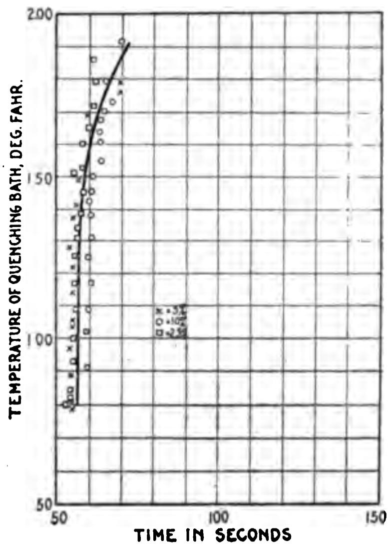


FIG. 1 TEST PIECE USED IN QUENCHING TESTS

›nsideration. At the start the quenching medium was maintained › room temperature. The time in seconds that it took the test ece to fall from a temperature of 1200 deg. fahr., to a temperature ' 700 deg. fahr., was noted by the aid of a stop-watch. It is clear ıat immersing the test piece in the quenching medium raised the mperature of the medium. The test piece was then replaced in ıe lead, heated to 1200 deg. fahr., quenched in the medium at





QUENCHING POWER OF LIQUIDS

FIG. 2 SYRACUSE CITY WATER FIG. 3 BRINE SOLUTIONS

ıis higher temperature and the time again taken with the stop-atch. These operations were continued until the quenching media, ı the case of oils, had attained a temperature of about 250 deg. fahr. 'he results obtained, time in seconds, for a fall from 1200 deg. fahr. › 700 deg. fahr., were plotted against the temperature of the quench-ıg medium and a series of curves as shown in Figs. 2 to 14 inclusive 'ere obtained.

30 A consideration of the results is interesting. City water Fig. 2) has a fairly constant quenching rate up to a temperature of)0 deg. fahr., where it begins to fall off. At 125 deg. fahr., the slope very marked. Brine solutions (Fig. 3) have both a quicker rate f cooling and are more effective at higher temperatures than water. 'he curve does not begin to fall off seriously until a temperature in

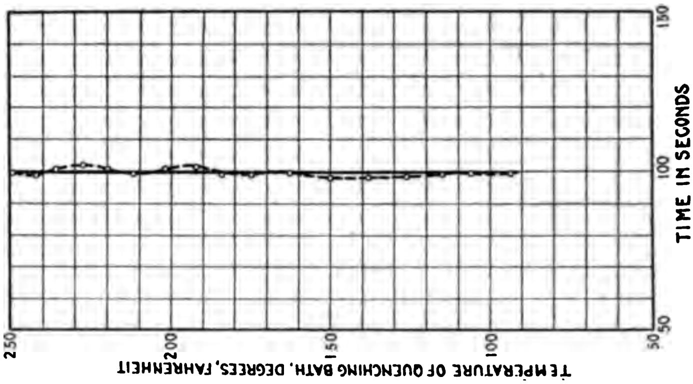


Fig. 6

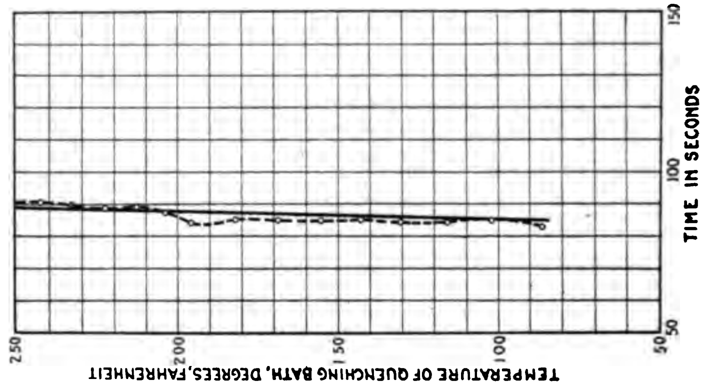


Fig. 5

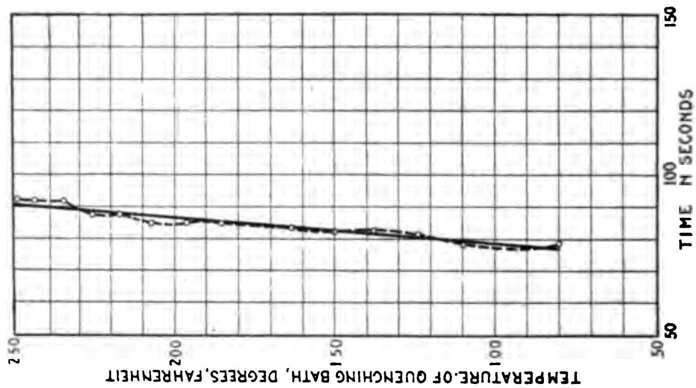


Fig. 4

Quenching Power of Liquids

Fig. 4 New Fish Oil. Average of Readings from 80 Deg. Fahr. to 250 Deg. Fahr.—85 Sec.
Fig. 5 No. 2 Lard Oil. Average of Readings from 80 Deg. Fahr. to 250 Deg. Fahr.—87 Sec.
Fig. 6 Prime Lard Oil in Use Two Years. Average of Readings from 80 Deg. Fahr. to 250 Deg. Fahr.—89 Sec.

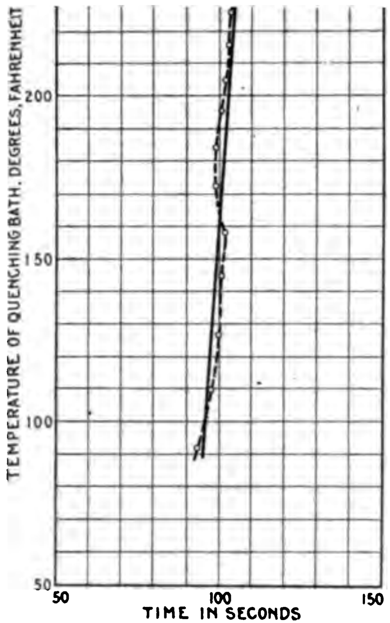


Fig. 7

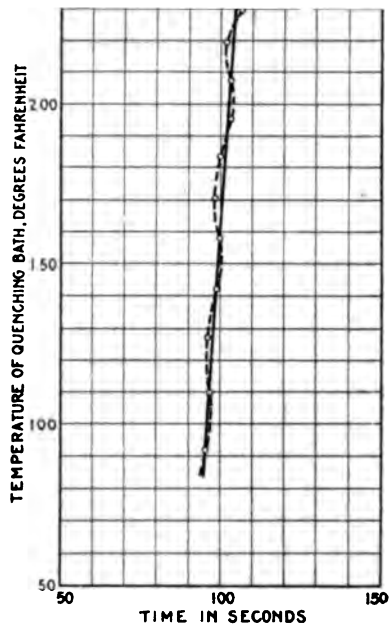


Fig. 8

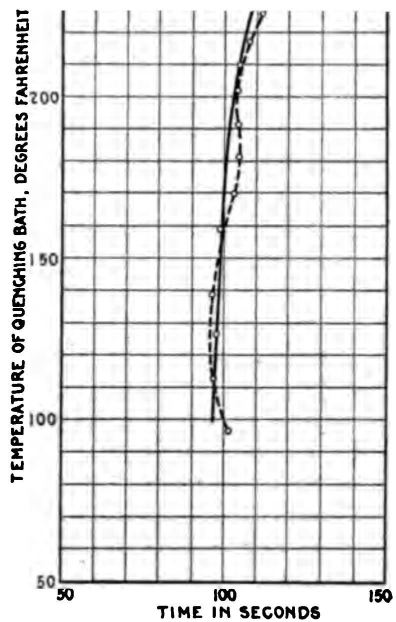


Fig. 9

Quenching Power of Liquids

Fig. 7 Boiled Linseed Oil. Average of Readings from 80 Deg. Fahr. to 250 Deg. Fahr.—101 Sec.
Fig. 8 Raw Linseed Oil. Average of Readings from 80 Deg. Fahr. to 250 Deg. Fahr.—102 Sec.
Fig. 9 New Extra-Bleached Fish Oil. Average of Readings from 80 Deg. Fahr. to 250 Deg. Fahr.—106 Sec.

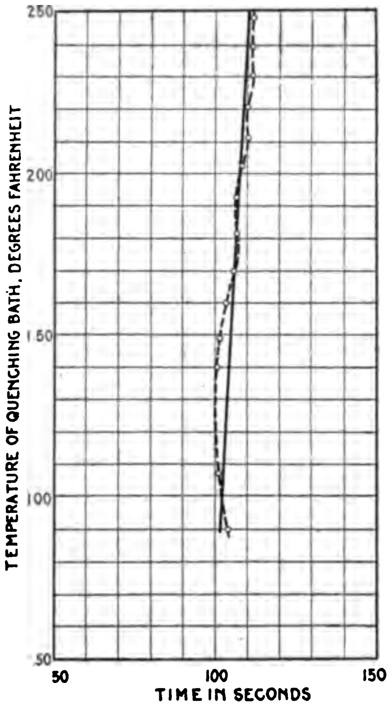


Fig. 10

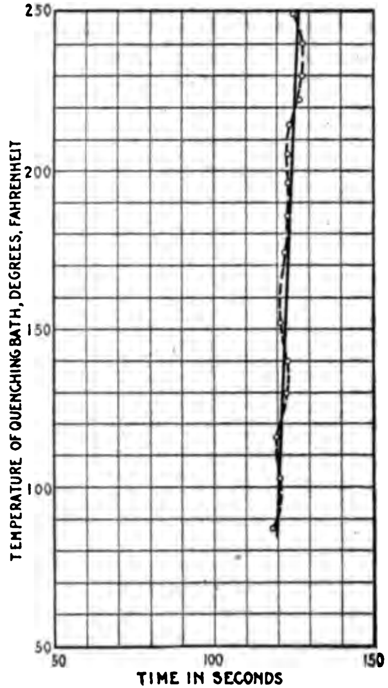


Fig. 11

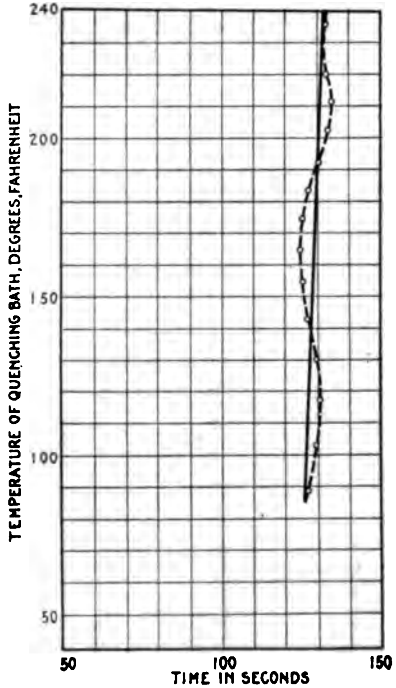


Fig. 12

Quenching Power of Liquids

Fig. 10 New Yellow Cottonseed Oil. Average of Readings from 80 Deg. Fahr. to 250 Deg. Fahr.—107 Sec.

Fig. 11 New Tempering Oil; 60 Per Cent Cottonseed, 40 Per Cent Mineral. Average of Readings from 80 Deg. Fahr. to 250 Deg. Fahr.—122.6 Sec.

Fig. 12 New Mineral Tempering Oil. Average of Readings from 80 Deg. Fahr. to 250 Deg. Fahr.—130 Sec.

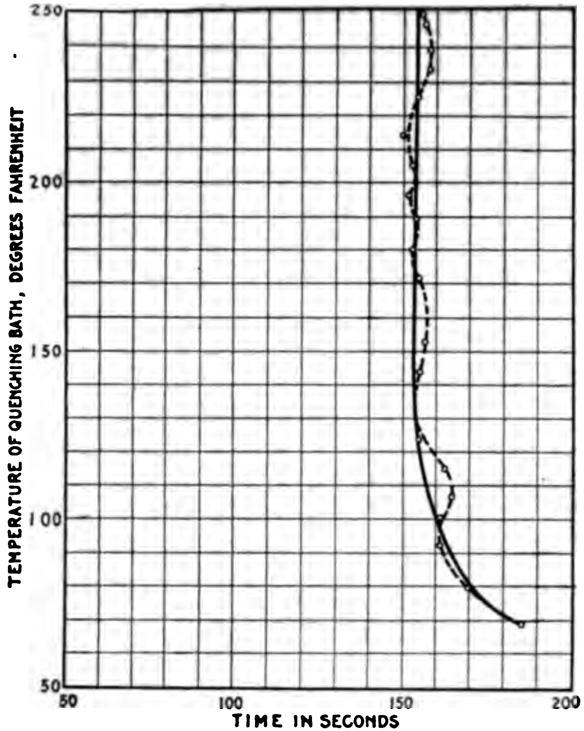


FIG. 13

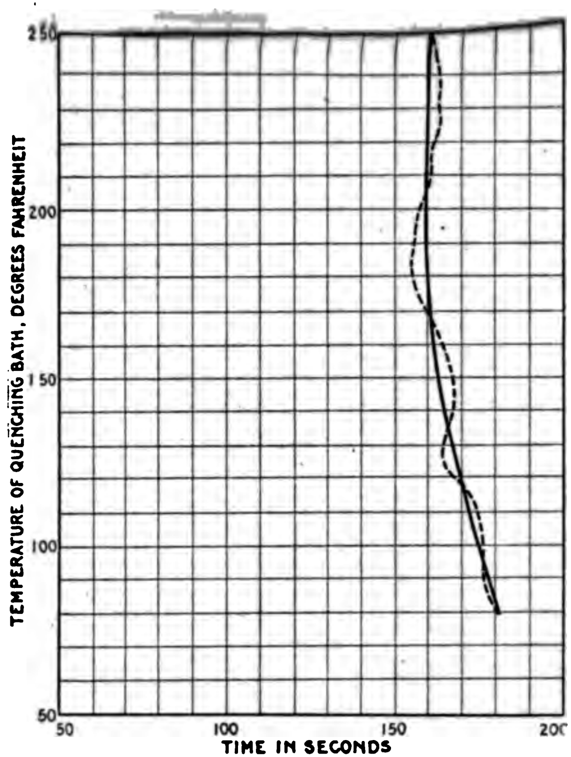


FIG. 14

QUENCHING POWER OF LIQUIDS

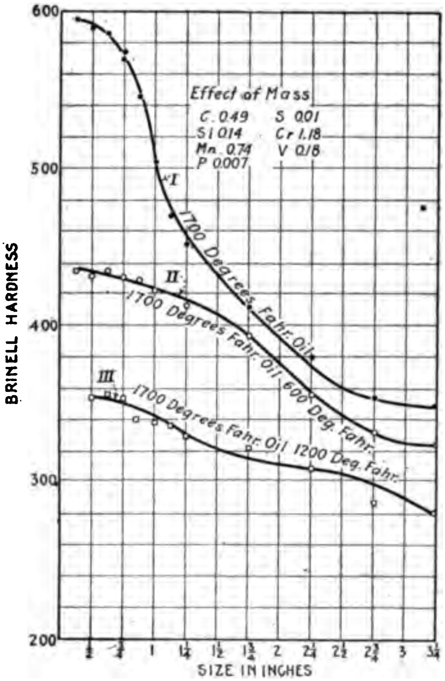
FIG. 13 No. 1 DARK TEMPERING OIL. AVERAGE OF READINGS FROM 80 DEG. FAHR. TO 250 DEG. FAHR.—157.3 SEC.

FIG. 14 SPECIAL "C" OIL. AVERAGE OF READINGS FROM 80 DEG. FAHR. TO 250 DEG. FAHR.—164.7 SEC.

the neighborhood of 150 deg. fahr. is reached. Where water at 70 deg. fahr. cooled the test piece in 60 sec., the brine solutions cooled it in 55 sec.

31 As is well known the oils are slower in their quenching powers than water or brine solutions, but the majority of them have a much more constant rate of cooling at higher temperatures than water or brine.

32 The curves shown in Figs. 13 and 14 are for thick viscous oils somewhat similar to cylinder oils. These curves are particularly



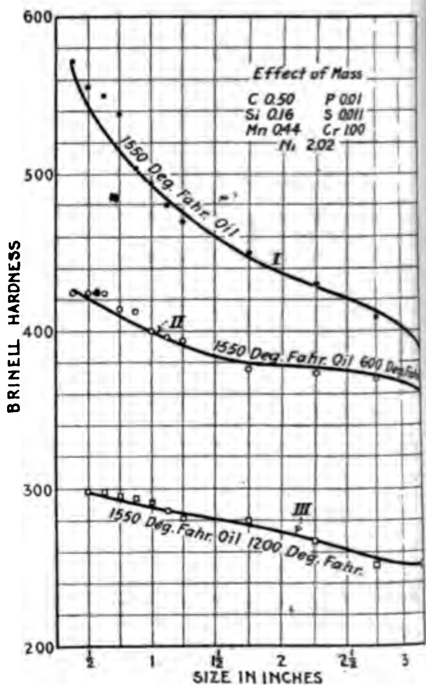


Fig. 15 Fig. 16

Brinell Hardness of Test Pieces after Quenching

interesting in that they have slower quenching abilities at low temperatures than at higher temperatures.

33 A comparison of curves in Figs. 5 and 6 show the variation in quenching power of the same oil due to continued service. The differences in quenching rates may well account for different results from the same steel in different shops, or in the same shop due to change of oil used.

HARDNESS AS AFFECTED BY MASS

34 It has been known for some time that different masses of the same material on being quenched under like conditions gave varying physical properties, but it is only within recent years that the quantitative effect has been measured. The authors give here a few results, which, although obtained several years ago, are printed for the first time.

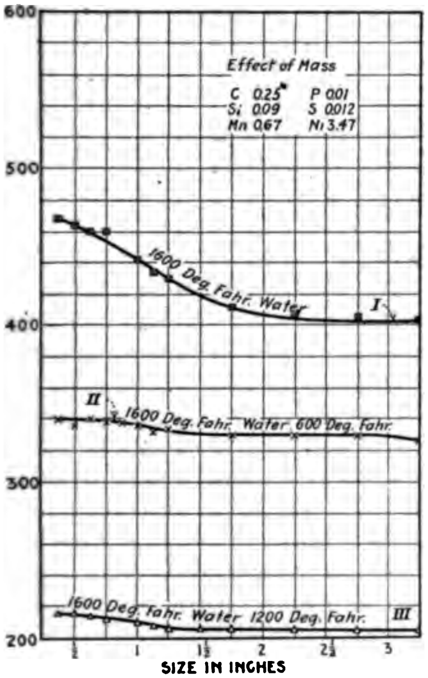


FIG. 17

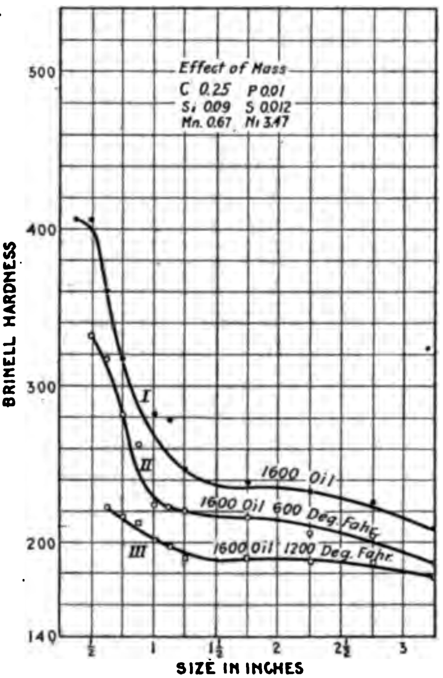


FIG. 18

BRINELL HARDNESS OF TEST PIECES AFTER QUENCHING

35 Test pieces 4 in. long were made from the same ingot in sizes increasing ⅛ in. in both breadth and thickness. The smallest was ⅜ in. square and the largest 3¼ in. square. Three ingots of different type analyses were chosen and a series of test pieces made from each. The test pieces were heated in a semi-muffle furnace to a constant temperature for each type of material, quenched, and the Brinell hardness test made. Each series was then drawn to 600 deg. fahr. in a salt bath and brinell tests again taken and then reheated to 1200 deg. fahr. in a salt bath and brinell hardness tests again run.

The results are graphically shown, brinell hardness plotted against test piece size (Figs. 15 to 18 inclusive.)

36 It will be noted that the smaller the sample the greater the figure of hardness, indicating that the smaller sections are cooled with greater rapidity than the larger, and hence more hardness is developed. The same agencies are at work in tool steel. The larger the mass the smaller the depth of hardness when quenched under similar conditions.

37 Benedicks[1] has shown that for steel of constant mass, the

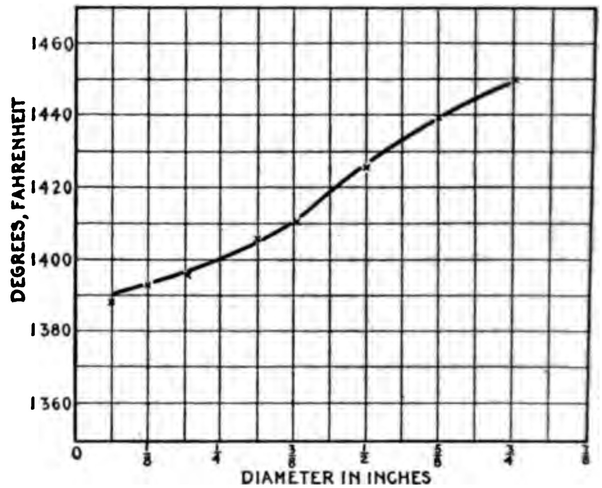


Fig. 19 Temperature—Size Curve for Hardening Tools

higher the temperature, the greater the rate of cooling. Two of his results will be sufficient to cite.

Weight of Specimen in Grams	Deg. Cent. Quenching Temperature	Cooling Time, Seconds
12.3	845	4.43
12.3	703	5.73

38 These results confirm our experience that in order to produce the same amount of hardness in a small and large section it is necessary to heat the larger section hotter than the smaller. A commercial application of this phenomenon will perhaps be interesting. The authors were recently confronted with the problem of finding out the correct temperature for hardening tools made from the same steel in sizes varying from $\frac{1}{16}$ in. diameter to $\frac{3}{4}$ in. diameter. The tem-

[1]Journal of the Iron and Steel Institute 1908, II, p. 212.

perature-size curve shown was finally adopted (Fig. 19). In other words, a $\frac{5}{16}$ in. round will harden at 1395 deg. fahr., while a $\frac{3}{4}$ in. round bar should be heated to 1450 deg. fahr.—a difference of 55 deg. fahr.

TIME AND DEGREE OF DRAWING TEMPER

39 After the hardening operation has been safely performed. the next important step is that of drawing the temper. This operation is necessary for two important reasons:

a The relieving of abnormal strains set up due to the quick contraction or expansion

b The breaking down of the extremely hard and brittle structure of the quenched steel

40 The authors have seen expensive tools such as broaches, dies, etc., actually burst and fly apart due to the fact that the strains set up in hardening were not relieved by drawing the temper soon enough after the hardening operation. If this paper can impress upon its readers the absolute importance and necessity of drawing the temper *immediately* after hardening, the authors feel it will not have been in vain.

41 As previously shown in a properly quenched and hardened steel the hardening carbon, *i.e.*, that up to 0.90 carbon, exists in the form of carbide of iron Fe_3C dissolved in iron, and the solution is known as martensite. If the steel is hyper-eutectoid, *i.e.*, higher than 0.90 carbon, all that up to 0.90 is dissolved and the remainder exists as globules of undissolved cementite scattered throughout the matrix. The drawing of the temper begins to break down the true martensitic structure and as the temperature increases there are formed intermediate micro-structures between martensite and pearlite, first troostite, then sorbite, and finally pearlite.

42 Professor Heyn has published some valuable results on the decrease of hardness on tempering. The results are expressed in per cent of the original hardness.

100 deg. Cent....	2.5 per cent.	400 deg. Cent....	70.0 per cent.
200 deg. Cent....	14.0 per cent.	500 deg. Cent....	87.5 per cent.
300 deg. Cent....	41.0 per cent.	600 deg. Cent....	97.5 per cent.

43 Regarding the effect of time on drawing the temper we submit the following. Standard $\frac{1}{2}$ in. round A.S.T.M. test pieces were quenched from constant temperature into the same medium, and the temper drawn in same salt bath at constant temperature for five minutes, fifteen minutes, etc.

Elastic Limit	Maximum Strength	Elongation	Reduction	Brinell	Remarks
228,750	260,137	2.5	....	425	1550-oil-800 deg. fahr. 8 min.
201,125	214,562	11.6	45.4	390	1550-oil-800 deg. fahr. 20 min.
175,000	183,187	12	49.35	340	1550-oil-800 deg. fahr. 40 min.

44 Each of these results is the average of four closely agreeing checks. A study of the above table shows that time at the drawing temperature has a marked effect. The act of breaking down the martensite is progressive and not sharply defined. Both time and temperature have their effects.

45 The greater the initial hardness of the piece, the more marked is the effect of drawing the temper. By referring to Figs. 15 to 18 inclusive the actual values in brinell hardness are shown. The piece of 0.25 carbon nickel, ⅝ in. sq., quenched in oil, shows a brinell of 360; drawn to 1200, a brinell of 223. The per cent decrease in hardness is 61. The piece 3¼ in. sq., quenched shows a brinell of 208; drawn to 1200 deg. fahr., brinell 183, showing a decrease in hardness of only 13 per cent.

46 Thallner[1] states that two kinds of strains are present in hardened steel: (*a*) those which occur in steel of small cross section which hardens throughout; (*b*) those which occur in steel of larger cross section due to unequal change in volume of the surface and interior. The first of these also occurs in steel of larger cross section, but to the greatest degree on the surface. Thallner also classifies steels as (*a*) those which become shorter and (*b*) those which become longer or shorter in hardening. The two classes are not sharply divided. In pure carbon steels, the line of demarcation is about 0.90 carbon. In steels which lengthen, an increase in both length and width may also occasionally be observed and the larger cooling surfaces usually become convex. Thallner cites five crucible steels which he examined as shortening and eight basic open hearth steels, as lengthening.

47 The tendency of steel is to become spherical by repeated quenchings. Mr. Law, working with a square piece of tool steel 3½ in. by ½ in. by ½ in., quenched it 550 times and at the end of this work, the piece was nearly round in cross-section. The ratio of length to diameter had changed from 3½:½ to less than 2:1. An equally interesting observation by Mr. Law was that the steel did not lose carbon or change in any way in composition.

[1]Tool Steel, Thallner.

48 Professor Howe has this to say in explanation of the change ı shape which results in hardening a round bar: "The exterior rst cools, contracts, becomes rigid, its dimensions being determined y the size of the still comparatively hot, expanded, mobile interior. 'he resistance of the interior to the return of the exterior to the limensions it had before heating acts on that exterior precisely as a ensile stress on a body at constant temperature. If very powerful, t strains it beyond its elastic limit, it takes a permanent set, is ermanently distended. The stress may exceed the ultimate strength f the outer layers, which then crack, the piece breaks in hardening. The interior continues to contract; its adhesion to the now rigid, listended exterior prevents its own complete return to its initial limensions. It may in its struggle to reach them somewhat compress he exterior, but not enough to efface the distention previously aused. The piece as a whole remains somewhat enlarged, and its pecific gravity is lowered. After the cooling has progressed slightly ınd the outside has contracted more than the still comparatively low cooling and disproportionately distended interior, it is no onger able to contain it and at the same time to preserve its original hape. It is, therefore, shortened and bulged thus slightly approaching the spherical shape in which the minimum of exterior holds he maximum of interior; and this distortion is not wholly effaced y the contraction of the interior."

49 Many years ago, one of the authors made several hundred ıardening experiments and several thousand measurements to study he change of shape. The materials used were cylinders of steel and aps. Crucible steel alone was examined and the following variables vere considered: (*a*) the effect of original form or diameter upon the liameter after hardening; (*b*) the influence of carbon on change of orm; (*c*) the influence of initial temperatures at quenching; (*d*) he influence of length of time of heating; (*e*) the influence of repeated ıardenings, and (*f*) the effect of annealing previously hardened steels, ıpon change of shape in rehardening. Obviously when plain ylinders of steel are considered, there are four changes of hape possible, expansion in length and diameter, contraction in ength and diameter, expansion in length and contraction in diameter, ınd contraction in length with expansion in diameter.

50 Under the influence of the variable conditions mentioned ıbove, all four changes were actually produced. Steel was also found vhich expanded in length on first hardening and contracted indefinitely thereafter on repeated hardenings. Another steel ex-

panded in length on two hardenings and contracted on the next two. In a variable carbon series of steels from 0.50 to 1.33 per cent carbon, the magnitude of the change in length after four hardenings increased as the carbon increased. For the same series it was noted that the volume changes were greater when hardening annealed rather than unannealed bars. The increase in length is greater the higher the hardening heat for all carbons. The details of this work would take us too far from the purpose of our paper. The point we wish to emphasize strongly is that it is variable conditions that give variable results. Hence, it is of vital importance that steel be furnished uniform, chemically as well as physically, and it is equally important that the user employ every possible refinement in the handling of his product. It is only under varying conditions of heat, size, time, composition, etc., that the results vary. Constant conditions give constant results. Different steels will not behave alike in all cases, but it is a simple matter to determine under any given set of conditions how a particular steel will behave. Other things being equal, therefore, the original composition, grain size, condition of annealing and the method of manufacture affect the resulting changes in form after hardening. Above the decalescence point, the coefficient of dilatation increases proportionately with the carbon and for all carbon percentages the rate of dilatation increases with the temperature. Resulting changes of form are conditioned by the original proportions of the piece quenched, by its chemical composition, by the temperature from which it is quenched, and within certain limits by the time of heating. Hardness, brittleness, change of form and liability to crack, generally speaking, increase with the carbon content and the temperature and time of heating. Nevertheless, constant conditions give constant results.

51 It cannot be overlooked, however, that constant conditions are not always attainable. The maker of steel cannot control conditions in his customer's shop and the customer cannot control conditions in the steel plant and the human element must be considered in both. The properties we have been describing are inherent properties of carbon steel, and because of them many a dispute has arisen over tools lost in hardening. The placing of the exact responsibility is very difficult even though it were not true that it is human nature to shirk responsibility.

52 The way to avoid such disputes would naturally be simplified if a steel possessing all the desirable qualities of carbon tool steel could be produced, omitting most of its faults and eccentricities.

A product introduced in this country nearly ten years ago by the company with which the authors are associated, is perhaps the nearest approach to this ideal. Since we were, personally, in no way responsible for its development, we feel it is not out of place to mention it here for we consider it an achievement, next only in importance to the discovery of high-speed steel in the evolution of tool steel metallurgy. This product has been so largely used for nearly ten years in America that it is not necessary to describe its peculiar characteristic of undergoing almost no change in shape, no warping, expansion or contraction in hardening. It is not so foolproof that it cannot be injured by abusive treatment, yet with reasonable care it permits the tool maker to produce parts which, after hardening, are of exact size and fit, to make threaded and threading tools to exact standards, and to produce most intricate punches and dies which can be hardened with safety and a minimum of risk.

FURNACES AND METHODS OF HEATING

53 Much has been said regarding the superiority of gas furnaces over oil furnaces and vice versa. The fuel used is immaterial for good practice so long as the following points are taken care of:

- *a* The furnace and hearth should be of sufficient size so as not to be affected materially in temperature by the introduction of the parts to be hardened.
- *b* The furnace should heat at a uniform rate.
- *c* The furnace should be of uniform temperature over its entire hearth.
- *d* The furnace should be run under neutral, or reducing, conditions. A good rough test for this is the introduction of a piece of wood or paper upon the hearth. If the paper, or wood, burn, the atmosphere is oxidizing. If they char, it is reducing or neutral.
- *e* The temperature control must be at all times exact and it must be possible of exact duplication on repetition work.

54 A blacksmith's fire is satisfactory under good handling but the difficulty is the fact that for constant work it is too exacting on the operator and requires too many manipulations to secure uniform and continuous results.

IN CONCLUSION

55 We have endeavored to enumerate the factors which enter into the every-day operation of hardening tool steel. It is the duty

of the user of steel to study these influences and through study and experience to properly weigh the many problems presented in what is frequently considered a simple operation. The various factors are not always of equal importance and must be considered in connection with the size and nature of the object being hardened and the duties expected of it after hardening. To expect uniformly good and consistent results from a hardener whom you have not provided with adequate or suitable equipment is unreasonable. When the question of good equipment in the way of furnace, quenching arrangements and media, pyrometers, etc., has been satisfactorily taken care of, your hardener still has plenty of variables to contend with which are beyond his control. We hope we have made clear what some of the variables are and have excited some interest and desire upon the part of those responsible for hardening results to study them as they have not studied them before. The hardener's task is a difficult one and if we have presented herein any suggestions of value our efforts will not have been in vain.

DISCUSSION

Henry M. Howe (written). The authors are particularly to be congratulated on their ingenious method of determining the rate of cooling of different liquids, a method which can be applied without the use of sensitive instruments. This method must be considered as a very great improvement over that of Benedicks, by which the results standard up to the present time have been reached.

In pars. 4 and 5 it should be understood that the pearlite and the excess, or pro-eutectoid, ferrite or cementite are not always recognizable under the microscope. Steel which has been hardened and then heated to 400 deg. does in a sense fit the description given by the authors, but in point of fact the pearlite and ferrite or cementite, as the case may be, are all mixed up in a state of such a fine emulsion that they cannot be recognized individually. The term "sorbite" is applied to such an emulsion, whether it be eutectoid or hyper- or hypo-eutectoid.

In par. 11 it should be understood that the influence of manganese and nickel in lowering the transformation range is primarily through their increasing the hysteresis. They do indeed lower the transformation range, but only to a relatively small extent. The observed lowering of the recalescence point represents chiefly hysteresis. When the decalescence points are determined, it is found that they have not been very greatly lowered. This is shown by Hopkinson and Hadfield, Journal Iron and Steel Institute, 1914, I, 418. With carbon 1.26 and manganese 13.38, the transformation occurs between 650 deg. and 750 deg. which is not so very much below that in carbon steel in which the observed recalescence commonly occurs at about 690 deg. and under conditions of exact equilibrium, that is to say when hysteresis is avoided, at about 725 deg.

In addition to the valuable researches by Le Chatelier, cited in par. 15, there are also very important ones by Charpy and Grenet, Bull. Soc. d'Incouragement, Vol. II, 1903, p. 464. The most accurate measurements of all, however, are given by Benedicks in the 1914 Vol. I of the Journal of the Iron and Steel Institute, p. 407.

The results in Table 1 giving the penetration of hardness are of very great value. It is to be understood that the hardness of the corners and edges in reality exceeds that of the interior of the piece even in a greater degree than these numbers would indicate, for the reason that when the brinell ball is pressed into the specimen near its edge, and more particularly near its corner, the indentation is abnormally great because of the proximity to the side of the piece. It is evident that if the brinell ball were applied at the very edge there would be only a slight resistance to the outward movement of the metal on the outer side of the ball.

The diagrams showing the influence of mass are of extreme interest.

Figs. 15 to 18, and especially Figs. 15 and 16, show that our previous belief as to the completeness of annealing at 600 deg. cent. was incorrect. Goerens'[1] results seemed to show that, at least for very low carbon steel, the effect of overstrain was removed almost completely at 600 deg., and it has been thought that this was also true of the hardening caused by rapid cooling, but here reheating to 649 deg. cent. (1200 deg. fahr.) evidently left a very important degree of hardening. Thus, with apparently no difference except the cross section of the piece, the hardness varies systematically from 280 deg. in the 3 1/4 in. piece to 352 deg. in the 1/2 in. piece.

Again, the results in par. 43, which show that at 430 deg. cent. (800 deg. fahr.) the tempering was very far from reaching the maximum for that temperature even after a sojourn of 20 minutes, disagree with the earlier and very precise determinations of Barus and

[1]Goerens, Carnegie Memoirs, Iron and Steel Inst., 1911, III, Fig. 42, p. 383.

Strouhal,[1] who found that the tempering at these temperatures reached its maximum very quickly, for instance, being almost as complete after 1 minute at 330 deg. as after 91 min. at 330. deg. The explanation of the discrepancy is to be awaited with great interest, and in the connection two possibilities suggest themselves: first, that the high content of the sluggardizing elements, manganese and chromium, in the authors' steel may have retarded the tempering; second, that the method of Barus and Strouhal may not have reported the tempering as trustworthily as that of the authors. Barus and Strouhal determined the degree of tempering by means of the thermoelectric power. Tempering is so complex a matter, involving both the re-crystallization of amorphous iron and the chemical change from gamma and perhaps beta to alpha iron, as well as the precipitation of the cementite from its solution in the martensite, that it may not be measured truly by this power. One is tempted at first to refer the softening observed after the authors' 20 min. and 40 min. exposures to opportunity for coalescence of the sorbite; but it seems that the loss of elastic limit and of hardness is too great to be accounted for in this way.

J. J. RALPH wrote that he was particularly interested in the statements regarding the permanent changes in dimensions produced when steel is hardened. They agreed with some experiences of his with hypo-eutectoid steel of about 0.45 per cent carbon. Hardening finished pieces of this steel produced variations in their diameters considerably over the specified tolerance. Observation showed that these variations were due to variations in quenching temperatures, and this led to care being taken to quench at a particular temperature. Further investigation showed that the facilities for measuring temperature were not adequate enough to secure the fine control necessary, then that quenching conditions both as to composition and temperature of quenching material were far from ideal, and finally that the steel was not running evenly enough chemically (it was a low price open-hearth low carbon, low phosphorus and sulphur) to allow the fixing of a definite quenching range.

In hardening a steel of about 0.6 per cent carbon, in another case, ideal results were only obtained by controlling the temperature to within a range of less than 5 deg. fahr. This is considerably less than the instrument error of the best indicating pyrometers and was

[1]Bulletin 14, U. S. Geological Survey, 1885, p. 55.

only made possible by the use of a bath furnace and the resistance thermometer.

Skilled practical men are willing to guarantee almost a finished hardened piece, exact to size and shape, but a comparison of results obtained by several skilled smiths will show a surprising difference, probably owing to the difference in the steels they have been accustomed to handling. It must not be overlooked, too, that the usual conception of "exact" in the hardening room and in the machine shop is far from perfect.

Investigation of hardening defects is not usually as thorough as it should be. Seldom is an attempt made to reproduce a defect and prove conclusively its cause. Lack of knowledge of the steel used, especially of its history and the effect of previous operations, hampers the investigation of defects.

In work on relatively long slender pieces, most of the trouble in distortion has been found by the writer to be due to bending in heating. Steel, when hot, seems to bend under the application of a steady, even though slight load, and sometimes under its own weight.

Another cause of trouble in hardening is initial strain due to forging, rolling or machining or resulting from accident. Such strain is relieved when the piece is heated, causing a bending or twisting. This is particularly annoying in fine work.

If a practical way of holding hardened pieces to size and shape can be found, the pieces can be finished when soft. A very material saving will thus be effected and, besides, pieces of more satisfactory design can be used in many cases.

The problem of hardening without distortion has been simplified by the introduction, within the past year, of the potentiometer-type pyrometer which has a commercial accuracy of about 1 deg. fahr. in skilled hands.

O. R. Cary[1] described an experience in connection with the effect of time of heating on the shrinkage of the metal when producing die blocks of an average size of 5 by 3 by 1 in. The blanks were treated in an electric resistance furnace. It was found that if one particular size piece was heated to the proper point in this furnace in 44 min., a die was obtained which required no further chemical treatment but which could be cleared perfectly by a cut of less than one-thousandth inch. If the same size piece was heated in 38 min., a cut of at least

[1] Leeds and Northrup Company, Philadelphia, Pa.

four-thousandths inch was required to clear the surface, the changes in shape being similar. It was found, too, that the time of heating for obtaining the best die was constant for this particular furnace and for this particular size piece. A smaller piece required a shorter time of heating and the time of heating appeared to depend on the furnace and on the size of the piece. It was also found that a variation of as little as 5 per cent in the time of heating of ordinary commercial tool steel caused a perceptible variation in the shape of the piece. The neglect to maintain a uniform time of heating is therefore probably the cause of many troubles which have been laid to the steel itself or to pyrometers.

BRADLEY STOUGHTON expressed his opinion that the results of this paper would be of great value if they were the means of reducing to an exact science some of the rules of thumb with which steel men were accustomed to work. This somewhat neglected side of steel metallurgy would thereby be raised to a very much higher plane. The experiments made on the effects of mass were particularly interesting in connection with the tempering of large pieces of steel, especially dies, difficulty in carrying out which was occasionally experienced. If a die is large and its mass considerable, its physical condition is liable to be a soft zone of metal immediately under a very hard exterior, and the die will frequently "drop." This phenomenon is undoubtedly explained by the theory of Professor Howe, outlined in the paper, that the exterior cools and shrinks on the interior, then the interior in its cooling shrinks in turn away from the hard exterior, producing a zone of soft metal. It would seem that the results in the paper might suggest some better quenching medium for pieces of steel of large mass whereby the hardening would be extended further into the metal and the soft zone eliminated.

JOHN A. BRASHEAR illustrated the extreme refinement required in the treatment of steel to secure homogeneous material by referring to a personal experience in connection with the making of a rotating mirror for measuring the velocity of light and also, if possible, the variation in speed of light of different wave-lengths. The mirror was required to rotate at 30,000 r.p.m. and its four sides to be absolutely equi-angular with the surfaces. The surfaces were about 1 1/4 in. square and these had to be hardened and so exact that the image of a star thrown on one of them could be projected about three miles and reflected without distortion. This allowed an error of not more than about one-fifth of the length of a light wave. Extreme difficulty was encountered in getting these surfaces of a standard hardness so that each surface would polish the same, and also in getting each surface homogeneous; if one spot on a surface was the slightest degree softer than any other spot, it would get a little low when the mirror was run. The work of getting the four surfaces of satisfactory uniformity and homogeneity was finally accomplished and the mirror has since been employed for making a number of measurements of speed of light.

THE AUTHORS. In reference to Mr. Cary's remarks, we are pleased to have this confirming testimony in reference to the effect of variable conditions in hardening. The experiment Mr. Cary mentions had to do principally with the effect of time in heating. While this point is very important, we would not be safe in concluding, from Mr. Cary's results, that it was more important than the temperature to which the steel is heated, the temperature and nature of the quenching bath, also the temperature and time in the drawing operation. Each of these conditions must be carefully controlled if consistent results are desired.

In reply to Mr. Stoughton, we would say that the depth of penetration in hardening tool steel dies is very important. It is not always desirable, however, that steel should harden very deeply for successful use. In fact, in the case of cold drop dies, the sorbitic interior seems to afford a cushioning and strengthening effect which is very desirable. Steel that hardens too deeply is apt to crack in service under shock conditions.

In reference to Mr. Ralph's remarks on temperature control, we believe that on large scale operations it is practically impossible to maintain temperatures within five degrees fahr. In experimental work, of course, this can be done.

We are particularly pleased to note the comments of Professor Howe upon our paper. In reference to the effect of mass upon penetration of hardness as shown in Table No. 1, we would point out that, in taking our brinell impressions, the distance of the impression from the extreme outside was sufficiently great so that no bulging occurred on the edges. In other words, the figures probably do not show the hardness on the edges and corners to be as great as it actually was. The extreme outer row of impressions was not closer than 3/8 in. from the edges or corners.

The writers hope that their paper will prove of value to those engaged in the practical heat-treatment of steel of all kinds and will lead to more careful study of the problems involved and make for uniformity and success.

No. 1465

STANDARDIZATION OF CHILLED IRON CRANE WHEELS

By F. K. Vial,[1] Chicago, Ill.

Non-Member

There is a wide variation in the character of wheel designs now offered by different manufacturers for similar conditions of crane service, and as far as known, none of them are based on proven or experimental data.

2 The purpose of this paper is to analyze the properties of chilled iron as related to crane wheel service, and to establish standards based on the results of tests on full size wheels, showing the bearing power of the wheel and rail, strength of flanges of various sections and other essential data. With this end in view, the Griffin Wheel Company, at Chicago, has just concluded a series of tests. The breaking strength and bearing powers were determined by the use of a 300,000-lb. Riehle testing machine in the R. W. Hunt & Company laboratory. As a result of these tests, the design of wheels to meet any particular condition of loading and service, which has long been a matter of judgment of the individual designer, can now be standardized to give a uniform factor of safety for any operating condition. This is particularly important in the heavy bridge type of cranes on account of the large investment involved in the enormous structures now carried on chilled iron wheels (Fig. 1), where a heavy loss must necessarily result in case of a wheel failure that would cause an interruption of service. The character of the service referred to is shown in Figs. 2 and 3.

STANDARDIZATION OF CHILLED IRON CRANE WHEELS

3 During the past century, chilled iron has been the standard material for the manufacture of car wheels, and notwithstanding the tremendous development in car capacities and the speed at which

[1]Ch. Engr., Griffin Wheel Co.

Presented at the Annual Meeting, December 1914, of The American Society of Mechanical Engineers.

traffic is moved, the chilled iron car wheel is standard today for rail-borne traffic, representing at least 97 per cent of wheels in freight service.

4 The reason why this type of wheel is standard is not because of its cheapness, but because of the remarkable properties adapted to wheel service. The qualities which are sought after in wheels of all descriptions are:

a Sufficient bearing strength to sustain the load imposed

FIG. 1 DOUBLE FLANGE CHILLED IRON CRANE WHEEL

b High resistance to wear and distortion through heavy pressures on the small area of contact between tread and rail

c The chilled iron tread, on account of the absence of ductility and coupled with slow wearing qualities, retains the rotundity of the wheel to a larger extent than any other metal

d Sufficient softness of hub to permit machining

e Flange must have high wearing qualities, and sufficient strength to withstand all side thrusts imposed

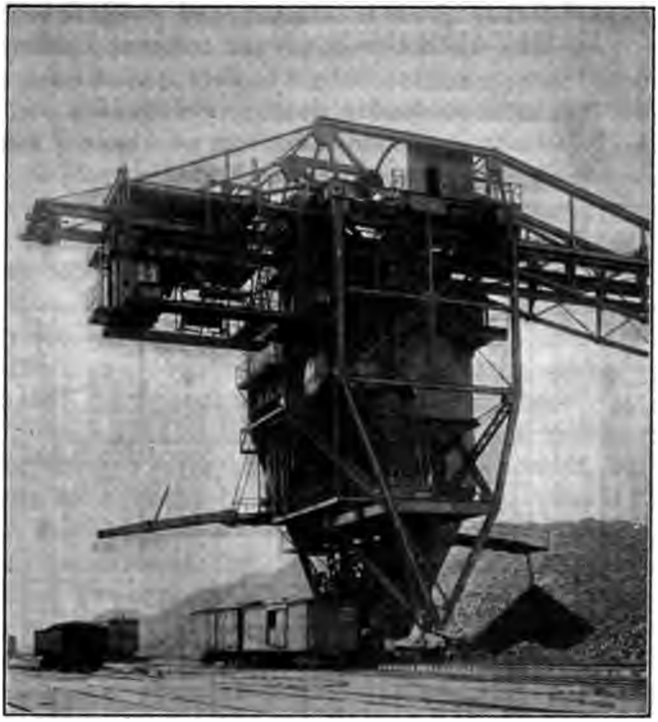


FIG. 2 SHOWING ENORMOUS STRUCTURES NOW CARRIED ON CHILLED IRON WHEELS

FIG. 3 DETAIL SHOWING CRANE WHEELS IN POSITION

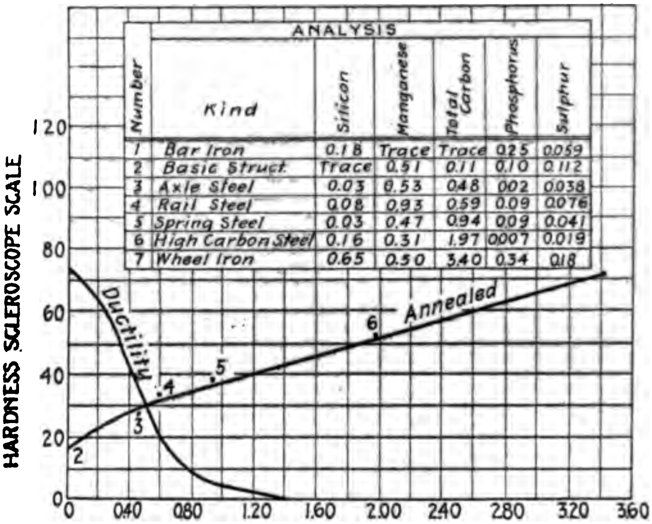
f Sufficient toughness in hubs to permit wheels to be pressed on axles without cracking, and sufficient elasticity and friction to keep them tight on their seats in service

g They must not weaken through crystallization

h Uniformity and hardness between all wheels of a set and in all parts of the tread of each wheel

PROPERTIES OF CHILLED IRON

5 The properties of chilled iron will indicate in how far all the



Number	Kind	Silicon	Manganese	Total Carbon	Phosphorus	Sulphur
1	Bar Iron	0.18	Trace	Trace	0.25	0.059
2	Basic Struct.	Trace	0.51	0.11	0.10	0.112
3	Axle Steel	0.03	0.53	0.48	0.02	0.038
4	Rail Steel	0.08	0.93	0.59	0.09	0.076
5	Spring Steel	0.03	0.47	0.94	0.09	0.041
6	High Carbon Steel	0.16	0.31	1.97	0.007	0.019
7	Wheel Iron	0.65	0.50	3.40	0.34	0.18

FIG. 4 HARDNESS COMPARISON OF IRON AND STEEL ACCORDING TO CARBON CONTENTS

above requisites can be met. The exceptional wearing qualities of the flange and tread are the result of the hardness of the metal, which reduces abrasion, and flange resistance to a minimum.

6 The hardness of iron or steel is due to the percentage of carbon alloyed with the metal. This percentage varies according to the grade of the iron or steel. Wrought iron and dead low steels contain practically no carbon. Structural steels contain from 0.2 per cent to 0.4 per cent; rolled steel wheels 0.7 per cent; rail steel 0.8 per cent; tool steels run as high as 2 per cent, and the tread of chilled iron wheels runs as high as 3.5 per cent. The hardness is directly proportional to the amount of carbon present. Fig. 4 shows the relation of hardness and ductility to the percentage of carbon. The tread of the

wheel is intensely hard, represented in the scale of the Shore sclerescope by 72, whereas in the ordinary steel used for wheel making, the hardness drops to 34 and 32. The wearing value, therefore, of chilled iron is superior to that of any other metal used in the manufacture of wheels.

7 The ductility of the metal drops very rapidly as the percentage of carbon increases, so that chilled iron is practically devoid of ductility, and, therefore, is not distorted, and the metal will not flow, lose its rotundity nor change position under the heaviest loads that can be applied. The plates in the center of the wheel, however, are comparatively soft, because most of the carbon, which in the white iron is in a combined state, is reduced to graphite, which is interspersed throughout the material in small flakes. It is this graphite that gives a dark color to the fracture and that softens the iron, for not only is it distributed through the metal, but if the remaining metal should be examined after the graphite is brushed away, it would be found that the material was white, carrying about 0.7 per cent combined carbon, which is identical in analysis with 0.7 per cent carbon steel, this being the common amount of carbon in steel used for making wheels. Exclusive of graphite then, the body of the wheel is very similar in quality to steel. Its strength, however, is less, on account of the graphite which is interspersed through its structure. The hub of the wheel is soft, and permits machining to exact size to produce a pressure fit against axle.

8 As the treads of chilled iron wheels have high resistance to wear, absence of ductility and do not distort or lose the rotundity under heavy loads, it is the best material for use under large towers, bridges, etc. This is especially true where the power is transmitted through the entire set of driving wheels by the use of a continuous worm meshing with gear on each wheel. In such construction it is essential that the wheels wear uniformly and remain of the same circumference. Should the tread section of one or two wheels in a set be of different hardness than the remaining wheels, then the rate of wear is different and changes the common circumference. This change in size of wheels causes excessive strain on the worm and gear operating the wheels, with the result that the gears are frequently stripped or badly worn.

9 Chilled iron, then, possesses all the qualities that are required in heavy wheel service, and if the design is in keeping with the requirements, there is no occasion for any structural failure, regardless of the loading. In fact, the limiting factor for heavy concentrated

loads will always be the ability of the rail to carry the load without permanent injury to the surface, rather than any consideration on the part of the wheel. There are less chances for flaws, seams, etc., in chilled iron than in steel, and chilled iron also has the advantage on account of not being affected by crystallization, and so hard that the metal will not crush or flow under the heaviest concentrated loads.

10 In order to design properly, we must know the relation of the diameter of the wheel to the bearing power of the rail, the power required to propel the crane, and the flange strength. We must also know the relation of flange pressure to the load carried. With all these factors determined, the designing of wheels for crane service can be placed on a rational basis.

BEARING POWER OF CHILLED IRON WHEELS AND STEEL RAILS

11 A rational design for a wheel must necessarily take into consideration the nature of the track on which the wheel is intended to run. The tread must be wide enough to permit the use of a rail having a sufficient width of head to correspond with the loads which are to be carried.

12 A series of tests was conducted for the purpose of determining the behavior of steel rails under heavy loads on chilled iron wheels, and particularly the effect of the diameter of the wheel on the bearing power of the rail.

13 *Method Followed.* In making these tests, a 150-ton Riehle testing machine was used for applying the load, and a deflectometer for measuring the depressions. The wheel was set up on a steel block on the platform of the testing machine, and a bracket was clamped to the wheel to carry the deflectometer, as shown in Fig. 5. The rail was set up in an inverted position on top of the wheel, and the load was applied at the base of the rail. A load of 5,000 lb. was first applied to insure that all slack was taken up in the machine, and the deflectometer was then set at zero with the load in this position.

14 The wheels used were chilled iron, 15 in., 20 in and 33 in. in diameter. Test was begun with wheels rough, just as they came from the foundry, but the results obtained were so erratic that all wheels were ground to a true circle and again tested. Treads were ground straight with no taper. The 20-in. wheel was unintentionally ground slightly hollow in the center of the tread. A few M.C.B. chilled iron wheels, having a taper of 1 in 20 in the tread were also tested. An 85-lb. A.S.C.E. rail was used in taking observations.

Each test was made on a new spot in the rail, and also on the wheels and the permanent set were measured with a micrometer surface gage. To ascertain the advantage to be gained from the use of a flat top rail from extremely heavy loads, one portion of this rail was planed

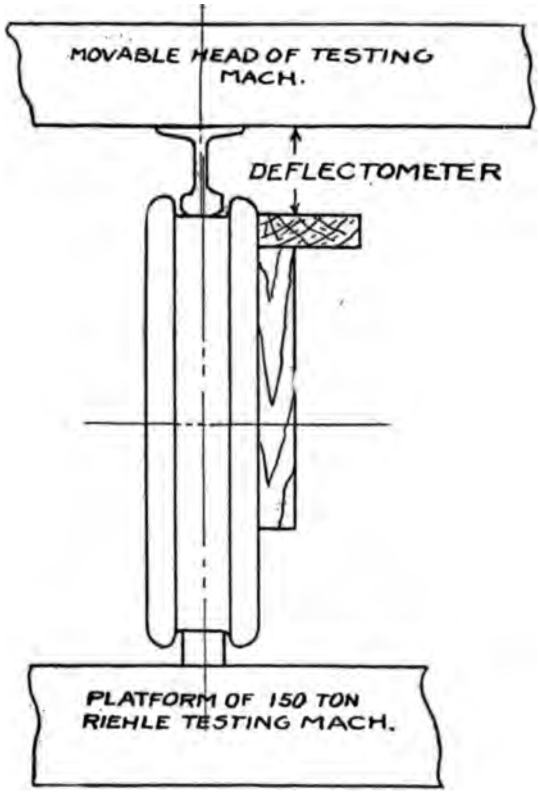


FIG. 5 METHOD OF APPLYING THE LOAD AND MEASURING DEPRESSION IN TESTING BEARING POWER OF RAILS

flat across the top and was tested in the same manner as the original section of the rail, which had a top radius of 8 in. The chemical analysis of the rail used was as follows:

	Per cent.
Carbon	0.763
Phos.	0.031
Mn.	0.83
Si.	0.15

15 The observations taken are tabulated in Tables 11-17, inclusive (see Appendix). Tests were made in duplicate and the

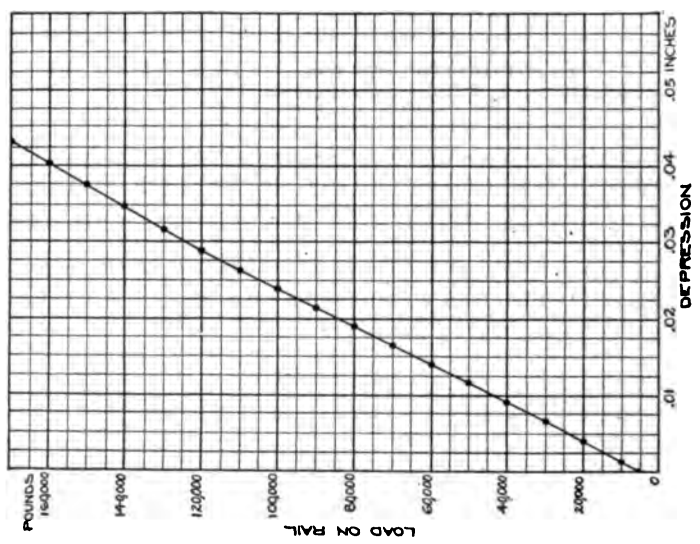


Fig. 6

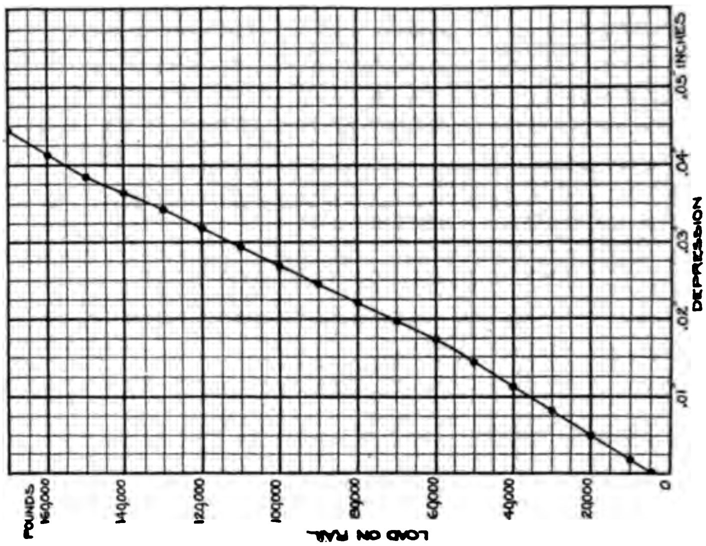


Fig. 7

Fig. 6 Curve showing Depression in 85-Lb. A.S.C.E. Rail under Load on 20-In. Chilled Iron Wheel.
Fig. 7 Curve showing Depression in 85-Lb. A.S.C.E. Rail under Load on 15-In. Chilled Iron Wheel

average values of these observations were used in plotting curves. Figs. 6, 7 and 8 show the curves plotted from the average values in Tables 11, 13 and 15 (Appendix). In placing the rail on the wheel, a piece of paper was inserted between the two, and in this way the actual area of the surfaces in contact at 200,000 lb. load was obtained. The first 5000 lb. pressure cut through the paper, so that this thickness of paper will not affect the deflectometer readings. The out-

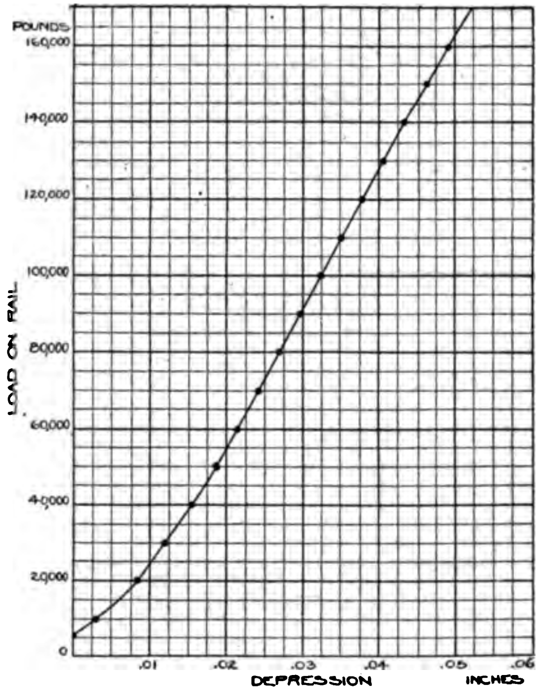


FIG. 8 CURVE SHOWING DEPRESSION IN 85-LB. A.S.C.E. RAIL UNDER LOAD ON 33-IN. CHILLED IRON WHEEL

lines of these depressions at 200,000 lb. pressure are shown in Fig. 9.

16 *Computing Results.* The diameter of the wheel is given in column 1, Table 1. The length of the bearing along the axis of the rail at 200,000 lb. pressure is given in column 3. This length was measured on paper impressions of contact. The areas of contact, column 2, were measured on the paper impressions by the planimeter. Column 4 contains the calculated depth the wheels sunk into the head of the rail. These depths were calculated from the length of the bearing and radii of the wheels by the formula:

$$\text{Indentation} = d = R - \sqrt{R^2 - \left(\frac{L}{2}\right)^2}$$

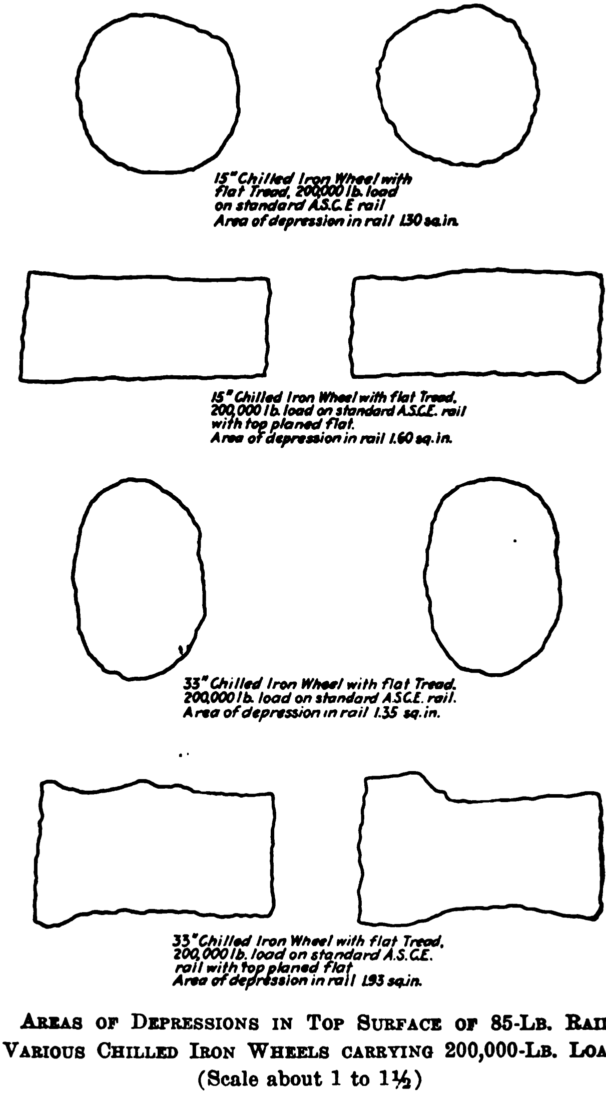


FIG. 9 AREAS OF DEPRESSIONS IN TOP SURFACE OF 85-LB. RAIL UNDER VARIOUS CHILLED IRON WHEELS CARRYING 200,000-LB. LOAD (Scale about 1 to 1½)

in which R = radius of the wheel and L = the length of bearing.

17 Chilled iron wheels are not appreciably flattened at any

d, and, therefore, all the depression is necessarily in the rail head. lumn 5 contains the permanent set in the rail head as measured the depth gage. The depressions were recorded and made of the permanent set, the temporary depression in the rail head d the temporary depression in the web of the rail. The total height the rail was measured with micrometer calipers before and after

3LE 1 BEARING OF WHEELS ON 85-LB. A.S.C.E. RAIL WITH 8-IN. TOP RADIUS, UNDER 200,000-LB. LOAD

Wheel	Area Bearing	Length Bearing	. Depth Contact or Indentation	Permanent Set in Rail	Pressure Per Sq. In.
n. straight tread chilled iron....	1.30	1.27	0.027	0.009	153,800
n. straight tread chilled iron....	1.34	1.30	0.0212	0.0115	149,200
n. straight tread chilled iron....	1.35	1.56	0.018	0.009	148,100
n. M. C. B. chilled iron........	1.60	1.77	0.024	0.0107	125,000
On 85-Lb. Flat Top Rail 2 In. Wide—Under 200,000-Lb. Load					
n. straight tread chilled iron....	1.60	0.800	0.0107	0.011	125,000
n. straight tread chilled iron....	1.68	0.840	0.0089	0.001	119,000
n. straight tread chilled iron....	1.93	0.965	0.0071	0.001	103,600

plying the loads from time to time, and there was little or no rmanent set in the web of the rail. The lower part of Table 1 ows results with top of rail planed flat, 2 in. wide. In order to npare the results obtained in these tests with results obtained in ier tests, the following is taken from Johnson's "Materials of

TABLE 2 CONTACT AREAS AND PRESSURES

Load in Lb.	33-In. Chilled Wheel		44-In. Steel Driver	
	Contact Area	Pressure per Sq. In.	Contact Area	Pressure per Sq. In.
5,000	0.07	71,500	0.07	71,500
10,000	0.12	83,300	0.15	66,700
15,000	0.16	93,750	0.19	79,000
20,000	0.22	90,900	0.25	80,000
25,000	0.27	92,600	0.30	83,300
30,000	0.35	85,750	0.36	83,300
40,000	0.40	100,000	0.47	85,000
50,000	0.44	113,600	0.50	100,000
60,000	0.57	105,000	0.68	88,300

nstruction," p. 508, the figures originally being obtained from Transactions of American Society of Civil Engineers," Vol. 32 394).

18 The tests in Table 2 show that the mean intensity of the stress over the area of contact was about 100,000 lb. per sq. in. for the chilled wheel and 86,000 lb. for the steel driver. It is evident that the steel driver was of softer material than the rail and the chilled iron wheel was harder. In the case of the chilled iron wheel the stress of 100,000 lb. per sq. in. represents the hardness of the rail and not that of the wheel. The elastic limit of the rail material was 50,000, from which we can assume that its ultimate compressive strength was about 100,000 lb. per sq. in., or exactly the same as the stress on the area of contact. The most remarkable element in these tests was the fact that not much less stress was produced over the smallest area of contact than over the largest, showing that the maximum stress does not vary much with the depth of the depression at the center. The stress produced was nearly uniform over the area of contact. No permanent set was produced in the rail in these experiments.

19 The Car Wheel, by Geo. L. Fowler, M.E., shows the following results from a series of tests:

TABLE 3 33-IN. CHILLED IRON WHEEL ON 100-LB. RAIL

Load	Area of Contact	Pressure per Sq. In.
500	0.055	9,000
1,000	0.070	14,000
10,000	0.120	83,000
19,000	0.190	100,000
30,000	0.230	130,000
100,000	0.830	120,000
150,000	1.210	124,000

20 Considering the data obtained in all tests for which we have information, we obtain approximately the following values for 33-in. chilled iron wheels on A.S.C.E. rail having 12-in. radius. (The higher loadings and bearing areas shown in this table are deduced from our tests by making a correction for the rail having an 8-in. top radius.) When the test was started we figured on using a standard 85-lb. A.S.C.E. rail but afterwards from calculations and checking the rail it was found that it had only an 8-in. top radius instead of 12 in.

Load	Area	Depth	Pressure per Sq. In.
5,000	0.072	0.00081	69,700
10,000	0.114	0.00129	87,800
20,000	0.203	0.00229	98,500

50,000	0.436	0.00492	114,800
100,000	0.777	0.00865	128,800
150,000	1.089	0.01229	137,800
200,000	1.383	0.01560	144,600
250,000	1.667	0.01888	150,000

21 The load carried by a flat tread wheel on a curved top rail produces an area of contact which is an ellipse. Let

$p = 3.1416$

d = depth of depression

r = radius of rail head

D = diameter of wheel

a = area of depression

$a = p\,\sqrt{2\,rd}\,\sqrt{dD}$

$a = p\,\sqrt{2 \cdot rd^2D}$

$a = 4.44\,d\,\sqrt{rD}$

22 In the experiments the radius of the rail head was 8 in. and the area was:

$$a = 12.56\,d\,\sqrt{D}$$

For rails having an actual radius of 12 in. the area would be:

$$a = 15.385\,d\,\sqrt{D}$$

For rails having a flat top whose width is w, the area is:

$$a = 2w\sqrt{Dd}$$

23 In Table 4, the first section shows bearing of straight tread chilled iron wheels on standard 85-lb. A.S.C.E. rail under 100,000 lb. load, giving area and depth of contact, permanent set in rail and pressure per square inch, on area of contact. Table 4, second section, gives the same information for a rail having a flat top 2 in. wide. In Table 5 the loads show the carrying capacity of the rail only and do not indicate the strength of the wheel. Loads given are 50 per cent of loads carried at the elastic limit in the rail as shown by a depression of 0.007 in. By curving the contour of the wheel tread to fit the rail, the same load can be carried on flat top rails, but where the gage dimensions are not accurately maintained, the hollow tread will be of doubtful value and probably would aggravate and cause greater distortion of the rail than is the case with flat treads.

24 Owing to the fact that a rail having a curved top is rolled or worn to a partially flat contour by the first few passages of a flat tread wheel over it, its bearing value in actual practice is much greater than the theoretical value assigned for a new rail.

THE EFFECT OF THE DIAMETER OF WHEEL ON POWER REQUIRED FOR LOCOMOTION

25 Whenever any load, no matter how small, is applied to the wheel on the rail, a certain depression or deflection takes place, and drawing a load over this rail is similar to drawing a load up an inclined plane of which the base is a horizontal line parallel to the base

TABLE 4 BEARING OF STRAIGHT TREAD CHILLED IRON WHEELS ON STANDARD 85-LB. A.S.C.E. RAIL UNDER 100,000-LB. LOAD

Diameter of Wheel	Area of Contact	Depth of Contact	Permanent Set in Rail	Pressure per Sq. In. on Area of Contact
12	0.737	0.0138	0.0068	135,800
16	0.745	0.0121	0.0051	134,200
20	0.753	0.0109	0.0039	132,800
24	0.761	0.0101	0.0031	131,400
30	0.769	0.0091	0.0021	130,000
33	0.777	0.0088	0.0018	128,800
36	0.785	0.0085	0.0015	127,400
ON FLAT TOP RAIL 2 IN. WIDE—UNDER 100,000-LB. LOAD				
12	0.950	0.0031	none	105,000
16	0.960	0.0027	none	104,000
20	0.970	0.0024	none	103,000
24	0.980	0.0022	none	102,000
30	0.990	0.0020	none	101,000
33	1.000	0.0019	none	100,000
36	1.010	0.0018	none	99,000

TABLE 5 LIMITING LOADS ON CRANE WHEELS

	0.00392-In. Indentation			0.00250-In. Indentation	
Diameter of Wheel	Length of Contact A.S.C.E. Rail	Load on New A.S.C.E. Rail	Load on Slightly Worn A.S.C.E. Rail	Length of Contact Flat Top Rail	Load on Flat Top Rail 2 In. Wide
12	0.434	23,000	46,000	0.347	78,300
16	0.501	26,600	53,000	0.400	90,300
20	0.561	29,800	60,000	0.448	101,000
24	0.614	32,600	65,000	0.490	111,000
30	0.687	36,400	73,000	0.548	124,000
33	0.720	38,150	76,000	0.575	130,000
36	0.752	39,900	80,000	0.600	135,000

of the rail and the surface a plane passed through the extreme point of contact between the wheel and the rail and tangent to the surface of the wheel at this point.

26 The two conditions are not exactly analogous since the inclined plane, by definition, is suppesed to be perfectly smooth and unyielding, while in the case of the steel rail under a heavy rolling

load, when the wheel advances, instead of climbing on top of the raised portion of rail in front of the depression on which the wheel is resting, the metal in the rail is squeezed downward until the bearing area reached is sufficient to sustain the resultant of the load and the tractive force applied.

27 In the case of a self-propelled moving machine, such as a crane, the tractive force is usually applied to the wheels through a shaft or axle by means of gears. In a drive of this variety, if we disregard friction in the bearings and gearing, the tractive force applied through the gearing is equivalent to a direct force applied parallel

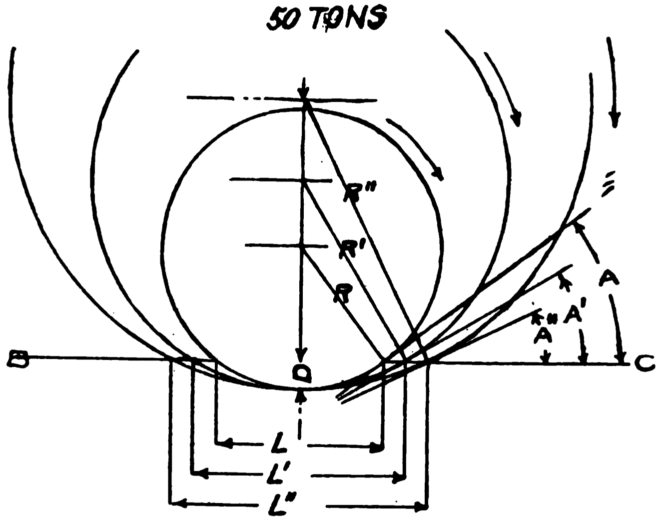


FIG. 10 DIAGRAM TO ILLUSTRATE THE EFFECT OF THE DIAMETER OF WHEEL ON POWER REQUIRED FOR LOCOMOTION

to the surface of the inclined plane, formed by the tangent plane at the extreme point of contact between the wheel and rail on the front side of the wheel, and making an angle A with the horizontal. As before stated, the condition here is not exactly the same as that encountered in the case of the inclined plane, since the wheel would roll up the inclined plane while in this case the metal must be pushed down and the wheel rolls along level. For this reason, the tractive force required to move the machine would be something less than W sine A, in which W equals the weight on the wheel. These tractive forces for wheels of different diameters would vary as the sines of the angles formed by a tangent line through the extreme point of contact with the horizontal. As an illustration let us con sider three wheels, 16 in., 24 in. and 33 in. in diameter (see Fig. 10)

28 Let R, R' and R'' represent radii of 16-in., 24-in. and 33-in

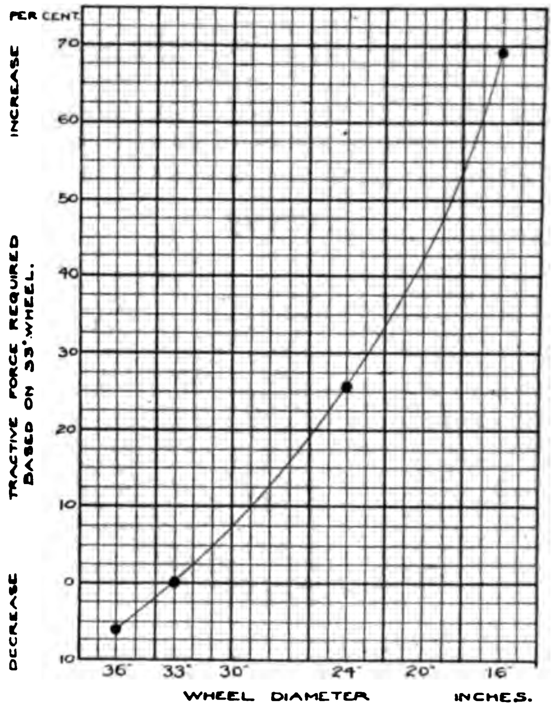


FIG. 11 PERCENTAGE OF TRACTIVE FORCE REQUIRED FOR VARIOUS DIAMETERS OF WHEELS COMPARED WITH 33-IN. DIAMETER, CHILLED IRON WHEELS

wheels resting on rail BC. Suppose a 50-ton load be applied to these wheels, making an indentation in the rail distance D. Draw lines tangent to these circles and at angles A, A' and A'' with BC.

$$\sin A = \frac{\frac{1}{2} L}{R} \quad \sin A' = \frac{\frac{1}{2} L'}{R'} \quad \sin A'' = \frac{\frac{1}{2} L''}{R''}$$

$D = 0.0121$ in. for 16-in. wheels; 0.0101 in. for 24-in. wheels; 0.0088 in. for 33-in. wheels.

$$\frac{1}{2} L = \sqrt{R^2 - \overline{R - D}^2}$$

$$\tfrac{1}{2} L' = \sqrt{R'^2 - \overline{R' - D}^2}$$

$$\tfrac{1}{2} L'' = \sqrt{R''^2 - \overline{R'' - D}^2}$$

ubstituting values of R, R', R'' and D and solving

$$\frac{L}{2} = 0.440 \text{ in.} \quad \frac{L'}{2} = 0.492 \text{ in.} \quad \frac{L''}{2} = 0.539 \text{ in.}$$

$$\text{Sin } A = 0.055 \quad \sin A' = 0.041 \quad \sin A'' = 0.0327$$

Tractive force 50 ton load for
- 16-in. wheel = 100,000 × 0.0550 = 5500 lb.
- 24-in. wheel = 100,000 × 0.0410 = 4100 lb.
- 33-in. wheel = 100,000 × 0.0327 = 3270 lb.

29 The tractive forces for these three sizes of wheels disregarding riction, would be 3270 lb., 4100 lb. and 5500 lb., respectively. Reducing these to percentages based on the 33-in. wheel we find that he 24-in. wheel would require 25 per cent more power and the 6-in. wheel 68 per cent more power than the 33-in. wheel under hese conditions. In Fig. 11 is shown a curve of the percentage ncrease of power required for wheels smaller than 33 in.

SAFE LOADS AND DEFLECTIONS OF RAILS

30 Let us consider the rail on ties at 18-in. centers and the wheels ıt 36-in. centers. We will assume that bearing plates are sufficiently arge to distribute the load over ties and that the support under the ies is firm but will yield just enough to permit a uniform distribution ıf the load between the ties.

31 Let

M = bending moment

S = safe unit stress in the rail — 16,000 for static loads

I = moment of inertia of rail

C = distance in inches from gravity axis to extreme fiber of rail

P = total load on one wheel

L = distance between centers of alternate ties = 36 in.

E = coefficient of elasticity of steel rail = 30,000,000

32 Starting with the general formula for flexure of beams

$$M=\frac{SI}{C}$$

and substituting proper values for 110-lb. rail, we have

$$M=\frac{16{,}000\times 55.2}{2.86}=308{,}800 \text{ in.-lb.}$$

which is the safe bending moment of a 110-lb. rail.

33 Consider the portion of the rail under one wheel as a continuous beam. By the terms of the conditions assumed, ½ P would be carried directly to the tie underneath the wheel; ½ P would be carried between the two adjacent ties. For this condition $M=\frac{\frac{1}{2}PL}{8}$. Substituting value of safe bending moment and solving for P

$$308{,}800=\frac{\frac{1}{2}P\times 36}{8};\quad P=137{,}200 \text{ lb.}$$

of this load one-half or 68,600 lb. is borne directly by the center tie, while 68,600 lb. is divided between the two adjacent ties.

34 The deflection under this load would be expressed by the formula $\frac{\frac{1}{2}PL^3}{192\,EI}$ substituting proper values in this formula, we have,

$$\text{Deflection}=\frac{0.5\times 137{,}200\times 36^3}{192\times 30{,}000{,}000\times 55.2}$$

solving deflection = 0.010 in.

35 From the bearing tests made, the average depression due to bearing alone was 0.0029 in. per 10,000 lb. load:

$$0.0029\times 13.7=0.0397$$

Combined deflection and depression, 0.0497.

36 Table 6 consists of these same quantities worked out for different weights of rails. In this discussion we have considered the stresses due to bending moments, alone, since these rails are capable

of withstanding much greater loads in bearing, than the safe loads herein computed for bending moments.

FLANGE STRENGTH

37 After a number of preliminary experiments, the method chosen was the use of toggles, applied against the wheel flanges under the ram of a 300,000-lb. Riehle testing machine, shown in Fig. 12. The position of the wheel and toggle is clearly shown in Figs. 12 and 13. Considerable difficulty was experienced in selecting the

TABLE 6 SAFE LOADS AND DEFLECTIONS OF RAILS UNDER STATIC LOAD

Weight of Rail, Lb.	Safe Bending Moment, Lb.	Safe Load, Lb.	Deflection Due to Bending Moment, In.	Depression Due to Bearing, In.	Combined Deflection and Depression, In.
110	308,800	137,200	0.010	0.0397	0.0497
100	248,800	110,000	0.010	0.0319	0.0419
90	217,600	96,000	0.0126	0.0278	0.0404
80	174,500	77,000	0.0119	0.0223	0.0342
70	142,500	63,000	0.0130	0.0182	0.0312
60	110,000	49,000	0.0251	0.0142	0.0393
50	82,000	36,000	0.0148	0.0104	0.0252
SAFE LOADS AND DEFLECTIONS OF RAILS UNDER LOADS SUBJECT TO MORE OR LESS IMPACT					
110	231,600	102,900	0.0075	0.0297	0.0372
100	186,600	82,500	0.0075	0.0239	0.0314
90	163,200	72,000	0.0094	0.0208	0.0302
80	130,800	57,000	0.0089	0.0167	0.0256
70	106,800	47,000	0.0097	0.0136	0.0233
60	82,500	36,000	0.0188	0.0106	0.0294
50	61,500	27,000	0.0111	0.0078	0.0189
SAFE LOADS FOR RAILS UNDER WHEELS SUBJECT TO VIOLENT IMPACTS					
110	154,400	68,600	0.005	0.0198	0.0248
100	124,400	55,000	0.005	0.0159	0.0209
90	108,800	48,000	0.0063	0.0139	0.0202
80	87,200	38,500	0.0059	0.0111	0.0170
70	71,200	31,500	0.0065	0.0091	0.0156
60	55,000	24,500	0.0125	0.0071	0.0196
50	41,000	18,000	0.0074	0.0052	0.0126

steel for the toggles that would take a temper sufficient to withstand the heavy pressure used without deforming to a serious degree or breaking in pieces. Fig. 14 shows the chilled iron in the tread of a double flange chilled iron crane wheel tested.

38 In testing these wheels, pressure was applied to the toggle until the weighing bar registered 80,000 lbs., when an accurate im-

pression was taken of the position of the toggle. From these impressions the angle formed by the arms of the toggle with the horizontal was measured, and the horizontal pressure against the flange computed. A diagram of the forces acting on the flange under test is shown in Fig. 15.

FIG. 12 300,000-LB. RIEHLE TESTING MACHINE SHOWING POSITIONS OF WHEEL AND TOGGLE WHEN TESTING STRENGTH OF FLANGES

39 Let

P = vertical pressure exerted by ram of testing machine
R and R' = reaction of flange along line of axis of toggles
H = horizontal components of this reaction
A = horizontal angle of thrust

esultant along axis of toggles

$$P : \sin 2a :: R : \sin 90 \text{ deg.} - a$$

$$P : \sin a \cos a :: R : \cos a$$

FIG. 13 TOGGLES USED IN TESTING STRENGTH OF FLANGES

$$P = \frac{2R \sin a \cos a}{\cos a} = 2R \sin a$$

$$R = \frac{P}{2 \sin a}$$

Resolving R into horizontal and vertical components

$$H : \sin 90 \text{ deg.} - a :: \tfrac{1}{2}P : \sin a$$

$$H : \cos a :: \tfrac{1}{2}P : \sin a$$

$$H \sin a = \tfrac{1}{2}P \cos a$$

$$P = \frac{H \sin a}{\tfrac{1}{2} \cos a} = 2H \ \frac{\sin a}{\cos a} = 2H \tan a$$

Fig. 14 Section of a Double Flange Crane Wheel showing Chilled Iron in Tread

It will be seen that each flange was subjected to a horizontal force H equal to $\frac{P}{2 \tan a}$. These forces are comparable to the forces acting on the flange in practice in case the inequality of rail spacing should cause the flange to climb part way upon the rail, or in case the wheel should climb through the impact caused by the trolley being suddenly started or stopped.

40 *Kind of Wheels Tested, Series I.* The wheels tested were double flange wheels with chilled tread and flanges. Wheels were 16 in., 20 in., 30 in., 33 in. and 36 in. in diameter. The 16 in., 20 in., 30 in. and 33 in. were cast with four thicknesses of flanges, viz., 1¼ in., 1¾ in., 2¼ in. and 2¾ in. This range of diameters and flange

thicknesses was considered sufficient to cover present day requirements, both as to strength and bearing area. The flange sections of the 36-in. wheels were not of the same design as those of the smaller diameters. Sections of two test wheels are shown in Figs. 16 and 17. Wheels used in series I were 5 in. or over in thickness through the throat along line of fracture. Since the metal in excess of 5 in. thickness in throat had no effect on the strength of the wheel, these wheels were all classed as being 5 in. through throat.

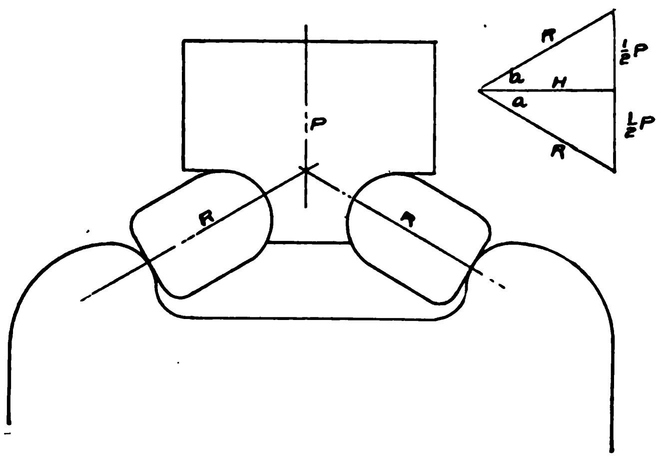


FIG. 15 DIAGRAM SHOWING FORCES ACTING ON THE FLANGE UNDER TEST

41 Nearly all wheels cracked through the chill at from 50 to 75 per cent of the load shown at ultimate failure. These cracks were not sufficient to cause the weighing beam of the testing machine to fall, and could rarely be seen until some time after they were first heard. Many of the wheels after final failure only showed open cracks, the broken piece of flange adhering at the end of the fracture. Final rupture was accompanied by a noise, explosive in violence. The first failure represents the ultimate strength of the chilled or white iron. The ultimate failure represents the rupture of the grey iron. The coefficient of elasticity is evidently different in the two kinds of iron, and the necessity for backing up the chilled iron with grey iron is clearly indicated. All fractures occurred through the throat of the flange and ranged downward through the tread at an angle approximating 30 deg. and ranged outward toward the face of

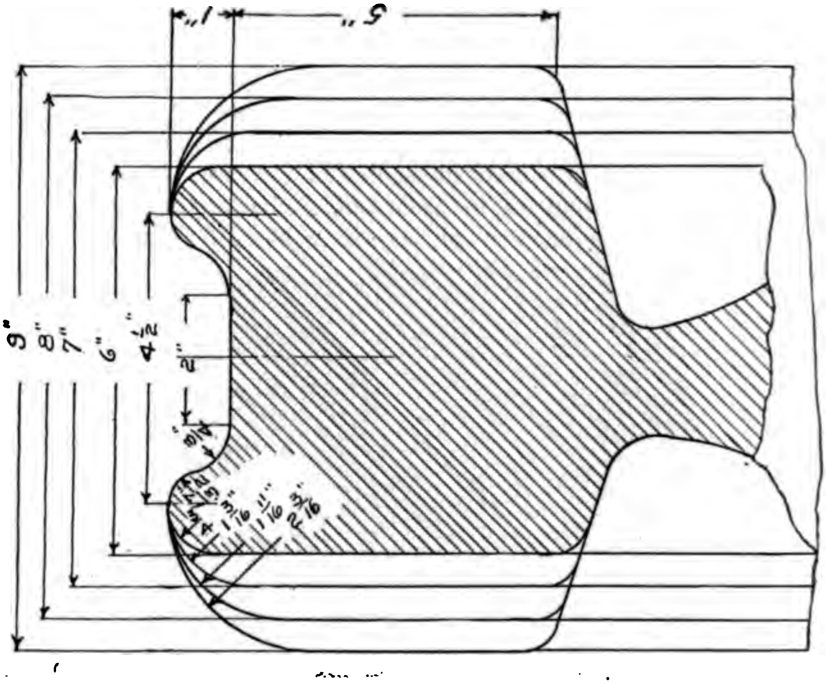


Fig. 17

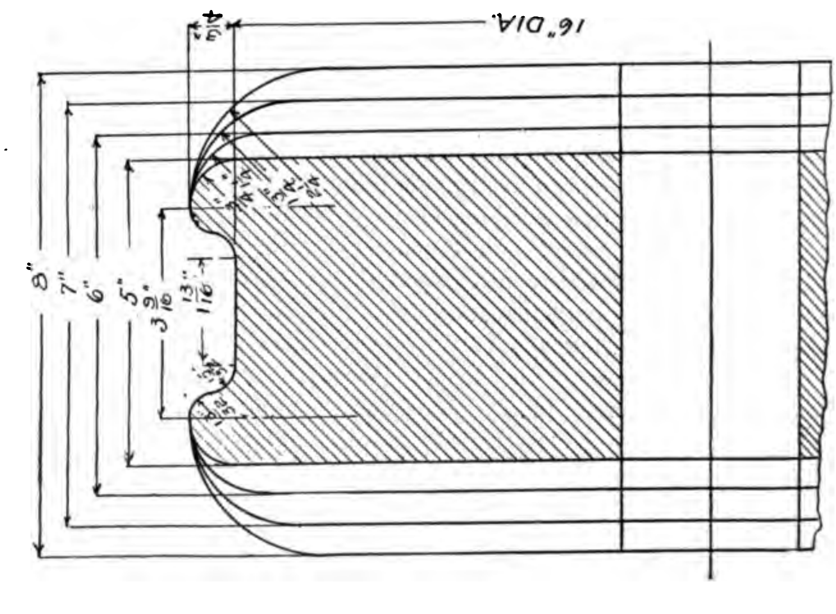


Fig. 16

e wheel. Dimensioned sketches of these fractures are shown in g. 18.

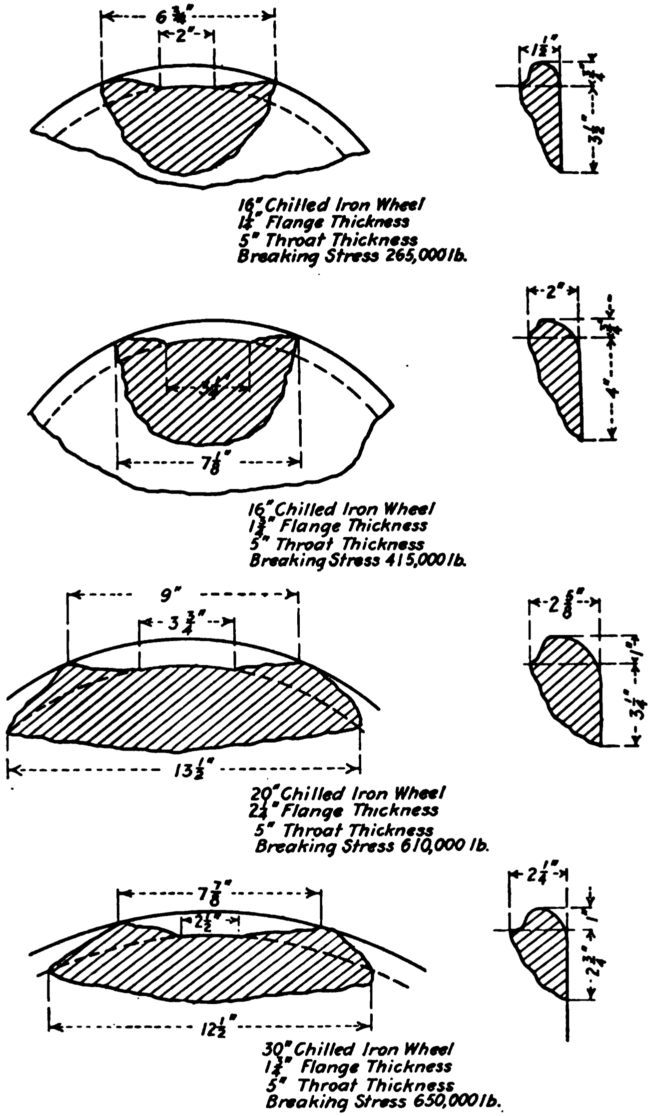


FIG. 18 TYPICAL FRACTURES OF VARIOUS CHILLED IRON CRANE WHEELS TESTED

42 The strength of flanges increases with the larger diameter of

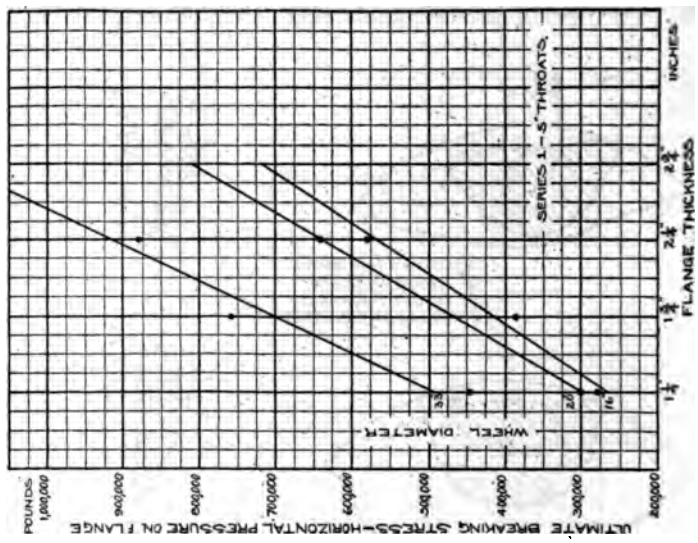


FIG. 20

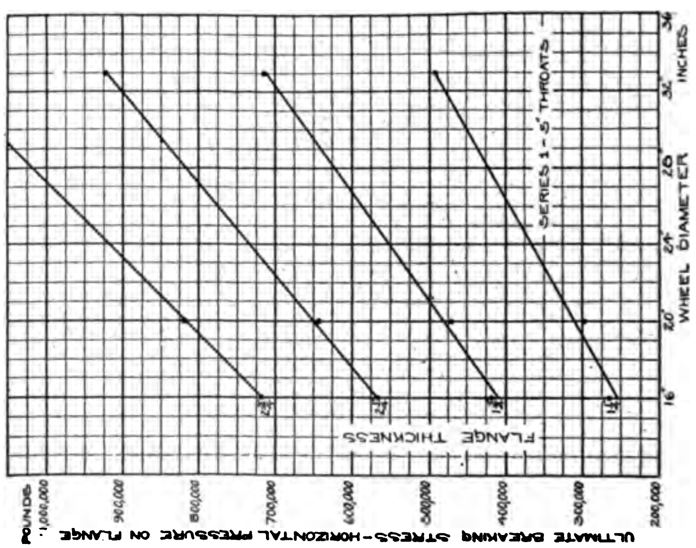
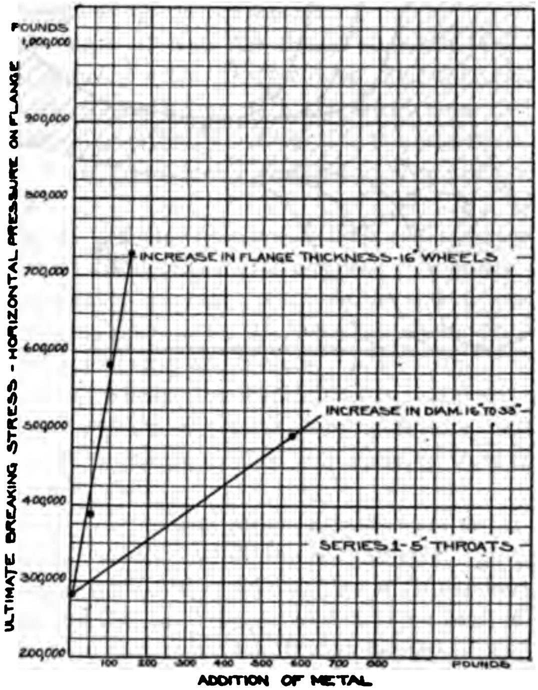


FIG. 19

FIG. 19 CURVES SHOWING EFFECT ON FLANGE STRENGTH PRODUCED BY INCREASE IN WHEEL DIAMETER, CHILLED IRON WHEELS

FIG. 20 CURVES SHOWING EFFECT ON FLANGE STRENGTH PRODUCED BY INCREASE IN FLANGE THICKNESS, CHILLED IRON WHEELS

›els and this rate of increase in strength with the increase in neter of wheel is higher with the heavier flanged wheels than h the thinner flanges. The curves in Fig. 19 show that from the -in. flange to the 2¾-in. flange, the rate of increase in strength igher with each successive flange thickness.



ɩ. 21 Curves showing Increase in Flange Strength of Chilled Iron Wheels Increase in Diameter compared with Increase of Flange Thickness

43 For a 1¼-in. flange between the limits of sizes of wheels ıted, there is an increase in ultimate strength of flange of 13,000 lb. · each 1 in. increase in diameter of wheel. For a 1¾-in. flange ere is an increase in ultimate strength of 17,000 lb. for each 1 in. rease in diameter. For a 2¼-in. flange there is an increase in imate strength of 19,000 lb. for each 1 in. increase in diameter. r a 2¾-in. flange there is an increase of 21,000-lb. for each 1 in. rease in diameter. These figures are all given in even thousands.

44 In a similar manner, a glance at curves in Fig. 20 will show

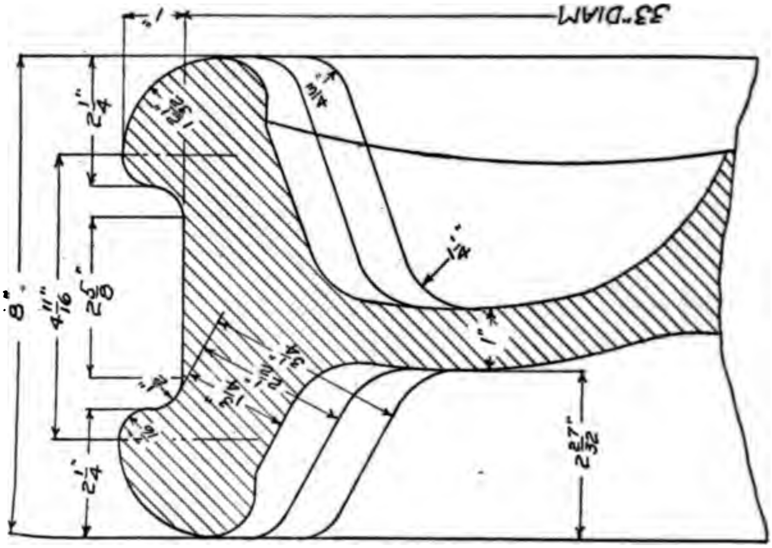


Fig. 23

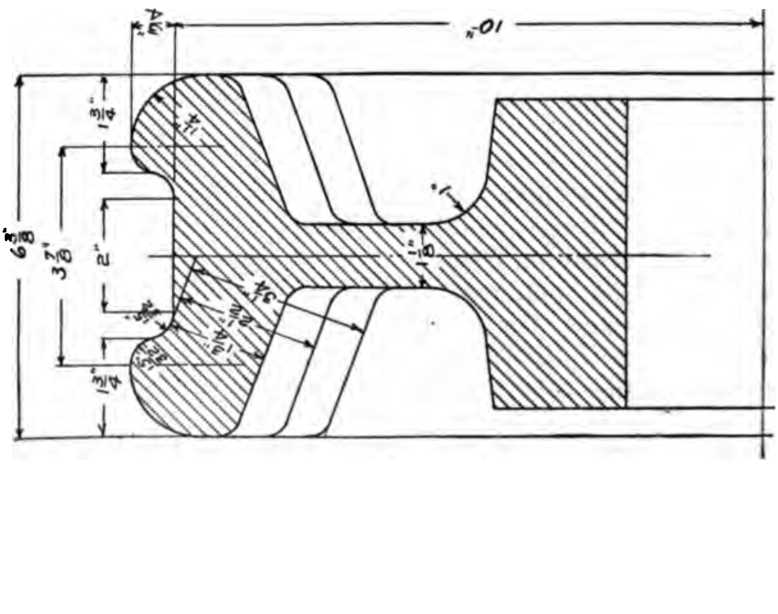


Fig. 22

Fig. 22 20-In. Double Flanged Chilled Iron Crane Wheels used in Tests 16, 17 and 18
Fig. 23 33-In. Double Flange Chilled Iron Crane Wheels used in Tests 7, 8 and 9

the increase in thickness of flange. It will be seen that the rate of increase of ultimate strength with increase in flange thickness is more rapid with the larger diameters of wheels. The 16-in. and 20-in. wheels were cast in a solid disk while the larger size wheels were cored out below the tread. For this reason the smaller wheels show more metal for their flange strength than they would if they were of the same design as the larger wheels.

45 In this series of tests the flange strength of the larger size wheels varies directly with the thickness, i.e., doubling the thickness doubles the strength but with the smaller sizes, doubling the flange thickness more than doubles the strength, the ratio being about 1:2.2. Final conclusions and general formulæ will be given under Series 2.

46 In Fig. 21 are shown curves which will afford a comparison of the amounts of additional metal required to increase the strength of a wheel a certain amount. One curve shows the increase in strength secured by increasing the wheel diameter, the other shows the increase by thickening the flanges. For reason of the difference in the design of the wheels, the real difference is actually greater than shown by these curves if all wheels were made cored out around the plates. The data obtained in this first series of tests are tabulated in Table 18 (Appendix).

47 *Series* 2. The second series of tests were made on standard size wheels, 16 in., 20 in. and 33 in. in diameter. In each of these diameters, wheels were tested having flange thicknesses of 1¼ in., 1¾ in., 2¼ in. and 2¾ in., respectively, and for each of these thicknesses, wheels were tested having throat depths of 1¾ in., 2½ in. and 3¼ in. The detail dimensions of the flanges and throats of two wheels are shown in Figs. 22 and 23. All wheels were tested to destruction. In these tests the load was applied through toggles in the same manner as in Series I, and the point of application of the toggle was ½ in. above the tread of the wheels.

48 The object of these tests was to determine the effect of varying the depth of the throat with each of the four flange thicknesses tested. The wheels of the first series were intended to be thick enough through the throat and tread to insure that all fractures would be through the flanges and not extend through the throat.

49 Together with the above described tests, other tests were made on 30 in. and 33 in. wheels with 1¼ in. flanges and with 5 in. and 1¾ in., 2½ in. and 3¼ in. throats, respectively with the point of application of the toggles ¼ in. above the tread. Tabulated

results showing diameters, flange and throat thicknesses, load applied at moment of fracture and components of this load along line of toggles, and also horizontal components, are shown in Tables 19, 20 and 21 (Appendix). In the tabulated figures the load applied was borne by both flanges but the resolved forces are calculated for a single flange. In Tables 19 and 20 is tabulated data obtained from the tests in which the load was applied ½ in. above the tread. In Table 21 is shown the data from tests in which the load was applied ¼ in. above the tread.

50 *General Results.* In general the results obtained from tests on the heavier flange sections gave more uniform results than those on the lighter sections. This was probably due to the fact that the chill or rather the percentage of chilled iron was more uniform in the cases of the heavier section.

51 As in the preceding series, there was in most cases a premonitory cracking when between 50 per cent and 75 per cent of the breaking load had been applied. These cracks were apparently in the chilled iron only and closed up so as to become invisible when the load was removed.

52 The results of these tests indicated that flange strength could be increased either by thickening the flange horizontally or by thickening the throat of the wheel. In round numbers, an increase of ½ in. in flange thickness was equivalent to an increase in ¾ in. in throat thickness. It is obvious, however, that in increasing the throat depth without altering flange thickness a point would soon be reached where further increase of throat depth would have little or no effect on flange strength, since the flange would not be strong enough to transmit the stress to the full depth of the throat. This condition was met in Series 1 in almost all cases and in several cases in Series 2.

53 The tests in which the load was applied ¼ in. from the tread showed about double the resistance to fracture of those in which the load was applied ½ in. above the tread. Although these points of application and areas of fracture were not measured closely enough to compute the unit stresses, the indication was that the action was similar to that in a cantilever beam. The ½ in. point of application was chosen since this was considered the severest possible condition, for if the wheel should climb this high it would probably climb on over the rail. For the 1¼-in. flanges the strength of the flange varied directly as the diameter of the wheel but with

flanges heavier than 1¼ in., the strength does not increase at quite as high a ratio as that of the diameters.

54 *Calculated Results.* Starting with the strength of a 16-in. wheel with 1¼-in. flange and 1¾-in. throat at 45,000 lb. as a basis, within the limits of these tests, the flange strengths may be said to vary as their diameters. Thus for any diameter of wheel with a 1¼-in. flange and 1¾-in. throat

$$S=45{,}000\times\frac{\text{diameter in inches}}{16}$$

55 The addition of ½ in. of metal to the flanges of this wheel was found to increase its strength to about the 1.03 power. The addition of ¾ in. of metal to the throat of the 1¼-in. flanged wheel netted practically the same gain in strength. Thus, with the addition of ½ in. of metal to the flanges or ¾ in. of metal to the throat, this formula would be

$$S=\left(45{,}000\times\frac{\text{diameter}}{16}\right)^{1.03}$$

56 Adding ½ in. of metal to the flanges and ¾ in. of metal to the throat would have the effect of raising this quantity to the 1.028th power twice and our formula would then become

$$S=\left[\left(45{,}000\times\frac{\text{diameter}}{16}\right)^{1.03}\right]^{1.03}$$

For 16-in. wheel with 1¾-in. flange and 1¾-in. throat

$$S=45{,}000^{1.03}=62{,}000$$

For 16-in. wheel with 2¼-in. flange and 1¾-in. throat or 1¾-in. flange and 2½-in. throat we would have

$$S=(45{,}000^{1.03})^{1.03}=62{,}000^{1.03}=86{,}400$$

For 16-in. wheel with 2¾-in. flange and 1¾-in. throat or 2¼-in. flange and 2½-in. throat or 1¾-in. flange and 3¼-in. throat we would have

$$S=86{,}400^{1.03}=121{,}500$$

For 20-in. wheels

$$S=\left(\frac{20}{16}\times45{,}000\right)=56{,}250 \text{ for 1¼-in. flange and 1¾-in. throat}$$

$$S=56{,}250^{1.03}=78{,}100 \text{ for 1¾-in. flange and 1¾-in. throat}$$

The preceding solutions will illustrate the manner of using this

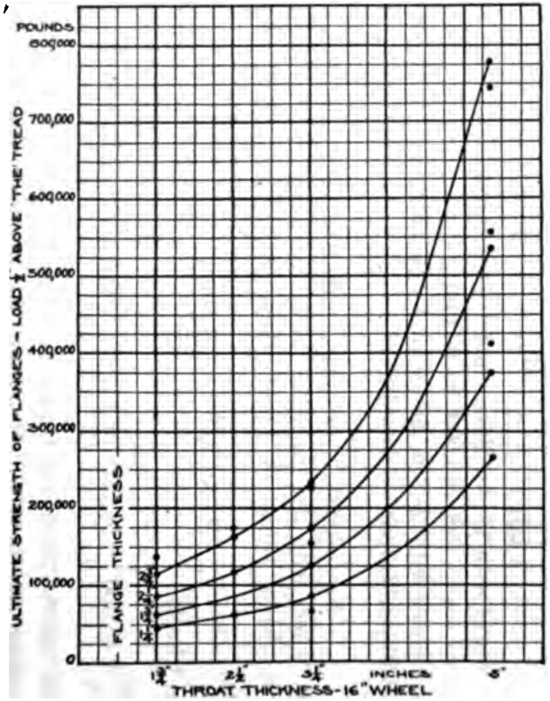


FIG. 24

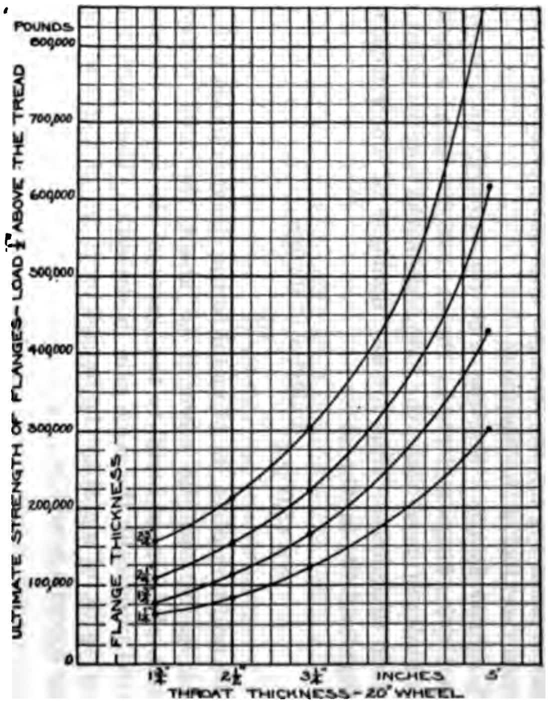


FIG. 25

FIG. 24 ULTIMATE STRENGTH OF FLANGES OF 16-IN. CHILLED IRON WHEELS WITH VARIOUS FLANGE AND THROAT THICKNESSES
FIG. 25 ULTIMATE STRENGTH OF FLANGES OF 20-IN. CHILLED IRON WHEELS WITH VARIOUS FLANGE AND THROAT THICKNESSES

formula. The 33-in. or any intermediate sizes would be approached in the same manner.

57 In Figs. 24, 25 and 26 are plotted curves using values calculated by the above formula. The points obtained by the formula are shown solid. The observed results of the actual tests seem to vary from this rule; the curves have been shifted slightly from the calculated value toward the test result.

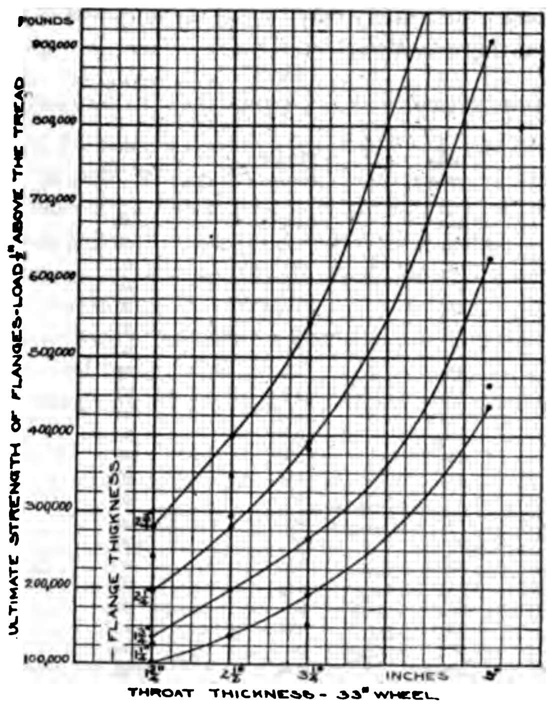


FIG. 26 ULTIMATE STRENGTH OF FLANGES OF 33-IN. CHILLED IRON WHEELS WITH VARIOUS FLANGE AND THROAT THICKNESSES

58 *Conclusions.* The line of fracture was usually at an angle of about 30 deg. with the plane of the wheel and the length of the fracture was roughly proportional to the flange thickness, i.e., a thick flange tends to produce a long fracture.

59 For consistent design there should be a fixed relation between flange thickness and throat thickness. Stated as a proportion, flange thickness is to throat thickness as two is to three. Stating

this relation in another way—the addition of ½ in. of metal to the flange is equivalent to adding ¾ in. of metal to the throat.

60 With wheels of different diameter, flange strength varies approximately as their diameters, other conditions remaining the same. The addition of ½ in. of metal to the flanges of a wheel or ¾ in. to the throat of a wheel raises its strength to the 1.03 power.

61 In general the results obtained demonstrated that it was possible to design wheel flanges of chilled iron with absolute certainty that they would safely carry loads far in excess of the greatest used in present day practice.

TABLE 7 SAFE STRENGTH OF CRANE WHEEL FLANGES FACTOR OF SAFETY, 5

Diameter Inches	Flange Inches	Throat Inches	Rail, Lb.	Strength
12	1	1¼	40	3,000
	1¼	1½	50	5,000
	1½	2	60	8,000
16	1	1¼	40	5,000
	1¼	1½	50	8,000
	1½	2	60	11,000
20	1	1½	50	8,000
	1¼	1⅞	60	11,000
	1½	2¼	80	15,000
24	1¼	1¾	60	12,000
	1½	2⅛	80	18,000
	1¾	2½	100	25,000
30	1¼	1¾	60	16,000
	1½	2	80	22,000
	1¾	2½	100	32,000
	2	3	100	47,000
	2¼	3½	150	69,000
33	1¼	1¾	60	18,000
	1½	2	80	24,000
	1¾	2½	100	35,000
	2	3	100	53,000
	2¼	3½	150	78,000
36	1¼	1¾	60	20,000
	1½	2	80	26,000
	1¾	2½	100	38,000
	2	3	100	56,000
	2¼	3½	150	86,000

62 That the limit of the bearing strength of the wheel itself is far in excess of anything that has yet been built was shown by tests made on 12-in. and 16-in. single plate wheels from which the flanges had been broken. Loads of 300,000 lb. were applied on the tops of these wheels without an appreciable deflection or flattening of the surface of the tread. This load was carried entirely by the plate and brackets of the wheel without any support from the flanges.

63 Table 7 gives the safe strength of crane wheel flanges using a factor of safety of five. This covers wheels of 12-in., 16-in., 20-in., 24-in., 30-in., 33-in. and 36-in. diameter, and flanges having thicknesses of 1 in., 1¼ in., 1½ in., 1¾ in., 2 in. and 2¼ in., and throat thicknesses of 1¼ in., 1½ in., 2 in., 2½ in., 3 in. and 3½ in. Figs. 27 to 32 inclusive show the curves oi safe strength of various thicknesses of flanges on various diameters of wheels.

STRENGTH OF FLANGES, M. C. B. WHEELS

64 During the last 50 years there has been added every decade, 10 tons to the car capacities. During this period the car capacities have increased so that nearly all new freight cars built are of 100,000 lb. to 120,000 lb. capacity, and quite a few ore cars are being constructed of 140,000 lb. capacity. The thickness of the flange on these 33-in. wheels has been practically the same on the light 10 and 15-ton capacity cars, as used today on the heavy ore cars of 70 tons capacity. There are fewer flange failures today than ever before, notwithstanding the great increase in flange pressures from the heavy capacities of modern equipment, showing the phenomenal strength of chilled iron wheels.

65 The flange pressure in a four-wheel truck amounts to the following:

Capacity, Lb.	Load on Wheel, Lb.	Flange Pressure Due to Curvature, Lb.	Possible Maximum, Lb.
20,000	5,000	3,750	7,500
60,000	12,000	9,000	18,000
80,000	15,500	11,625	23,250
100,000	19,000	14,250	28,500
140,000	25,000	18,750	37,500

The possible maximum flange pressure is caused by combining miscellaneous items of impacts, centrifugal force, etc., which may double the amount ordinarily required for changing the direction of the truck at high speeds.

66 All parts going to make up a railway system, such as roadbed, bridges, car, track or structure have been materially increased during the growth of the American railway system, and as the flange of the wheel is the most remarkable exception to this rule, the Association of Manufacturers of Chilled Car Wheels have recently requested an increase in the flange thickness of wheels so as to give ample factor of safety on the wheel.

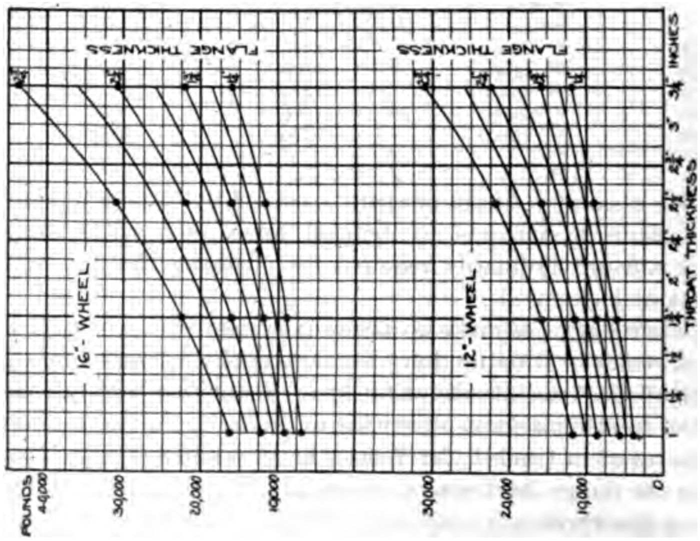


FIG. 27

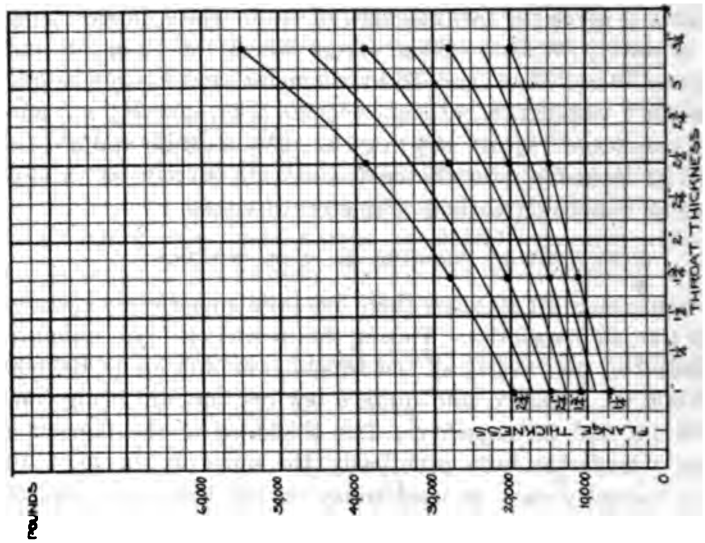


FIG. 28

FIG. 27 SAFE STRENGTH OF 12-IN. AND 16-IN. CHILLED IRON CRANE WHEEL FLANGES UNDER STATIC LOADS. FACTOR OF SAFETY, 5

FIG. 28 SAFE STRENGTH OF 20-IN. CHILLED IRON CRANE WHEEL FLANGES UNDER STATIC LOADS. FACTOR OF SAFETY, 5

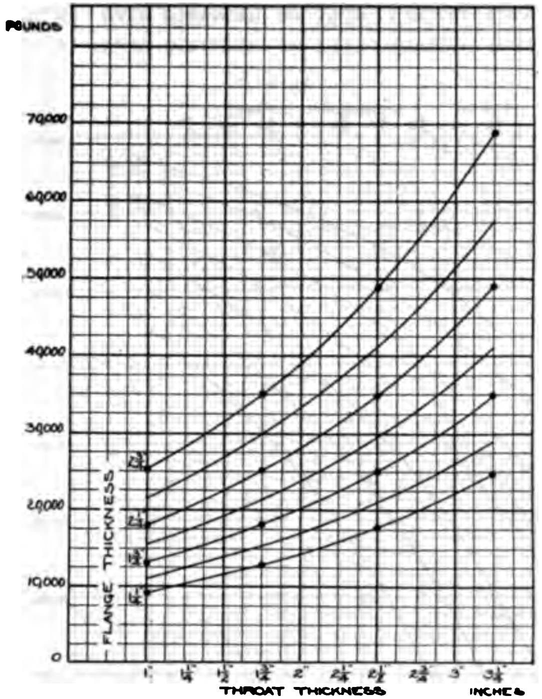


FIG. 29

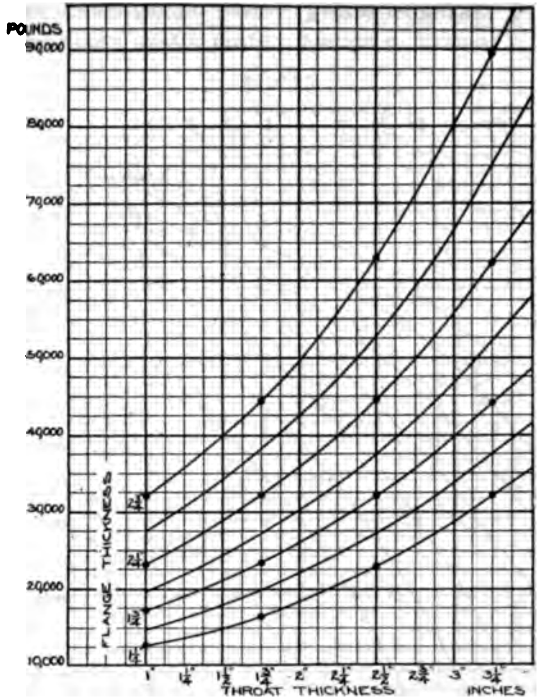


FIG. 30

FIG. 29 SAFE STRENGTH OF 24-IN. CHILLED IRON CRANE WHEEL FLANGES UNDER STATIC LOADS. FACTOR OF SAFETY, 5

FIG. 30 SAFE STRENGTH OF 30-IN. CHILLED IRON CRANE WHEEL FLANGES UNDER STATIC LOADS. FACTOR OF SAFETY, 5

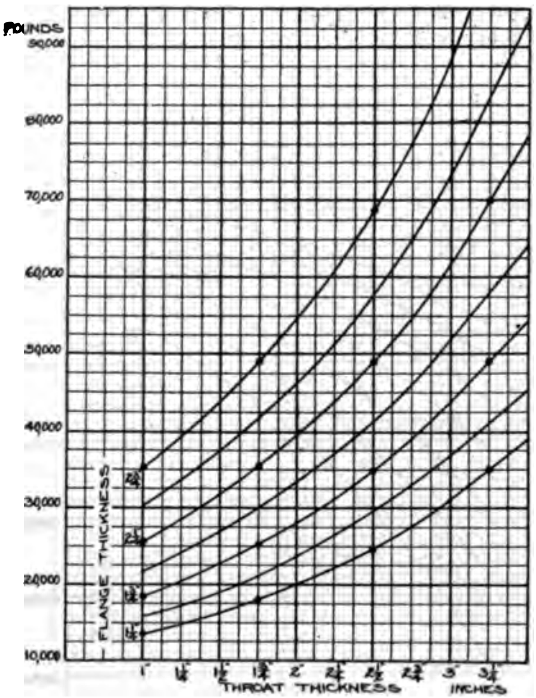


Fig. 31

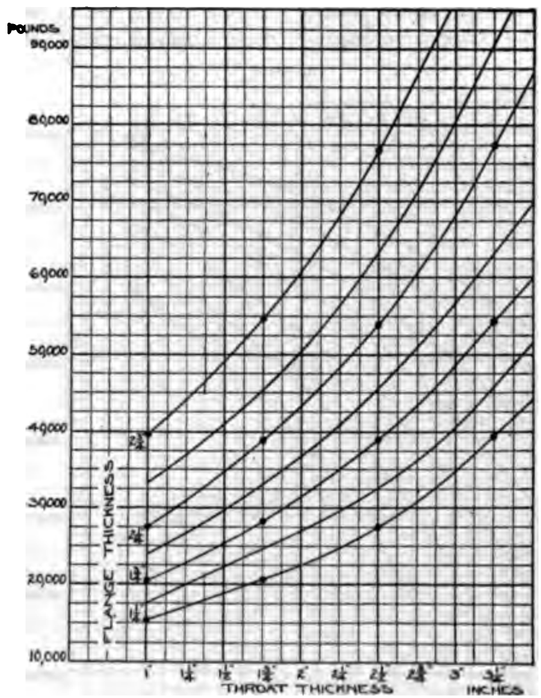


Fig. 32

Fig. 31 Safe Strength of 33-In. Chilled Iron Crane Wheel Flanges under Static Loads. Factor of Safety, 5
Fig. 32 Safe Strength of 36-In. Chilled Iron Crane Wheel Flanges under Static Loads. Factor of Safety, 5

67 The ultimate strength of 33-in. M.C.B. wheel flanges where the load is applied ½ in. above the tread is as follows:

Wheel, Lb.	Flange Thickness M.C.B. Standard Measured ⅜ In. above Base Line, In.	Throat Thickness, In.	Ultimate Strength, Lb.
625	1 15/64	1 27/32	90,000
675	1 15/64	2 3/32	110,000
725	1 15/64	2 3/32	110,000

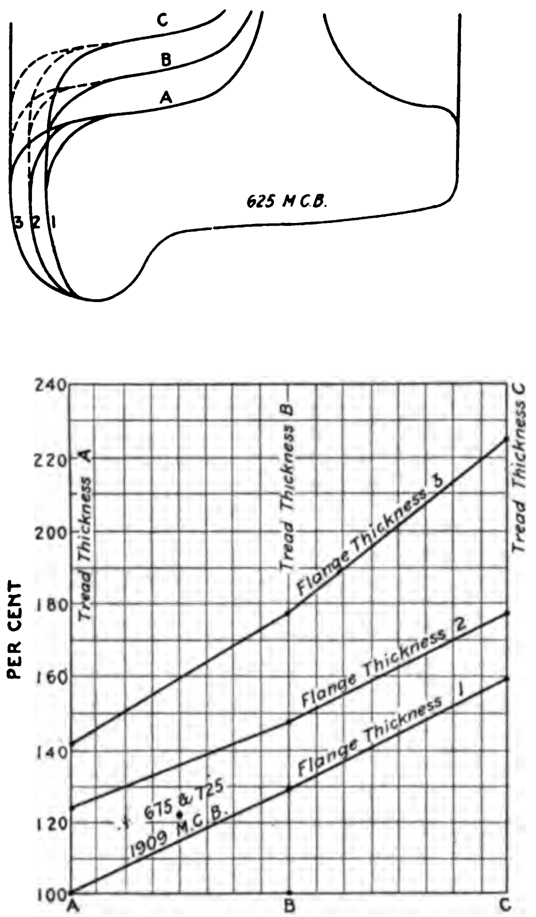


FIG. 33 RELATIVE STRENGTH OF FLANGES FOR VARIOUS THICKNESSES

The strength of flange is the same on wheels used for 80,000 lb. and 100,000 lb. capacity cars, and the difference in weight of 675 lb.

and 725 lb. wheels is in the thickness of plates of the two wheels, as the tread sections are the same thickness.

68 From the foregoing tests there are shown in Fig. 33 the relative increase in strength of flanges for various thicknesses of flanges and tread sections. The inner lines are the contour of the 625 lb. M.C.B. flange and tread. Lines 2 and 3 are ¼ in. and ½ in. increase in flange thickness, and lines *B* and *C* are ½ in. and 1 in. increase in thickness of tread.

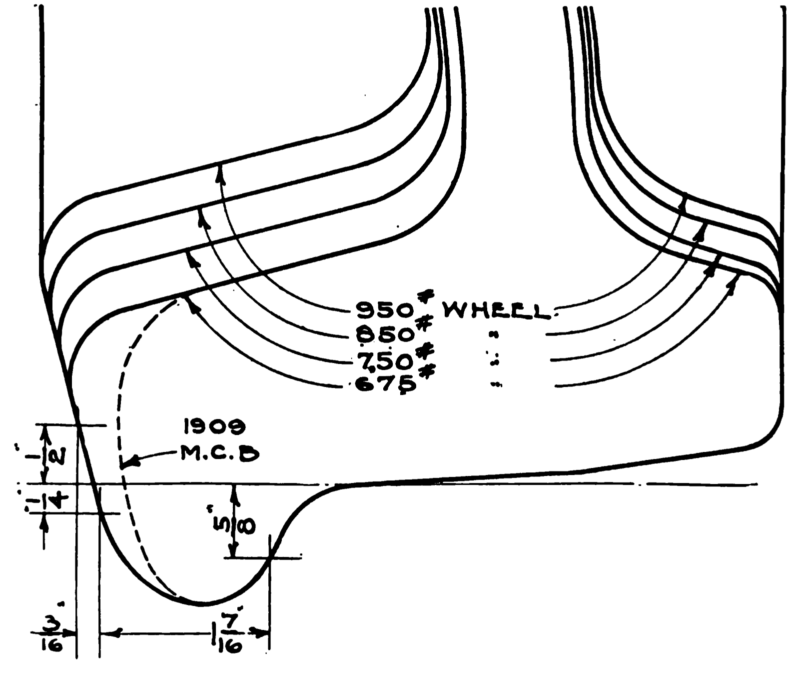


FIG. 34 PROPOSED THICKNESS OF FLANGE FOR M. C. B. WHEELS

69 The flanges that the Association of Manufacturers of Chilled Iron Car Wheels are recommending on various wheels are shown in Fig. 34, and their use and ultimate strengths are as follows where the load is applied ½ in. above the tread:

Weight of 33-In. Wheels, Lb.	Used Under Cars Maximum Gross Load Not to Exceed, Lb.	Maximum Braking Power not to Exceed, Lb.	Ultimate Strength of Flange, Lb.
675	112,000	40,000	110,000
750	161,000	40,000	125,000
850	200,000	50,000	155,000
950	280,000	65,000	185,000

70 *Wheels with Worn Flanges.* Arguments have been presented that the thickness of flange does not increase the strength of flanges as shown by the tests and calculations, claiming that worn flanges do not break more frequently than those with comparatively little wear. This idea originated from records of wheels held for replacement from which all flanges worn to the M.C.B. limits are excluded because they are not replaceable. In order to demonstrate the relation between the new and the worn flanges, tests were made on 30-in. wheels with 1¼-in., 1½-in. and 1¾-in. flanges ground out on the inside of the flange to the contour of a badly worn flange. These thicknesses after grinding were 27/32 in.,

TABLE 8 ULTIMATE STRENGTH OF WORN WHEEL FLANGES, 30-IN. WHEEL LOAD ⅜-IN. FROM TREAD

Test	Flange Thickness, In.	Angle Applied	Sin *A*	Tan *A*	Load, Lb.	Component Along Toggle	Horizontal Component
1	27/32	22° 21′	0.3800	0.4111	35,480	46,700	43,000
2	27/32	21° 7′	0.3600	0.3862	33,860	47,000	43,800
3	1 3/16	21° 11′	0.3450	0.3676	42,120	61,000	57,000
4	1 3/16	21° 7′	0.3600	0.3862	45,700	63,000	59,000
5	1 ⅜	18° 40′	0.3200	0.3378	51,360	80,200	76,000
6	1⅜	28° 42′	0.4800	0.5475	70,690	73,600	64,500

TABLE 9 COMPARISON OF NEW AND WORN 30-IN. WHEEL FLANGES

New Flange Thickness, In.	Worn Flange Thickness, In.	New Flange Strength	Worn Flange Strength	Per Cent Thickness Lost	Per Cent Strength Lost
1¼	27/32	80,000	43,400	32	45
1½	1 3/16	100,000	58,000	21	42
1¾	1⅜	115,000	70,000	21	39

1 3/16 in., and 1 ⅜ in. The fillet in all cases was about ¼ in. radius. Tabulated data from these tests are shown in Tables 8 and 9. These flanges were broken in the same manner as those in Series 1 and 2, but the load was applied ⅜ in. above the tread of the wheel.

71 Fractures in these tests were without premonitory cracking

or else occurred almost immediately after the first crack observed. As a rule, the planes of fracture were shorter than was the case with new flange sections, and the plane of fracture was at an angle of about 45 deg. instead of an angle of 30 deg. as was the case with the new flanges. The per cent reduction in strength of the flanges was greater than the per cent reduction of section of metal in the flange and this difference was greater in the case of the thin flanges. In the case of the new flanges it was found that the addition of ½ in. of metal to the flange raised the strength to the 1.03 power. In the case of the worn flanges, ½ in. metal on the flange raised the strength to the 1.038 power in the one side of wheel tested. The number of tests made, however, was not sufficient to establish this fact positively.

72 While the strength of flanges on 33-in. M.C.B. wheels has no direct bearing on the flanges of crane wheels, this short article is given to show that chilled iron possesses all the qualities that are required in heavy wheel service, and that a design can be made to carry any load if all the requirements are taken into consideration.

73 The value of chilled iron for wheels to carry the heaviest concentrated loads is being more and more recognized. This is shown in crane work and other locations where loads of 100,000 lb. and upwards are required per wheel. An inquiry for wheels for use under a heavy traveling crane reads as follows: "The steel wheels have been so unsatisfactory that it led us to inquire of you relative to the furnishing of regular chilled cast iron wheels for this purpose." Chilled iron wheels were furnished and have served with satisfaction for three years. This indicates that for heavy concentrated loads, chilled iron has superior qualities, and that the only limit to car capacity is the ability of the rail to carry the load.

74 Heretofore a good many crane builders have used the standard M.C.B. flange on wheels for crane service. This certainly is not correct, for in railroad service the thickness of flange is limited on account of crossings, switches, guard rails, etc., while in crane service, where the load carried by the wheel and the resulting flange pressure is several times greater than encountered in railroad service, there is unlimited space for designing flanges in proportion to the work which they must perform. Furthermore, for heavy cranes where the expense of changing wheels is large, and in case of renewals keeps the crane idle, an ample factor of safety should be used. This is also essential on wheels having two flanges, when the rail is out of level, giving excess work on one wheel, or the track is out of align-

ment, which changes the track gage, and one flange receives considerably more stress than calculated.

STANDARD DESIGN FOR CRANE WHEELS

75 The foregoing tests furnish data from which crane manufacturers can decide for any given condition the rail to be used, the

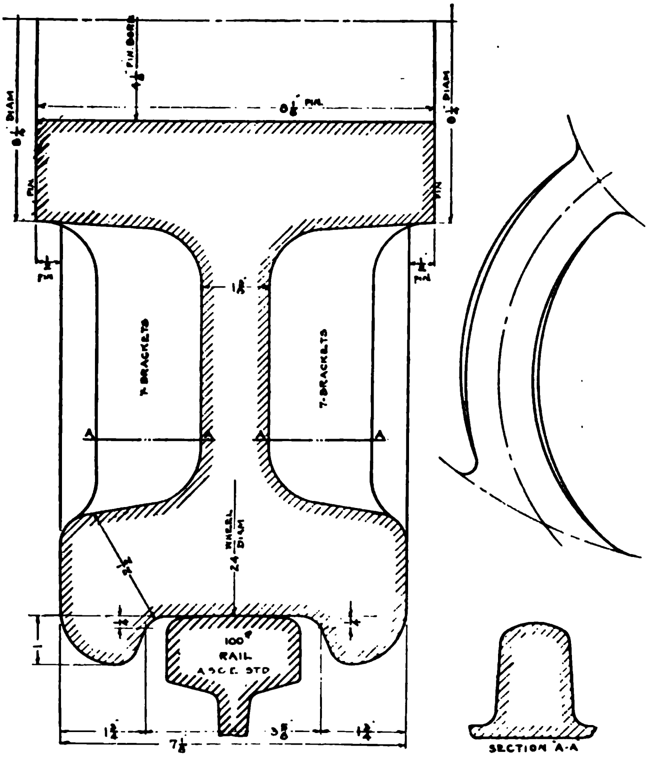


FIG. 35 24-IN. 640-LB. DOUBLE FLANGE CHILLED IRON CRANE WHEEL, SINGLE PLATE TYPE. FOR MAXIMUM VERTICAL LOAD 34,000 LB. MAXIMUM SAFE FLANGE PRESSURE 25,000 LB.

diameter of wheel and proper flange section. The diameter of wheel is based on economic power consumption, necessary clearances, etc., for the particular crane or tower in question. The flange pressure cannot be calculated directly, but on account of irregularities in track and other operating conditions, it is necessary that the section of flange shall safely resist a horizontal pressure equal to 75 per cent of the vertical load. The safe vertical load for any wheel is largely based upon the section of flange that will safely guide the load rather than upon the ability of the body of the wheel to sustain the load.

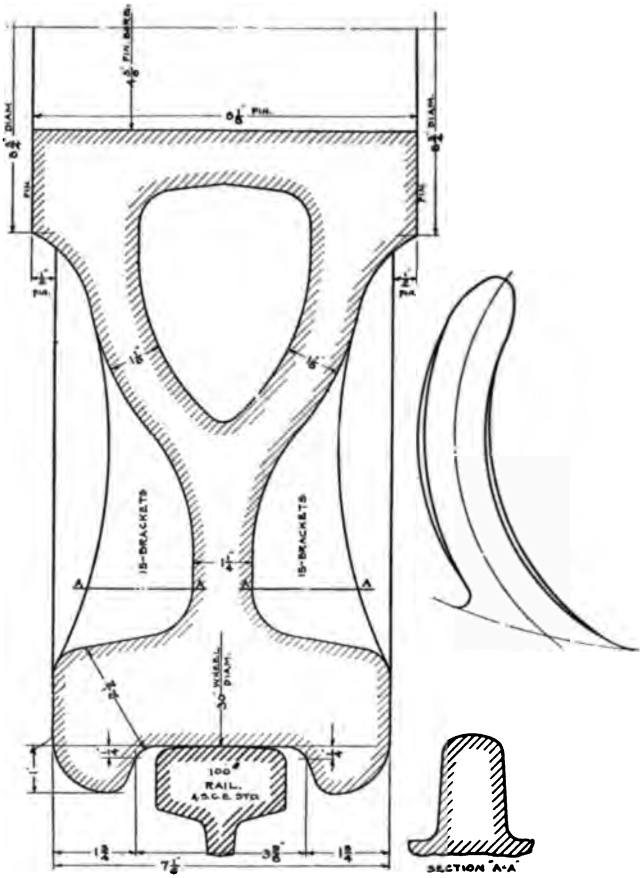


FIG. 36 30-IN. 875-LB. DOUBLE FLANGE CHILLED IRON CRANE WHEEL, DOUBLE PLATE TYPE. FOR MAXIMUM VERTICAL LOAD 43,000 LB. MAXIMUM SAFE FLANGE PRESSURE 32,000 LB.

76 The use of uniform standards would eliminate the cost of special patterns and equipment (which often amount to as much or more than the wheels themselves), and permit of prompt manufacture. As a step in this direction, a complete set of designs has

been prepared ranging from 12-in. to 36-in. wheels, each diameter being represented by several different designs for light, medium and heavy operating conditions. Table 10 is a tabulated list of wheels of various flange and throat or tread thicknesses, as well as the safe load and flange pressure for each design. Detail drawings of each type of wheel are shown in Figs. 35 and 36.

TABLE 10 DIAMETER AND WEIGHTS OF DOUBLE FLANGE CRANE WHEELS FOR VARIOUS LOADS AND FLANGE PRESSURES

	Diameter of Wheel, In	Weight, Lb.	Weight of Rail Used, Lb.	Tread of Wheel, In.	Height of Flange, In.	Thickness of Flange, In.	Thickness of Throat, In.	Maximum Safe Flange Pressure, Lb.	Maximum Safe Vertical Load, Lb.
Single Plate Type	12	95	40	2¼	¾	1	1¼	3,000	4,000
	12	130	50	2½	¾	1¼	1½	5,000	7,000
	12	165	60	2¾	¾	1½	2	8,000	11,000
	16	145	40	2¼	¾	1	1¼	5,000	7,000
	16	200	50	2½	¾	1¼	1½	8,000	11,000
	16	250	60	2¾	¾	1½	2	11,000	15,000
	20	250	50	2¾	¾	1	1½	8,000	11,000
	20	325	60	3	1	1¼	1⅞	11,000	15,000
	20	400	80	3¼	1	1½	2¼	15,000	20,000
	24	415	60	3	1	1¼	1¾	12,000	16,000
	24	530	80	3¼	1	1½	2⅛	18,000	24,000
	24	640	100	3⅝	1	1¾	2½	25,000	34,000
Double Plate Type	30	650	60	3	1	1¼	1¾	16,000	22,000
	30	760	80	3¼	1	1½	2	22,000	30,000
	30	875	100	3⅝	1	1¾	2½	32,000	43,000
	30	1,000	100	3⅝	1	2	3	47,000	63,000
	30	1,275	150	4⅞	1	2¼	3½	69,000	92,000
	33	740	60	3	1	1¼	1¾	18,000	24,000
	33	850	80	3¼	1	1½	2	24,000	32,000
	33	1,040	100	3⅝	1	1¾	2½	35,000	46,000
	33	1,200	100	3⅝	1	2	3	53,000	71,000
	33	1,525	150	4⅞	1	2¼	3½	78,000	104,000
	36	850	60	3	1	1¼	1¾	20,000	27,000
	36	985	80	3¼	1	1½	2	26,000	35,000
	36	1,200	100	3⅝	1	1¾	2½	38,000	51,000
	36	1,425	100	3⅝	1	2	3	56,000	75,000
	36	1,800	150	4⅞	1	3½	3½	86,000	115,000

APPENDIX NO. 1

Column 1 of Tables 11 to 17 is made up of the loads applied from 5000 to 200,000 lb. by 10,000 lb. gradation; columns 2 and 3 are made up of deflectometer readings, column 4 being the average for figures given in columns 2 and 3. Deflections in columns 2 and 3 are cumulative and the difference between any two successive readings represents the depression for that particular increment of load. These differences are given in columns 5 and 6 and the averages of columns 5 and 6 are shown in column 7. Table 17 gives the results of a similar test by using a 33-in. M.C.B. chilled iron wheel, the tread being cone-shaped; or having a taper of 1 in 20.

TABLE 11 DEPRESSION OF 85-LB. A.S.C.E. RAIL UNDER LOAD ON 15-IN. CHILLED IRON WHEEL WITH STRAIGHT TREAD

Load, Lb.	Depression			Increments of Depression		
	1st Trial	2nd Trial	Average	1st Trial	2nd Trial	Average
5,000	0.0	0.0	0.0	0.0	0.0	0.0
10,000	0.0015	0.002	0.0018	0.0015	0.002	0.0017
20,000	0.0050	0.0055	0.0052	0.0035	0.0035	0.0035
30,000	0.0080	0.0090	0.0085	0.0030	0.0035	0.0032
40,000	0.0110	0.0120	0.0115	0.0030	0.0030	0.0030
50,000	0.0140	0.0150	0.0145	0.0030	0.0030	0.0030
60,000	0.0165	0.0180	0.0172	0.0025	0.0030	0.0027
70,000	0.0188	0.0200	0.0194	0.0023	0.0020	0.0021
80,000	0.0210	0.0230	0.0220	0.0022	0.0030	0.0026
90,000	0.0238	0.0255	0.0246	0.0028	0.0025	0.0026
100,000	0.0260	0.0280	0.0270	0.0022	0.0025	0.0023
110,000	0.0285	0.0305	0.0295	0.0025	0.0025	0.0025
120,000	0.0310	0.0330	0.0320	0.0025	0.0025	0.0025
130,000	0.0335	0.0355	0.0347	0.0025	0.0025	0.0025
140,000	0.0360	0.0380	0.0365	0.0025	0.0025	0.0025
150,000	0.0390	0.0405	0.0387	0.0030	0.0025	0.0027
160,000	0.0415	0.0430	0.0412	0.0025	0.0025	0.0025
170,000	0.0440	0.0460	0.0447	0.0025	0.0030	0.0027
180,000	0.0470	0.0488	0.0479	0.0030	0.0028	0.0029
190,000	0.0500	0.0517	0.0505	0.0030	0.0029	0.0029
200,000	0.0528	0.0542	0.0535	0.0028	0.0025	0.0026
	0.200	0.199				
	0.190	0.191				
Per set......	0.010	0.008	0.009			

TABLE 12 DEPRESSION OF 85-LB. A.S.C.E. RAIL UNDER LOAD ON 15-IN. CHILLED IRON WHEEL—STRAIGHT TREAD—RAIL PLANED ON TOP

Load, Lb.	Depressions			Increments of Depression		
	1st Trial	2nd Trial	Average	1st Trial	2nd Trial	Average
5,000	0.0	0.0	0.0	——	——	——
10,000	0.002	0.002	0.002	0.002	0.002	0.002
20,000	0.007	0.007	0.007	0.005	0.005	0.005
30,000	0.0105	0.011	0.0108	0.0055	0.004	0.0047
40,000	0.0140	0.015	0.0145	0.0035	0.004	0.0037
50,000	0.0170	0.019	0.0180	0.0030	0.004	0.0035
60,000	0.0195	0.023	0.0212	0.0025	0.004	0.0032
70,000	0.0215	0.0265	0.0240	0.0020	0.0035	0.0027
80,000	0.0240	0.0294	0.0267	0.0025	0.0030	0.0027
90,000	0.0260	0.0330	0.0295	0.0020	0.0036	0.0028
100,000	0.0285	0.0360	0.0322	0.0025	0.0030	0.0027
110,000	0.0305	0.0385	0.0345	0.0020	0.0025	0.0022
120,000	0.0330	0.0405	0.0365	0.0025	0.0020	0.0022
130,000	0.0350	0.0430	0.0390	0.0020	0.0025	0.0022
140,000	0.0370	0.0460	0.0415	0.0020	0.0030	0.0025
150,000	0.0390	0.0485	0.0437	0.0020	0.0025	0.0022
160,000	0.0410	0.0505	0.0457	0.0020	0.0020	0.0040
170,000	0.0435	0.0530	0.0482	0.0025	0.0025	0.0025
180,000	0.0460	0.0550	0.0505	0.0025	0.0020	0.0022
190,000	0.0485	0.0575	0.0530	0.0025	0.0025	0.0025
200,000	0.0510	0.0600	0.0555	0.0025	0.0025	0.0025
	0.177 0.166	0.177 0.166				
Per set......	0.011	0.011				

TABLE 13 DEPRESSION OF 85-LB. A.S.C.E. RAIL UNDER LOAD ON 20 IN. CHILLED IRON WHEEL STRAIGHT TREAD

Load, Lb.	Depressions			Increment of Depression		
	1st Trial	2nd Trial	Average	1st Trial	2nd Trial	Average
5,000	0.00	0.00	0.00	——	——	——
10,000	0.002	0.000	0.0010	0.0020	0.000	0.001
20,000	0.005	0.003	0.0040	0.0030	0.003	0.003
30,000	0.008	0.005	0.0065	0.0030	0.0020	0.0025
40,000	0.0110	0.008	0.0095	0.0030	0.0030	0.0030
50,000	0.0140	0.0105	0.0122	0.0030	0.0025	0.0027
60,000	0.0160	0.0125	0.0142	0.0020	0.0020	0.0020
70,000	0.0185	0.0150	0.0167	0.0025	0.0025	0.0025
80,000	0.0205	0.0175	0.0190	0.0020	0.0025	0.0022
90,000	0.0230	0.0200	0.0215	0.0025	0.0025	0.0025
100,000	0.0260	0.0220	0.0240	0.0030	0.0020	0.0025
110,000	0.0288	0.0240	0.0264	0.0028	0.0020	0.0024
120,000	0.0315	0.0265	0.0290	0.0028	0.0025	0.0026
130,000	0.0345	0.0290	0.0317	0.0030	0.0025	0.0027
140,000	0.0375	0.0310	0.0342	0.0030	0.0020	0.0025
150,000	0.0410	0.0340	0.0375	0.0035	0.0030	0.0032
160,000	0.0445	0.0360	0.0402	0.0035	0.0020	0.0027
170,000	0.0480	0.0390	0.0435	0.0035	0.0030	0.0032
180,000	0.0520	0.0420	0.0470	0.0040	0.0030	0.0035
190,000	0.0560	0.0450	0.0505	0.0040	0.0030	0.0035
200,000	0.0610	0.0485	0.0547	0.0050	0.0035	0.0042
	0.202 0.194	0.206 0.191				
Per set......	*0.008*	*0.015*	0.0115			

TABLE 14 DEPRESSION ON 85-LB. A.S.C.E. RAIL UNDER LOAD ON 20-IN. CHILLED IRON WHEEL, STRAIGHT TREAD, RAIL PLANED ON TOP

Load, Lb.	Depressions			Increments of Depression		
	1st Trial	2nd Trial	Average	1st Trial	2nd Trial	Average
5,000	0.0	0.0	0.0	0.0	0.00	0.0
10,000	0.002	0.002	0.002	0.002	0.002	0.002
20,000	0.007	0.007	0.007	0.005	0.005	0.005
30,000	0.0105	0.011	0.0107	0.0035	0.004	0.0037
40,000	0.0140	0.015	0.0145	0.0035	0.004	0.0037
50,000	0.0170	0.019	0.0180	0.0030	0.004	0.0035
60,000	0.0195	0.023	0.0212	0.0025	0.004	0.0032
70,000	0.0215	0.0265	0.0240	0.0020	0.0035	0.0028
80,000	0.0240	0.0294	0.0267	0.0025	0.0029	0.0027
90,000	0.0260	0.0330	0.0295	0.0020	0.0036	0.0028
100,000	0.0285	0.0360	0.0322	0.0025	0.0030	0.0027
110,000	0.0305	0.0385	0.0345	0.0020	0.0025	0.0022
120,000	0.0330	0.0405	0.0365	0.0025	0.0020	0.0022
130,000	0.0350	0.0430	0.0390	0.0020	0.0025	0.0022
140,000	0.0370	0.0460	0.0415	0.0020	0.0030	0.0025
150,000	0.0390	0.0485	0.0437	0.0020	0.0025	0.0022
160,000	0.0410	0.0505	0.0457	0.0020	0.0020	0.0020
170,000	0.0435	0.0530	0.0482	0.0025	0.0025	0.0025
180,000	0.0460	0.0550	0.0505	0.0025	0.0020	0.0022
190,000	0.0485	0.0575	0.0530	0.0025	0.0025	0.0025
200,000	0.0510	0.0600	0.0550	0.0025	0.0025	0.0025
	0.177	0.177				
	0.176	0.176				
Per set......	0.001	0.001				

TABLE 15 DEPRESSION OF 85-LB. A.S.C.E. RAIL UNDER LOAD ON 33-IN. STRAIGHT TREAD CHILLED IRON WHEEL

Load, Lb.	Depressions			Increments of Depression		
	1st Trial	2nd Trial	Average	1st Trial	2nd Trial	Average
5,000	0.00	0.00	0.00	0.00	0.00	0.00
10,000	0.0030	0.0030	0.0030	0.0030	0.0030	0.003
20,000	0.0080	0.0080	0.0080	0.0050	0.0050	0.005
30,000	0.0115	0.0120	0.0117	0.0035	0.0040	0.0037
40,000	0.0150	0.0155	0.0152	0.0035	0.0035	0.0035
50,000	0.0180	0.0180	0.0180	0.0030	0.0025	0.0027
60,000	0.0215	0.0210	0.0212	0.0035	0.0030	0.0032
70,000	0.0240	0.0245	0.0242	0.0025	0.0035	0.0030
80,000	0.0265	0.0275	0.0270	0.0025	0.0035	0.0030
90,000	0.0290	0.0300	0.0295	0.0025	0.0025	0.0025
100,000	0.0315	0.0325	0.0320	0.0025	0.0025	0.0025
110,000	0.0345	0.0350	0.0347	0.0030	0.0025	0.0027
120,000	0.0370	0.0380	0.0375	0.0025	0.0030	0.0027
130,000	0.0405	0.0410	0.0407	0.0035	0.0030	0.0032
140,000	0.0435	0.0440	0.0437	0.0030	0.0030	0.0030
150,000	0.0470	0.0470	0.0470	0.0035	0.0030	0.0032
160,000	0.0500	0.0505	0.0502	0.0030	0.0035	0.0032
170,000	0.0535	0.0540	0.0537	0.0035	0.0035	0.0035
180,000	0.0570	0.0570	0.0570	0.0035	0.0030	0.0032
190,000	0.0605	0.0610	0.0607	0.0035	0.0040	0.0037
200,000	0.0645	0.0650	0.0647	0.0040	0.0040	0.0040
	0.197	0.1985				
	0.1875	0.1900				
......	0.0095	0.0085	0.009			

TABLE 16 DEPRESSION OF 85-LB. A.S.C.E. RAIL UNDER LOAD ON 33-IN. CHILLED IRON WHEEL, STRAIGHT TREAD, RAIL PLANED FLAT ON TOP

Load, Lb.	Depressions			Increments of Depression		
	1st Trial	2nd Trial	Average	1st Trial	2nd Trial	Average
5,000	0.0	0.0	0.0	0.0	0.0	0.0
10,000	0.003	0.003	0.003	0.0030	0.0030	0.0030
20,000	0.0085	0.0085	0.0085	0.0055	0.0055	0.0055
30,000	0.0120	0.0120	0.0120	0.0035	0.0035	0.0035
40,000	0.0155	0.0160	0.0157	0.0035	0.0040	0.0037
50,000	0.0185	0.0190	0.0187	0.0030	0.0030	0.0030
60,000	0.0210	0.0220	0.0215	0.0025	0.0030	0.0027
70,000	0.0235	0.0250	0.0242	0.0025	0.0030	0.0027
80,000	0.0265	0.0280	0.0272	0.0030	0.0030	0.0030
90,000	0.0295	0.0305	0.0300	0.0030	0.0025	0.0027
100,000	0.0320	0.0335	0.0327	0.0025	0.0030	0.0027
110,000	0.0345	0.0365	0.0355	0.0025	0.0030	0.0027
120,000	0.0370	0.0390	0.0380	0.0025	0.0025	0.0025
130,000	0.0395	0.0420	0.0407	0.0025	0.0030	0.0027
140,000	0.0420	0.0445	0.0432	0.0025	0.0025	0.0025
150,000	0.0445	0.0470	0.0457	0.0025	0.0025	0.0025
160,000	0.0480	0.0500	0.0490	0.0035	0.0030	0.0032
170,003	0.0510	0.0530	0.0520	0.0030	0.0030	0.0030
180,000	0.0540	0.0560	0.0550	0.0030	0.0030	0.0030
190,000	0.0575	0.0590	0.0582	0.0035	0.0030	0.0032
200,000	0.0610	0.0630	0.0620	0.0035	0.0040	0.0037
	0.177 0.176	0.178 0.1765				
Per set......	0.001	0.0015				

TABLE 17 DEPRESSION OF 85-LB. A.S.C.E. RAIL UNDER LOAD ON 33-IN. M.C.B. CHILLED IRON WHEEL

Load, Lb.	Depressions			Increment of Depression		
	1st Trial	2nd Trial	Average	1st Trial	2nd Trial	Average
5,000	0.00	0.00	0.00	0.00	0.00	0.00
10,000	0.001	0.001	0.001	0.001	0.001	0.001
20,000	0.004	0.006	0.005	0.004	0.005	0.0045
30,000	0.006	0.008	0.007	0.002	0.002	0.002
40,000	0.008	0.011	0.009	0.002	0.003	0.0025
50,000	0.010	0.014	0.012	0.002	0.003	0.0025
60,000	0.013	0.017	0.015	0.003	0.003	0.003
70,000	0.016	0.020	0.018	0.003	0.003	0.003
80,000	0.017	0.022	0.019	0.001	0.002	0.0015
90,000	0.020	0.025	0.022	0.003	0.003	0.003
100,000	0.022	0.028	0.025	0.002	0.003	0.0025
110,000	0.024	0.031	0.027	0.002	0.003	0.0025
120,000	0.026	0.034	0.030	0.002	0.003	0.0025
130,000	0.031	0.038	0.034	0.005	0.004	0.0045
140,000	0.033	0.040	0.036	0.002	0.002	0.002
150,000	0.037	0.043	0.040	0.004	0.003	0.0035
160,000	0.040	0.047	0.043	0.003	0.004	0.0035
170,000	0.044	0.049	0.046	0.004	0.002	0.003
180,000	0.047	0.053	0.050	0.003	0.004	0.0035
190,000	0.053	0.056	0.054	0.006	0.003	0.0045
200,000	0.057	0.060	0.058	0.004	0.004	0 004
	0.201 0.189	0.199 0.1895				
Per set......	0.012	0.0095	0.0107			

TABLE 18 ULTIMATE STRENGTH OF DOUBLE FLANGE CRANE WHEEL FLANGES
5-In. Throat

Test	Diameter, In.	Flange		Height of Point of Application above Tread	Weight, Lb.	A, Angle of Thrust	Sin A	Tan A	Load Applied, Lb.	Reaction along Toggle	Horizontal Component of Reaction
		Height	Thickness								
1	16	¾	1¼	⅜	275	11° 32′	0.1999	0.2040	117,000	292,000	286,000
						12° 22′	0.2140	0.2192	119,000	277,000	271,000
2	16	¾	1¾	⅜	331	7° 16′	0.1265	0.1275	100,000	395,000	392,000
						7° 16′	0.1265	0.1275	97,000	383,000	380,000
3	16	¾	2¼	⅜	381	13° 54′	0.2402	0.2474	275,000	572,000	555,000
						13° 54′	0.2402	0.2474	300,000	624,000	606,000*
4	16	¾	2¾	⅜	434	17° 10′	0.2951	0.3089	300,000	508,000	485,000*
5	20	1	1¼	½	484	8° 38′	0.1501	0.1518	95,850	319,000	315,000
						8° 38′	0.1501	0.1518	86,500	288,000	284,000
6	20	1	1¾	¼	570	35° 27′	0.5800	0.7119	192,000	165,000	133,000
						36° 53′	0.6001	0.7504	186,000	154,000	123,000
						37° 50′	0.6133	0.7766	297,000	242,000	190,000
7	20	1	2¼	¼	647	13° 54′	0.2402	0.2474	167,000	348,000	337,000
						9° 5′	0.1578	0.1599	129,000	408,000	403,000
						8° 19′	0.1446	0.1462	220,000	760,000	752,000
8	20	1	2¾	⅜	740	7° 37′	0.1325	0.1337	143,000	539,000	534,000
						6° 27′	0.1125	0.1130	143,000	636,000	633,000
						9° 51′	0.1710	0.1736	148,000	432,000	426,000
9	33	1	1¼	¼	860	14° 40′	0.2532	0.2617	259,000	511,000	494,000
						9° 13′	0.1601	0.1622	147,000	459,000	453,000
						7° 16′	0.1265	0.1275	137,000	541,000	537,000
10	33	1	1¾	¼	1100	9° 13′	0.1601	0.1622	250,000	780,000	770,000
						9° 13′	0.1601	0.1622	241,000	752,000	742,000
						6° 54′	0.1201	0.1210	217,000	903,000	896,000
11	33	1	2¼	¼	1260	6° 54′	0.1201	0.1210	208,000	865,000	859,000
						13° 6′	0.2266	0.2327	300,000	672,000	644,000*
12	33	1	2¼	½	1260	12° 32′	0.2170	0.2223	180,000	414,000	404,000
						12° 55′	0.2235	0.2293	185,000	423,000	405,000
						4° 54′	0.0854	0.0857	232,000	1,359,000	1,353,000
16	30	1	2¾	¼	1130	4° 54′	0.0854	0.0857	231,000	1,352,000	1,344,000
						8° 22′	0.1455	0.1470	300,000	1,030,000	1,020,000*
17	36	1¼	2	¾	1660	26° 45′	0.4500	0.5040	180,000	200,000	178,000
						27° 43′	0.4650	0.5253	207,000	222,000	199,000
18	36	1¼	2	¾	1660	27° 4′	0.4550	0.5110	179,000	196,000	175,000
						27° 23′	0.4599	0.5180	182,000	197,000	175,000
22	20	1	1¼	¼	484	15° 28′	0.2666	0.2767	231,000	433,000	417,000
						15° 28′	0.2666	0.2767	300,000	562,000	542,000*
20	20	1	1¾	¼	570	16° 16′	0.2800	0.2918	300,000	535,000	514,000*
23	20	1	2¼	¼	647	17° 10′	0.2951	0.3089	300,000	508,000	485,000*
19	20	1	2¾	¼	740	16° 16′	0.2800	0.2918	300,000	535,000	514,000

* Did not break.

LOAD APPLIED ½ IN. ABOVE TREAD

Test	Diameter, In.	Flange Thickness, In.	Throat Thickness, In.	Height of Flange, In.	A, Angle of Thrust	Sin A	Tan A	Actual Load, Lb.	Load when 1st Crack Appeared	Horizontal Component	Component along Toggle
1	33	1¼	1¾	1	21° 6′	0.3600	0.3858	163,000	....	211,000	226,000
					20° 11′	0.3450	0.3676	96,000	....	130,000	139,000
2	33	1¼	2½	1	20° 11′	0.3450	0.3676	129,000	....	175,000	187,000
					20° 11′	0.3450	0.3676	98,000	87,000	133,000	142,000
3	33	1¼	3¼	1	20° 11′	0.3450	0.3676	110,000	106,000	149,000	159,000
					19° 53′	0.3401	0.3616	99,000	80,000	136,000	145,000
4	33	1¾	1¾	1	19° 16′	0.3299	0.3495	101,000	78,000	144,000	153,000
					20° 29′	0.3499	0.3735	104,000	95,000	139,000	148,000
5	33	1¾	2½	1	21° 6′	0.3600	0.3858	152,000	79,000	197,000	211,000
					18° 40′	0.3200	0.3378	143,000	123,000	211,000	223,000
6	33	1¾	3¼	1	19° 16′	0.3299	0.3495	177,000	128,000	253,000	268,000
					17° 46′	0.3051	0.3204	166,000	109,000	260,000	272,000
7	33	2¼	1¾	1	18° 4′	0.3101	0.3262	127,000	99,000	195,000	204,000
					18° 4′	0.3101	0.3262	135,000	86,000	207,000	217,000
8	33	2¼	2½	1	17° 46′	0.3051	0.3204	186,000	106,000	290,000	304,000
					17° 46′	0.3051	0.3204	190,000	74,000	296,000	311,000
9	33	2¼	3¼	1	17° 10′	0.2951	0.3089	213,000	107,000	344,000	360,000
					15° 5′	0.2602	0.2695	207,000	151,000	384,000	397,000
10	33	2¾	1¾	1	16° 34′	0.2851	0.2974	143,000	74,000	240,000	250,000
					18° 4′	0.3101	0.3262	140,000	79,000	214,000	225,000
11	33	2¾	2½	1	18° 40′	0.3200	0.3378	178,000	73,000	263,000	278,000
					15° 5′	0.2602	0.2695	185,000	89,000	343,000	355,000
12	33	2¾	3¼	1	7° 29′	0.1302	0.1313	199,000	171,000	757,000	764,000
					15° 40′	0.2700	0.2804	258,000	105,000	460,000	477,000
13	20	1¼	1¾	1	17° 28′	0.3001	0.3146	39,000	....	62,000	64,000
					18° 22′	0.3151	0.3320	45,000	....	67,000	71,000
14	20	1¼	2½	1	13° 6′	0.2266	0.2327	38,000	....	81,000	83,000
					16° 16′	0.2801	0.2918	48,000	....	82,000	85,000
15	20	1¼	3¼	1	14° 58′	0.2585	0.2673	30,000	....	56,000	58,000
					18° 22′	0.3151	0.3320	36,000	....	54,000	57,000

TABLE 20 BREAKING STRENGTH OF DOUBLE FLANGE WHEELS

LOAD APPLIED ½ IN. ABOVE TREAD

Test	Diameter, In.	Flange Thickness, In.	Throat Thickness, In.	Height of Flange, In.	A, Angle of Thrust	Sin A	Tan A	Actual Load, Lb.	Load when 1st Crack Appeared	Horizontal Component	Component along Toggle
16	20	1¾	1¾	1	14° 47′	0.2551	0.2639	51,000	....	96,000	99,000
					15° 40′	0.2700	0.2804	45,000	....	80,000	83,000
17	20	1¾	2½	1	14° 17′	0.2467	0.2546	54,000	....	106,000	109,000
					16° 34′	0.2851	0.2974	62,000	....	104,000	108,000
18	20	1¾	3¼	1	17° 46′	0.3051	0.3204	61,000	....	95,000	100,000
					11° 32′	0.2002	0.2043	41,000	....	100,000	102,000
19	20	2¼	1¾	1	8° 38′	0.1501	0.1518	61,000	....	200,000	203,000
					8° 21′	0.1452	0.1467	64,000	....	218,000	220,000
20	20	2¼	2½	1	15° 5′	0.2602	0.2695	54,000	....	100,000	103,000
					10° 23′	0.1802	0.1832	75,000	65,000	204,000	208,000
21	20	2¼	3¼	1	10° 40′	0.1851	0.1883	85,000	59,000	225,000	229,000
					10° 40′	0.1851	0.1883	67,000	50,000	177,000	180,000
22	16	1¼	1¾	¾	18° 40′	0.3200	0.3378	37,000	....	54,000	57,000
23	16	1¼	2½	¾	21° 6′	0.3600	0.3659	44,000	....	60,000	61,000
24	16	1¼	3¼	¾	22° 57′	0.3900	0.4234	55,000	....	64,000	70,000
25	16	1¾	1¾	¾	14° 11′	0.2450	0.2527	77,000	....	152,000	157,000
26	16	1¾	2½	¾	20° 11′	0.3450	0.3676	74,000	....	106,000	108,000
27	16	1¾	3¼	¾	19° 16′	0.3300	0.3495	88,000	....	125,000	130,000
28	16	2¼	1¾	¾	29° 1′	0.4850	0.5547	98,000	78,000	88,000	101,000
29	16	2¼	2½	¾	25° 48′	0.4352	0.4834	105,000	79,000	108,000	120,000
30	16	2¼	3¼	¾	25° 10′	0.4252	0.4698	138,000	106,000	146,000	162,000
31	16	2¾	1¾	¾	21° 25′	0.3651	0.3922	106,000	82,000	135,000	145,000
32	16	2¾	2½	¾	21° 7′	0.3602	0.3862	135,000	86,000	174,000	187,000
33	16	2¾	3¼	¾	19° 53′	0.3401	0.3616	100,000	105,000	221,000	235,000

TABLE 21 BREAKING STRENGTH OF DOUBLE FLANGE CRANE WHEELS

LOAD APPLIED ¼ IN. ABOVE TREAD

Test	Diameter, In.	Flange Thickness, In.	Throat Thickness, In.	Height of Flange, In.	A, Angle of Thrust	Sin A	Tan A	Actual Load, Lb.	Load when 1st Crack Appeared	Horizontal Component	Component along Toggle
34	33	1¼	1¾	1	12° 8′	0.2101	0.2150	91,000	81,000	211,000	216,000
35	33	1¼	1¾	1	10° 40′	0.1851	0.1883	74,000	168,000	196,000	200,000
36	33	1¼	2½	1	11° 15′	0.1951	0.1989	125,000	95,000	314,000	320,000
37	33	1¼	2½	1	12° 43′	0.2201	0.2256	127,000	83,000	281,000	288,000
38	33	1¼	3¼	1	10° 40′	0.1850	0.1883	152,000	111,000	403,000	410,000
39	33	1¼	3¼	1	10° 58′	0.1902	0.1938	131,000	91,000	337,000	344,000
40	30	1¼	5	1	12° 43′	0.2201	0.2256	97,000	....	214,000	220,000
41	30	1¼	5	1	10° 40′	0.1851	0.1883	96,000	79,000	254,000	259,000
42	30	1¼	5	1	11° 33′	0.2002	0.2043	87,000	80,000	212,000	217,000
43	30	1¼	5	1	11° 15′	0.1951	0.1989	85,000	75,000	213,000	217,000
44	30	1¼	5	1	13° 18′	0.2300	0.2364	123,000	....	260,000	267,000
45	30	1¼	5	1	12° 25′	0.2150	0.2201	77,000	70,000	174,000	179,000
46	30	1¼	5	1	12° 25′	0.2150	0.2201	103,000	96,000	233,000	239,000
47	30	1¼	5	1	9° 48′	0.1702	0.1727	93,000	71,000	269,000	273,000

DISCUSSION

ARTHUR L. WILLISTON in commenting on the method described of finding the power required for locomotion by drawing a load up an inclined plane, called attention to the question of the friction of rolling between a smooth ground wheel and a smooth rail. The author had calculated this on the theory of the wheel running uphill. If the rail were of material like lead, which is absolutely inelastic, that would be a correct way of calculating, as the wheel would make successive depresssions in the rail as it moved forward. With an elastic material like chilled iron, the condition is somewhat different. There is another force behind the wheel tending to push it forward as the material of the rail tends to return to its natural condition. With a material like chilled iron running on an open hearth steel rail, from one-half to two-thirds of the work done in compressing the rails is returned by the elasticity of the materials.

W. A. BENNETT who presented the paper in the absence of the author said in reply that the chilled iron used was so hard that it had no ductility whatever; the give or flow of metal was entirely in the steel rail. While it is not claimed that the theory of a body rolling up an inclined plane is absolutely correct, it gives a result within working limits.

AUGUSTUS SMITH (written). The author's paper is not always convincing, though the tests on the strength of flanges are valuable. The suggestion that a crane wheel should be designed according to the strength of the flange is new to the best of the writer's knowledge, and this seems to be a very logical method of designing such a wheel.

The author infers from his experiments on the strength of flanges that the thickness of the flange should be 2/3 that of the throat in order to obtain the greatest economy of metal, and this is a welcome contribution to our knowledge of the subject.

The statement in par. 75 that the flange shall safely resist a horizontal pressure of 75 per cent of the vertical load on the wheel is not justified by the author in any way. The horizontal pressure is often an unknown quantity and can be sometimes limited to 25 per cent of the vertical load by properly designing the trucks and track. If we assume, however, that the author is entitled by his experience as a wheel maker to assert that for average conditions a wheel flange should be designed for 75 per cent of the vertical load, his experiments lead us directly to the proper thickness of the flange and thence to the proper thickness of throat. The paper does not tell us how to proportion the depth of the tread, but, having the proper throat thickness, the thickness of the tread will probably follow from the designer's sense of symmetry and proportion. Even if other engineers should differ from Mr. Vial as to the percentage of vertical wheel load that the flange should be designed to resist, his method of designing can nevertheless be followed for any agreed-upon ratio of horizontal flange stress to vertical wheel load.

Pars. 25 to 29 are devoted to an analysis of the theoretical tractive force that should be required for different diameters of wheels as a result of the depressions observed in the compression tests. No experiments were made on the tractive force. The experiments were all vertical loadings to produce certain measured depressions. The tractive force required for wheels of different diameters is derived by the author by a mathematical analysis which neglects the elastic properties of the rail and wheel in regaining their respective contours after the load is relieved or passes along, which shifting of the load to successive portions of the rail and wheel even aids in restoring the depressed contours. In the writer's opinion, the results given by the author are undoubtedly incorrect.

A line of investigation is suggested by these paragraphs, however, which, it seems to the writer, would be a much more accurate method of testing rail and wheel resistance to vertical loads than the direct compressive tests originally described by Johnson and followed by the author. This is to make tests in which the tractive force required to roll wheels on rails under different loadings and different diameters of wheels is directly measured. The writer would expect the tractive force to vary directly with the load and be practically independent of the diameter of the wheel, after correction for journal friction, so long as the rail and wheel were perfectly smooth and the load did not exceed the elastic limit of either wheel or rail. As soon as the elastic limit of either rail or wheel was exceeded, however, the tractive force should suddenly increase for the reason pointed out by the author. If, therefore, such tests were made with a glass-like unyielding wheel, the results would indicate the elastic limit of the bearing power of the rail. Another series of tests on a special rail of glassy hardness would indicate the elastic limit of the bearing power of different wheels made of softer material than the test rail. As the author tells us, with a good chilled wheel all we need find out for practical purposes is the proper diameter of the wheel and the proper weight of rail to carry the load. The information the writer predicts would be readily forthcoming from experiments made as suggested.

WILFORD L. STORK (written). The hardness of cast-iron (par. 6) is more a matter of the combined carbon than of the amount of graphite present. The size, shape and distribution of the graphite; the amount and distribution of the cementite; the grain size and character of the matrix—all have a great influence on the strength of the iron. The graphite and the cementite affect the continuity of the structure and the binding of the dendrites.

Car wheels differ very much in wearing qualities, some wheels wearing out much more quickly than others. There have been produced wheels which gave an average of 95,000 miles in service, as against an average of from 30,000 to 45,000 miles of the ordinary commercial wheel foundries.

The properties and qualities of car wheels can be determined from photomicrographs of their structure. Figs. 37 to 42 are photomicrographs taken from two car wheels, one good and one bad. The bad wheel was so termed because it did not give the ordinary amount of service.

Car wheel No. 18. *Good wheel.* Fig. 37. Photograph taken ¼ in. from the chilled outside surface. This is a characteristic white cast-iron, having a very fine grain as shown by the dendrites. The dark areas of pearlite are set in a eutectic of pearlite and cementite. The fineness of the grain is the result of very rapid cooling.

Fig. 38. Photograph taken in the center of the tread. This is a characteristic mottled cast-iron. Large dendrites of pearlite containing some graphite are set in a matrix of white cast-iron. These larger dendrites show that the rate of cooling was not as rapid as above.

Fig. 39. Photograph taken at the back of the tread and near the surface next to the sand mold. Similar to Fig. 38, but more of the gray and less of the white iron is seen. The iron is still very hard and metallographically it is still a mottled iron.

Car wheel No. 2. *Bad wheel.* Fig. 40. Though this photograph was taken in the chill, it nevertheless shows the results of carbide decomposition, by the presence of areas of graphite. The pearlite, as compared with Fig. 37, is not very fine grained. The wheel is evidently not so hard and strong as the other wheel. The structure shows decidedly that the chilling action was neither very severe nor very effective.

FIG. 37 GOOD WHEEL. ¼ IN. FROM CHILL

FIG. 40 BAD WHEEL. ¼ IN. FROM CHILL

FIG. 38 GOOD WHEEL. CENTER OF TREAD

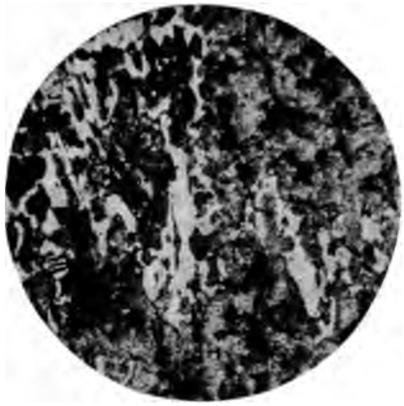


FIG. 41 BAD WHEEL. CENTER OF TREAD

FIG. 39 GOOD WHEEL. BACK OF TREAD

FIG. 42 BAD WHEEL. BACK OF TREAD

MAGNIFIED 75 DIAMETERS

Fig. 41. Photograph taken in the center of the tread. Note the coarseness of the pearlite as compared with Fig. 38. There is much graphite and little, but well-distributed cementite.

Fig. 42. Photograph taken at the back of the tread. This is a fine grained and a decided gray iron. There are large dendrites of pearlite, with few and small interstices of cementite eutectic. The graphite is long, coarse and abundant as the result of slow cooling. This iron is soft and is entirely different from the similar section of the other wheel.

Photomicrographs taken from a number of wheels show:

a As we pass from the chill in each wheel the structure changes from white, then to mottled and finally to gray iron.

b Good wheels have structures which are similar and identical. These structures show the wheels hard, strong and dense.

c The structures of good wheels and of bad wheels differ. Consequently, the wearing qualities and strength of two wheels having different structures must differ.

d Wheels in which the chilling action is more severe and to a greater depth are closer grained and harder in structure.

Wheel No. 18 was in actual service for over nine years, while wheel No. 2 only lasted three years. In both wheels the silicon, manganese, phosphorus and sulphur contents were practically the same so that they could not account for any difference in structure.

The carbon content of wheel No. 2 was considerably higher than that of No. 18. (Table 22.) The higher the carbon content in a

TABLE 22. COMPOSITION OF WHEELS AND TIME IN ACTUAL USE

ALL WHEELS REMOVED DECEMBER 1, 1911

No.	Total Carbon	Si.	Mn.	P.	S.	Months in use
2	3.00	0.65	0.40	0.44	0.137	36
18	2.62	0.50	0.53	0.30	0.153	111

wheel, the greater the tendency toward a graphitic structure and the less the chance of chilling the casting. For high carbon contents the cooling and freezing cannot be rapid enough to retain all the carbon in the combined form. Does not the chemical analysis justify the metallography as shown in the photographs and are not the increase in graphite, the coarser structures and the decrease in cementite justified by the chemical composition?

The photomicrography of car wheels reveals their differences in wearing qualities due to structure. Chemical analysis of the wheels discloses variations in their composition. Differences in structure are caused by variations in chemical analysis and in rate of cooling. Differences in physical qualities of cast-iron exist only by virtue of differences in structure.

The chemical analysis and the conditions of casting are equally, if not more, important in the standardization of crane wheels than is design. The latter can have no influence whatever upon the quality of the wheel if the quality of the iron and the method of casting are neglected.

THE AUTHOR. The object of this paper was to furnish data that might be of some assistance in choosing the proper diameter and weight of wheel to correspond with various operating conditions, and the conclusions were not intended as being mathematically rigid, but simply an index to safe working rules.

The remarks of Mr. Smith and Mr. Williston, regarding tractive force for wheels of different diameters, take exception to the conclusions given in the paper, and yet nothing is substituted for them. It is true that if the rail were perfectly true and glassy hard, the effect on traction of wheels of different diameters would not be as large as those indicated, but these conditions do not exist in practice.

The fundamental idea throughout is the use of wheels on tracks that are not in perfect alignment, such as exist in coal and ore unloading cranes, where the track is not smooth and clean; often covered with sand, ore or coal; joints not perfectly rigid; gauge irregular and a thousand and one conditions that are not mathematically true. Under these conditions, it is believed that the method of analysis given is more nearly correct than any statement based on mathematically ideal conditions, and, in the absence of any positive rules, the conclusions form a safe basis for meeting operating conditions of maximum severity.

In regard to the discussion of Mr. Stork, the qualities of various grades of cast iron were in no way touched upon in the paper. I cannot, however, accept the last conclusion, that chemical analysis and condition of casting are equally, if not more important in the standardization of crane wheels than the design. This is so far from the experience of foundrymen that it would be out of place to discuss it here. There are certain chemical relations and casting conditions that are considered best practice; these produce properties of chilled iron which are practically fixed, and no amount of change in chemical analyses or condition of casting can greatly improve these properties. Therefore, having these high standards of tensile strength, compression strength, etc., it is absolutely essential that these be compared with stresses which are possible to develop in service, and a standardization made according to the well-known principles of mechanics. In fact, this is the only method that can be followed in the standardization of designs, because if mixtures of various chemical analyses can materially affect the qualities of iron, then we will have standards for various grades of iron which can easily be followed by simply cutting down the sections to correspond with the increased strength of the new metal. It has not been my experience that anyone has been successful in increasing the strength of chilled iron by modifying the chemical analysis that is commonly used. This discussion of the microstructure of chilled iron is foreign to the scope of the paper.

I am very much pleased with the discussion of the paper, and the interest that has developed in personal correspondence on the subject, indicating the appreciation of a start toward the formation of a basis for design of chilled iron crane wheels.

No. 1466

THE MECHANICAL ELIMINATION OF SEAMS IN STEEL PRODUCTS, NOTABLY STEEL RAILS

By Robert W. Hunt, Chicago, Ill.

Past-President of the Society

No part of railway maintenance has been given more discussion ,nd greater publicity by scientific bodies, technical publications, ,nd the general press than steel rails. The question of safety to ıuman life and limb, to say nothing of property, is so dependent ıpon the quality of rails, that the reason for this publicity is easily ınderstood. Moreover, the duty required of rails and the resulting tresses have so constantly increased, and the controlling factors ncident to their manufacture have changed so much that the whole ›roblem is an involved and interesting one.

2 Increased weight of rolling stock and speed of traffic have ıecessitated increasing the size of the rail sections, and hence their veight; and as many of the details of rail manufacture have been hanged with such alterations, it is not surprising that new and ınexpected physical weaknesses developed in the heavier rails.)ne of the most notable was failure through cresent-shaped pieces ›reaking out of the rail flanges, followed by at least one, and in nany cases several, ruptures across the whole section of the rail. nvestigation showed that in practically every instance of such ailure there was a more or less pronounced seam running longiudinally in the bottom of the rail near its center, and thus imnediately under its web. This seam occurs at the top of the curve ›f the crescent-shaped break and is undoubtedly the point at which he fracture starts.

Those familiar with steel rail making knew that it was practially impossible to make rails entirely free from seams, and that as he seamy conditions of the steel forming the head of the rail in-

Presented at the Annual Meeting, December 1914, of The American Society of Mechanical Engineers.

creased, so would its wearing quality decrease, but I think it was not until the disastrous experiences with the "moon-shaped" failures that the danger from seams in the base of the rails was fully realized. It is true that rails with actual flaws in their flanges have been

Fig. 1

Fig. 2

FIG. 1 FACE OF AN INGOT BEFORE HEATING
FIG. 2 FACE OF AN INGOT AFTER HEATING, WITH THE ADHERING SCALE REMOVED

rejected as first quality ones and that a very pronounced seamy condition of the bottom of the rail would also cause its rejection. Such rejections were the cause of frequent disputes between the mill operatives and the inspectors, the point being as to how far the tors were warranted in carrying their condemnation; but, as y said, it was not felt that a single seam, unless very pro- ed, would be dangerous.

The crescent-shaped breaks were of such frequent occurrence ey indicated a very serious condition and led rail makers to nent with the design of their rolling passes with a view to ing the formation of the bottom seams. It was found that seams were produced by such changes, but they were not y eliminated. While more or less successful in preventing mation of seams through lapping on the bottom of the rails, mation of seams in other parts of the section was not par- ly affected.

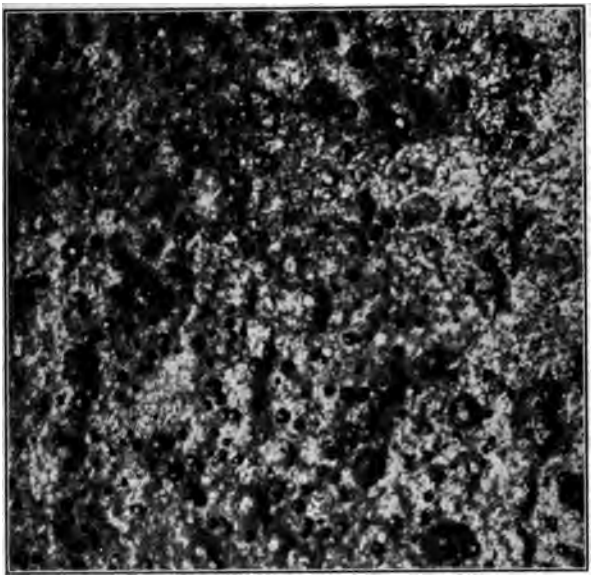


FIG. 3 SECTION OF FACE OF INGOT, FULL SIZE

It is a well-known fact that it is not alone the quality of rails deteriorates through the use of seamy steel, and the funda- l causes in one will more or less apply to all cases. T. H. as, assistant general superintendent of the Lackawanna Company, determined that the most certain way of getting eams was to remove that portion of the metal which contained and, as applied to steel rails, thus to eliminate them from both se and head of the rail. This was a reasonable assumption, but its execution. I think would have seemed very impractical to the minds of most metallurgical engineers. Mr. Mathias reasoned that the primary causes of seams existed previous to any rolling of the steel, in fact, were incident to the casting of the molten metal into ingots. He knew that disk-like apertures were formed on the

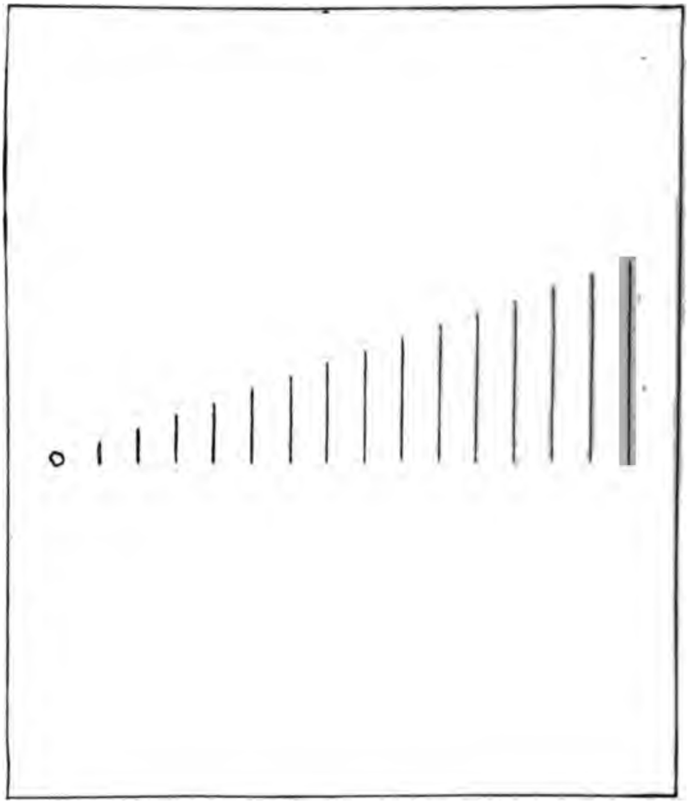


FIG. 4 EFFECT ON PRACTICALLY ROUND IMPERFECTIONS WHEN ELONGATED BY 15 PASSES IN THE ROLLING MILL

sides of ingots while the molten metal was being cast and were probably caused from air being entrapped against the sides of the ingot molds by the hot steel as it raised in the molds, a condition which was not controlled in regular manufacturing routine. This condition is illustrated by Figs. 1 and 2, which are photographs of the same face of an ingot, Fig. 1 showing the side as it would appear before heating, while Fig. 2 shows it after heating, with the adhering scale removed. Fig. 3 represents the actual size of a section of a face of such an ingot, and gives an illustration of how serious such apertures may be.

6 It will be appreciated that, as the section of the ingot is reduced and elongated in the rolling process, so, of course, will the apertures be stretched longitudinally and thus be formed into seams. Fig. 4 shows what would occur in that way to any practically round

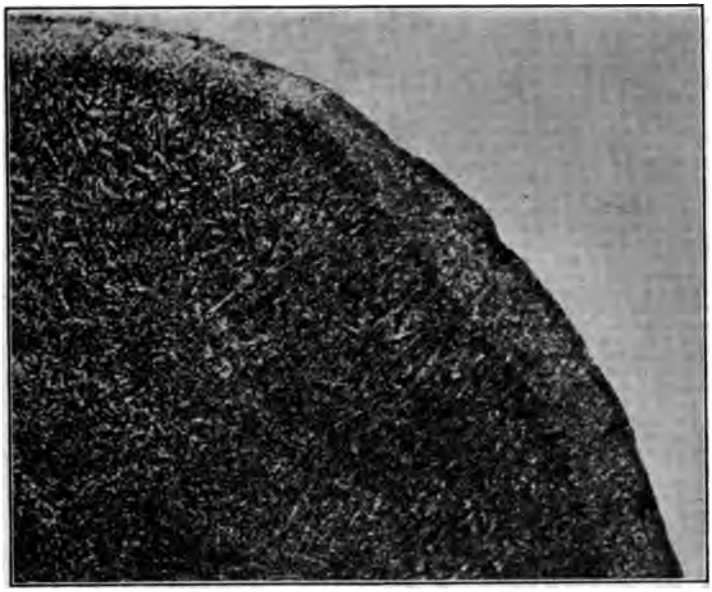


FIG. 5 ETCHED SURFACE SHOWING LOWER CARBON ENVELOPE OR SKIN OF INGOT

imperfections of the size indicated when elongated by 15 passes in the rolling mill. If so small an imperfection would give such a result of course the seams resulting from larger ones would be proportionately greater and, therefore, more serious, both in length and depth.

7 Mr. Mathias demonstrated that there is another constant condition present in the rolling of large steel ingots, in the formation of a decarburized surface on all of their four faces, about $\frac{1}{16}$ in. deep, and containing from eight to ten points lower carbon than the metal immediately under it, the decarburized envelope undoubtedly being produced through the oxidizing conditions to which ingots are sub-

jected in the soaking pits where they are heated preparatory to rolling. A thick oxide scale is always formed on the surface of ingots in the pits, so that conditions are invariably present for the production of such a layer of lower carbon metal on their outside faces. Fig. 5 illustrates the presence of this lower carbon envelope or skin. It shows a polished and etched cross-section of a part of an ingot which has been heated to a rolling temperature in the soaking pits, but not rolled, from which it will be realized that ingots of large

FIG. 6 HOT SAWING OR MILLING MACHINE IN OPERATION

section have both disk-like apertures on their four faces and a decarburized envelope in which they are contained.

8 Mr. Mathias was convinced that during the process of rolling ingots into rails it was practical to remove mechanically the parts of the enveloping steel which would form the top of the head and bottom of the flange of the rail, and experimented accordingly. He designed and his company installed as an addition to their rail train, a milling, or a hot sawing machine, as I believe Mr. Mathias designates it, to cut off that metal without retarding the regular operation and thus interfering with the production of the mill. This is il-

ated by Fig. 6, which is a photograph of the machine in opera- The machine is located in echelon in relation to the rest of the train.

The ingot is reduced in the blooming rolls to an 8-in. by 8-in. -section and after cropping the ends the bloom is further re- d in the roughing or shaping stand of rolls by five passes. When aves these rolls, it is approximately 75 per cent finished and at period it is carried to the right and entered between two pinch with its base or flange side up. A bar which will make four . rails is at this point in the rolling operation about 60 ft. in

7 CROSS-SECTION OF BAR PREPARATORY TO ENTERING MILLING MACHINE

th; therefore, the area of metal to be cut off or removed in the ng machine is approximately ⅛ in. deep, 7 in. wide and 60 ft. . It is driven through the pinch rolls at a rate of 60 ft. in 30 nds. The pinch rolls have a draft of about ⅜ in. and thus force bar between the two milling saws, which are so arranged in the ing that they may be raised or lowered as desired. There is $\frac{1}{32}$ to $\frac{1}{16}$ in. of metal milled from the head and base of the bar, front end of which, immediately on passing from between the , is caught by a second set of pinch rolls which have a draft of it 1/16 in. These pinch rolls force the bar between the tools, it from between them, and also hold it in practically perfect for the milling operation. The milling apparatus is driven elec- lly and requires about 600 h.p. for its operation.

10 Fig. 7 shows an etched cross-section of the piece preparatory to its entering the milling machine, and on it is clearly shown the

FIG. 8 CUTTINGS PRODUCED BY MILLING

FIG. 9 MILLING TOOL

enveloping layer of lower carbon steel. As stated, it is treated with the wider, or flange side up.

11 As the milled dust or particles of steel are thrown out, they are hit by water under pressure which forces them into a chute and

also prevents the material from adhering together. By the chute they are carried below the mill and caught in boxes or receptacles suitable for charging as scrap into the open-hearth furnaces.

12 Fig. 8 shows the condition of the accumulated material which, as will be seen, is in regular open-hearth furnace charging boxes.

13 Fig. 9 shows one of the milling tools. It is 5 ft. in diameter with an 8 in. width of face and revolves at a peripheral speed of 2500 ft. per minute, thus causing an engagement of about 400,000 teeth per minute on the hot rail bar. The teeth are of 0.80 carbon steel, and it has been demonstrated that they will mill at least

FIG. 10 APPEARANCE OF BAR AFTER IT LEAVES THE MILLING MACHINE

30,000 tons of material without requiring dressing. The one shown had milled about 15,000 tons.

14 Fig. 10 presents the shape of the bar after it leaves the milling machine preparatory to further reduction in the regular rail rolls.

15 It will be noticed that the milling on the flange has not reached the extreme edges of the bar, and on the head side has not affected the corners, and it will be recalled that Fig. 9 showed the milling tool with a straight face. It is apparent that either by a modification of the shape of the piece as presented for treatment in the milling machine or, what will probably be more practical, changing the face of the tool, the milling can be extended to the extreme edge of the flange portion of the bar and somewhat around the

corners of the top or head side. This will undoubtedly be perfectly practical and thereby eliminate the seams which may be located in those parts of the bar. It will be observed in figures which will be subsequently presented that such elimination is not accomplished at present, and perhaps it may not be necessary. The primary object was to eliminate the seams from the central portion of the bottom of the rail which had been the starting point of the moon-

Fig. 11 Piece of Rail broken under the Drop Press

shaped failures, and to remove them from the top or bearing surface of the head of the rail. Personally I think it will be desirable to extend the milling by the use of convex-faced tools.

16 The work of rolling which the steel receives after the removal of the more or less laminated metal must produce a better product than if such elimination had not taken place, and, in the

ase of steel rails, it should not only make them less liable to breakage n account of seams in their flanges, but also enable them better to esist the abrasive effects of traffic.

17 During the many years of my connection with rail making have examined a great many etched specimens of rails, not only irectly in connection with the process under consideration, but for arious other reasons. From such experience I can fully appreciate hat Mr. Mathias has accomplished. The surfaces of practically all ails, when etched, will show some seams on both base and head, nd very frequently the extent of such defects will not be appreciable the scale has not been removed. Even then, it is not always an asy or certain matter to estimate the depth of the seams. When he rails have been subjected to the Mathias milling operation and till show pronounced seams, it has been found that breaking tests ill practically always develop the fact that the suspicious marking s an actual seam.

18 Fig. 11, which is a piece of rail broken under the drop press, lainly shows a pronounced seam in its flange directly under the enter of its base, and is an illustration of a dangerous rail.

19 As the original defects on the sides of the ingots vary in xtent, so will the character of the resulting seams vary and it can be eadily appreciated that some of them may have been too deep to ave been completely eliminated by the milling.

20 To illustrate the appearance of many ordinary steel rails of ommerce when etched, Figs. 12 to 17 show the surfaces of both heads nd flanges. These specimens were taken from rails made by everal different makers, including the Lackawanna Steel Company. These illustrations not only clearly show the field for such an operaion as I have described, but also the extent to which Mr. Mathias as been able to accomplish it.

21 While I have confined myself to the matter of steel rails, it is atent that the process will be of great value in the preparation of blooms for axles and all other kinds of forgings. As is well known, t is practically the universal custom to endeavor to remove the eams developed in rolling axle billets by chipping them out through he use of pneumatic hammers, and for some of the higher characters f forgings, notably for automobile parts, the endeavor to eliminate he seams is carried to the extent of turning off the whole surface of he billets. I am confident that by the Mathias plan the greater part, f not all, of such work can be superseded, and I regard the invention nd its practical installation as a notable achievement in the art.

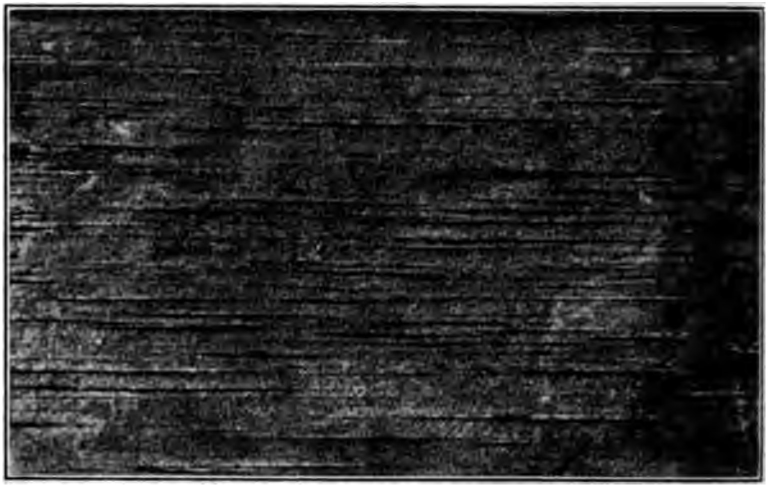
TOP SURFACE

BOTTOM SURFACE

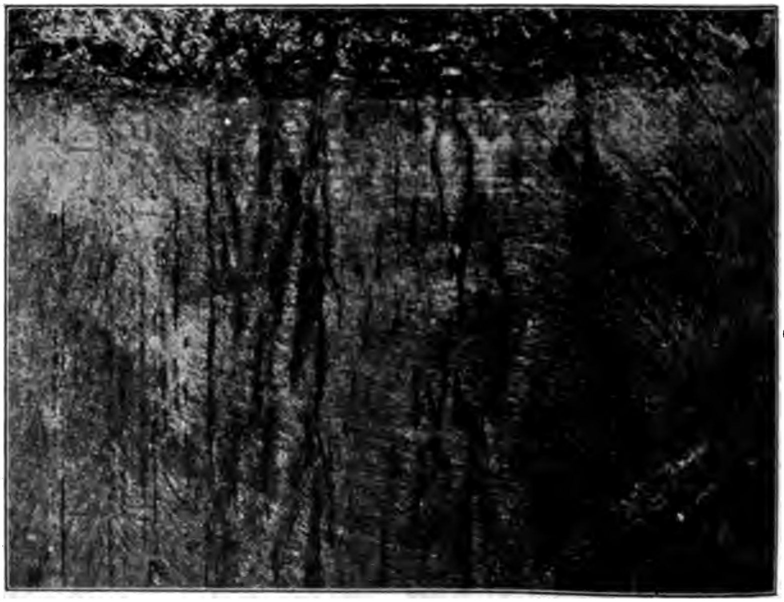
FIG. 12 UNTREATED RAIL

Top Surface

Bottom Surface
Fig. 13 Untreated Rail

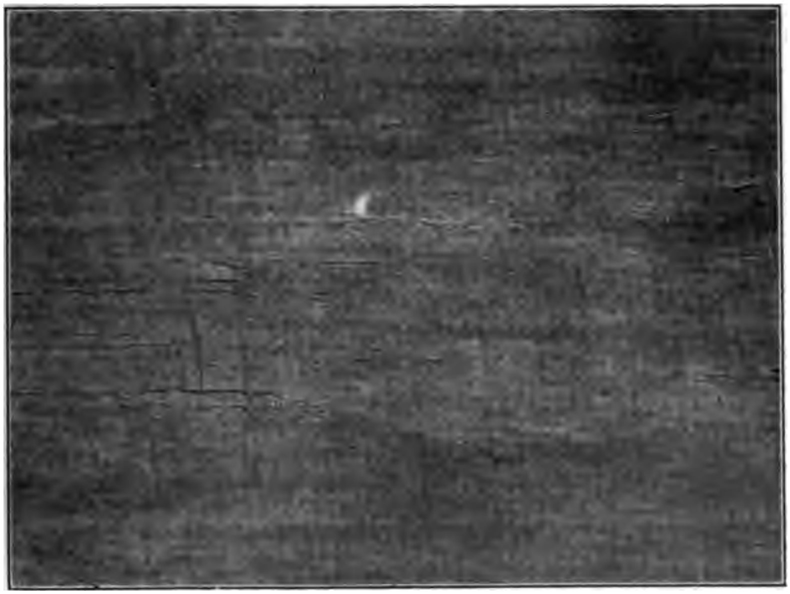


Top Surface

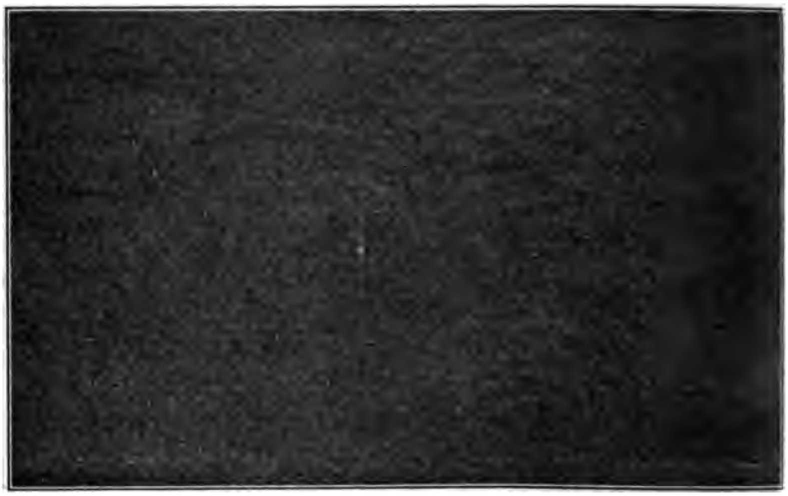


Bottom Surface
Fig. 14 Untreated Rail

Top Surface

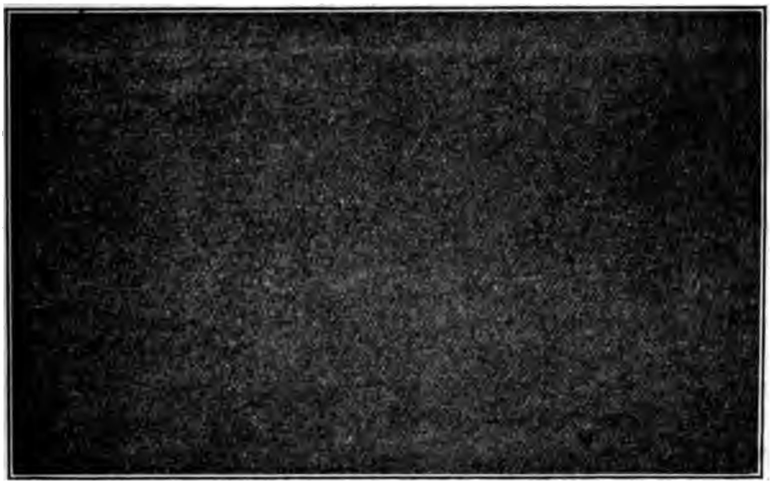


Bottom Surface
Fig. 15 Untreated Rail

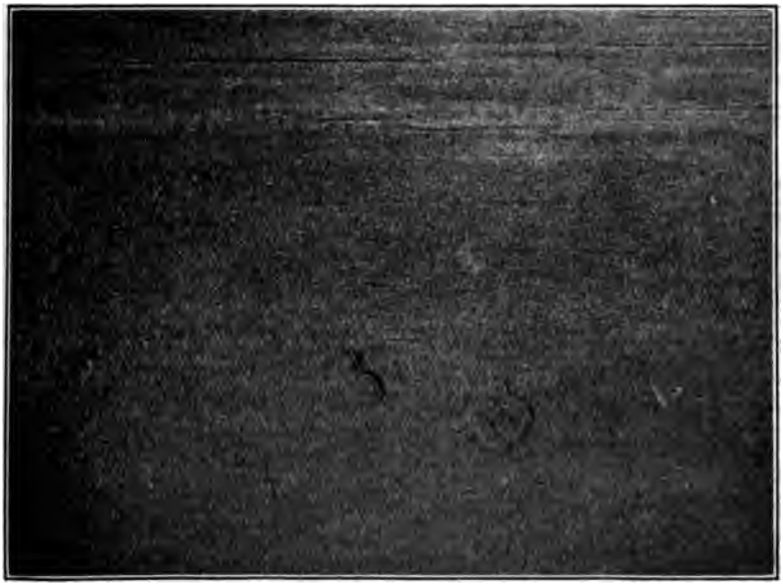


Top Surface

Bottom Surface
Fig. 16 Milled Rail



Top Surface



Bottom Surface
Fig. 17 Milled Rail

DISCUSSION

H. C. HIBBARD said that a sound ingot, properly rolled, will produce a rail without seams and that the paper might therefore be considered as dealing with a factor in the production of steel rails which should not exist.

Although some of the seams are the result of rolling, it is probable that a large number of them are started from surface skin holes which should really not be present in good steel ingots.

Good steel was formerly made by proper furnace management, proper care of the gases and proper care of the impurities; and rails rolled from ingots of such steel were actually perfect and showed no seams. When split, the rails were found to be clear, sound, solid steel from one end to the other, and from top to bottom. The ingots did not require to be milled to be free from seams.

None of the rail ingots now made in representative current practice are sound. They all have pipes and a number of them have blow-holes. The difficulties which many rail mills have to meet to produce solid ingots are fully realized but, at the same time, until these difficulties are overcome and the production starts with the solid, sound ingot, it will be impossible to get a sound, solid rail.

Properly made steel should have a full liberty to pipe and the pipe should not be reduced or eliminated by holes in the other parts of the ingot. In an ingot cast without any special precautions, the only hole that should be present should be the pipe.

There are two well-tested means of getting rid of the pipe and of securing a sound ingot. One is by lateral pressure, and the other by keeping the top of the ingot hot. The interior of a rail ingot will probably keep melted from 1¼ to 1½ hrs., according to its size, after it has been cast, and whatever means is taken to prevent the pipe should probably be applied within fifteen minutes after the ingot is cast and should be continued until the metal is all solidified. This being properly done, a good, sound ingot will result.

J. J. HOWARD, in a written discussion, pointed out that the report of the Committee on Rails and Equipment of the National Association of Railway Commissioners, presented at its recent Convention in Washington, D. C., furnished statistics of train accidents indicating that the average daily losses due to derailments alone, for a term of ten years, were 1.04 persons killed, 14.4 persons injured, and $15,900 property loss. An amelioration of such conditions is demanded and a reduction in the number of broken rails, a frequent cause of accidents, is highly desirable.

It is believed that milling the running surfaces of the heads and the lower surfaces of the bases of steel rails will remove certain recognized defects. The writer witnessed the process described, the efficacy of which will, it is hoped, be demonstrated within a short time upon the rails now in service.

It is understood that in this process no claim is made for the effacement of other than surface defects, although the removal of such defects is regarded as a matter of importance in reducing the number of contributory causes of failure of steel rails.

The presence of streaked metal in steel rails, including both interior and exterior streaks, and also of low carbon surface metal, has occasioned comments in reports upon tests of such rails. Features of this kind have been the subject of admonitory remarks in the Reports of the Interstate Commerce Commission, Division of Safety, in its investigations of the causes of accidents, to some of which reports reference is here made.

The unfavorable influence which attends the presence of soft surface metal located over a hard steel core, when exposed to wheel pressures, is manifest, particularly when interior streaks or seaminess is present. Such surface metal by reason of its low resistance against lateral flow promotes the formation of longitudinal seams in the rail and augments the wedging and splitting tendency of the wheel loads when the metal of the head is penetrated and the interior streaks or lamination are encountered.

In a report on a derailment, issued by the Interstate Commerce Commission in May, 1912, a difference of sixteen points in carbon between the center of the head of the rail and the metal near the running surface was considered responsible for the derailment. Still earlier, Tests of Metals, 1909, showed a difference of twenty-eight points in carbon between the center and the sides of the head of a 75-lb. rail. Such carbon differences are common and their frequency constitutes a sufficient basis for the claim advanced in the paper that an advantage of the process is the removal of partially decarburized steel existing on the surfaces of the ingots. However, the presence of decarburized surface metal at the base of the rail has not been proven disadvantageous, as it may display the functions of a deterrent against the detrimental influence of seaminess. It is well known that certain defects such as slight serrations and indentations are negligible in soft steel, though serious in hard steels. When judging of the influence of structural defects, the use to which the metal is put must be considered in all cases.

Streaky conditions in steel doubtless constitute serious problems for the steel maker, but streaks and seams are not believed to be more prevalent in rails of current manufacture than in those of earlier rolling. Examples of earlier rails show a state of seaminess decidedly greater than is found in rails of present manufacture. Inferentially, present rail troubles in this direction seem due to the development of seams by reason of the greater stresses which the rails are called upon to endure, and not to an increased number of such seams. With greatly increased wheel loads, immunity from failures will be aided by the elimination of those defects which under former track conditions were negligible.

Interior streaks tend to result in split heads and base fractures and are the cause of many rail failures, and they should be eliminated if possible. The removal of such seams is a metallurgical question.

Referring again to the investigations of rails conducted by the Interstate Commerce Commission, the metal of the heads and bases of a number of rails has been planed off to different depths, and a streaked state has been disclosed at each stage. There is obviously no reason for expecting the metal on the side of the ingot which chances to become the head of the rail to be different from that which happens to be rolled into the base. Interior streaks in the metal of the head should have their counterpart in the metal of the base. The examination of the metal of a 100-lb. rail of recent manufacture—an "A" rail—showed the presence of twenty-two seams in the metal of the head, ranging in length from 1/2 to 5 1/2 in. These existed at various depths up to 3/4 in., and while some were at the surface, they were generally most prevalent at depths of 1/8 to 3/8 in. below the surface. Those of the base ranged in lengths from 1/2 to 7 1/2 in., and were found at depths up to 9/16 in. measured from the lower surface, and in from the edge of the flange 1 to 2 3/4 in. Twenty-three of these base seams were disclosed in this rail. Other rails from other heats and other parts of the ingot were free from interior streaks so far as disclosed by the examination.

M. H. Wickhorst[1] expressed his opinion that the cause of the seams in steel rails is somewhat different from what the author con-

[1]Eng. of Tests, Rail Committee, Am. Ry. Eng. Assn., Chicago.

siders it to be. The deep seams in rail flaws, which extend anywhere from 0.08 to 0.12 or possibly 0.15 in. deep from the surface, seem rather to start from cracks in the ingot.

In most ingots, if the scale is removed so that the surface of the metal is exposed, cracks are more or less apparent. When an ingot is rolled, these cracks each open an amount depending upon the draft, and in the subsequent passes they are modified so that they resemble first a "V," then a "Y," until finally, in a rail or small billet, they resemble an elongated "Y," or generally a series of "Y's" together.

It seems that these flaws occur mostly on what are the two open sides of the ingot as it first enters the rolls. On the top and bottom sides, where there is a compression and not an elongation of the skin, the tendency is for the cracks to become eliminated. It appears, therefore, the seams can be confined either to the tread of the rail or to the bottom or sides of it, a fact which might well be considered in practice.

Surface flaws which occur in the web do not apparently result in rail fractures, while those which occur in the base, particularly near the center under the web, do cause failures; in fact, as near as can be determined, an average of about 40 per cent of the rail fractures in this country have their origin in deep seams at the base, and particularly near the center, of the rail.

P. H. Dudley,[1] in a written discussion, stated that the adoption of basic open hearth steel for rails in the past six or eight years had reduced the breakages and failures to a marked extent. The checking of the basic open hearth ingots in blooming is not nearly so frequent as it is in Bessemer ingots, and the crescent-shaped breaks in the same section rails of the former and latter steels are about in the proportion of one to fifty.

The provision of heavier steel rails for increased wheel loads and speeds was investigated over three decades ago by some railroad companies and stiffer sections, with a distribution of the metal to carry the loads with lower unit strains, were designed. Service tests demonstrated that, with the higher standards of track secured, the mechanical abrasion of the crossties under the rail seats and disturbance of the ballast and roadbed were reduced, as was also the number of failures of rails in service for the tonnage carried. It could not be expected, however, that the sections which were satisfactory under the

[1] Consulting Eng., New York Central Lines.

negligible in soft steel, though serious in hard steels. When judging of the influence of structural defects, the use to which the metal is put must be considered in all cases.

Streaky conditions in steel doubtless constitute serious problems for the steel maker, but streaks and seams are not believed to be more prevalent in rails of current manufacture than in those of earlier rolling. Examples of earlier rails show a state of seaminess decidedly greater than is found in rails of present manufacture. Inferentially, present rail troubles in this direction seem due to the development of seams by reason of the greater stresses which the rails are called upon to endure, and not to an increased number of such seams. With greatly increased wheel loads, immunity from failures will be aided by the elimination of those defects which under former track conditions were negligible.

Interior streaks tend to result in split heads and base fractures and are the cause of many rail failures, and they should be eliminated if possible. The removal of such seams is a metallurgical question.

Referring again to the investigations of rails conducted by the Interstate Commerce Commission, the metal of the heads and bases of a number of rails has been planed off to different depths, and a streaked state has been disclosed at each stage. There is obviously no reason for expecting the metal on the side of the ingot which chances to become the head of the rail to be different from that which happens to be rolled into the base. Interior streaks in the metal of the head should have their counterpart in the metal of the base. The examination of the metal of a 100-lb. rail of recent manufacture—an "A" rail—showed the presence of twenty-two seams in the metal of the head, ranging in length from 1/2 to 5 1/2 in. These existed at various depths up to 3/4 in., and while some were at the surface, they were generally most prevalent at depths of 1/8 to 3/8 in. below the surface. Those of the base ranged in lengths from 1/2 to 7 1/2 in., and were found at depths up to 9/16 in. measured from the lower surface, and in from the edge of the flange 1 to 2 3/4 in. Twenty-three of these base seams were disclosed in this rail. Other rails from other heats and other parts of the ingot were free from interior streaks so far as disclosed by the examination.

M. H. Wickhorst[1] expressed his opinion that the cause of the seams in steel rails is somewhat different from what the author con-

[1]Eng. of Tests, Rail Committee, Am. Ry. Eng. Assn., Chicago.

siders it to be. The deep seams in rail flaws, which extend anywhere from 0.08 to 0.12 or possibly 0.15 in. deep from the surface, seem rather to start from cracks in the ingot.

In most ingots, if the scale is removed so that the surface of the metal is exposed, cracks are more or less apparent. When an ingot is rolled, these cracks each open an amount depending upon the draft, and in the subsequent passes they are modified so that they resemble first a "V," then a "Y," until finally, in a rail or small billet, they resemble an elongated "Y," or generally a series of "Y's" together.

It seems that these flaws occur mostly on what are the two open sides of the ingot as it first enters the rolls. On the top and bottom sides, where there is a compression and not an elongation of the skin, the tendency is for the cracks to become eliminated. It appears, therefore, the seams can be confined either to the tread of the rail or to the bottom or sides of it, a fact which might well be considered in practice.

Surface flaws which occur in the web do not apparently result in rail fractures, while those which occur in the base, particularly near the center under the web, do cause failures; in fact, as near as can be determined, an average of about 40 per cent of the rail fractures in this country have their origin in deep seams at the base, and particularly near the center, of the rail.

P. H. Dudley,[1] in a written discussion, stated that the adoption of basic open hearth steel for rails in the past six or eight years had reduced the breakages and failures to a marked extent. The checking of the basic open hearth ingots in blooming is not nearly so frequent as it is in Bessemer ingots, and the crescent-shaped breaks in the same section rails of the former and latter steels are about in the proportion of one to fifty.

The provision of heavier steel rails for increased wheel loads and speeds was investigated over three decades ago by some railroad companies and stiffer sections, with a distribution of the metal to carry the loads with lower unit strains, were designed. Service tests demonstrated that, with the higher standards of track secured, the mechanical abrasion of the crossties under the rail seats and disturbance of the ballast and roadbed were reduced, as was also the number of failures of rails in service for the tonnage carried. It could not be expected, however, that the sections which were satisfactory under the

[1]Consulting Eng., New York Central Lines.

light wheel loads and speeds three decades ago would be adequate to meet the present far greater wheel loads and volume of traffic.

Weight is but one element of steel rails, and it must be distributed so that the combined mechanical and physical properties resulting from a good design and metal will be capable of not only meeting the intensities of the wheel contact pressures, but of carrying and distributing the wheel loads as a girder to the crossties, ballast and roadbed.

The writer considered the introduction of the process described to be a step in advance in rail manufacture, and to evidence the manufacturers' efforts to eliminate the slight defects in their products, so that they will meet all of the exacting conditions of present service.

The Author in conclusion said that he fully agreed in regard to the necessity for making sound ingots, but as sound ingots are not generally made, he considered it a good thing to try to ameliorate the bad effects of unsound ones as far as possible.

He stated the process will not remove deep seams. It will simply eliminate a certain class of seams which occur in practice however careful the manufacturer may be, and it will also remove the decarburized skin. In other words, the process removes the superficial seams, after which, if the inspector still finds defects of this character, he knows he has a deep seam and ought to condemn the rail.

No. 1467

ELECTRIC DRIVE FOR ECONOMIC OPERATION AND DEVELOPMENT OF CEMENT MILLS

By J. Benton Porter, Philadelphia, Pa.

Member of the Society

In the early cement mills, electricity was used only for lighting; ext it was employed to drive machinery located in inconvenient laces; then it was used for driving the auxiliary apparatus, and it ater enabled the manufacturer to locate this auxiliary apparatus nore conveniently; next it provided more flexibility and greater out-ut from the kilns; and finally, electricity is being universally adopted or the entire plant.

2 The last five plants put into operation have installed individual otor drive and five other plants have changed to the electrical drive uring the last two years.

3 The reasons for this growth in the applications of electricity to ement manufacture are:

a It enables the manufacturer to purchase power from central stations, thereby eliminating one of the greatest cost fluctuations from the cost of manufacturing cement.

b It gives a greater flexibility, permitting economical operation under varying conditions of output.

c It keeps the driven machine nearer to a predetermined speed, thereby increasing the output and maintaining the quality. As an example, one plant increased its output over 6 per cent by improving its speed regulation.

d The first cost and maintenance are no longer a nightmare to the management, as years of practical experience have shown that the advantages obtained have justified the cost and that the maintenance compared very favorably with the balance of the equipment.

Abstract of paper presented at the Annual Meeting, December 1914, of HE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

e The electric drive has largely eliminated the human element in making reports, and automatically keeps a record of the power consumed in a plant with an accuracy that cannot be attempted with the mechanical drive.

4 Only a few managers have realized, or indeed utilized this last factor, and this paper is presented in order to call attention more strongly to the value of this salient attribute of electricity, by showing some of the records that have already been compiled, and suggesting some future potentialities.

5 The subject will be dealt with under the following captions:

A Advantage of Economy.
B Necessity for Economy.
C Elimination of Variables.
D Improving the Load Factor.
E Building a Ground Plan.
F Automatic Superintendence.

ADVANTAGE OF ECONOMY

6 If it were possible to save one cent for every barrel manufactured, how much money would a manager be justified in spending to obtain such an improvement? The saving in a plant turning out 1000 barrels a day would amount to about $3600 a year, and such a plant would be justified in borrowing about $20,000.00 in order to accomplish such a saving.

A 2000 barrel plant could afford to expend about $40,000.00
A 3000 barrel plant could afford to expend about $60,000.00
A 5000 barrel plant could afford to expend about $100,000.00

NECESSITY FOR ECONOMY

7 The gradual but persistent depreciation in the selling price of cement is so well known that the manufacturer has had to inaugurate different systems to find out where the weak points are in his process; but he has been badly handicapped, for he has had to base his records on reports that are not wholly accurate.

8 The assumption that all mills are running at their maximum capacity as long as they are in operation has to a very great extent been the ground plan; but accurate tests taken on any one machine show that it is almost impossible to keep a mill at a constant load and output, even when meters are installed and the feed regulated to keep the meter needle at a predetermined point.

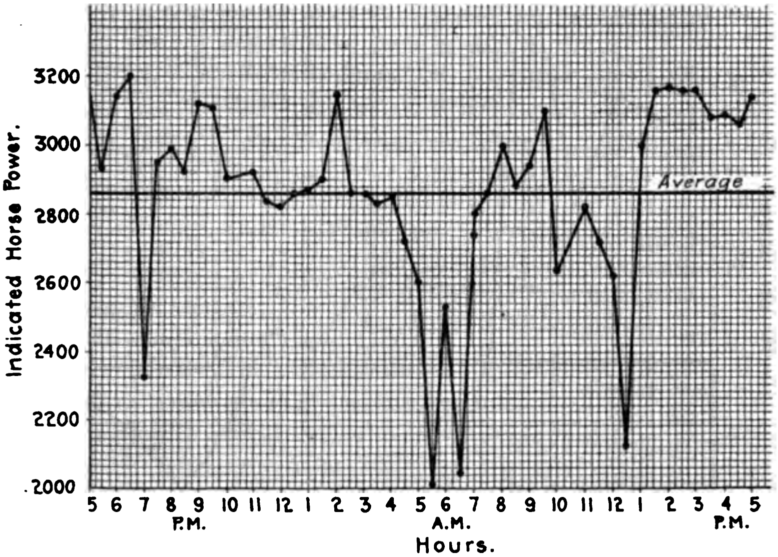


Fig. 1 Horsepower from Indicator Cards in Mechanically-driven Plant

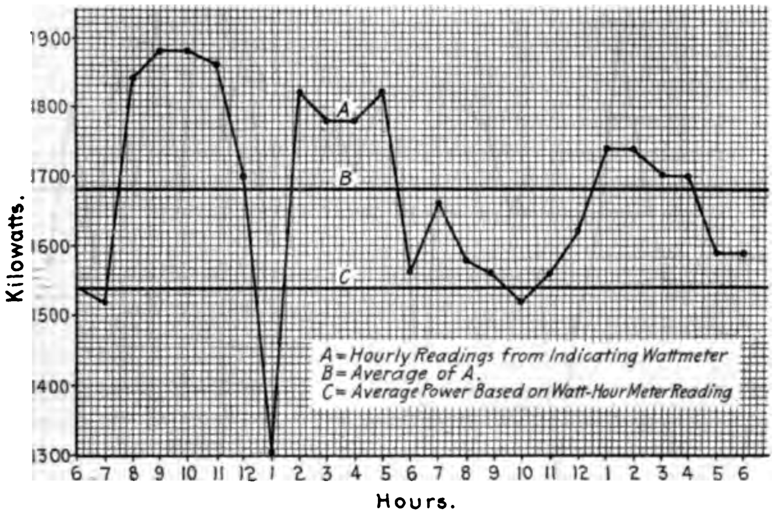


Fig. 2 Readings from Electrically-driven Plant

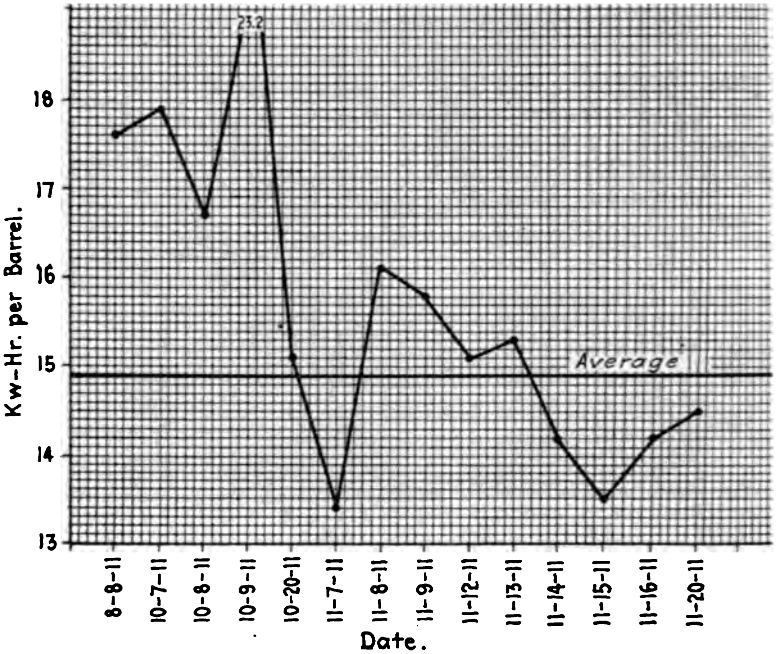


FIG. 3 KILOWATTS PER BARREL, INTERMITTENT PERIODS

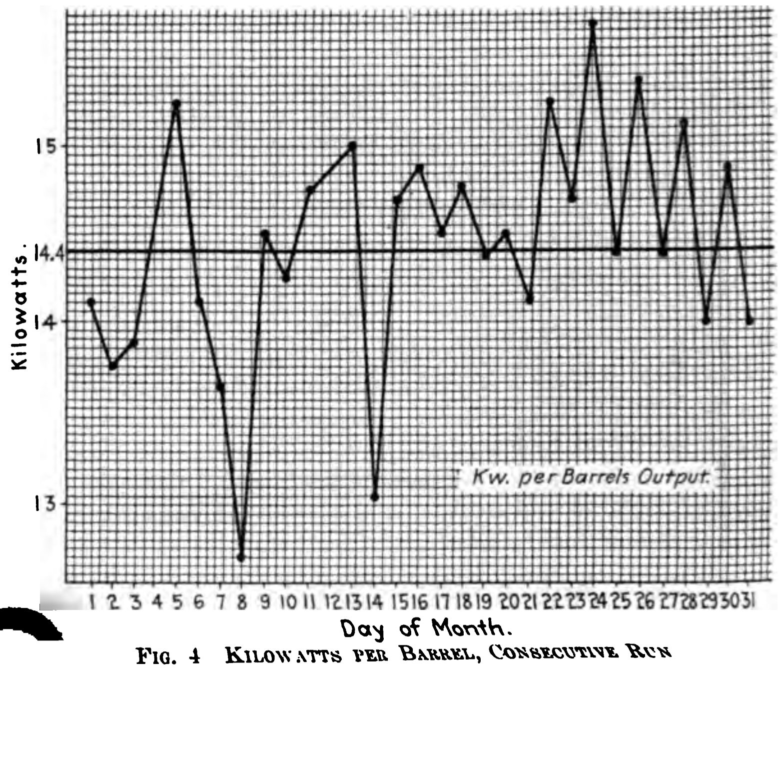


FIG. 4 KILOWATTS PER BARREL, CONSECUTIVE RUN

9 If the management has felt justified in going to the expense f elaborate records based on the above assumption, it should welcome system which automatically shows the power taken at any one time r over any long period; and which is sufficiently flexible to show raphically what is happening in the entire mill, in any department f the mill, or on any one machine.

ELIMINATING VARIABLES

10 The advantage of eliminating variables from the manufactur- ıg of cement is apparent when we realize that coal may be pur- hased with a variation of from 11,000 to 15,000 B.t.u. The evapora- ion of steam by this coal varies from 4 lb. up to 10 lb. for each lb. of oal. In the production of power from this steam, the consump- ion of steam may vary from 30 lb. down to 12½ lb. per i.h.p. and ven lower. These variables, as far as records have shown in cement ıanufacture, are by far the greatest.

11 The particular process of the manufacture of power should e delegated to a corps of engineers whose special study is to obtain he highest possible efficiency even at elaborate cost, and to sell that ower at a fixed charge.

IMPROVING THE LOAD FACTOR

12 The standard forms of contracts for the sale of power sup- lied by central stations call attention very strongly to the fact that he customer can purchase power more advantageously if his load actor is kept high. This means that if the daily readings of power equired for the operations of the plant were plotted, the curve should ome as near as possible to a *straight line*. This would result in many ntrinsic advantages both to the consumer and producer of power.

BUILDING A GROUND PLAN—PAST METHOD

13 It is interesting to note the old system used to determine the mount of power consumed in a cement plant and to figure the cost f power developed.

14 Fig. 1 shows the horsepower taken from indicator cards in a nechanically driven plant where the readings were made every half ıour for a full 24 hours. The horizontal line is the average of these eadings.

15 Fig. 2 shows the readings taken from an electrically driven ılant. The line *A* gives readings similar to those in Fig. 1, while *B*

is the average of these readings. The lower line *C* is determined by taking the total kilowatts consumed during the entire 24 hours and dividing this total by 24; and, therefore, is the only accurate record of the power consumed.

16 It is impossible to obtain a line like *C* from a mechanically driven plant and the difference between the lines *B* and *C* shows the possibility of error, even from the best records of the mechanically driven plant. Fig. 1, however, has been the basis for figuring the cost of horsepower for the entire year and has also been used to determine the amount of power in that particular plant to produce a barrel of cement.

17 Fig. 3 shows the kilowatts consumed to produce a barrel of cement and covers intermittent periods; while Fig. 4 shows this ratio over 31 consecutive days, and from these two curves it is almost impossible to find two consecutive days where the ratio is constant.

18 From this information shown by the above curves, it does not seem fair to try to compare the mechanical drive with the electric drive either in the cost of power or in the amount of power required to produce a barrel of cement.

BUILDING A GROUND PLAN—PRESENT METHOD

19 Continuous operation has been and always must be the watchword for the cement manager. In addition to this he has always striven to run his machines at their maximum capacity; in other words, he has tried to keep his load constant and at the highest possible average.

20 The curves, Figs. 5 to 8, show the power taken in different departments each day and over a period of an entire month. Those departments that show the greatest variation from the average *straight line* are the departments that require the greatest study in order to bring them into the closest possible relation to the *straight line*. Fig 9 shows the barrels output.

AUTOMATIC SUPERINTENDENCE

21 By the installation of individual motor drive, the separation of the various departments in the daily reports and the compilation of these records systematically arranged, the plant manager has a report which enables him to place his finger on loose ends and even anticipate where trouble may arise, to trace out an individual machine that is causing an over-demand of power, and after investiga-

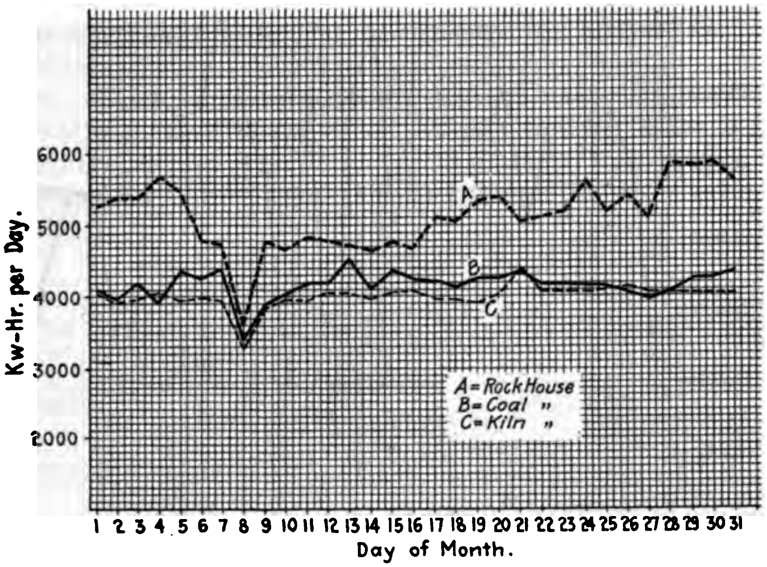


FIG. 5 POWER USED IN ROCK, KILN AND COAL MILL

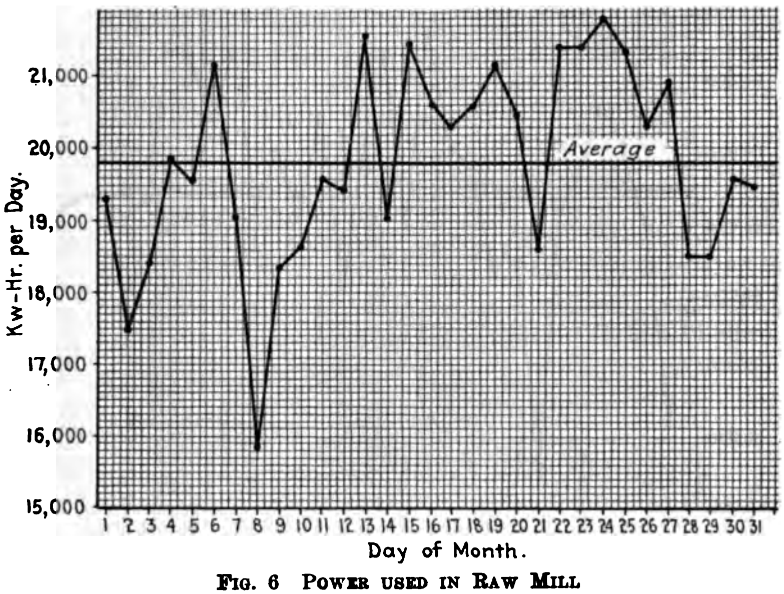


FIG. 6 POWER USED IN RAW MILL

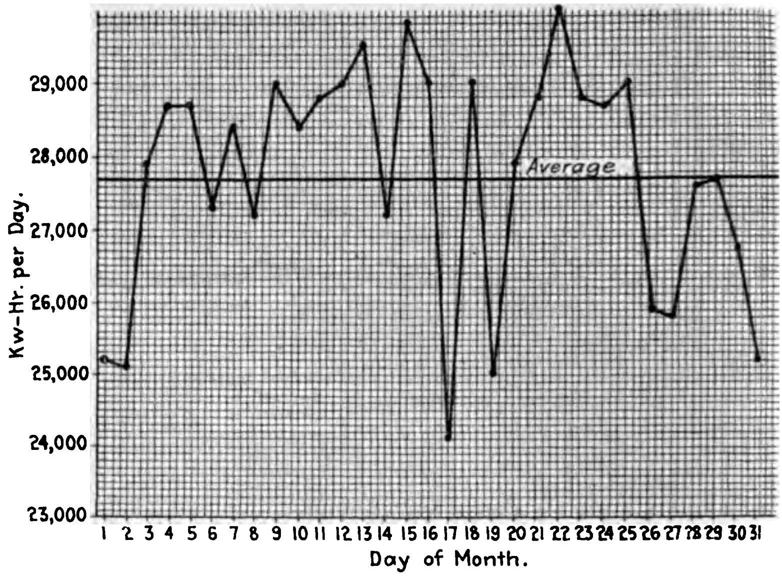


FIG. 7 POWER USED IN FINISHING MILL

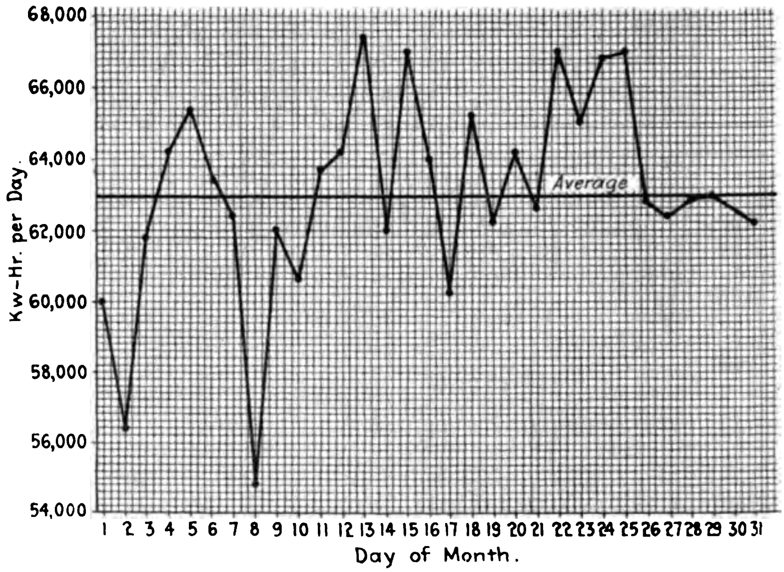


FIG. 8 POWER REQUIRED BY ENTIRE MILL

tion to correct the trouble. The old way was to wait until the machine broke down.

22 No one can predict how great are the improvements that can be affected in the efficiency of cement manufacture. There is no general law that can be laid down for any particular class of mills, as the conditions of installation and the raw material are so entirely different.

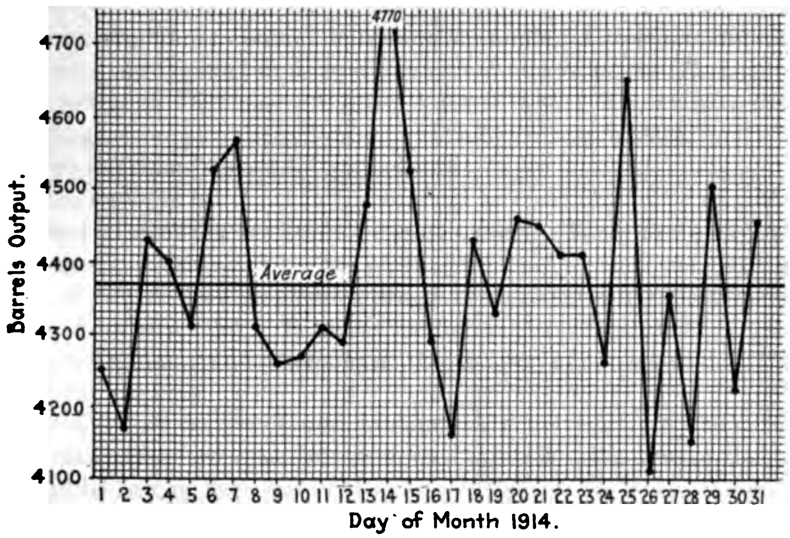


FIG. 9 BARRELS OUTPUT

23 Making improvements in any plant depends upon its history; the records of operation, the accuracy with which they have been compiled; and upon the systematic analysis of such information.

24 Such records of accuracy as are exhibited by curves of the nature of those here given, placed in the hands of the management of cement plants, furnish a stable foundation upon which many improvements may be confidently based.

No. 1468

℞EPORT OF THE COMMITTEE ON STAND-ARD CROSS-SECTIONS AND SYMBOLS

We, the undersigned committee appointed by the President under he direction of the Council, to take up the matter of cross-sections and ymbols, as suggested in a paper[1] presented at the Annual Meeting of he Society in December 1911, beg leave to report that we have held ıeetings, have also carried on our work by correspondence, and now onvey our unanimous findings as below:

We strongly believe that there should be recognition of a standard ıethod of showing materials in cross-section. There are many ad-antages in encouraging the use of standard cross-sections and symbols. t is as easy to draw an adopted design to represent a specific material s to draw any other. It makes mechanical drawings easier to read nd understand, and diminishes the danger of interpreting their ıeaning wrongly.

We do not believe it wise to complicate the matter by adopting oo many standard cross-sectionings or symbols. We believe that it ould be best to have standard cross-sections for the most commonly sed materials, and that these should be of such a character as to ermit of subdivision, if found desirable.

To this end, we propose the use of standard cross-sections to repre-ent nineteen materials as shown on Fig. 1, viz., cast-iron, wrought-:on, cast-steel, wrought-steel, babbitt (or white metal), copper (brass r composition), aluminum, rubber (vulcanite or insulation), glass, ood, water, puddle, concrete, brick, rubble, ashlar, rock, earth and ınd. To facilitate the drawing of cross-sections, the committee have sed the same thickness for all lines made with the drawing pen.

On some drawings it may be desired to specify a material other han those mentioned above, or some particular kind of material which he above generic names would not clearly indicate. To cover this ontingency, we recommend writing the name of such material on the

[1]Standard cross-sections, H. de B. Parsons, Trans. A. S. M. E., vol. 33, . 561.

Presented at the Annual Meeting, December 1914, of THE AMERICAN SO-IETY OF MECHANICAL ENGINEERS.

section and cross-hatching the section, as shown on Fig. 1 under the title Other Materials.

We recommend that subdivisions of any of the materials shown generically on Fig. 1, should be made by taking one of these standard

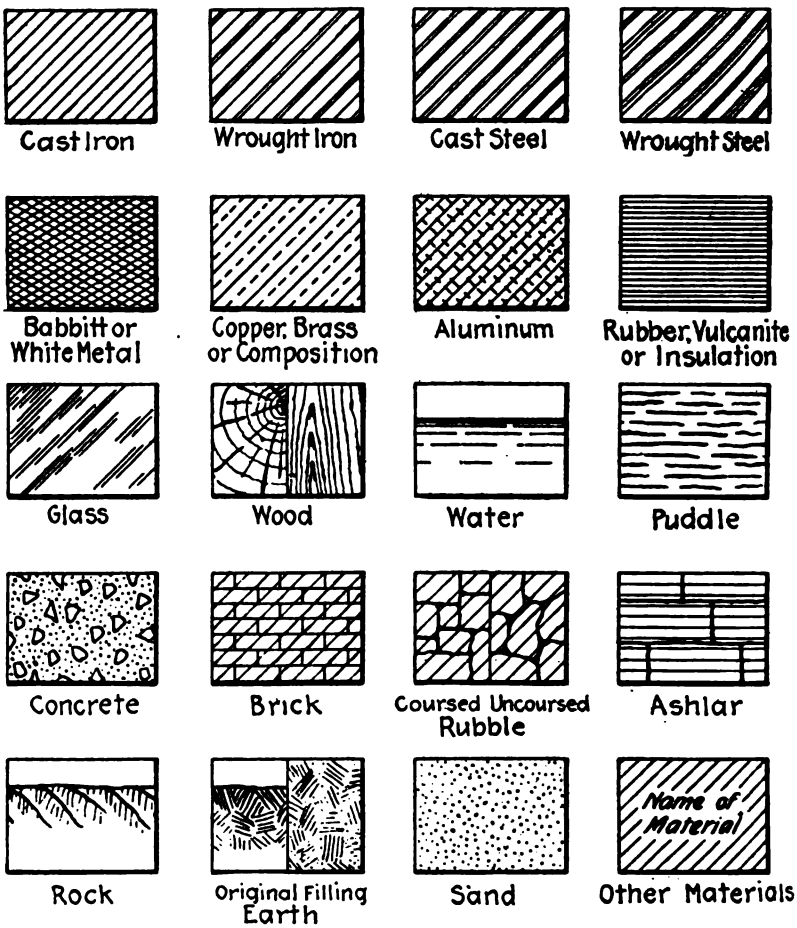


FIG. 1 RECOMMENDED STANDARD CROSS-SECTIONS

cross-sections as a basis and making minor changes, but maintaining the general characteristics; or by writing on the standard section the name of the material. To illustrate, the committee have subdivided concrete into concrete-blocks, cyclopean-concrete and reinforced-con-as shown on Fig. 2, and also wrought-steel into nickel, chrome ınadium steels.

e urge the Society to recommend standard cross-sections. Such ırd cross-sections should be printed in a suitable form for hang- ι walls of drafting rooms of engineers, architects, and educational ıtions, so as to encourage their universal use.

:fore closing, we acknowledge the valued assistance of Mr. D. C.

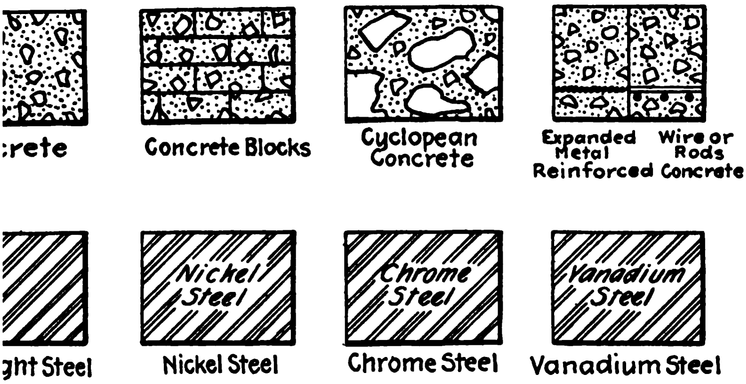


Fig. 2 Typical Subdivisions

on in obtaining data for the committee and extend our thanks to ıny manufacturing establishments, government departments and duals who have sent us such standards as are in use by them.

Respectfully submitted,

H. de B. Parsons, *Chairman*
F. De R. Furman
A. E. Norton
Bradley Stoughton
John W. Upp

Committee on Cross-Section and Symbols

DISCUSSION

A. A. Adler said that he felt there was no demand for standard cross-sections and saw no advantage in them. To show how cumbersome the system is it will be observed that nickel, chrome and vanadium steels are marked in addition to their characteristic cross-sectioning. This is due to the limited number of combinations that may be formed by the variety of lines used.

A much more serious objection is found in the burden that such a set of standards would impose upon the memory. In order to insure that the workman would use the intended materials, a legend would have to be employed to describe the meaning of the standards. This appears contrary to logical procedure. The present method of specifying the material in a "material list" is by far the most convenient method, as it also includes heat treatment and such other data as are necessary for accurate description.

There is, however, one possible use for such standard cross-sections as, for instance, where a change of section indicates a change of material. But in this case no standards of any kind seem necessary.

J. H. Norris said that in his practice he had used about 12 different compositions of what is listed in the report (Fig. 1) as "copper, brass or composition." He had for years sectionalized simply with a plain line, and then marking the materials, although this latter was not usually done, but was indicated on the material list accompanying the drawings. Then if the material is changed, the drawing does not have to be corrected but simply the list. The list of standards proposed seemed to him to be unnecessary.

A. E. Norton thought that Professor Adler had misinterpreted Fig. 2 in respect to the use of printed labels to indicate chrome steel, nickel steel and other variations of chemical composition.

Such labeling is entirely optional, the hatching lines being used only to indicate the process of manufacture, that is, whether the steel is a casting or a forging.

F. De R. Furman, speaking as a member of the committee, said that the putting out of these specifications for the representation of different materials had been induced by the fact that a number of different standards are in use in different drafting rooms. It seemed a desirable thing to secure coöperation between the drafting rooms, which already used a special kind of cross-section line, and have them adopt a uniform standard, to avoid confusion.

SPENCER MILLER regarded the plan as valuable since it allows of the adoption of as many or as few of these standards as may be desired in any drawing room. If any plan is to be adopted at all by a drafting room, it would seem better to adopt one which others have agreed to.

L. P. ALFORD and ARTHUR L. ORMAY.[1] The authors of this discussion are firm believers in the principle of engineering standardization and its application to engineering work. Thus when the report of the Committee on Standard Cross-sections and Symbols was published, they at once turned to it with the purpose of adopting the standards there recommended in their own work. Careful study, however, led to the conclusion that it was impractical to make use of the material thus presented, for a number of reasons, and further consideration led to the preparation of this discussion.

The most serious objection is incompleteness. There are no symbols for a large number of the materials frequently used in mechanical engineering and represented on drawings of members of this Society. Other objections are, a failure to use lines of uniform direction, the sacrifice of individuality in the symbols to a uniform weight of line, and finally an apparent failure to consider the practice and standardization work of others. Further, the general scheme of classification is open to a difference of opinion, for another viewpoint has been taken in the cross-sections and symbols accompanying this discussion.

The Symbols Suggested. The meaning of these objections can best be seen by turning to the symbols shown in Figs. 3-6, which are offered by way of suggestion. There are four groups: cross-sections for metals (Fig. 3), symbols for building materials (Fig. 4), symbols for geologic formations (Fig. 5), and symbols for miscellaneous materials (Fig. 6).

In all of these cross-sections and symbols having ruled lines, the direction of the lines is standardized to two, horizontal and inclined at an angle of 45 deg. with the horizontal. In addition to these the committee's report includes inclined lines, at an angle of 30 deg. with the horizontal, as seen in the symbol for babbitt or white metal.

[1]Chief draftsman, Hill Publishing Co., New York.

Four weights of line are used. The committee's report standardized this feature to a single one. This is a simplification of practice at the expense of result. To the authors' minds such a course is unjustifiable. The quality of the results can be judged by referring to the cross-sections for wrought iron, cast steel and wrought steel

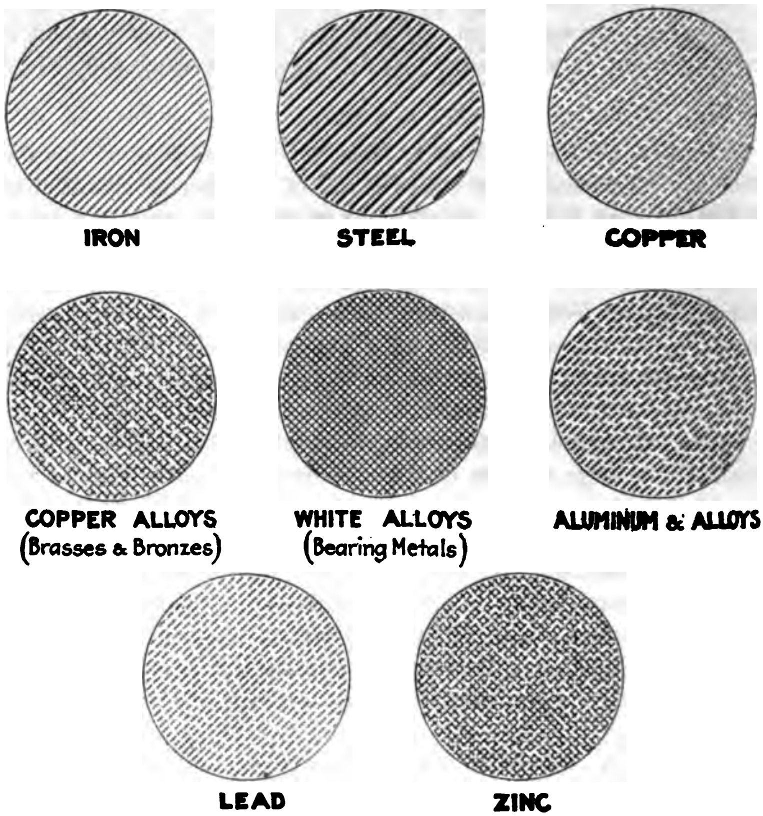


Fig. 3 Cross-Sections for Metals

in the committee's report. From the casual glance of a person familiar with reading drawings, there is but little difference between these cross-sections, not enough to individualize any one of them. In fact, these are so similar that it is doubtful if draftsmen would readily remember them and their differences.

As a detail in the method of presenting these suggested cross-sections and symbols, a difference in form has been made for different materials. This is intended to have some reference to the shape in which the material is met with or used in engineering work. That is, the metal cross-sections are presented by a circular cross-hatched area which might represent the end of a bar, or rod. Earth and rock are shown by an irregular outline that might be part of a section of

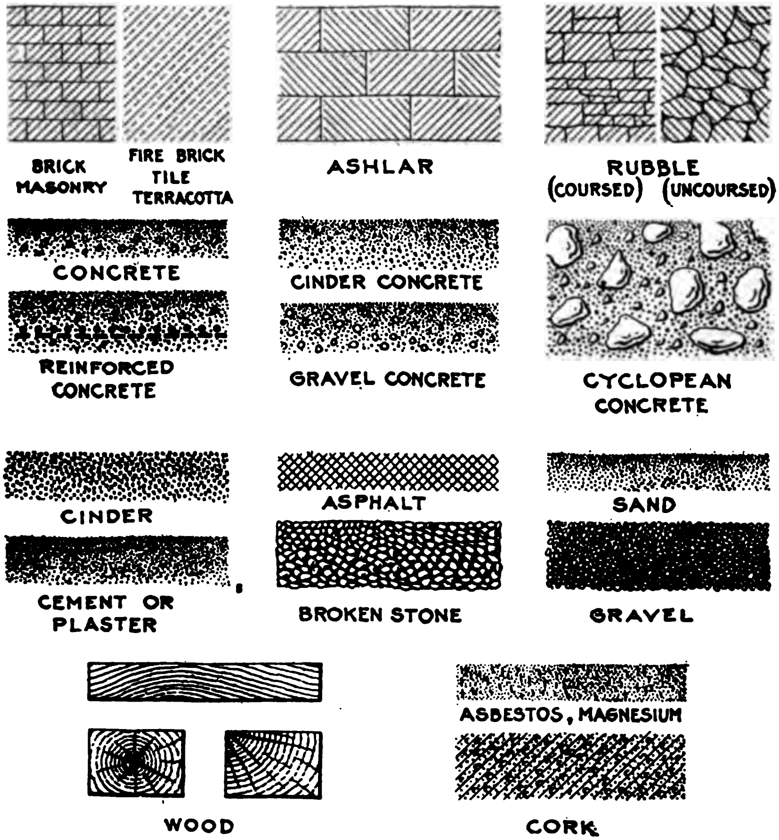


FIG. 4 SYMBOLS FOR BUILDING MATERIALS

a bank or ledge. This same idea has been carried out in connection with some of the others.

The general scheme followed in developing this series has been to distinguish between families of materials by cross-sections and symbols easily remembered, and then make use of abbreviations or names to distinguish subdivisions of these groups. This group system is best illustrated by the cross-sections for metals and the symbols for concrete.

Cross-Sections for Metals. The metals group has eight cross-sections (Fig. 3); of these, five are family groups. The iron group includes cast iron, malleable iron, wrought iron, ingot iron and perhaps others. The steel group includes tool and cast steel, high-speed steel, crucible and high-carbon steel, alloy steels, as nickel, manganese, crome nickel, vanadium, and the ordinary steels of machinery construction, such as bessemer, cold rolled, open hearth, machinery,

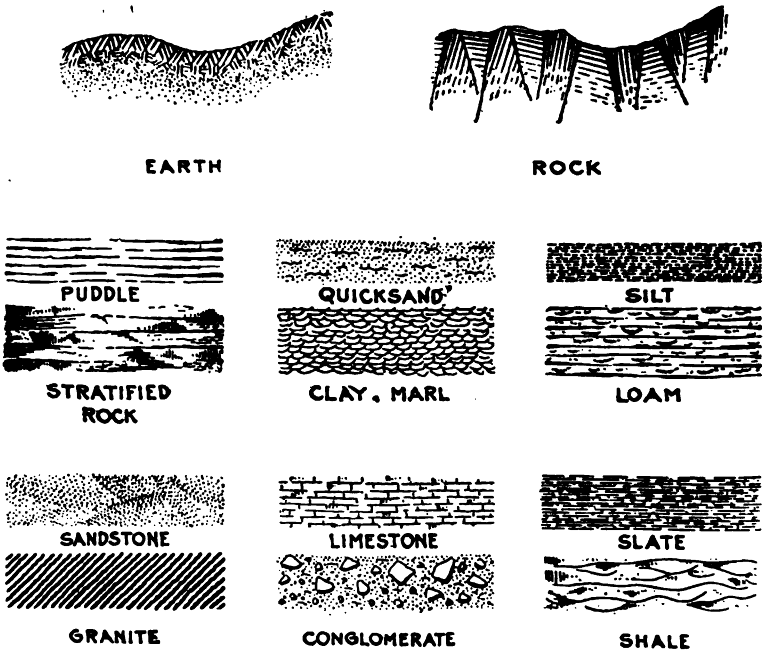


FIG. 5 SYMBOLS FOR GEOLOGIC FORMATIONS

cold drawn and low carbon. The copper alloys include brasses and bronzes in all their variety; white alloys include babbitt and all kinds of white metals; and the aluminum group, aluminum and its alloys. The other three symbols are for copper, lead and zinc, respectively. It should be noted that the copper alloy cross-section is a combination of the copper and lead rulings.

It is believed that these cross-sections cover all of the important families and ordinary engineering metals that are used unalloyed. In practice, the symbol for iron would ordinarily be applied to cast iron, and if any of the other kinds were to be specified its abbreviation or name would be printed across the section. Similarly the steel cross-section would be taken to mean a low-carbon machinery steel and the other grades indicated by abbreviations or names. This same method could be applied to the copper alloys.

Symbols for Building Materials. But little comment need be given to the 19 symbols for building materials (Fig. 4), except that

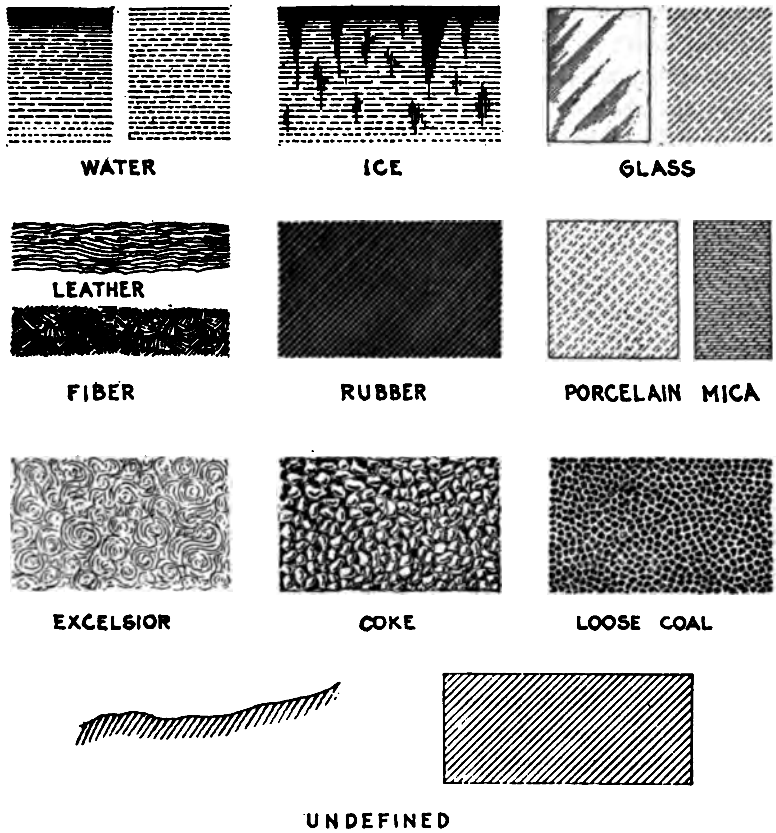


FIG. 6 SYMBOLS FOR MISCELLANEOUS MATERIALS

those presented are believed to cover the ordinary materials met with in the work of members of this Society. Attention is called to the symbol for ashlar, which is believed to represent this important material better than the one shown in the committee's report.

Symbols for Geologic Formation. Here are 14 symbols (Fig. 5), which are believed to cover the formations ordinarily met by members of this Society in connection with foundations for buildings, dams, and other engineering structures. In general, they follow the symbols prepared and published by the United States Geological Survey, and thus have the advantage of being already in use.

Symbols for Miscellaneous Materials. The symbols for miscellaneous materials (Fig. 6) are 11 in number. Some of these may seem new, but all have found use in the work of the authors. The reason for most of them is apparent. By way of explanation, excelsior, coke and coal are represented on power plant drawings, in cross-sections of boilers, coal pockets, gas producers and gas scrubbers, as the case may be.

The final symbol on this chart is for undefined or unclassified material, and follows the suggestion contained in the committee's report.

In conclusion, the authors have written this discussion with a single motive, that of aiding in the constructive work of preparing a series of cross-sections and symbols adequate to the entire field of the work of the mechanical engineer and arranged in a form to be adopted and used. It is hoped that the report which has been discussed will be considered merely as preliminary and that further consideration will be given to this important subject.

In connection with further work, two suggestions are in order. The first is the preparation of a series of abbreviations of the names of the materials forming the subdivisions of the general groups. The second is much broader and is to make a complete study of drawing-room conventions. The modern conception of mechanical drawing is that it is an engineering language. Though this characterization is true, it is a language without uniformity, without grammar, and filled with dialect and peculiarities of expression. A careful investigation of mechanical drawing conventions, with a report putting them in comprehensive form, would be of great value to the members of this Society and to our engineering colleges.

O. K. Harlan wrote that for the cross-sectioning for wrought iron he would prefer a light and heavy line in pairs, similar to that for cast steel but having one of the two light lines made heavier. This has been used for many years and he believed it to be now in quite general use. It gives a clearer distinction between wrought iron and steel than the sections shown in the report, and can be made with the same number of strokes of the pen by retracing one of the two light lines and making it twice as heavy. The sections shown in the report require a second glance to tell which is which, wrought iron or steel, since they are so nearly alike.

The sectioning for rubber did not seem to him to be the best obtainable. Insulation as used in electrical work often involves small pieces, and to use the sectioning shown would admit of confusion between the section lines and the actual lines of the mechanism. In some cases he had used solid black, as rivet holes are sometimes shown in structural steel work, and he had also used soft black pencil on the tracing, which gives an effect on the print which is easily distinguishable. By lettering hard rubber, fiber, vulcanite, etc., in ink on the tracing, it shows clearly on the print and seems to cause less confusion than the light horizontal lines recommended by the committee. He was not disposed, however, to urge the use as standard of either the black pencil or solid black ink.

The Authors. Referring to the suggestion of using lines of more than one thickness, the committee have reached the conclusion, after careful consideration, that lines of uniform thickness will not only facilitate the drawing of cross-sections, but will save much time in waiting for heavy ink lines to dry. If draftsmen had always been in the habit of using lines of uniform thickness in cross-section work, the committee doubt very much if they would now adopt sections made of lines having variable weights.

The underlying principle of the standard sections recommended is the use of single lines for cast iron, then the wrought and forged irons are indicated by making every alternate line double. In a similar way cast steel is shown by double lines in pairs and all the wrought and forged steels by adding an additional line to each alternate pair.

The committee have avoided the use of dotted lines in all cross-section work, except when such lines are used in combination with solid lines, thus preventing confusion with dotted lines which represent objects behind the plane of section.

It is true that frequently rubber and insulation materials are shown in solid black. When these sections are narrow there is no objection to this practice, but when the sections are wide, heavy patches of ink tend to crumple the tracing cloth or paper, and in such cases the section recommended by the committee would be clearer and not liable to confusion.

In cross-sections showing babbitt or white metal, which usually occur in narrow widths, the committee recommend the use of a 30-60 deg. line because it facilitates the act of drawing by requiring a fewer number of lines.

The committee believe it would not be wise to attempt to formulate a standard for every material.

Symbols for various building materials; symbols for geologic formations and symbols for miscellaneous materials, the committee believe, are best worked out by subdividing one of the standard cross-sections as recommended, according to the scheme reported on by the committee under typical subdivisions. Such subdivisions are chiefly used by specific trades or by those working along particular lines. The committee see no objection to the use of many of the symbols submitted by L. P. Alford and Arthur L. Ormay, but believe that they should be classified under typical subdivisions, rather than included as standard cross-sections or symbols.

No. 1469

REPORT OF THE COMMITTEE TO FORMULATE STANDARD SPECIFICATIONS FOR THE CONSTRUCTION OF STEAM BOILERS AND OTHER PRESSURE VESSELS AND FOR THEIR CARE IN SERVICE

TO THE COUNCIL OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

Gentlemen: Your Committee appointed September 15th, 1911 to "Formulate Standard Specifications for the Construction of Steam Boilers and Other Pressure Vessels and for Their Care in Service" respectfully submits its final report on Rules for the construction and allowable working pressures of stationary boilers, which forms a portion of the task assigned to it.

The primary object of these Rules is to secure safe boilers. The interests of boiler users and manufacturers have been carefully considered and the requirements made such that they will not entail undue hardship by departing too widely from present practice.

Your Committee recommends that you appoint a permanent committee to make such revisions as may be found desirable in these Rules, and to modify them as the state of the art advances, and that such committee should hold meetings at least once in two years at which all interested parties may be heard.

Yours truly,

JOHN A. STEVENS, *Chairman*
WM. H. BOEHM
ROLLA C. CARPENTER
RICHARD HAMMOND
CHAS. L. HUSTON
EDWARD F. MILLER
H. C. MEINHOLTZ*
E. D. MEIER*

} COMMITTEE

Deceased*

Presented at the Annual Meeting, December 1914, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS. Approved by the Council, February 13, 1915.

Your Committee secured the assistance of the following Engineers as an Advisory Committee, representing various phases of the design, installation and operation of boilers and the Rules were unanimously approved by them.

F. H. CLARK, Railroad Sub-Committee, The American Society of Mechanical Engineers.

F. W. DEAN, Consulting Engineers.

THOS. E. DURBAN, Boiler Manufacturers' Association, Uniform Specifications Committee, for all types of boilers.

CARL FERRARI, National Tubular Boiler Manufacturers' Association.

ELBERT C. FISHER, Scotch marine and other types of boilers.

ARTHUR M. GREENE, JR., Engineering Education.

CHAS. E. GORTON, Steel heating boilers.

A. L. HUMPHREY, Railroad Sub-Committee, The American Society of Mechanical Engineers.

D. S. JACOBUS, Water-tube boilers.

S. F. JETER, Boiler insurance.

WM. F. KIESEL, JR., Railroad Sub-Committee, The American Society of Mechanical Engineers.

W. F. MACGREGOR, National Association of Thresher Manufacturers.

M. F. MOORE, Steel heating boilers.

I. E. MOULTROP, Boiler users.

RICHARD D. REED, National Boiler & Radiator Manufacturers' Association.

H. G. STOTT, Boiler users.

H. H. VAUGHAN, Railroad Sub-Committee, The American Society of Mechanical Engineers.

C. W. OBERT, Secretary to Committee.

RULES FOR THE CONSTRUCTION OF STATIONARY BOILERS AND FOR ALLOWABLE WORKING PRESSURES

These Rules do not apply to boilers which are subject to federal inspection and control, including marine boilers, boilers of steam locomotive and other self-propelled railroad apparatus.

The Rules are divided into two parts:

PART I applies to new installations. { Section I, Power Boilers. / Section II, Heating Boilers.

PART II applies to existing installations.

PART I NEW INSTALLATIONS

SECTION I

POWER BOILERS

Selection of Materials

1 Specifications are given in these Rules for the important materials used in the construction of boilers, and where given, the materials shall conform thereto.

2 Steel plates for any part of a boiler when exposed to the fire or products of combustion, and under pressure, shall be of firebox quality as designated in the Specifications for Boiler Plate Steel.

3 Steel plates for any part of a boiler, where firebox quality is not specified, when under pressure, shall be of firebox or flange quality as designated in the Specifications for Boiler Plate Steel.

4 Braces when welded, shall be of wrought-iron of the quality designated in the Specifications for Refined Wrought-Iron Bars.

5 Manhole and handhole covers and other parts subjected to pressure, and braces and lugs when made of steel plate, shall be of firebox or flange quality, as designated in the Specifications for Boiler Plate Steel.

6 Steel bars for braces and for other boiler parts, except as otherwise specified herein, shall be of the quality designated in the Specifications for Steel Bars.

7 Staybolts shall be of iron or steel of the quality designated in the Specifications for Staybolt Iron or in the Specifications for Staybolt Steel.

8 Rivets shall be of steel or iron of the quality designated in the Specifications for Boiler Rivet Steel or in the Specifications for Boiler Rivet Iron.

9 Cross pipes connecting the steam and water drums of water-tube boilers, headers and cross boxes and all pressure parts of the boiler

proper over 2-in. pipe size, or equivalent cross-sectional area, shall be of wrought steel, or cast steel of Class B grade, as designated in the Specifications for Steel Castings, when the maximum allowable working pressure exceeds 160 lb. per sq. in.

10 Mud drums of boilers used for other than heating purposes shall be of wrought steel, or cast steel of Class B grade, as designated in the Specifications for Steel Castings.

11 Pressure parts of superheaters, separately fired or attached to stationary boilers, unless of the locomotive type, shall be of wrought steel, or cast steel of Class B grade, as designated in the Specifications for Steel Castings.

12 Cast iron shall not be used for boiler and superheater mountings, such as nozzles, connecting pipes, fittings, valves and their bonnets, for steam temperatures of over 450 deg. fahr.

13 Water-leg and door-frame rings of vertical fire-tube boilers 36 in. or over in diameter, and of locomotive and other type boilers, shall be of wrought iron or steel, or cast steel of Class B grade, as designated in the Specifications for Steel Castings. The O G or other flanged construction may be used as a substitute in any case.

Ultimate Strength of Material used in Computing Joints

14 *Tensile Strength of Steel Plate.* The tensile strength used in the computations for steel plates shall be that stamped on the plates as herein provided, which is the minimum of the stipulated range, or 55,000 lbs. per sq. in. for all steel plates, except for special grades having a lower tensile strength.

15 *Crushing Strength of Steel Plate.* The resistance to crushing of steel plate shall be taken at 95,000 lb. per sq. in. of cross-sectional area.

16 *Strength of Rivets in Shear.* In computing the ultimate strength of rivets in shear, the following values in pounds per square inch of the cross-sectional area of the rivet shank shall be used:

Iron rivets in single shear	38,000
Iron rivets in double shear	76,000
Steel rivets in single shear	44,000
Steel rivets in double shear	88,000

The cross-sectional area used in the computations shall be that of the rivet shank after driving.

Minimum Thicknesses of Plates and Tubes

17 *Thickness of Plates.* The minimum thickness of any boiler plate under pressure shall be 1/4 in.

18 The minimum thicknesses of shell plates, and dome plates after flanging, shall be as follows:

When the Diameter of Shell is			
36 In. or Under	Over 36 In. to 54 In.	Over 54 In. to 72 In.	Over 72 In.
1/4 in.	5/16 in.	3/8 in.	1/2 in.

19 The minimum thicknesses of butt straps shall be as given in Table 1.

TABLE 1 MINIMUM THICKNESSES OF BUTT STRAPS

Thickness of Shell Plates, In.	Minimum Thickness of Butt Straps, In.	Thickness of Shell Plates, In.	Minimum Thickness of Butt Straps, In.
1/4	1/4	17/32	7/16
9/32	1/4	9/16	7/16
5/16	1/4	5/8	1/2
11/32	1/4	3/4	1/2
3/8	5/16	7/8	5/8
13/32	5/16	1	3/4
7/16	3/8	1 1/8	3/4
15/32	3/8	1 1/4	7/8
1/2	7/16		

20 The minimum thicknesses of tube sheets for horizontal return tubular boilers, shall be as follows:

When the Diameter of Tube Sheet is			
42 In. or Under	Over 42 In. to 54 In.	Over 54 In. to 72 In.	Over 72 In.
3/8 in.	7/16 in.	1/2 in.	9/16 in.

21 *Tubes for Water-Tube Boilers.* The minimum thicknesses of tubes used in water-tube boilers measured by Birmingham wire gage, for maximum allowable working pressures not exceeding 165 lb. per sq. in., shall be as follows:

Diameters less than 3 in. . . . . No. 12 B.W.G.
Diameter 3 in. or over, but less than 4 in. . . . . No. 11 B.W.G.
Diameter 4 in. or over, but less than 5 in. . . . . No. 10 B.W.G.
Diameter 5 in. . . . . No. 9 B.W.G.

The above thicknesses shall be increased for maximum allowable working pressures higher than 165 lb. per sq. in. as follows:

Over 165 lb. but not exceeding 235 lb.	1 gage
Over 235 lb. but not exceeding 285 lb.	2 gages
Over 285 lb. but not exceeding 400 lb.	3 gages

Tubes over 4-in. diameter shall not be used for maximum allowable working pressures above 285 lb. per sq. in.

22 *Tubes for Fire-Tube Boilers.* The minimum thicknesses of tubes used in fire tube boilers measured by Birmingham wire gage, for maximum allowable working pressures not exceeding 175 lb. per sq. in., shall be as follows:

Diameters less than 2½ in.	No. 13 B.W.G.
Diameter 2½ in. or over, but less than 3¼ in.	No. 12 B.W.G.
Diameter 3¼ in. or over, but less than 4 in.	No. 11 B.W.G.
Diameter 4 in. or over, but less than 5 in.	No. 10 B.W.G.
Diameter 5 in.	No. 9 B.W.G.

For higher maximum allowable working pressures than given above the thicknesses shall be increased one gage.

SPECIFICATIONS FOR BOILER PLATE STEEL

THESE SPECIFICATIONS[1] ARE SIMILAR TO THOSE OF THE AMERICAN SOCIETY FOR TESTING MATERIALS, SERIAL DESIGNATION A 30-14.

23 *Grades.* These specifications cover two grades of steel for boilers, namely: FLANGE and FIREBOX.

I MANUFACTURE

24 *Process.* The steel shall be made by the open-hearth process

II CHEMICAL PROPERTIES AND TESTS

25 *Chemical Composition.* The steel shall conform to the following requirements as to chemical composition:

		FLANGE	FIREBOX
Carbon		....	Plates ¾ in. thick and under. .0.12—0.25 per cent Plates over ¾ in. thick........0.12—0.30 per cent
Manganese		0.30—0.60 per cent	0.30—0.50 per cent
Phosphorus	Acid	Not over 0.05 per cent	Not over 0.04 per cent
	Basic	Not over 0.04 per cent	Not over 0.035 per cent
Sulphur		Not over 0.05 per cent	Not over 0.04 per cent
Copper		....	Not over 0.05 per cent

26 *Ladle Analyses.* An analysis shall be made by the manufacturer from a test ingot taken during the pouring of each melt, a copy of which shall be given to the purchaser or his representative. This analysis shall conform to the requirements specified in Par. 25.

27 *Check Analyses.* Analyses may be made by the purchaser from a broken tension test specimen representing each plate as rolled, which shall conform to the requirements specified in Par. 25.

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[1]Approved and recommended in its modified form, October 9, 1914, by the Association of American Steel Manufacturers, the American Boiler Manufacturers' Association, the National Tubular Boiler Manufacturers' Association, the National Association of Thresher Manufacturers and the representatives present of leading Water Tube Boiler Manufacturers, with whom the Boiler Code Committee was in conference on September 16, 1914, and by whom further modifications were afterwards offered.

III Physical Properties and Tests

28 *Tension Tests.* *a* The material shall conform to the following requirements as to tensile properties:

	FLANGE	FIREBOX
Tensile strength, lb. per sq. in.	55,000—65,000	55,000—63,000
Yield point, min., lb. per sq. in.	0.5 tens. str.	0.5 tens. str.
Elongation in 8-in., min., per cent (See Par. 29)	$\frac{1,500,000}{\text{Tens. str.}}$	$\frac{1,500,000}{\text{Tens. str.}}$

b If desired steel of lower tensile strength than the above may be used in an entire boiler, or part thereof, the desired tensile limits to be specified, having a range of 10,000 lb. per sq. in. for flange or 8000 lb. per sq. in. for firebox, the steel to conform in all respects to the other corresponding requirements herein specified, and to be stamped with the minimum tensile strength of the stipulated range.

c The yield point shall be determined by the drop of the beam of the testing machine.

29 *Modifications in Elongation.* *a* For material over ¾ in. in thickness, a deduction of 0.5 from the percentages of elongation specified in Par. 28*a*, shall be made for each increase of ⅛ in. in thickness above ¾ in., to a minimum of 20 per cent.

b For material ¼ in. or under in thickness, the elongation shall be measured on a gage length of 24 times the thickness of the specimen.

30 *Bend Tests.* *a* *Cold-bend Tests*—The test specimen shall bend cold through 180 deg. without cracking on the outside of the bent portion, as follows: For material 1 in. or under in thickness, flat on itself; and for material over 1 in. in thickness, around a pin the diameter of which is equal to the thickness of the specimen.

b *Quench-bend Tests*—The test specimen, when heated to a light cherry red as seen in the dark (not less than 1200 deg. fahr.), and quenched at once in water the temperature of which is between 80 deg. and 90 deg. fahr., shall bend through 180 deg. without cracking on the outside of the bent portion, as follows: For material 1 in. or under in thickness, flat on itself; and for material over 1 in. in thickness, around a pin the diameter of which is equal to the thickness of the specimen.

31 *Homogeneity Tests.* For firebox steel, a sample taken from a broken tension test specimen shall not show any single seam or cavity more than ¼ in. long, in either of the three fractures obtained in the test for homogeneity, which shall be made as follows:

The specimen shall be either nicked with a chisel or grooved on a machine, transversely, about 1/16 in. deep, in three places about 2 in. apart. The first groove shall be made 2 in. from the square end; each succeeding groove shall be made on the opposite side from the preceding one. The specimen shall then be firmly held in a vise, with the first groove about ¼ in. above the jaws, and the projecting end broken off by light blows of a hammer, the bending being away from the groove. The specimen shall be broken at the other two grooves in the same manner. The object of this test is to open and render visible to the eye any seams due to failure to weld or to interposed foreign matter, or any cavities due to gas bubbles in the ingot. One side of each fracture shall be examined and the length of the seams and cavities determined, a pocket lens being used if necessary.

32 *Test Specimens.* Tension and bend test specimens shall be taken from the finished rolled material. They shall be of the full

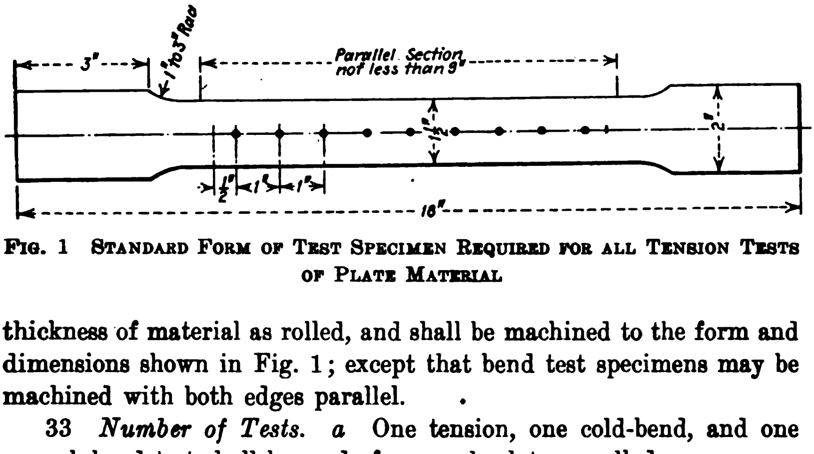

FIG. 1 STANDARD FORM OF TEST SPECIMEN REQUIRED FOR ALL TENSION TESTS OF PLATE MATERIAL

thickness of material as rolled, and shall be machined to the form and dimensions shown in Fig. 1; except that bend test specimens may be machined with both edges parallel.

33 *Number of Tests.* *a* One tension, one cold-bend, and one quench-bend test shall be made from each plate as rolled.

b If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

c If the percentage of elongation of any tension test specimen is less than that specified in Pars. 28 and 29, and any part of the fracture is outside the middle third of the gaged length, as indicated by the scribe scratches marked on the specimen before testing, a retest shall be allowed.

IV PERMISSIBLE VARIATION IN GAGE

34 *Permissible Variation.* The thickness of each plate shall not vary under the gage specified more than 0.01 in. The overweight

limits are considered a matter of contract between the steel manufacturer and the boiler builder.

V Finish

35 *Finish.* The finished material shall be free from injurious defects and shall have a workmanlike finish.

VI Marking

36 *Marking.* *a* Each shell plate shall be legibly stamped by the manufacturer with the melt or slab number, name of manufacturer, grade and the minimum tensile strength of the stipulated range as specified in Par. 28, in three places, two of which shall be located at diagonal corners about 12 in. from the edge and one about the center of the plate, or at a point selected and designated by the purchaser so that the stamp shall be plainly visible when the boiler is completed.

b Each head shall be legibly stamped by the manufacturer in two places, about 12 in. from the edge, with the melt or slab number, name of manufacturer, grade, and the minimum tensile strength of the stipulated range as specified in Par. 28, in such manner that the stamp is plainly visible when the boiler is completed.

c Each butt strap shall be legibly stamped by the manufacturer in two places on the center line about 12 in. from the ends with the melt or slab number, name of manufacturer, grade, and the minimum tensile strength of the stipulated range as specified in Par. 28.

d The melt or slab number shall be legibly stamped on each test specimen.

VII Inspection and Rejection

37 *Inspection.* The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

38 *Rejection.* *a* Unless otherwise specified, any rejection based on tests made in accordance with Par. 27 shall be reported within five working days from the receipt of samples.

b Material which shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

39 *Rehearing.* Samples tested in accordance with Par. 27, which represent rejected material, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

SPECIFICATIONS FOR BOILER RIVET STEEL

THESE SPECIFICATIONS ARE SUBSTANTIALLY THE SAME AS THOSE OF THE AMERICAN SOCIETY FOR TESTING MATERIALS, SERIAL DESIGNATION A 31-14.

A Requirements for Rolled Bars

I Manufacture

40 *Process.* The steel shall be made by the open-hearth process.

II Chemical Properties and Tests

41 *Chemical Composition.* The steel shall conform to the following requirements as to chemical composition:

Manganese	0.30–0.50 per cent
Phosphorus	not over 0.04 per cent
Sulphur	not over 0.045 per cent

42 *Ladle Analyses.* An analysis to determine the percentages of carbon, manganese, phosphorus and sulphur shall be made by the manufacturer from a test ingot taken during the pouring of each melt, a copy of which shall be given to the purchaser or his representative. This analysis shall conform to the requirements specified in Par. 41.

43 *Check Analyses.* Analyses may be made by the purchaser from finished bars, representing each melt, which shall conform to the requirements specified in Par. 41.

III Physical Properties and Tests

44 *Tension Tests.* *a* The bars shall conform to the following requirements as to tensile properties:

Tensile strength, lb. per sq. in.	45,000–55,000
Yield point, min., lb. per sq. in.	0.5 tens. str.
Elongation in 8 in., min., per cent but need not exceed 30 per cent.	$\frac{1,500,000}{\text{Tens. str.}}$

b The yield point shall be determined by the drop of the beam of the testing machine.

45 *Bend Tests.* *a* *Cold-bend Tests*—The test specimen shall bend cold through 180 deg. flat on itself without cracking on the outside of the bent portion.

b *Quench-bend Tests*—The test specimen, when heated to a light cherry red as seen in the dark (not less than 1200 deg. fahr.), and quenched at once in water the temperature of which is between 80 deg. and 90 deg. fahr., shall bend through 180 deg. flat on itself without cracking on the outside of the bent portion.

46 *Test Specimens.* Tension and bend test specimens shall be of the full-size section of bars as rolled.

47 *Number of Tests.* *a* Two tension, two cold-bend, and two quench-bend tests shall be made from each melt, each of which shall conform to the requirements specified.

b If any test specimen develops flaws, it may be discarded and another specimen substituted.

c If the percentage of elongation of any tension test specimen is less than that specified in Par. 44 and any part of the fracture is outside the middle third of the gaged length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

48 *Permissible Variations in Gage.* The gage of each bar shall not vary more than 0.01 in. from that specified.

V Workmanship and Finish

49 *Workmanship.* The finished bars shall be circular within 0.01 in.

50 *Finish.* The finished bars shall be free from injurious defects and shall have a workmanlike finish.

VI Marking

51 *Marking.* Rivet bars shall, when loaded for shipment, be properly separated and marked with the name or brand of the manufacturer and the melt number for identification. The melt number shall be legibly marked on each test specimen.

VII Inspection and Rejection

52 *Inspection.* The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the bars ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the bars are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

53 *Rejection.* *a* Unless otherwise specified, any rejection based on tests made in accordance with Par. 43 shall be reported within five working days from the receipt of samples.

b Bars which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

54 *Rehearing.* Samples tested in accordance with Par. 43, which represent rejected bars, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

B Requirements for Rivets

I Physical Properties and Tests

55 *Tension Tests.* The rivets, when tested, shall conform to the requirements as to tensile properties specified in Par. 44, except that the elongation shall be measured on a gaged length not less than four times the diameter of the rivet.

56 *Bend Tests.* The rivet shank shall bend cold through 180 deg. flat on itself, as shown in Fig. 2, without cracking on the outside of the bent portion.

57 *Flattening Tests.* The rivet head shall flatten, while hot, to a diameter 2½ times the diameter of the shank, as shown in Fig. 3, without cracking at the edges.

58 *Number of Tests.* *a* When specified, one tension test shall be made from each size in each lot of rivets offered for inspection.

b Three bend and three flattening tests shall be made from each size in each lot of rivets offered for inspection, each of which shall conform to the requirements specified.

II Workmanship and Finish

59 *Workmanship.* The rivets shall be true to form, concentric, and shall be made in a workmanlike manner.

60 *Finish.* The finished rivets shall be free from injurious defects.

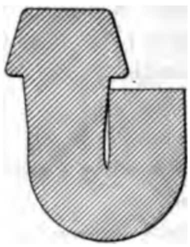

Fig. 2 The Bend Test for Rivets

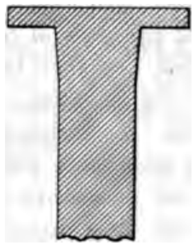

Fig. 3 The Flattening Test for Rivets

III Inspection and Rejection

61 *Inspection.* The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the rivets ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the rivets are being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

62 *Rejection.* Rivets which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

SPECIFICATIONS FOR STAYBOLT STEEL

REQUIREMENTS FOR ROLLED BARS

63 Steel for staybolts shall conform to the requirements for Boiler Rivet Steel specified in Pars. 40 to 62, except that the tensile properties shall be as follows:

Tensile strength, lb. per sq. in.	50,000–60,000
Yield point, min., lb. per sq. in.	0.5 tens. str.
Elongation in 8 in., min., per cent	$\frac{1,500,000}{\text{Tens. str.}}$

Also with the exception that the permissible variations in gage shall be as follows:

Permissible Variations in Gage. The bars shall be truly round within 0.01 in. and shall not vary more than 0.005 in. above, or more than 0.01 in. below the specified size.

SPECIFICATIONS FOR STEEL BARS

THESE SPECIFICATIONS ARE ABSTRACTED FROM THOSE FOR STEEL FOR BRIDGES OF THE AMERICAN SOCIETY FOR TESTING MATERIALS, SERIAL DESIGNATION A 7-14.

I Manufacture

64 *Process.* The steel shall be made by the open-hearth process.

II Chemical Properties and Tests

65 *Chemical Composition.* The steel shall conform to the following requirements as to chemical composition:

Phosphorus	Acid	not over 0.06 per cent
	Basic	not over 0.04 per cent
Sulphur		not over 0.05 per cent

66 *Ladle Analysis.* An analysis to determine the percentages of carbon, manganese, phosphorus and sulphur shall be made by the manufacturer from a test ingot taken during the pouring of each melt, a copy of which shall be given to the purchaser or his representative. This analysis shall conform to the requirements specified in Par. 65.

III PHYSICAL PROPERTIES AND TESTS

67 *Tension Tests.* *a* The material shall conform to the following requirements as to tensile properties:

Tensile strength, lb. per sq. in.	55,000–65,000
Yield point, min., per sq. in.	0.5 tens. str.
Elongation in 8 in., min., per cent*	$\frac{1,500,000}{\text{Tens. str.}}$
Elongation in 2 in., min., per cent	22

*See Par. 68.

b The yield point shall be determined by the drop of the beam of the testing machine.

68 *Modifications in Elongation.* *a* For bars over ¾ in. in thickness or diameter a deduction of 1 from the percentage of elongation in 8 in. specified in Par. 67, shall be made for each increase of ⅛ in. in thickness or diameter above ¾ in., to a minimum of 18 per cent.

b For bars under 5/16 in. in thickness or diameter a deduction of 2.5 from the percentage of elongation in 8 in. specified in Par. 67, shall be made for each decrease of 1/16 in. in thickness or diameter below 5/16 in.

69 *Bend Tests.* *a* The test specimen shall bend cold through 180 deg. without cracking on the outside of the bent portion, as follows: For material ¾ in. or under in thickness or diameter flat on itself; for material over ¾ in. to and including 1¼ in. in thickness or diameter around a pin the diameter of which is equal to the thickness or diameter of the specimen; and for material over 1¼ in. in thickness or diameter around a pin the diameter of which is equal to twice the thickness or diameter of the specimen.

b The test specimen for bars over 1½ in. in thickness or diameter when prepared as specified in Par. 70, shall bend cold through 180 deg. around a 1-in. pin without cracking on the outside of the bent portion.

70 *Test Specimens.* *a* Tension and bend test specimens except as specified in *b*, shall be of the full thickness of material as rolled. They may be machined to the form and dimensions shown in Fig. 1, or may have both edges parallel.

b Tension test specimens for bars over 1½ in. in thickness or diameter may be of the form and dimensions shown in Fig. 4. Bend test specimens may be 1 by 1/2 in. in section. The axis of the specimen shall be located at any point midway between the center and surface and shall be parallel to the axis of the bar.

71 *Number of Tests.* *a* One tension and one bend test shall be made from each melt; except that if material from one melt differs 3/8 in. or more in thickness, one tension and one bend test shall be made from both the thickest and the thinnest material rolled.

b If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

c If the percentage of elongation of any tension test specimen is less than that specified in Par. 67, and any part of the fracture is more than 3/4 in. from the center of the gage length of a 2-in. specimen or is outside the middle third of the gage length of an 8-in. specimen, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

IV Permissible Variations in Gage

72 *Permissible Variation.* The thickness or cross-section of each piece of steel shall not vary under that specified more than 2.5 per cent. (Note: Overweight variation is a matter of contract between the steel manufacturer and boiler builder.)

V Finish

73 *Finish.* The finished material shall be free from injurious defects and shall have a workmanlike finish.

VI Marking

74 *Marking.* Bars shall, when loaded for shipment, be properly separated and marked with the name or brand of the manufacturer and melt number for identification. The melt number shall be legibly marked on each test specimen.

VII Inspection and Rejection

75 *Inspection.* The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works

which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

76 *Rejection.* Material which shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

SPECIFICATIONS FOR STEEL CASTINGS

THESE SPECIFICATIONS ARE ABSTRACTED FROM THOSE FOR STEEL CASTINGS OF THE AMERICAN SOCIETY FOR TESTING MATERIALS, SERIAL DESIGNATION A 27-14.

77 *Classes.* These specifications cover two classes of castings, namely:

Class A, ordinary castings for which no physical requirements are specified.

Class B, castings for which physical requirements are specified. These are of three grades: hard, medium, and soft.

78 *Patterns.* *a* Patterns shall be made so that sufficient finish is allowed to provide for all variations in shrinkage.

b Patterns shall be painted three colors to represent metal, cores, and finished surfaces. It is recommended that core prints shall be painted black and finished surfaces red.

79 *Basis of Purchase.* The purchaser shall indicate his intention to substitute the test to destruction specified in Par. 87, for the tension and bend tests, and shall designate the patterns from which castings for this test shall be made.

I MANUFACTURE

80 *Process.* The steel may be made by the open-hearth, crucible, or any other process approved by the purchaser.

81 *Heat Treatment.* *a* Class *A* castings need not be annealed unless so specified.

b Class *B* castings shall be allowed to become cold. They shall then be uniformly reheated to the proper temperature to refine the grain (a group thus reheated being known as an "annealing charge"), and allowed to cool uniformly and slowly. If, in the opinion of the purchaser or his representative, a casting is not properly annealed, he may at his option require the casting to be re-annealed.

II Chemical Properties and Tests

82 *Chemical Composition.* The castings shall conform to the following requirements as to chemical composition:

	Class A	Class B
Carbon	not over 0.30 per cent	....
Phosphorus	not over 0.06 per cent	not over 0.05 per cent
Sulphur	....	not over 0.05 per cent

83 *Ladle Analyses.* An analysis to determine the percentages of carbon, manganese, phosphorus and sulphur shall be made by the manufacturer from a test ingot taken during the pouring of each melt, a copy of which shall be given to the purchaser or his representative. This analysis shall conform to the requirements specified in Par. 82. Drillings for analysis shall be taken not less than ¼ in. beneath the surface of the test ingot.

84 *Check Analyses.* *a* Analyses of Class *A* castings may be made by the purchaser, in which case an excess of 20 per cent above the requirement as to phosphorus specified in Par. 82, shall be allowed. Drillings for analysis shall be taken not less than ¼ in beneath the surface.

b Analyses of Class *B* castings may be made by the purchaser from a broken tension or bend test specimen, in which case an excess of 20 per cent above the requirements as to phosphorus and sulphur specified in Par. 82, shall be allowed. Drillings for analysis shall be taken not less than ¼ in. beneath the surface.

III Physical Properties and Tests

(For Class *B* Castings only.)

85 *Tension Tests.* *a* The castings shall conform to the following minimum requirements as to tensile properties:

	Hard	Medium	Soft
Tensile strength, lb. per sq. in.	80,000	70,000	60,000
Yield point, lb. per sq. in.	36,000	31,500	27,000
Elongation in 2 in., per cent	15	18	22
Reduction of area, per cent	20	25	30

b The yield point shall be determined by the drop of the beam of the testing machine.

86 *Bend Tests.* *a* The test specimen for soft castings shall bend cold through 120 deg., and for medium castings through 90 deg., around a 1-in. pin, without cracking on the outside of the bent portion.

b Hard castings shall not be subject to bend test requirements.

87 *Alternative Tests to Destruction.* In the case of small or unimportant castings, a test to destruction on three castings from a lot may be substituted for the tension and bend tests. This test shall show the material to be ductile, free from injurious defects, and suitable for the purpose intended. A lot shall consist of all castings from one melt, in the same annealing charge.

88 *Test Specimens.* *a* Sufficient test bars, from which the test specimens required in Par. 89, may be selected, shall be attached to castings weighing 500 lb. or over, when the design of the castings will permit. If the castings weigh less than 500 lb., or are of such a design that test bars cannot be attached, two test bars shall be cast to represent each melt; or the quality of the castings shall be determined by tests to destruction as specified in Par. 87. All test bars shall be annealed with the castings they represent.

b The manufacturer and purchaser shall agree whether test bars can be attached to castings, on the location of the bars on the castings, on the castings to which bars are to be attached, and on the method of casting unattached bars.

c Tension test specimens shall be of the form and dimensions shown in Fig. 4. Bend test specimens shall be machined to 1 by ½ in. in section with corners rounded to a radius not over 1/16 in.

89 *Number of Tests.* *a* One tension and one bend test shall be made from each annealing charge. If more than one melt is represented in an annealing charge, one tension and one bend test shall be made from each melt.

b If any test specimen shows defective machining or develops flaws, it may be discarded; in which case the manufacturer and the purchaser or his representative shall agree upon the selection of another specimen in its stead.

c If the percentage of elongation of any tension test specimen is less than that specified in Par. 85, and any part of the fracture is more than ¾ in. from the center of the gaged length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

IV Workmanship and Finish

90 *Workmanship.* The castings shall substantially conform to the sizes and shapes of the patterns, and shall be made in a workmanlike manner.

91 *Finish.* *a* The castings shall be free from injurious defects.

b Minor defects which do not impair the strength of the castings may, with the approval of the purchaser or his representative, be

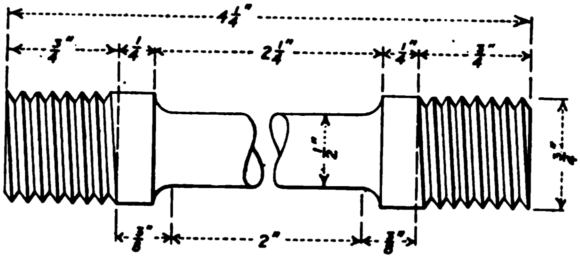

Fig. 4 Standard Form of Test Specimen Required for all Tension Tests of Steel Casting Material

welded by an approved process. The defects shall first be cleaned out to solid metal; and after welding, the castings shall be annealed, if specified by the purchaser or his representative.

c The castings offered for inspection shall not be painted or covered with any substance that will hide defects, nor rusted to such an extent as to hide defects.

V Inspection and Rejection

92 *Inspection.* The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the castings ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the castings are being furnished in accordance with

these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

93 *Rejection.* *a* Unless otherwise specified, any rejection based on tests made in accordance with Par. 84, shall be reported within five working days from the receipt of samples.

b Castings which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

94 *Rehearing.* Samples tested in accordance with Par. 84, which represent rejected castings, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

SPECIFICATIONS FOR GRAY IRON CASTINGS

THESE SPECIFICATIONS ARE IDENTICAL WITH THOSE OF THE AMERICAN SOCIETY FOR TESTING MATERIALS, SERIAL DESIGNATION A 48-05.

95 *Process of Manufacture.* Unless furnace iron is specified, all gray castings are understood to be made by the cupola process.

96 *Chemical Properties.* The sulphur contents to be as follows:

Light castings	not over 0.08 per cent
Medium castings	not over 0.10 per cent
Heavy Castings	not over 0.12 per cent

97 *Classification.* In dividing castings into light, medium and heavy classes, the following standards have been adopted:

98 Castings having any section less than ½ in. thick shall be known as *light castings.*

99 Castings in which no section is less than 2 in. thick shall be known as *heavy castings.*

100 *Medium castings* are those not included in the above classification.

Physical Properties and Tests

101 *Transverse Test.* The minimum breaking strength of the "Arbitration Bar" under transverse load shall be not under:

Light castings	2500 lbs.
Medium castings	2900 lbs.
Heavy castings	3300 lbs.

In no case shall the deflection be under 0.10 in.

102 *Tensile Test.* Where specified, this shall not run less than:

Light castings	18,000 lb. per sq. in.
Medium castings	21,000 lb. per sq. in.
Heavy castings	24,000 lb. per sq. in.

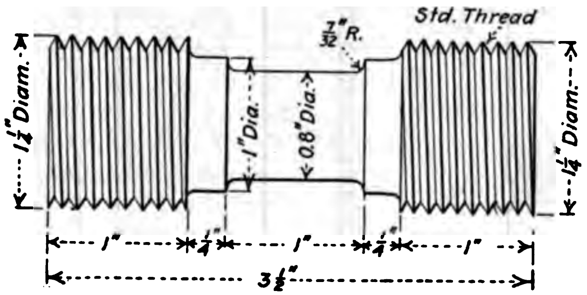

Fig. 5 Standard Form of Test Specimen Required for Tension Tests of Gray-Iron Casting Material

103 *Arbitration Bar.* The quality of the iron going into castings under specification shall be determined by means of the "Arbitration Bar." This is a bar 1¼ in. in diameter and 15 in. long. It shall be prepared as stated further on and tested transversely. The tensile test is not recommended, but in case it is called for, the bar as shown in Fig. 5, and turned up from any of the broken pieces of the transverse test shall be used. The expense of the tensile test shall fall on the purchaser.

104 *Number of Test Bars.* Two sets of two bars shall be cast from each heat, one set from the first and the other set from the last iron going into the castings. Where the heat exceeds twenty tons, an additional set of two bars shall be cast for each twenty tons or fraction thereof above this amount. In case of a change of mixture during the heat, one set of two bars shall also be cast for every mixture other

than the regular one. Each set of two bars is to go into a single mold. The bars shall not be rumbled or otherwise treated, being simply brushed off before testing.

105 *Method of Testing.* The transverse test shall be made on all the bars cast, with supports 12 in. apart, load applied at the middle,

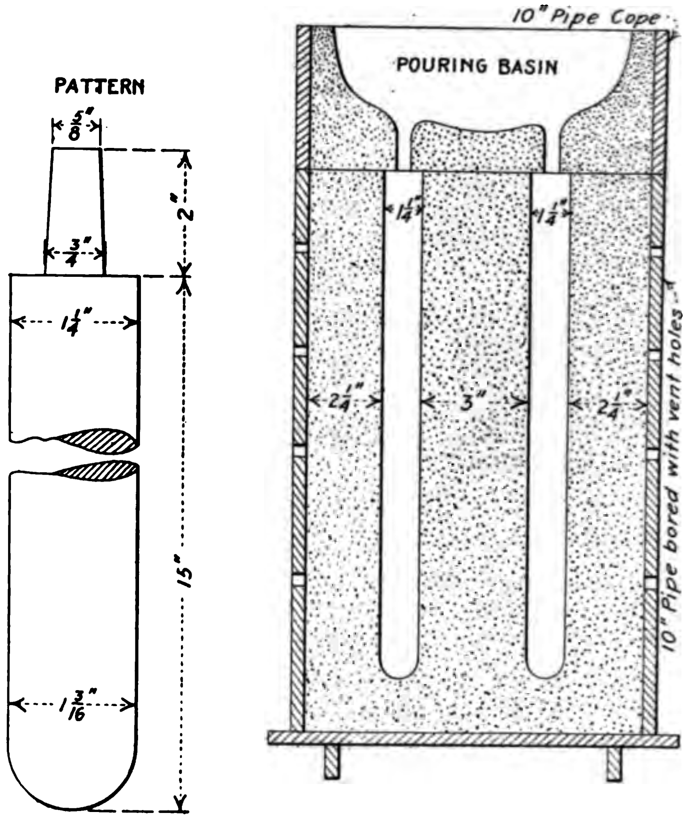

FIG. 6 DETAILS OF PATTERN AND MOLD REQUIRED FOR ARBITRATION BARS IN TESTING GRAY-IRON CASTING MATERIAL

and the deflection at rupture noted. One bar of every two of each set made must fulfill the requirements to permit acceptance of the castings represented.

106 *Mold for Test Bar.* The mold for the bars is shown in Fig. 6. The bottom of the bar is 1/16 in. smaller in diameter than the top, to allow for draft and for the strain of pouring. The pattern shall not be rapped before withdrawing. The flask is to be rammed up

with green molding sand, a little damper than usual, well mixed and put through a No. 8 sieve, with a mixture of one to twelve bituminous facing. The mold shall be rammed evenly and fairly hard, thoroughly dried and not cast until it is cold. The test bar shall not be removed from the mold until cold enough to be handled.

107 *Speed of Testing.* The rate of application of the load shall be from 20 to 40 seconds for a deflection of 0.10 in.

108 *Samples for Analysis.* Borings from the broken pieces of the "Arbitration Bar" shall be used for the sulphur determinations. One determination for each mold made shall be required. In case of dispute, the standards of the American Foundrymen's Association shall be used for comparison.

109 *Finish.* Castings shall be true to pattern, free from cracks, flaws and excessive shrinkage. In other respects they shall conform to whatever points may be specially agreed upon.

110 *Inspection.* The inspector shall have reasonable facilities afforded him by the manufacturer to satisfy him that the finished material is furnished in accordance with these specifications. All tests and inspections shall, as far as possible, be made at the place of manufacture prior to shipment.

SPECIFICATIONS FOR MALLEABLE CASTINGS

THESE SPECIFICATIONS ARE IDENTICAL WITH THOSE OF THE AMERICAN SOCIETY FOR TESTING MATERIALS, SERIAL DESIGNATION A 47-04.

111 *Process of Manufacture.* Malleable iron castings may be made by the open-hearth, air furnace, or cupola process. Cupola iron. however, is not recommended for heavy nor for important castings.

112 *Chemical Properties.* Castings for which physical requirements are specified shall not contain over 0.06 sulphur nor over 0.225 phosphorus.

Physical Properties and Tests

113 *Standard Test Bar.* This bar shall be 1 in. sq. and 14 in. long, without chills and with ends left perfectly free in the mold. Three shall be cast in one mold, heavy risers insuring sound bars. Where the full heat goes into castings which are subject to specifica-

tion, one mold shall be poured two minutes after tapping into the first ladle, and another mold from the last iron of the heat. Molds shall be suitably stamped to insure identification of the bars, the bars being annealed with the castings. Where only a partial heat is required for the work in hand, one mold should be cast from the first ladle used and another after the required iron has been tapped.

a Of the three test bars from the two molds required for each heat, one shall be tested for tensile strength and elongation, the other for transverse strength and deflection. The other remaining bar is reserved for either the transverse or tensile test, in case of the failure of the two other bars to come up to requirements. The halves of the bars broken transversely may also be used for the tensile test.

b Failure to reach the required limit for the tensile strength with elongation, as also the transverse strength with deflection, on the part of at least one test, shall reject the castings from that heat.

114 *Tensile Test.* The tensile strength of a standard test bar for castings under specification shall not be less than 40,000 lb. per sq. in. The elongation measured in 2 in. shall not be less than 2½ per cent.

115 *Transverse Test.* The transverse strength of a standard test bar, on supports 12 in. apart, pressure being applied at the center, shall not be less than 3000 lb., deflection being at least ½ in.

116 *Test Lugs.* Castings of special design or of special importance may be provided with suitable test lugs at the option of the inspector. At least one of these lugs shall be left on the casting for his inspection upon his request therefor.

117 *Annealing.* Malleable castings shall neither be "over" nor "under" annealed. They must have received their full heat in the oven at least sixty hours after reaching that temperature.

118 The "saggers" shall not be dumped until the contents shall at least be "black hot."

119 *Finish.* Castings shall be true to pattern, free from blemishes, scale or shrinkage cracks. A variation of 1/16 in. per foot shall be permissible. Founders shall not be held responsible for defects due to irregular cross sections and unevenly distributed metal.

120 *Inspection.* The inspector representing the purchaser shall have all reasonable facilities given him by the founder to satisfy him that the finished material is furnished in accordance with these specifications. All tests and inspections shall be made prior to shipment.

SPECIFICATIONS FOR BOILER RIVET IRON

THESE REQUIREMENTS ARE AN ADAPTATION, WITH SLIGHT MODIFICATIONS IN THE PHYSICAL PROPERTIES AND TESTS, OF THE SPECIFICATIONS FOR ENGINE BOLT IRON OF THE AMERICAN SOCIETY FOR TESTING MATERIALS.

A Requirements for Rolled Bars

I Manufacture

121 *Process.* The iron shall be made wholly from puddled iron or knobbled charcoal iron, and shall be free from any admixture of iron scrap or steel.

122 *Iron Scrap.* This term applies only to foreign or bought scrap and does not include local mill products free from foreign or bought scrap.

II Physical Properties and Tests

123 *Tension Tests.* *a* The iron shall conform to the following requirements as to tensile properties:

Tensile strength, lb. per sq. in.	48,000–52,000
Yield point, min., lb. per sq. in.	0.6 tens. str.
Elongation in 8 in., min., per cent	28
Reduction of area, min., per cent	45

b The yield point shall be determined by the drop of the beam of the testing machine. The speed of the cross-head of the machine shall not exceed 1½ in. per minute.

124 *Bend Tests.* *a* *Cold-bend Tests*—The test specimen shall bend cold through 180 deg. flat on itself without cracking on the outside of the bent portion.

b *Hot-bend Tests*—The test specimen, when heated to a bright cherry red, shall bend through 180 deg. flat on itself, without fracture on the outside of the bent portion.

c *Nick-bend Tests*—The test specimen, when nicked 25 per cent around with a tool having a 60-deg. cutting edge, to a depth of not less than 8 nor more than 16 per cent of the diameter of the specimen, and broken, shall show a wholly fibrous fracture.

d Bend tests may be made by pressure or by blows.

125 *Etch Tests.*[1] The cross-section of the test specimen shall be ground or polished, and etched for a sufficient period to develop the structure. This test shall show the material to be free from steel.

126 *Test Specimens.* All test specimens shall be of the full section of material as rolled.

127 *Number of Tests.* *a* Bars of one size shall be sorted into lots of 100 each. Two bars shall be selected at random from each lot or fraction thereof, and tested as specified in Pars. 123 and 124; but only one of these bars shall be tested as specified in Par. 125.

b If any test specimen from either of the bars originally selected to represent a lot of material, contains surface defects not visible before testing but visible after testing, or if a tension test specimen breaks outside the middle third of the gage length, one retest from a different bar will be allowed.

III PERMISSIBLE VARIATIONS IN GAGE

128 *Permissible Variations.* The gage of each bar shall not vary more than 0.01 in. from that specified.

IV FINISH

129 *Finish.* The bars shall be smoothly rolled and free from slivers, depressions, seams, crop ends and evidences of being burnt.

V MARKING

130 *Marking.* The bars shall be stamped or marked as designated by the purchaser.

VI INSPECTION AND REJECTION

131 *Inspection.* *a* The inspector representing the purchaser shall have free entry at all times, while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with

[1]A solution of two parts water, one part concentrated hydrochloric acid, and one part concentrated sulphuric acid is recommended for the etch test.

these specifications. Tests and inspection at the place of manufacture shall be made prior to shipment.

b The purchaser may make the tests to govern the acceptance or rejection of material in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

132 *Rejection.* If either of the test bars selected to represent a lot does not conform to the requirements specified in Pars. 123, 124 and 125, the lot will be rejected.

B Requirements for Rivets

I Physical Properties and Tests

133 *Number of Tests.* When specified, three rivets of each diameter shall be taken at random from each lot offered for inspection, and if they fail to stand the following tests the lot will be rejected.

134 *Bend Tests.* *a* The rivet shank shall bend cold through 180 deg. flat on itself, as shown in Fig. 2, without cracking on the outside of the bent portion.

b The heads must stand bending back, showing that they are firmly joined.

c When nicked and broken gradually the fracture must show a clean, long and fibrous iron.

II Workmanship and Finish

135 *Workmanship.* The rivets shall be true to form, concentric, and shall be made in a workmanlike manner.

136 *Finish.* The finished rivets shall be free from injurious defects.

III Inspection and Rejection

137 *Inspection.* The inspector representing the purchaser shall have free entry at all times, while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the rivets ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the rivets are being furnished in accordance with these specifications. All tests and inspection shall be made at the

place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

138 *Rejection.* Rivets which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

SPECIFICATIONS FOR STAYBOLT IRON

THESE SPECIFICATIONS ARE IDENTICAL WITH THOSE OF THE AMERICAN SOCIETY FOR TESTING MATERIALS, SERIAL DESIGNATION A 39-14.

I Manufacture

139 *Process.* The iron shall be rolled from a bloom or boxpile, made wholly from puddled iron or knobbled charcoal iron. The puddle mixture and the component parts of the bloom or boxpile shall be free from any admixture of iron scrap or steel.

140 *Definition of Terms.* *a* *Bloom*—A bloom is a solid mass of iron that has been hammered into a convenient size for rolling.

b *Boxpile*—A boxpile is a pile, the sides, top and bottom of which are formed by four flat bars and the interior of which consists of a number of small bars the full length of the pile.

c *Iron Scrap*—This term applies only to foreign or purchased scrap and does not include local mill products free from foreign or purchased scrap.

II Physcial Properties and Tests

141 *Tension Tests.* *a* The iron shall conform to the following requirements as to tensile properties:

Tensile strength, lb. per sq. in.	49,000–53,000
Yield point, min., lb. per sq. in.	0.6 tens. str.
Elongation in 8 in., min., per cent	30
Reduction of area, min., per cent	48

b The yield point shall be determined by the drop of the beam of the testing machine. The speed of the cross-head of the machine shall not exceed 1½ in. per minute.

142 *Bend Tests.* *a* *Cold-bend Tests*—The test specimen shall end cold through 180 deg. flat on itself in both directions without racture on the outside of the bent portion.

b *Quench-bend Tests*—The test specimen, when heated to a yel-ow heat and quenched at once in water the temperature of which is etween 80 deg. and 90 deg. fahr., shall bend through 180 deg. flat on self without fracture on the outside of the bent portion.

c *Nick-bend Tests*—The test specimen, when nicked 25 per cent round with a tool having a 60-deg. cutting edge, to a depth of not ess than 8 nor more than 16 per cent of the diameter of the specimen, nd broken, shall show a clean fiber entirely free from crystallization.

d Bend tests may be made by pressure or by blows.

143 *Etch Tests.*[1] The cross-section of the test specimen shall be round or polished, and etched for a sufficient period to develop the tructure. This test shall show the material to have been rolled from bloom or a boxpile, and to be free from steel.

144 *Test Specimens.* All test specimens shall be of the full sec-ion of material as rolled.

145 *Number of Tests.* *a* Bars of one size shall be sorted into ots of 100 each. Two bars shall be selected at random from each lot r fraction thereof, and tested as specified in Pars. 141 and 142; but nly one of these bars shall be tested as specified in Par. 143.

b If any test specimen from either of the bars originally selected o represent a lot of material, contains surface defects not visible be-ore testing but visible after testing, or if a tension test specimen reaks outside the middle third of the gage length, one retest from a ifferent bar will be allowed.

c When retests as specified in *b* are not permitted, a reduction f 2 per cent in elongation and 3 per cent in reduction of area from hat specified in Par. 141, shall be allowed.

III Permissible Variations in Gage

146 *Permissible Variations.* The bars shall be truly round vithin 0.01 in., and shall not vary more than 0.005 in. above or more han 0.01 in. below the specified size.

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[1]A solution of two parts water, one part concentrated hydrochloric acid, and one part concen-ated sulphuric acid is recommended for the etch test.

IV Finish

147 *Finish.* The bars shall be smoothly rolled and free from slivers, depressions, seams, crop ends and evidences of being burnt.

V Marking

148 *Marking.* The bars shall be stamped or marked as designated by the purchaser.

VI Inspection and Rejection

149 *Inspection.* *a* The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. Tests and inspection at the place of manufacture shall be made prior to shipment.

b The purchaser may make the tests to govern the acceptance or rejection of material in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

150 *Rejection.* *a* If either of the test bars selected to represent a lot does not conform to the requirements specified in Pars. 141, 142 and 143, the lot will be rejected.

b Bars which will not take a clean, sharp thread with dies in fair condition, or which develop defects in forging or machining, will be rejected, and the manufacturer shall be notified.

SPECIFICATIONS FOR REFINED WROUGHT-IRON BARS

THESE SPECIFICATIONS ARE SIMILAR TO THOSE OF THE AMERICAN SOCIETY FOR TESTING MATERIALS, SERIAL DESIGNATION A 41-18.

I MANUFACTURE

151 *Process.* Refined wrought-iron bars shall be made wholly from puddled iron, and may consist either of new muck-bar iron or a mixture of muck-bar iron and scrap, but shall be free from any admixture of steel.

II PHYSICAL PROPERTIES AND TESTS

152 *Tension Tests.* *a* The iron shall conform to the following minimum requirements as to tensile properties.

Tensile strength, lb. per sq. in. (See Pars. 153 and 154.)	48,000
Yield point, lb. per sq. in.	25,000
Elongation in 8 in., per cent (See Par. 155.)	22

b The yield point shall be determined by the drop of the beam of the testing machine. The speed of the cross-head of the machine shall not exceed 1½ in. per minute.

153 *Permissible Variations.* Twenty per cent of the test specimens representing one size may show tensile strengths 1000 lb. per sq. in. under, or 5000 lb. per sq. in. over that specified in Par. 152; but no specimen shall show a tensile strength under 45,000 lb. per sq. in.

154 *Modifications in Tensile Strength.* For flat bars which have to be reduced in width, a deduction of 1000 lb. per sq. in. from the tensile strength specified in Pars. 152 and 153, shall be made.

155 *Permissible Variations in Elongation.* Twenty per cent of the test specimens representing one size may show the following percentages of elongation in 8 in.:

ROUND BARS

½ in. or over, tested as rolled	20 per cent
Under ½ in., tested as rolled	16 per cent
Reduced by machining	18 per cent

FLAT BARS

⅝ in. or over, tested as rolled	18 per cent
Under ⅝ in., tested as rolled	16 per cent
Reduced by machining	16 per cent

156 *Bend Tests.* *a* *Cold-bend Tests*—Cold bend tests will be made only on bars having a nominal area of 4 sq. in. or under, in which case the test specimen shall bend cold through 180 deg. without fracture on the outside of the bent portion, around a pin the diameter of which is equal to twice the diameter or thickness of the specimen.

b *Hot-bend Tests*—The test specimen, when heated to a temperature between 1700 deg. and 1800 deg. fahr., shall bend through 180 deg. without fracture on the outside of the bent portion, as follows: for round bars under 2 sq. in. in section, flat on itself; for round bars 2 sq. in. or over in section and for all flat bars, around a pin the diameter of which is equal to the diameter or thickness of the specimen.

c *Nick-bend Tests*—The test specimen, when nicked 25 per cent around for round bars, and along one side for flat bars, with a tool having a 60-deg. cutting edge, to a depth of not less than 8 nor more than 16 per cent of the diameter or thickness of the specimen, and broken, shall not show more than 10 per cent of the fracture surface to be crystalline.

d Bend tests may be made by pressure or by blows.

157 *Etch Tests.*[1] The cross-section of the test specimen shall be ground or polished, and etched for a sufficient period to develop the structure. This test shall show the material to be free from steel.

158 *Test Specimens.* *a* Tension and bend test specimens shall be of the full section of material as rolled, if possible; otherwise the specimens shall be machined from the material as rolled. The axis of the specimen shall be located at any point one-half the distance from the center to the surface of round bars, or from the center to the edge of flat bars, and shall be parallel to the axis of the bar.

b Etch test specimens shall be of the full section of material as rolled.

159 *Number of Tests.* *a* All bars of one size shall be piled separately. One bar from each 100 or fraction thereof will be selected at random and tested as specified.

b If any test specimen from the bar originally selected to represent a lot of material contains surface defects not visible before test-

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[1]A solution of two parts water, one part concentrated hydrochloric acid, and one part concentrated sulphuric acid is recommended for the etch test.

ing but visible after testing, or if a tension test specimen breaks outside the middle third of the gage length, one retest from a different bar will be allowed.

III Permissible Variations in Gage

160 *Permissible Variations.* *a* Round bars shall conform to the standard limit gages adopted by the Master Car Builders' Association given in Table 2.

TABLE 2 PERMISSIBLE VARIATIONS IN GAGE FOR ROUND WROUGHT-IRON BARS

Nominal Diameter, Inches	Maximum Diameter, Inches	Minimum Diameter, Inches	Total Variation, Inches
¼	0.2550	0.2450	0.010
5/16	0.3180	0.3070	0.011
⅜	0.3810	0.3690	0.012
7/16	0.4440	0.4310	0.013
½	0 5070	0.4930	0.014
9/16	0.5700	0.5550	0.015
⅝	0.6330	0.6170	0.016
¾	0.7585	0.7415	0.017
⅞	0.8840	0.8660	0.018
1	1.0095	0.9905	0.019
1⅛	1.1350	1.1150	0.020
1¼	1.2605	1.2395	0.021

b The widths or thicknesses of flat bars shall not vary more than 2 per cent from that specified.

IV Finish

161 ***Finish.*** The bars shall be smoothly rolled and free from slivers, depressions, seams, crop ends and evidences of being burnt.

V Inspection and Rejection

162 *Inspection.* *a* The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. Tests and inspection at the place of manufacture shall be made prior to shipment.

b The purchaser may make the tests to govern the acceptance or rejection of material in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

163 *Rejection.* All bars of one size will be rejected if the test specimens representing that size do not conform to the requirements specified.

SPECIFICATIONS FOR LAPWELDED AND SEAMLESS BOILER TUBES

Approved by the Boiler Tube Manufacturers of America
September 25, 1914

I Manufacture

164 *Process.* *a* Lapwelded tubes shall be made of open-hearth steel or knobbled hammered charcoal iron.

b Seamless tubes shall be made of open-hearth steel.

II Chemical Properties and Tests

165 *Chemical Composition.* *a* The steel shall conform to the following requirements as to chemical composition:

Carbon	0.08–0.18	per cent
Manganese	0.30–0.50	per cent
Phosphorus	not over 0.04	per cent
Sulphur	not over 0.045	per cent

b Chemical analyses will not be required for charcoal iron tubes.

166 *Check Analyses.* *a* Analyses of two tubes in each lot of 250 (or on total order if less than 250) may be made by the purchaser which shall conform to the requirements specified in Par. 165. Drillings for analyses shall be taken from several points around each tube.

b If the analysis of only one tube does not conform to the requirements specified, analyses of two additional tubes from the same lot shall be made, each of which shall conform to the requirements specified.

III Physical Properties and Tests

167 *Flange Test.* *a* A test specimen not less than 4 in. in length shall have a flange turned over at right angles to the body of the tube

without showing cracks or flaws. This flange as measured from the outside of the tube shall be 3/8 in. wide.

b In making the flange test, the flaring tool and die block as shown in Fig. 7, may be used.

168 *Flattening Tests.* A test specimen 3 in. in length shall stand hammering flat until the inside walls are brought parallel and separated by a distance equal to three (3) times the wall thickness, without showing cracks or flaws. In the case lapwelded tubes, the test shall be made with the weld at the point of maximum bend.

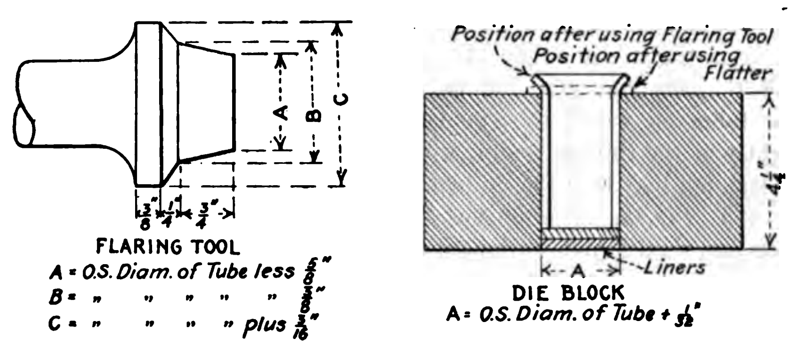

FIG. 7 DETAILS OF FLARING TOOL AND DIE BLOCK REQUIRED FOR MAKING FLANGE TESTS OF BOILER TUBES

169 *Hydrostatic Tests.* Tubes under 5 in. in diameter shall stand an internal hydrostatic pressure of 1000 lb. per sq. in. and tubes 5 in. in diameter or over, an internal hydrostatic pressure of 800 lb. per sq. in. Lapwelded tubes shall be struck near both ends, while under pressure, with a two-pound hand hammer or the equivalent.

170 *Test Specimens.* *a* All test specimens shall be taken from tubes before being cut to finished lengths and shall be smooth on the ends and free from burrs. *b* All tests shall be made cold.

171 *Number of Tests.* One flange and one flattening test shall be made from each of two tubes in each lot of 250 or less. Each tube shall be subjected to the hydrostatic test.

172 *Retests.* If the result of the physical tests of only one tube from any lot do not conform to the requirements specified in Pars. 167 and 168, retests of two additional tubes from the same lot shall be made, each of which shall conform to the requirements specified.

ETCH TESTS FOR CHARCOAL IRON

173 *Etch Tests.*[1] A cross section of tube may be turned or ground to a perfectly true surface polished free from dirt or cracks, and etched until the soft parts are sufficiently dissolved for the iron tube to show a decided ridged surface with the weld very distinct, while a steel tube would show a homogeneous surface.

IV Workmanship and Finish

174 *Workmanship.* The finished tubes shall be circular within 0.02 in. and the mean outside diameter shall not vary more than 0.015 in. from the size ordered. All tubes shall be carefully gaged with a B.W.G. gage and shall not be less than the gage specified, except the tubes on which the standard slot gage, specified, will go on tightly at the thinnest point, will be accepted. The length shall not be less, but may be 0.125 in. more than that ordered.

175 *Finish.* The finished tubes shall be free from injurious defects and shall have a workmanlike finish and shall be practically free from kinks, bends and buckles.

V Marking

176 *Marking.* The name or brand of the manufacturer, the material from which it is made, whether steel or charcoal iron, and "Tested at 1000 lb." for tubes under 5 in. in diameter, or "Tested at 800 lb." for tubes 5 in. in diameter or over, shall be legibly stenciled on each tube.

VI Inspection and Rejection

177 *Inspection.* All tests and inspection shall be made at the place of manufacture. The manufacturer of boiler tubes shall furnish the purchaser of each lot of tubes a statement of the kind of material of which the tubes are made, and that the tubes have been tested and have met all the requirements of these rules. This statement shall be furnished to the manufacturer using the tubes.

178 *Rejection.* Tubes when inserted in the boiler shall stand expanding and beading without showing cracks or flaws, or opening at the weld. Tubes which fail in this manner will be rejected and the manufacturer shall be notified.

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[1] A solution of two parts of water, one part concentrated hydrochloric acid, and one part concentrated sulphuric acid is recommended for the etch test.

Construction and Maximum Allowable Working Pressures for Power Boilers

179 *Maximum Allowable Working Pressure.* The maximum allowable working pressure is that at which a boiler may be operated as determined by employing the factors of safety, stresses, and dimensions designated in these Rules.

No boiler shall be operated at a higher pressure than the maximum allowable working pressure except when the safety valve or valves are blowing, at which time the maximum allowable working pressure shall not be exceeded by more than six per cent.

Wherever the term maximum allowable working pressure is used herein, it refers to gage pressure, or the pressure above the atmosphere, in pounds per square inch.

180 The maximum allowable working pressure on the shell of a boiler or drum shall be determined by the strength of the weakest course, computed from the thickness of the plate, the tensile strength stamped thereon, as provided for in Par. 36, the efficiency of the longitudinal joint, or of the ligament between the tube holes in shell or drum, (whichever is the least), the inside diameter of the course, and the factor of the safety.

$$\frac{TS \times t \times E}{R \times FS} = \text{maximum allowable working pressure, lb. per sq. in.}$$

where

TS = ultimate tensile strength stamped on shell plates, as provided for in Par. 36, lb. per sq. in.

t = minimum thickness of shell plates in weakest course, in.

E = efficiency of longitudinal joint or of ligaments between tube holes (whichever is the least)

R = inside radius of the weakest course of the shell or drum, in.

FS = factor of safety, or the ratio of the ultimate strength of the material to the allowable stress. For new constructions covered in Part I, FS in the above formula = 5.

BOILER JOINTS

181 *Efficiency of a Joint.* The efficiency of a joint is the ratio which the strength of the joint bears to the strength of the solid plate. In the case of a riveted joint this is determined by calculating the breaking strength of a unit section of the joint, considering each possible mode of failure separately, and dividing the lowest result by the breaking strength of the solid plate of a length equal to that of the section considered. (See Appendix, Par. 410 to 416, for detailed methods and examples.)

182 The distance between the center lines of any two adjacent rows of rivets, or the "back pitch" measured at right angles to the direction of the joint, shall be at least twice the diameter of the rivets and shall also meet the following requirements:

a Where each rivet in the inner row comes midway between two rivets in the outer row, the sum of the two diagonal sections of the plate between the inner rivet and the two outer rivets shall be at least 20 per cent greater than the section of the plate between the two rivets in the outer row.

b Where two rivets in the inner row come between two rivets in the outer row, the sum of the two diagonal sections of the plate between the two inner rivets and the two rivets in the outer row shall be at least 20 per cent greater than the difference in the section of the plate between the two rivets in the outer row and the two rivets in the inner row.

183 On longitudinal joints, the distance from the centers of rivet holes to the edges of the plates, except rivet holes in the ends of butt straps, shall be not less than one and one-half times the diameter of the rivet holes.

184 *a* *Circumferential Joints.* The strength of circumferential joints of boilers, the heads of which are not stayed by tubes or through braces shall be at least 50 per cent that of the longitudinal joints of the same structure.

b When 50 per cent or more of the load which would act on an unstayed solid head of the same diameter as the shell, is relieved by the effect of tubes or through stays, in consequence of the reduction of the area acted on by the pressure and the holding power of the tubes and stays, the strength of the circumferential joints in the shell shall be at least 35 per cent that of the longitudinal joints.

185 When shell plates exceed 9/16 in. in thickness in horizontal

return tubular boilers, the portion of the plates forming the laps of the circumferential joints, where exposed to the fire or products of combustion, shall be planed or milled down as shown in Fig. 8, to ½ in. in thickness, provided the requirement in Par. 184 is complied with.

186 *Welded Joints.* The ultimate tensile strength of a longitudinal joint which has been properly welded by the forging process, shall be taken as 28,500 lb. per sq. in., with steel plates having a range in tensile strength of 47,000 to 55,000 lb. per sq. in.

187 *Longitudinal Joints.* The longitudinal joints of a shell or drum which exceeds 36 in. in diameter, shall be of butt and double-strap construction.

188 The longitudinal joints of a shell or drum which does not

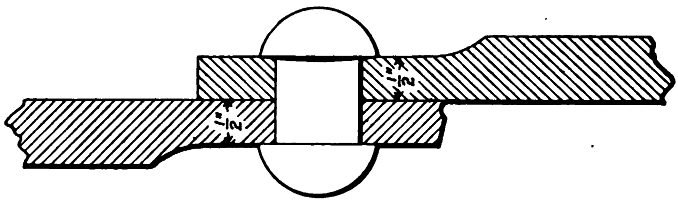

FIG. 8 CIRCUMFERENTIAL JOINT FOR THICK PLATES OF HORIZONTAL RETURN TUBULAR BOILERS

exceed 36 in. in diameter, may be of lap-riveted construction; but the maximum allowable working pressure shall not exceed 100 lb. per sq. in.

189 The longitudinal joints of horizontal return tubular boilers shall be located above the fire-line of the setting.

190 A horizontal return tubular boiler on which a longitudinal lap joint is permitted shall not have a course over 12 ft. in length. With butt and double-strap construction, longitudinal joints of any length may be used provided the plates are tested transversely to the direction of rolling, which tests shall show the standards prescribed under the Specifications of Boiler Plate Steel.

191 Butt straps and the ends of shell plates forming the longitudinal joints shall be rolled or formed by pressure, not blows, to the proper curvature.

LIGAMENTS

192 *Efficiency of Ligament.* When a shell or drum is drilled for tubes in a line parallel to the axis of the shell or drum, the efficiency of the ligament between the tube holes shall be determined as follows:

a When the pitch of the tube holes on every row is equal (Fig. 9), the formula is:

$$\frac{p-d}{p} = \text{efficiency of ligament}$$

where

p = pitch of tube holes, in.
d = diameter of tube holes, in.

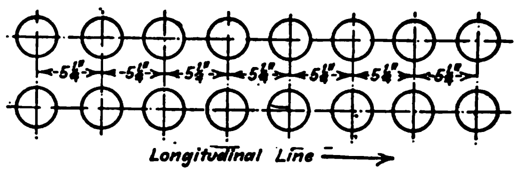

FIG. 9 EXAMPLE OF TUBE SPACING WITH PITCH OF HOLES EQUAL IN EVERY ROW

Example: Pitch of tube holes in the drum as shown in Fig. 9 = 5¼ in. Diameter of tubes = 3¼ in. Diameter of tube holes = 3 9/32 in.

$$\frac{p-d}{p} = \frac{5.25-3.281}{5.25} = 0.375, \text{ efficiency of ligament}$$

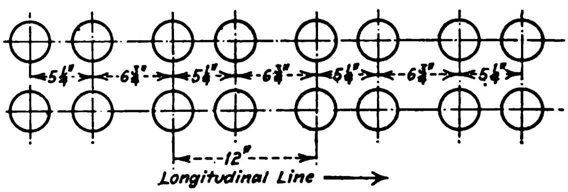

FIG. 10 EXAMPLE OF TUBE SPACING WITH PITCH OF HOLES UNEQUAL IN EVERY SECOND ROW

b When the pitch of tube holes on any one row is unequal (as in Figs. 10 or 11), the formula is:

$$\frac{p-n\,d}{p} = \text{efficiency of ligament}$$

where

p = unit length of ligament, in.
n = number of tube holes in length, p.
d = diameter of tube holes, in.

Example: Spacing shown in Fig. 10. Diameter of tube holes = 3 9/32 in.

$$\frac{p-n\,d}{p} = \frac{12-2\times 3.281}{12} = 0.453, \text{ efficiency of ligament}$$

Example: Spacing shown in Fig. 11. Diameter of tube holes = 3 9/32 in.

$$\frac{p-n\,d}{p} = \frac{29.25-5\times 3.281}{29.25} = 0.439, \text{ efficiency of ligament}$$

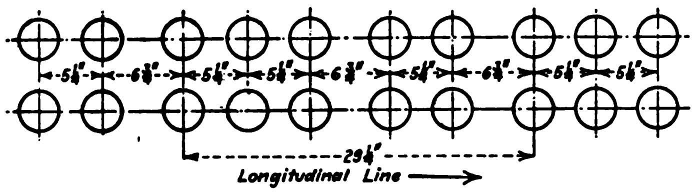

FIG. 11 EXAMPLE OF TUBE SPACING WITH PITCH OF HOLES VARYING IN EVERY SECOND AND THIRD ROW

193 When a shell or drum is drilled for tube holes in a line diagonal with the axis of the shell or drum as shown in Fig. 12, the efficiency of the ligament between the tube holes shall be determined by the following methods and the lowest value used.

a $$\frac{0.95(p_1-d)}{p_1} = \text{efficiency of ligament}$$

b $$\frac{p-d}{p} = \text{efficiency of ligament}$$

where

p_1 = diagonal pitch of tube holes, in.
d = diameter of tube holes, in.
p = longitudinal pitch of tube holes or distance between centers of tubes in a longitudinal row, in.

The constant 0.95 in formula *a* applies provided $\frac{p_1}{d}$ is 1.5 or over.

Example: Diagonal pitch of tube holes in drum as shown in Fig 12 = 6.42 in.

Diameter of tube holes = 4 1/32 in.

Longitudinal pitch of tube holes = 11½ in.

a $$\frac{0.95(6.42-4.031)}{6.42} = 0.353, \text{ efficiency of ligament}$$

b $$\frac{11.5-4.031}{11.5} = 0.649, \text{ efficiency of ligament}$$

The value determined by formula *a* is the least and is the one that shall be used in this case.

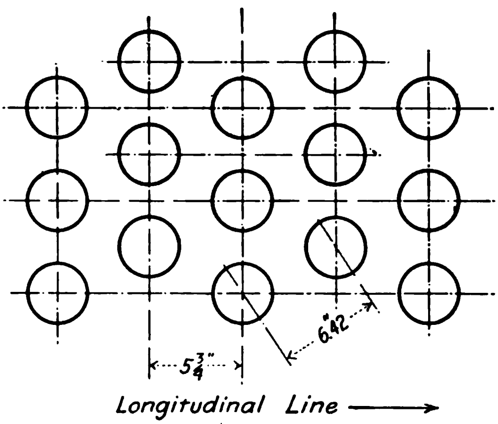

FIG. 12 EXAMPLE OF TUBE SPACING WITH TUBE HOLES ON DIAGONAL LINES

194 *Domes.* The longitudinal joint of a dome 24 in. or over in diameter shall be of butt and double-strap construction, and its flange shall be double riveted to the boiler shell when the maximum allowable working pressure exceeds 100 lb. per sq. in.

The longitudinal joint of a dome less than 24 in. in diameter may be of the lap type, and its flange may be single riveted to the boiler shell provided the maximum allowable working pressure on such a dome is computed with a factor of safety of not less than 8.

The dome may be located on the barrel or over the fire-box on traction, portable or stationary boilers of the locomotive type up to and including 48 in. barrel diameter. For larger barrel diameters, the dome shall be placed on the barrel.

Dished Heads

195 *Convex Heads.* The thickness required in an unstayed dished head with the pressure on the concave side, when it is a segment of a sphere, shall be calculated by the following formula:

$$t = \frac{5.5 \times P \times L}{2 \times TS} + 1/8$$

where

t = thickness of plate, in.
P = maximum allowable working pressure, lb. per sq. in.
TS = tensile strength, lb. per sq. in.
L = radius to which the head is dished, in.

Where the radius is less than 80 per cent of the diameter of the shell or drum to which the head is attached the thickness shall be at least that found by the formula by making L equal to 80 per cent of the diameter of the shell or drum.

Concave Heads. Dished heads with the pressure on the convex side shall have a maximum allowable working pressure equal to 60 per cent of that for heads of the same dimensions with the pressure on the concave side.

When a dished head has a manhole opening, the thickness as found by these Rules shall be increased by not less than 1/8 in.

196 When dished heads are of a less thickness than called for by Par. 195, they shall be stayed as flat surfaces, no allowance being made in such staying for the holding power due to the spherical form.

197 The corner radius of an unstayed dished head measured on the concave side of the head shall not be less than 1 1/2 in. or more than 4 in. and within these limits shall be not less than 3 per cent of L in Par. 195.

198 A manhole opening in a dished head shall be flanged to a depth of not less than three times the thickness of the head measured from the outside.

Braced and Stayed Surfaces

199 The maximum allowable working pressure for various thicknesses of braced and stayed flat plates and those which by these Rules required staying as flat surfaces with braces or staybolts of uni-

form diameter symmetrically spaced, shall be calculated by the formula:

$$P = C \times \frac{t^2}{p^2}$$

where

P = maximum allowable working pressure, lb. per sq. in.

t = thickness of plate in *sixteenths* of an inch

P = maximum pitch measured between straight lines passing through the centers of the staybolts in the different rows, which lines may be horizontal, vertical or inclined, in.

C = 112 for stays screwed through plates not over 7/16 in. thick with ends riveted over

C = 120 for stays screwed through plates over 7/16 in. thick with ends riveted over

C = 135 for stays screwed through plates and fitted with single nuts outside of plate

C = 175 for stays fitted with inside and outside nuts and outside washers where the diameter of washers is not less than $0.4p$ and thickness not less than t.

If flat plates not less than 3/8 in. thick are strengthened with doubling plates securely riveted thereto and having a thickness of not less than 2/3 t, nor more than t, then the value of t in the formula shall be 3/4 of the combined thickness of the plates and the values of C given above may also be increased 15 per cent.

200 *Staybolts.* The ends of screwed staybolts shall be riveted over or upset by equivalent process. The outside ends of such staybolts shall be drilled with a hole at least 3/16 in. diameter to a depth extending 1/2 in. beyond the inside of the plates, except on boilers having a grate area not exceeding 15 sq. ft., where the drilling of the staybolts is optional.

201 When channel irons or other members are securely riveted to the boiler heads for attaching through stays the transverse stress on such members shall not exceed 12,500 lb. per sq. in. In computing the stress, the section modulus of the member shall be used without addition for the strength of the plate. The spacing of the rivets over the supported surface shall be in conformity with that specified for staybolts.

202 The ends of stays fitted with nuts shall not be exposed to the direct radiant heat of the fire.

203 The maximum spacing between centers of rivets attaching the crowfeet of braces to the braced surface, shall be determined by the formula in Par. 199, using 135 for value of C.

The maximum spacing between the inner surface of the shell and lines parallel to the surface of the shell passing through the centers of the rivets attaching the crowfeet of braces to the head, shall be determined by the formula in Par. 199, using 160 for the value of C.

TABLE 3 MAXIMUM ALLOWABLE PITCH, IN INCHES, OF SCREWED STAYBOLTS, ENDS RIVETED OVER

Pressure, Lb. per Sq. In.	Thickness of Plate, In.						
	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{11}{16}$
	Maximum Pitch of Staybolts, In.						
100	$5\frac{1}{4}$	$6\frac{3}{8}$	$7\frac{3}{8}$	....	....	....	....
110	5	6	7	$8\frac{3}{8}$	....	....	....
120	$4\frac{3}{4}$	$5\frac{3}{4}$	$6\frac{3}{4}$	8	....	....	....
125	$4\frac{3}{4}$	$5\frac{5}{8}$	$6\frac{5}{8}$	$7\frac{3}{4}$	....	....	....
130	$4\frac{5}{8}$	$5\frac{1}{2}$	$6\frac{1}{2}$	$7\frac{5}{8}$	....	....	....
140	$4\frac{1}{2}$	$5\frac{3}{8}$	$6\frac{1}{4}$	$7\frac{3}{8}$	$8\frac{3}{8}$	....	....
150	$4\frac{1}{4}$	$5\frac{1}{8}$	6	$7\frac{1}{8}$	8	....	....
160	$4\frac{1}{8}$	5	$5\frac{7}{8}$	$6\frac{7}{8}$	$7\frac{3}{4}$	....	....
170	4	$4\frac{7}{8}$	$5\frac{5}{8}$	$6\frac{3}{4}$	$7\frac{1}{2}$	$8\frac{5}{8}$	....
180	....	$4\frac{3}{4}$	$5\frac{1}{2}$	$6\frac{1}{2}$	$7\frac{3}{8}$	$8\frac{1}{8}$	....
190	....	$4\frac{5}{8}$	$5\frac{3}{8}$	$6\frac{3}{8}$	$7\frac{1}{8}$	$7\frac{7}{8}$	....
200	....	$4\frac{1}{2}$	$5\frac{1}{4}$	$6\frac{1}{8}$	7	$7\frac{3}{4}$	$8\frac{1}{2}$
225	....	$4\frac{1}{4}$	$4\frac{7}{8}$	$5\frac{7}{8}$	$6\frac{1}{2}$	$7\frac{1}{4}$	8
250	....	4	$4\frac{5}{8}$	$5\frac{1}{2}$	$6\frac{1}{4}$	$6\frac{7}{8}$	$7\frac{5}{8}$
300	....	....	$4\frac{1}{4}$	5	$5\frac{5}{8}$	$6\frac{1}{4}$	7

204 The formula in Par. 199 was used in computing Table 3. Where values for screwed stays with ends riveted over are required for conditions not given in Table 3, they may be computed from the formula and used, provided the pitch does not exceed $8\frac{1}{2}$ in.

205 The distance from the edge of a staybolt hole to a straight line tangent to the edges of the rivet holes may be substituted for p for staybolts adjacent to the riveted edges bounding a stayed surface. When the edge of a stayed plate is flanged, p shall be measured from the inner surface of the flange, at about the line of rivets to the edge of the staybolts or to the projected edge of the staybolts.

206 The distance between the edges of the staybolt holes may be substituted for p for staybolts adjacent to a furnace door or other boiler fitting, tube hole, hand hole or other opening.

207 In water leg boilers, the staybolts may be spaced at greater distances between the rows than indicated in Table 3, provided the portions of the sheet which come between the rows of staybolts have the proper transverse strength to give a factor of safety of at least 5 at the maximum allowable working pressure.

208 The diameter of a screw stay shall be taken at the bottom of the thread, provided this is the least diameter.

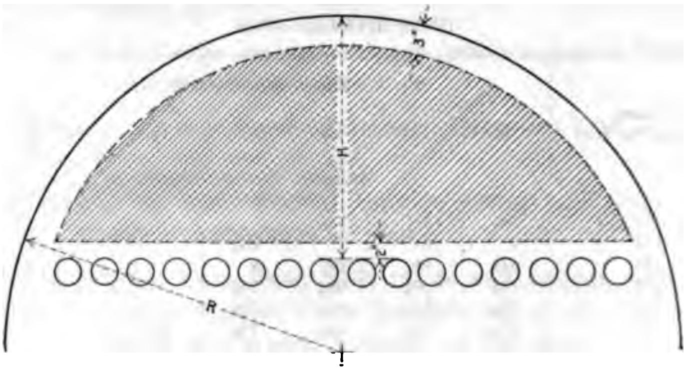

FIG. 13 METHOD OF DETERMINING NET AREA OF SEGMENT OF A HEAD

209 The least cross-sectional area of a stay shall be taken in calculating the allowable stress, except that when the stays are welded and have a larger cross-sectional area at the weld than at some other point, in which case the strength at the weld shall be computed as well as in the solid part and the lower value used.

210 Holes for screw stays shall be drilled full size or punched not to exceed $\frac{1}{4}$ in. less than full diameter of the hole for plates over 5/16 in. in thickness, and $\frac{1}{8}$ in. less than the full diameter of the hole for plates not exceeding 5/16 in. in thickness, and then drilled or reamed to the full diameter. The holes shall be tapped fair and true, with a full thread.

211 The ends of steel stays upset for threading, shall be thoroughly annealed.

212 An internal cylindrical furnace which requires staying shall be stayed as a flat surface as indicated in Table 3.

213 *Staying Segments of Heads.* A segment of a head shall be stayed by head to head, through, diagonal, crowfoot or gusset stays, except that a horizontal return tubular boiler may be stayed as provided in Pars. 225 to 229.

214 *Areas of Segments of Heads to be Stayed.* The area of a segment of a head to be stayed shall be the area enclosed by lines drawn 3 in. from the shell and 2 in. from the tubes, as shown in Figs. 13 and 14.

215 In water tube boilers, the tubes of which are connected to drum heads, the area to be stayed shall be taken as the total area of the head less a 5 in. annular ring, measured from the inner circumference of the drum shell.

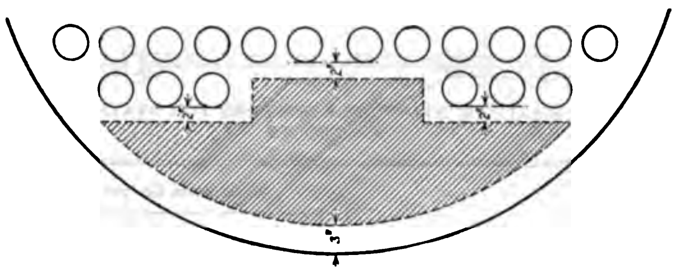

FIG. 14 METHOD OF DETERMINING NET AREA OF IRREGULAR SEGMENT OF A HEAD

When such drum heads are 30 in. or less in diameter and the tube plate is stiffened by flanged ribs or gussets, no stays need be used if a hydrostatic test to destruction of a boiler or unit section built in accordance with the construction, shows that the factor of safety is at least 5.

216 In a fire tube boiler, stays shall be used in the tube sheets if the distances between the edges of the tube holes exceed the maximum pitch of staybolts given in Table 3. That part of the tube sheet which comes between the tubes and the shell, need not be stayed when the distance from the inside of the shell to the outer surface of the tubes does not exceed that given by the formula in Par. 199, using 160 for the value of C.

217 The net area to be stayed in a segment of a head may be determined by the following formula:

$$\frac{4}{3}\frac{(H-5)^2}{}\sqrt{\frac{2\ (R-3)}{(H-5)}}-0.608 = \text{area to be stayed, sq. in.}$$

where

H = distance from tubes to shell, in.

R = radius of boiler head, in.

218 When the portion of the head below the tubes in a horizontal return tubular boiler is provided with a manhole opening, the flange of which is formed from the solid plate and turned inward to a depth of not less than three times the thickness of the head, measured from the outside, the area to be stayed as indicated in Fig. 14, may be reduced by 100 sq. in. The surface around the manhole shall be supported by through stays with nuts inside and outside at the front head.

TABLE 4 MAXIMUM ALLOWABLE STRESSES FOR STAYS AND STAYBOLTS

Description of Stays	Stresses, Lb. per Sq. In.	
	For Lengths between Supports not Exceeding 120 Diameters	For Lengths between Supports Exceeding 120 Diameters
a Unwelded stays less than twenty diameters long screwed through plates with ends riveted over..	7500	....
b Unwelded stays and unwelded portions of welded stays, except as specified in line *a*............	9500	8500
c Welded portions of stays.....................	6000	6000

219 When stay rods are screwed through the sheets and riveted over, they shall be supported at intervals not exceeding 6 ft. In boilers without manholes, stay rods over 6 ft. in length may be screwed through the sheets and fitted with nuts and washers on the outside.

220 The maximum allowable stress per square inch net cross sectional area of stays and staybolts shall be as given in Table 4.

The length of the stay between supports shall be measured from the inner faces of the stayed plates. The stresses are based on tension only. For computing stresses in diagonal stays, see Pars. 221 and 222.

221 *Stresses in Diagonal and Gusset Stays.* Multiply the area of a direct stay required to support the surface by the slant or diagonal

length of the stay; divide this product by the length of a line drawn at right angles to surface supported to center of palm of diagonal stay. The quotient will be the required area of the diagonal stay.

$$A = \frac{a \times L}{l}$$

where

A = sectional area of diagonal stay, sq. in.
a = sectional area of direct stay, sq. in.
L = length of diagonal stay, as indicated in Fig. 15, in.
l = length of line drawn at right angles to boiler head or surface supported to center of palm of diagonal stay, as indicated in Fig. 15, in.

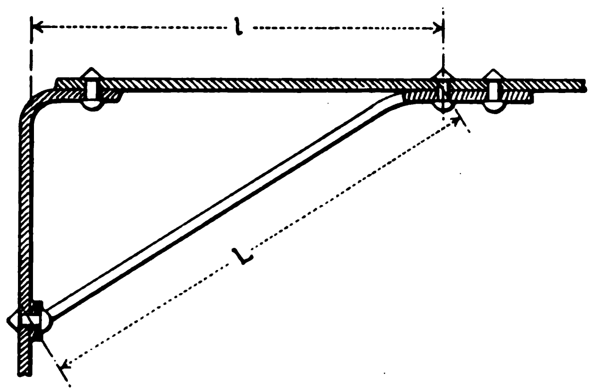

FIG. 15 MEASUREMENTS FOR DETERMINING STRESSES IN DIAGONAL STAYS

Given diameter of direct stay = 1 in., $a = 0.7854$, $L = 60$ in., $l = 48$ in.; substituting and solving:

$$A = \frac{0.7854 \times 60}{48} = 0.981 \text{ sectional area, sq. in.}$$

Diameter = 1.11 in. = $1\frac{1}{8}$ in.

222 For staying segments of tube sheets such as in horizontal return tubular boilers, where L is not more than 1.15 times l for any brace, the stays may be calculated as direct stays, allowing 90 per cent of the stress given in Table 4.

223 *Diameter of Pins and Area of Rivets in Brace.* The sectional area of pins to resist double shear and bending when secured in crowfoot, sling, and similar stays shall be at least equal to three-

fourths of the required cross-sectional area of the brace. The combined cross section of the eye at the sides of the pin shall be at least 25 per cent greater than the required cross-sectional area of the brace.

The cross-sectional area of the rivets attaching a brace to the shell or head shall be not less than one and one quarter times the required sectional area of the brace. Each branch of a crowfoot shall be designed to carry two-thirds of the total load on the brace. The net sectional areas through the sides of the crowfeet, tee irons or similar fastenings at the rivet holes shall be at least equal to the required rivet section. All rivet holes shall be drilled and burrs removed, and the pins shall be made a neat fit.

TABLE 5 SIZES OF ANGLES REQUIRED FOR STAYING SEGMENTS OF HEADS

With the short legs of the angles attached to the head of the boiler

Height of Segment, Dimension B in Fig. 16	30" Boiler			34" Boiler			36" Boiler			Dimension A in Fig. 16
	Angle 3"x2½"	Angle 3½"x3"	Angle 4"x3"	Angle 3½"x3"	Angle 4"x3"	Angle 5"x3"	Angle 4"x3"	Angle 5"x3"	Angle 6"x3½"	
	Thickness, inches	Thickness, inches	Thickness, inches	Thickness, inches	Thickness, inches	Thickness, inches	Thickness, inches	Thickness, inches	Thickness, inches	
10	3/8	5/16	5/16	—	—	—	—	—	—	6½
11	7/16	3/8	5/16	7/16	5/16	5/16	—	—	—	7
12	9/16	7/16	3/8	1/2	7/16	5/16	7/16	7/16	—	7½
13	—	9/16	7/16	11/16	1/2	5/16	9/16	5/8	—	8
14	—	—	1/2	—	5/8	5/8	5/8	7/16	3/8	8½
15	—	—	—	—	—	1/2	3/4	1/2	3/8	9
16	—	—	—	—	—	—	—	5/8	7/16	9½

224 Gusset stays when constructed of triangular right-angled web plates secured to single or double angle bars along the two sides at right angles shall have a cross-sectional area (in a plane at right angles to the longest side and passing through the intersection of the two shorter sides) not less than 10 per cent greater than would be required for a diagonal stay to support the same surface, figured by the formula in Par. 221, assuming the diagonal stay is at the same angle as the longest side of the gusset plate.

225 *Staying of Upper Segments of Tube Heads by Steel Angles.* When the shell of a boiler does not exceed 36 in. in diameter and is designed for a maximum allowable working pressure not exceeding 100 lb. per sq. in., the segment of heads above the tubes *may* be stayed by steel angles as specified in Table 5 and Fig. 16, except that angles of

equal thickness and greater depth of outstanding leg, or of greater thickness and the same depth of outstanding leg, may be substituted for those specified. The legs attached to the heads may vary in depth ½ in. above or below the dimensions specified in Table 5.

226 When this form of bracing is to be placed on a boiler, the diameter of which is intermediate to or below the diameters given in Table 5, the tabular values for the next higher diameter shall govern. Rivets of the same diameter as used in the longitudinal seams of the boiler shall be used to attach the angles to the head and to connect the outstanding legs.

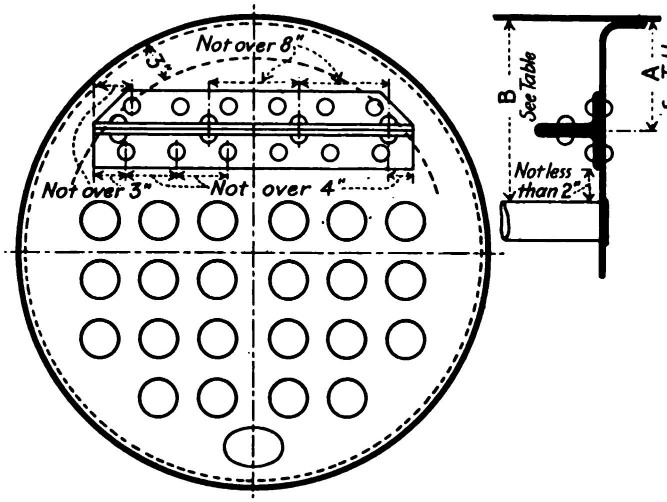

FIG. 16 STAYING OF HEAD WITH STEEL ANGLES IN TUBULAR BOILER

227 The rivets attaching angles to heads shall be spaced not over 4 in. apart. The centers of the end rivets shall be not over 3 in. from the ends of the angle. The rivets through the outstanding legs shall be spaced not over 8 in. apart; the centers of the end rivets shall be not more than 4 in. from the ends of the angles. The ends of the angles shall be considered those of the outstanding legs and the lengths shall be such that their ends overlap a circle 3 in. inside the inner surface of the shell as shown in Fig. 16.

228 The distance from the center of the angles to the shell of the boiler, marked A in Fig. 16, shall not exceed the values given in Table 5, but in no case shall the leg attached to the head on the lower angle come closer than 2 in. to the top of the tubes.

229 When segments are beyond the range specified in Table 5, the heads shall be braced or stayed in accordance with the requirements in these Rules.

230 *Crown Bars and Girder Stays.* Crown bars and girder stays for tops of combustion chambers and back connections, or wherever used, shall be proportioned to conform to the following formula:

$$\text{Maximum allowable working pressure} = \frac{C \times d^2 \times T}{(W - P) \times D \times W}$$

where

W = extreme distance between supports, in.
P = pitch of supporting bolts, in.
D = distance between girders from center to center, in.
d = depth of girder, in.
T = thickness of girder, in.
C = 7000 when the girder is fitted with one supporting bolt
C = 10,000 when the girder is fitted with two or three supporting bolts
C = 11,000 when the girder is fitted with four or five supporting bolts
C = 11,500 when the girder is fitted with six or seven supporting bolts
C = 12,000 when the girder is fitted with eight or more supporting bolts

Example: Given W = 34 in., P = 7.5 in., D = 7.75 in., d = 7.5 in., T = 2 in.; three stays per girder, C = 10.000; then substituting in formula:

Maximum allowable working pressure =

$$\frac{10{,}000 \times 7.5 \times 7.5 \times 2}{(34 - 7.5) \times 7.75 \times 34} = 161.1 \text{ lb. per sq. in.}$$

231 *Maximum Allowable Working Pressure on Truncated Cones.* Upper combustion chambers or vertical submerged tubular boilers made in the shape of a frustum of a cone when not over 38 in. diameter at the large end, may be used without stays if figured by the rule for plain cylindrical furnaces (Par. 239) making D in the formula equal to the diameter at the large end. When over 38 in. in diameter, that portion over 30 in. in diameter shall be fully supported by staybolts or gussets to conform to the provisions for the staying of flat surfaces.

232 *Stay Tubes.* When stay tubes are used in multitubular

boilers to give support to the tube plates, the sectional area of such stay tubes may be determined as follows:

$$\text{Total section of stay tubes, sq. in.} = \frac{(A-a)\ P}{T}$$

where

A = area of that portion of the tube plate containing the tubes, sq. in.

a = aggregate area of holes in the tube plate, sq. in.

P = maximum allowable working pressure, lb. per sq. in.

T = working tensile stress allowed in the tubes, not to exceed 7000 lb. per sq. in.

233 The pitch of stay tubes shall conform to the formula given in Par. 199, using the values of C as given in Table 6.

TABLE 6. VALUES OF C FOR DETERMINING PITCH OF STAY TUBES.

Pitch of Stay Tubes in the Bounding Rows	When tubes have no Nuts Outside of Plates	When tubes are Fitted with Nuts Outside of Plates
Where there are two plain tubes between each stay tube....	120	130
Where there is one plain tube between each stay tube......	140	150
Where every tube in the bounding rows is a stay tube and each alternate tube has a nut........................	....	170

When the ends of tubes are not shielded from the action of flame or radiant heat, the values of C shall be reduced 20 per cent. The tubes shall project about ¼ in. at each end and be slightly flared. Stay tubes when threaded shall not be less than 3/16 in. thick at bottom of thread; nuts on stay tubes are not advised. For a nest of tubes C shall be taken as 140 and S as the mean pitch of stay tubes. For spaces between nests of tubes S shall be taken as the horizontal distance from center to center of the bounding rows of tubes and C as given in Table 6.

TUBE SHEETS OF COMBUSTION CHAMBERS

234 The maximum allowable working pressure on a tube sheet of a combustion chamber, where the crown sheet is not suspended from the shell of the boiler, shall be determined by the following formula:

$$P = \frac{(D-d)\ T \times 27{,}000}{W \times D}$$

where

P = maximum allowable working pressure, lb. per sq. in.
D = least horizontal distance between tube centers, in.
d = inside diameter of tubes, in.
T = thickness of tube plate, in.
W = distance from tube sheet to opposite combustion chamber sheet, in.

Example: Required the working pressure of a tube sheet supporting a crown sheet braced by crown bars. Horizontal distance between centers, 4⅛ in.; inside diameter of tubes, 2.782 in.; thickness of tube sheets, 11/16 in.; distance from tube sheet to opposite combustion chamber sheet, 34¼ in., measured from outside of tube plate to outside of back plate; material, steel. Substituting and solving:

$$P = \frac{(4.125-2.782)\times 0.6875\times 27{,}000}{34.25\times 4.125} = 176 \text{ lb. per sq. in.}$$

235 Sling stays may be used in place of girders in all cases covered in Par. 234, provided, however, that when such sling stays are

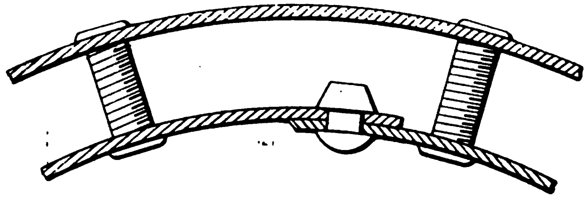

FIG. 17 PROPER LOCATION OF STAYBOLTS ADJACENT TO LONGITUDINAL JOINT IN FURNACE SHEET

used, girders or screw stays of the same sectional area shall be used for securing the bottom of the combustion chamber to the boiler shell.

236 When girders are dispensed with and the top and bottom of combustion chambers are secured by sling stays or braces, the sectional area of such stays shall conform with the requirements of rules for stays and stayed surfaces.

237 *Furnaces of Vertical Boilers.* In a vertical fire-tube boiler the furnace length, for the purpose of calculating its strength and spacing staybolts over its surface, shall be measured from the center of rivets in the bottom of the water-leg to the center of rivets in the flange of the lower tube sheet.

238 When the longitudinal joint of the furnace sheet of a vertical fire-tube boiler is of lap-riveted construction and staybolted, a staybolt in each circular row shall be located near the longitudinal joint, as shown in Fig. 17.

239 *Plain Circular Furnaces.* The maximum allowable working pressure for unstayed, riveted, seamless or lap welded furnaces, where the length does not exceed 6 times the diameter and where the thickness is at least 5/16 in. shall be determined by one or the other of the following formulae:

a Where the length does not exceed 120 times the thickness of the plate

$$P = \frac{51.5}{D} \left\{ (18.75 \times T) - (1.03 \times L) \right\}$$

b Where the length exceeds 120 times the thickness of the plate

$$P = \frac{4250 \times T^2}{L \times D}$$

where

P = maximum allowable working pressure, lb. per sq. in.

D = outside diameter of furnace, in.

L = length of furnace, in.

T = thickness of furnace walls, in sixteenths of an inch.

Where the furnaces have riveted longitudinal joints no deduction need be made for the joint provided the efficiency of the joint is greater than $P \times D$ divided by $1{,}250 \times T$.

Example. Given a furnace 26 in. in diameter, 94 in. long and ½ in. thick. The length exceeds 120 times the thickness of the plate, hence the formula (*b*) should be used. Substituting the values in this formula:

$$P = \frac{4250 \times 8 \times 8}{94 \times 26} = 111 \text{ lb. per sq. in.}$$

240 A plain cylindrical furnace exceeding 38 in. in diameter shall be stayed in accordance with the rules governing flat surfaces.

241 *Circular Flues.* The maximum allowable working pressure for seamless or welded flues more than 5 in. in diameter and up to and including 18 in. in diameter shall be determined by one or the other of the following formulae:

a Where the thickness of the wall is less than 0.023 times the diameter

$$P = \frac{10{,}000{,}000 \times T^3}{D^3}$$

b Where the thickness of the wall is greater than 0.023 times the diameter

$$P = \frac{17{,}300 \times T}{D} - 275$$

where

P = maximum allowable working pressure, lb. per sq. in.
D = outside diameter of flue, in.
T = thickness of wall of flue, in.

c The above formulae may be applied to riveted flues of the sizes specified provided the sections are not over 3 ft. in length and provided the efficiency of the joint is greater than $P \times D$ divided by $20{,}000 \times T$.

Example. Given a flue 14 in. in diameter and 5/16 in. thick. The thickness of the wall is less than 0.023 times the diameter; hence the formula (*a*) should be used. Substituting the values in this formula:

$$P = \frac{10{,}000{,}000 \times 5/16 \times 5/16 \times 5/16}{14 \times 14 \times 14} = 110 \text{ lb. per sq. in.}$$

242 *Adamson Type.* When plain horizontal flues are made in sections not less than 18 in. in length, and not less than 5/16 in. thick:

a They shall be flanged with a radius measured on the fire side, of not less than three times the thickness of the plate, and the flat portion of the flange outside of the radius shall be at least three times the diameter of the rivet holes.

b The distance from the edge of the rivet holes to the edge of the flange shall be not less than the diameter of the rivet hole, and the diameter of the rivets before driving shall be at least ¼ in. larger than the thickness of the plate.

c The depth of the Adamson ring between the flanges shall be not less than three times the diameter of the rivet holes, and the ring shall be substantially riveted to the flanges. The fire edge of the ring shall terminate at or about the point of tangency to the curve of the flange, and the thickness of the ring shall be not less than ½ in.

The maximum allowable working pressure shall be determined by the following formula:

$$P = \frac{57.6}{D} \left\{ (18.75 \times T) - (1.03 \times L) \right\}$$

where

P = maximum allowable working pressure, lb. per sq. in.
D = outside diameter of furnace, in.
L = length of furnace section, in.
T = thickness of plate, in sixteenths of an inch.

Example. Given a furnace 44 in. in diameter, 48 in. in length, and ½ in. thick. Substituting values in formula:

$$P = \frac{57.6}{44} \left\{ (18.75 \times 8) - (1.03 \times 48) \right\}$$
$$= 1.309\ (150 - 49.44) = 131 \text{ lb. per sq. in.}$$

243 The maximum allowable working pressure on corrugated furnaces, such as the Leeds suspension bulb, Morison, Fox, Purves, or Brown, having plain portions at the ends not exceeding 9 in. in length (except flues especially provided for) when new and practically circular, shall be computed as follows:

$$P = \frac{C \times T}{D}$$

where

P = maximum allowable working pressure, lb. per sq. in.

T = thickness, in.—not less than 5/16 in. for Leeds, Morison, Fox and Brown, and not less than 7/16 in. for Purves and other furnaces corrugated by sections not over 18 in. long.

D = mean diameter, in.

C = 17,300, a constant for *Leeds furnaces,* when corrugations are not more than 8 in. from center to center and not less than 2¼ in. deep.

C = 15,600, a constant for *Morison furnaces,* when corrugations are not less than 8 in. from center to center and the radius of the outer corrugations is not more than one half that of the suspension curve.

C = 14,000, a constant for *Fox Furnaces,* when corrugations are not more than 8 in. from center to center and not less than 1½ in. deep.

C = 14,000, a constant for *Purves furnaces* when rib projections are not more than 9 in. from center to center and not less than 1⅜ in. deep.

C = 14,000, a constant for *Brown Furnaces,* when corrugations are not more than 9 in. from center to center and not less than 1⅝ in. deep.

C = 10,000, a constant for furnaces corrugated by sections not more than 18 in. from center to center and not less than 2½ in. deep, measured from the least inside to the greatest outside diameter of the corrugations, and having the ends fitted one into the other and substantially riveted together, provided that the plain parts at the ends do not exceed 12 in. in length.

In calculating the mean diameter of the Morison furnace, the least inside diameter plus 2 in., may be taken as the mean diameter.

244 The thickness of a corrugated or ribbed furnace shall be ascertained by actual measurement. The furnace shall be drilled for a $\frac{1}{4}$-in. pipe tap and fitted with a screw plug that can be removed for the purpose of measurement. For the Brown and Purves furnaces, the holes shall be in the center of the second flat; for the Morison, Fox and other similar types, in the center of the top corrugation, at least as far in as the fourth corrugation from the end of the furnace.

245 *Cast Iron Headers.* The pressure allowed on a water-tube boiler, the tubes of which are secured to cast-iron or malleable-iron headers, shall not exceed 160 lb. per sq. in. The form and size of the internal cross section of a cast-iron or malleable-iron header at any point shall be such that it will fall within a 6 in. by 7 in. rectangle.

246 The cast-iron used for the headers of water-tube boilers shall conform with the Specifications for Gray-iron Castings given in Pars. 95 to 110, the header to be arbitrarily classified as a "medium casting" as to physical properties and tests, and as a "light casting" as to chemical properties.

247 A cast-iron header when tested to destruction, shall withstand a hydrostatic pressure of at least 1200 lb. per sq. in. A hydrostatic test at 400 lb. per sq. in. gage pressure shall be made on all new headers with tubes attached.

Tubes

248 *Tube Holes and Ends.* Tube holes shall be drilled full size from the solid plate, or they may be punched at least $\frac{1}{2}$ in. smaller in diameter than full size, and then drilled, reamed or finished full size with a rotating cutter.

249 The sharp edges of tube holes shall be taken off on both sides of the plate with a file or other tool.

250 A fire-tube boiler shall have the ends of the tubes substantially rolled and beaded, or welded at the firebox or combustion chamber end.

251 The ends of all tubes, suspension tubes and nipples shall be flared not less than $\frac{1}{8}$ in. over the diameter of the tube hole on all water-tube boilers and superheaters, or they may be beaded.

252 The ends of all tubes, suspension tubes and nipples of water-tube boilers and superheaters shall project through the tube sheets or headers not less than $\frac{1}{4}$ in. nor more than $\frac{1}{2}$ in. before flaring.

Riveting

253 *Riveting.* Rivet holes, except for attaching stays or angle bars to heads, shall be drilled full size with plates, butt straps and heads bolted in position; or they may be punched not to exceed ¼ in. less than full diameter for plates over 5/16 in. in thickness, and ⅛ in. less than full diameter for plates not exceeding 5/16 in. in thickness, and then drilled or reamed to full diameter with plates, butt straps and heads bolted in position.

254 After drilling rivet holes, the plates and butt straps shall be separated and the burrs removed.

255 *Rivets.* Rivets shall be of sufficient length to completely fill the rivet holes and form heads at least equal in strength to the bodies of the rivets.

256 Rivets shall be machine driven wherever possible, with sufficient pressure to fill the rivet holes, and shall be allowed to cool and shrink under pressure.

Calking

257 *Calking.* The calking edges of plates, butt straps and heads shall be beveled. Every portion of the calking edges of plates, butt straps and heads shall be planed, milled or chipped to a depth of not less than ⅛ in. Calking shall be done with a round-nosed tool.

Manholes

258 *Manholes.* An elliptical manhole opening shall be not less than 11 × 15 in. or 10 × 16 in. in size. A circular manhole opening shall be not less than 15 in. in diameter.

259 A manhole reinforcing ring when used, shall be of steel or wrought-iron, and shall be at least as thick as the shell plate.

260 Manhole frames on shells or drums when used, shall have the proper curvature, and on boilers over 48 in. in diameter shall be riveted to the shell or drum with two rows of rivets, which may be pitched as shown in Fig. 18. The strength of the rivets in shear on manhole frames and reinforcing rings shall be at least equal to the tensile strength of that part of the shell plate removed, on a line parallel to the axis of the shell, through the center of the manhole, or other opening.

261 The proportions of manhole frames and other reinforcing rings to conform to the above specifications may be determined by the use of the following formulae, which are based on the assumption that the rings shall have the same tensile strength per square inch of section as, and be of not less thickness than, the shell plate removed.

For a single-riveted ring: $W = \frac{l \times t_1}{2 \times t} + d$

For a double-riveted ring: $W = \frac{l \times t_1}{2 \times t} + 2d$

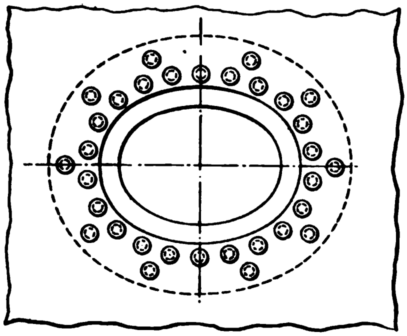

FIG. 18 METHOD OF RIVETING MANHOLE FRAMES TO SHELLS OR DRUMS WITH TWO ROWS OF RIVETS

For two single-riveted rings: $W = \frac{l \times t_1}{4 \times t} + d$

For two double-riveted rings: $W = \frac{l \times t_1}{4 \times t} + 2d$

Where

W = least width of reinforcing ring, in.

t_1 = thickness of shell plate, in.

d = diameter of rivet when driven, in.

t = thickness of reinforcing ring—not less than thickness of the shell plate, in.

T = tensile strength of the ring, lb. per sq. in. of section

a = net section of one side of the ring or rings, sq. in.

S = shearing strength of rivet, lb. per sq. in. of section (see Par. 16)

l = length of opening in shell in direction parallel to axis of shell, in.

N = number of rivets

To find the number of rivets for a single or double reinforcing ring:

$$N = \frac{5.1 \times T \times a}{S \times d^2}$$

262 Manhole plates shall be of wrought steel or shall be steel castings.

263 The minimum width of bearing surface, for a gasket on a manhole opening shall be ½ in. No gasket for use on a manhole or handhole of any boiler shall have a thickness greater than ¼ in.

264 A manhole shall be located in the front head, below the tubes, of a horizontal return tubular boiler 48 in. or over in diameter. Smaller boilers shall have either a manhole or a handhole below the tubes. There shall be a manhole in the upper part of the shell or head of a fire-tube boiler over 40 in. in diameter, except a vertical fire-tube boiler, or except on internally fired boilers not over 48 in. in diameter. The manhole may be placed in the head of the dome. Smaller boilers shall have either a manhole or a handhole above the tubes.

Washout Holes

265 A traction, portable or stationary boiler of the locomotive type shall have not less than six handholes, or washout plugs, located as follows: one in the rear head below the tubes; one in the front head at or about the line of the crown sheet; four in the lower part of the waterleg; also, where possible, one near the throat sheet.

266 A vertical fire-tube boiler, except the boiler of a steam fire-engine, shall have not less than seven handholes, located as follows: three in the shell at or about the line of the crown sheet; one in the shell at or about the line of the fusible plug when used; three in the shell at the lower part of the waterleg. A vertical fire-tube boiler, submerged tube type, shall have two or more handholes in the shell, in line with the upper tube sheet.

267 A vertical fire-tube boiler of a steam fire-engine shall have at least three brass washout plugs of not less than 1-in. iron pipe size, screwed into the shell and located as follows: one at or about the line of the crown sheet; two at the lower part of the waterleg.

Threaded Openings

268 *Threaded Openings.* An opening in a boiler for a threaded pipe connection 1 in. in diameter or over shall have not less than the number of threads given in Table 7.

TABLE 7 MINIMUM NUMBER OF PIPE THREADS FOR CONNECTIONS TO BOILERS

Size of pipe connection, in.	1 and 1¼	1½ and 2	2½ to 4 inclusive	4½ to 6 inclusive	7 and 8	9 and 10	12
Number of threads per in.	11½	11½	8	8	8	8	8
Minimum number of threads required in opening	4	5	7	8	10	12	13
Minimum thickness of material required to give above number of threads, in.	0.348	0.435	0.875	1	1.25	1.5	1.625

If the thickness of the material in the boiler is not sufficient to give such number of threads, there shall be a pressed steel flange, bronze composition flange, steel-cast flange or steel plate, so as to give the required number of threads, constructed and riveted to the boiler in accordance with methods given in Par. 261. A steam main or safety valve opening may be fitted with either a steel cast, wrought-steel or bronze composition nozzle. A feed-pipe connection may be fitted with a brass or steel boiler bushing.

Safety Valves

269 *Safety Valve Requirements.* Each boiler shall have two or more safety valves, except a boiler for which one safety valve 3-in. size or smaller is required by these Rules.

270 The safety valve capacity for each boiler shall be such that the safety valve or valves will discharge all the steam that can be generated by the boiler without allowing the pressure to rise more than six per cent above the maximum allowable working pressure, or more than six per cent above the highest pressure to which any valve is set.

271 One or more safety valves on every boiler shall be set at or below the maximum allowable working pressure. The remaining

valves may be set within a range of three per cent above the maximum allowable working pressure, but the range of setting of all of the valves on a boiler shall not exceed ten per cent of the highest pressure to which any valve is set.

272 Safety valves shall be of the direct spring loaded pop type with seat and bearing surface of the disc either inclined at an angle of about 45 deg. or flat at an angle of about 90 deg. to the center line of the spindle. The vertical lift of the valve disc measured immediately after the sudden lift due to the pop may be made any amount desired up to a maximum of 0.15 in. irrespective of the size of the valve. The nominal diameter measured at the inner edge of the valve seat shall be not less than 1 in. or more than 4½ in.

273 Each safety valve shall have plainly stamped or cast on the body:

a The name or identifying trade-mark of the manufacturer

b The nominal diameter with the words "Bevel Seat" or "Flat Seat"

c The steam pressure at which it is set to blow

d The lift of the valve disc from its seat, measured immediately after the sudden lift due to the pop

e The weight of steam discharged in pounds per hour at the pressure for which it is set to blow.

274 The minimum capacity of a safety valve or valves to be placed on a boiler shall be determined on the basis of 6 lb. of steam per hour per sq. ft. of boiler heating surface for water tube boilers, and 5 lb. for all other types of power boilers, and upon the relieving capacity marked on the valves by the manufacturer, provided such marked relieving capacity does not exceed that given in Table 8. In case the relieving capacity marked on the valve or valves exceeds the maximum given in Table 8, the minimum safety valve capacity shall be determined on the basis of the maximum relieving capacity given in Table 8 for the particular size of valve and working pressure for which it was constructed. The heating surface shall be computed for that side of the boiler surface exposed to the products of combustion, exclusive of the superheating surface. In computing the heating surface for this purpose only the tubes, shells, tube sheets and the projected area of headers need be considered.

TABLE 8 DISCHARGE CAPACITIES FOR DIRECT SPRING-LOADED POP SAFETY VALVES WITH 45 DEG. BEVEL SEATS

Gage Pres., Lb. per Sq. In.		Diameter, 1 In.			Diameter, 1¼ In.			Diameter, 1½ In.		
		Min.	Int.	Max.	Min.	Int.	Max.	Min.	Int.	Max.
15	Lift, in....	0.02	0.04	0.05	0.03	0.04	0.05	0.03	0.05	0.06
	CH.......	95,500	191,000	238,900	179,200	238,800	293,500	214,900	358,300	429,900
	Lb. hr....	65	131	163	122	163	203	146	245	[illegible]
25	Lift, in....	0.02	0.04	0.05	0.03	0.04	0.05	0.03	0.05	0.06
	CH.......	127,700	255,400	319,300	239,500	319,300	399,100	287,400	478,900	574,700
	Lb. hr....	87	174	218	164	218	272	196	326	[illegible]
50	Lift, in....	0.02	0.04	0.05	0.03	0.04	0.05	0.03	0.05	0.06
	CH.......	208,200	416,400	520,400	390,300	520,400	650,500	468,300	780,600	936,600
	Lb. hr....	142	284	354	266	354	444	320	532	[illegible]
75	Lift, in....	0.02	0.04	0.05	0.03	0.04	0.05	0.03	0.05	0.06
	CH.......	288,600	577,200	721,400	541,100	721,400	901,800	649,300	1,082,000	1,299,000
	Lb. hr....	197	393	492	369	492	615	443	738	886
100	Lift, in....	0.02	0.04	0.05	0.03	0.04	0.05	0.03	0.05	0.06
	CH.......	369,000	738,000	922,500	691,900	922,500	1,153,000	830,300	1,384,000	1,661,000
	Lb. hr....	252	503	629	472	629	786	566	944	1133
125	Lift, in....	0.02	0.04	0.05	0.03	0.04	0.05	0.03	0.05	0.06
	CH.......	449,400	898,900	1,124,000	842,700	1,124,000	1,404,000	1,011,000	1,685,000	2,022,000
	Lb. hr....	307	613	767	575	767	957	689	1149	1379
150	Lift, in....	0.02	0.04	0.05	0.03	0.04	0.05	0.03	0.05	0.06
	CH.......	529,900	1,060,000	1,325,000	993,500	1,325,000	1,656,000	1,192,000	1,987,000	2,384,000
	Lb. hr....	362	723	904	677	904	1129	813	1355	1625
175	Lift, in....	0.02	0.04	0.05	0.03	0.04	0.05	0.03	0.05	0.06
	CH.......	610,300	1,221,000	1,526,000	1,144,000	1,526,000	1,907,000	1,373,000	2,289,000	2,746,000
	Lb. hr....	416	833	1040	780	1040	1301	936	1561	1872
200	Lift, in....	0.02	0.04	0.05	0.03	0.04	0.05	0.03	0.05	0.06
	CH.......	690,700	1,381,000	1,727,000	1,295,000	1,727,000	2,158,000	1,554,000	2,590,000	3,108,000
	Lb. hr....	471	941	1178	883	1178	1472	1060	1766	2119
225	Lift, in....	0.02	0.04	0.05	0.03	0.04	0.05	0.03	0.05	0.06
	CH.......	771,100	1,542,000	1,928,000	1,446,000	1,928,000	2,410,000	1,735,000	2,892,000	3,470,000
	Lb. hr....	526	1052	1315	986	1315	1643	1183	1972	2366
250	Lift, in....	0.02	0.04	0.05	0.03	0.04	0.05	0.03	0.05	0.06
	CH.......	851,600	1,703,000	2,129,000	1,597,000	2,129,000	2,661,000	1,916,000	3,193,000	3,832,000
	Lb. hr....	581	1161	1451	1089	1451	1814	1307	2177	2613
275	Lift, in....	0.02	0.04	0.05	0.03	0.04	0.05	0.03	0.05	0.06
	CH.......	932,000	1,864,000	2,330,000	1,748,000	2,330,000	2,913,000	2,097,000	3,495,000	4,194,000
	Lb. hr....	635	1271	1589	1192	1589	1986	1430	2383	2860
300	Lift, in....	0.02	0.04	0.05	0.03	0.04	0.05	0.03	0.05	0.06
	CH.......	1,024,000	2,048,000	2,531,000	1,898,000	2,531,000	3,164,000	2,278,000	3,797,000	4,556,000
	Lb. hr....	698	1397	1746	1294	1726	2157	1553	2589	3107

The Discharge capacity of a Flat Seat Valve of a given diameter with a given lift may be obtained by multiplying the discharge capacity given in the Table for a 45 deg. bevel seat valve of same diameter and same lift, by 1.4.

TABLE 8 (CONTINUED) DISCHARGE CAPACITIES FOR DIRECT SPRING-LOADED POP SAFETY VALVES, WITH 45 DEG. BEVEL SEATS

ge s., per In.		Diameter, 2 In.			Diameter, 2½ In.			Diameter, 3 In.		
		Min.	Int.	Max.	Min.	Int.	Max.	Min.	Int.	Max
	Lift, in....	0.04	0.06	0.07	0.04	0.06	0.08	0.05	0.08	0.10
[illegible]	CH.......	382,200	573,300	668,900	477,700	716,600	955,500	716,600	1,147,000	1,433,000
	Lb. hr....	261	391	456	326	488	651	489	782	977
	Lift, in....	0.04	0.06	0.07	0.04	0.06	0.08	0.05	0.08	0.10
5	CH.......	510,900	766,300	894,000	638,500	957,900	1,277,000	957,900	1,533,000	1,916,000
	Lb. hr....	349	523	610	435	653	871	653	1046	1307
	Lift, in....	0.04	0.06	0.07	0.04	0.06	0.08	0.05	0.08	0.10
0	CH.......	832,600	1,249,000	1,457,000	1,041,000	1,561,000	2,081,000	1,561,000	2,498,000	3,122,000
	Lb. hr....	568	851	994	710	1064	1419	1064	1703	2129
	Lift, in....	0.04	0.06	0.07	0.04	0.06	0.08	0.05	0.08	0.10
5	CH.......	1,154,000	1,731,000	2,020,000	1,443,000	2,164,000	2,886,000	2,164,000	3,463,000	4,329,000
	Lb. hr....	787	1181	1377	984	1475	1968	1475	2361	2951
	Lift, in....	0.04	0.06	0.07	0.04	0.06	0.08	0.05	0.08	0.10
0	CH.......	1,476,000	2,214,000	2,583,000	1,845,000	2,768,000	3,690,000	2,768,000	4,428,000	5,535,000
	Lb. hr....	1007	1510	1761	1258	1887	2516	1887	3019	3774
	Lift, in....	0.04	0.06	0.07	0.04	0.06	0.08	0.05	0.08	0.10
5	CH.......	1,795,000	2,693,000	3,146,000	2,247,000	3,371,000	4,494,000	3,371,000	5,393,000	6,741,000
	Lb. hr....	1224	1836	2145	1532	2299	3064	2299	3677	4596
	Lift, in....	0.04	0.06	0.07	0.04	0.06	0.08	0.05	0.08	0.10
0	CH.......	2,109,000	3,179,000	3,709,000	2,649,000	3,974,000	5,299,000	3,974,000	6,358,000	7,948,000
	Lb. hr....	1438	2158	2529	1806	2710	3613	2710	4335	5419
	Lift, in....	0.04	0.06	0.07	0.04	0.06	0.08	0.05	0.08	0.10
5	CH.......	2,441,000	3,662,000	4,272,000	3,051,000	4,577,000	6,103,000	4,577,000	7,323,000	9,154,000
	Lb. hr....	1664	2497	2913	2081	3121	4161	3121	4993	6242
	Lift, in....	0.04	0.06	0.07	0.04	0.06	0.08	0.05	0.08	0.10
0	CH.......	2,763,000	4,144,000	4,835,000	3,454,000	5,180,000	6,907,000	5,180,000	8,289,000	10,361,000
	Lb. hr....	1884	2826	3296	2354	3532	4709	3532	5651	7064
	Lift, in....	0.04	0.06	0.07	0.04	0.06	0.08	0.05	0.08	0.10
5	CH.......	3,085,000	4,626,000	5,398,000	3,856,000	5,784,000	7,711,000	5,784,000	9,254,000	11,567,000
	Lb. hr....	2104	3154	3680	2629	3944	5258	3944	6310	7890
	Lift, in....	0.04	0.06	0.07	0.04	0.06	0.08	0.05	0.08	0.10
0	CH.......	3,406,000	5,109,000	5,961,000	4,258,000	6,387,000	8,516,000	6,387,000	10,219,000	12,774,000
	Lb. hr....	2322	3484	4064	2903	4355	5807	4355	6968	8708
	Lift, in....	0.04	0.06	0.07	0.04	0.06	0.08	0.05	0.08	0.10
5	CH.......	3,728,000	5,592,000	6,524,000	4,660,000	6,990,000	9,320,000	6,990,000	11,180,000	13,980,000
	Lb. hr....	2542	3813	4448	3177	4766	6355	4766	7620	9533
	Lift, in....	0.04	0.06	0.07	0.04	0.06	0.08	0.05	0.08	0.10
0	CH.......	4,050,000	6,075,000	7,087,000	5,062,000	7,593,000	10,124,000	7,593,000	12,149,000	15,186,000
	Lb. hr....	2762	4143	4832	3452	5177	6903	5177	8280	10,358

he Discharge capacity of a Flat Seat Valve of a given diameter with a given lift may be obtained by multiplying scharge capacity given in the Table for a 45 deg. bevel seat valve of same diameter and same lift, by 1.4.

This table is concluded on the following page.

TABLE 8 (CONCLUDED) DISCHARGE CAPACITIES FOR DIRECT SPRING-LOADED POP SAFE VALVES, WITH 45 DEG. BEVEL SEATS

Gage Pres., Lb. per Sq. In.		Diameter, 3½ In.			Diameter, 4 In.			Diameter, 4½ In.	
		Min.	Int.	Max.	Min.	Int.	Max.	Min.	Int.
15	Lift, in....	0.06	0.09	0.11	0.07	0.10	0.12	0.08	0.11
	CH.......	1,003,000	1,505,000	1,839,000	1,338,000	1,911,000	2,293,000	1,720,000	2,365,000
	Lb. hr....	684	1026	1254	912	1303	1564	1173	1613
25	Lift, in....	0.06	0.09	0.11	0.07	0.10	0.12	0.08	0.11
	CH.......	1,341,000	2,012,000	2,459,000	1,788,000	2,554,000	3,065,000	2,299,000	3,161,000
	Lb. hr....	914	1372	1676	1219	1742	2090	1568	2156
50	Lift, in....	0.06	0.09	0.11	0.07	0.10	0.12	0.08	0.11
	CH.......	2,186,000	3,278,000	4,007,000	2,914,000	4,163,000	4,996,000	3,747,000	5,152,000
	Lb. hr....	1490	2235	2732	1987	2839	3406	2555	3513
75	Lift, in....	0.06	0.09	0.11	0.07	0.10	0.12	0.08	0.11
	CH.......	3,030,000	4,545,000	5,555,000	4,040,000	5,772,000	6,926,000	5,194,000	7,142,000
	Lb. hr....	2066	3099	3788	2754	3935	4722	3542	4870
100	Lift, in....	0.06	0.09	0.11	0.07	0.10	0.12	0.08	0.11
	CH.......	3,875,000	5,812,000	7,103,000	5,166,000	7,380,000	8,856,000	6,642,000	9,133,000
	Lb. hr....	2642	3963	4843	3522	5032	6038	4529	6227
125	Lift, in....	0.06	0.09	0.11	0.07	0.10	0.12	0.08	0.11
	CH.......	4,719,000	7,079,000	8,652,000	6,292,000	8,988,000	10,786,000	8,089,000	11,123,000
	Lb. hr....	3218	4826	5899	4290	6128	7354	5516	7583
150	Lift, in....	0.06	0.09	0.11	0.07	0.10	0.12	0.08	0.11
	CH.......	5,564,000	8,345,000	10,199,000	7,418,000	10,597,000	12,717,000	9,537,000	13,114,000
	Lb. hr....	3794	5690	6954	5058	7226	8670	6503	8940
175	Lift, in....	0.06	0.09	0.11	0.07	0.10	0.12	0.08	0.11
	CH.......	6,408,000	9,612,000	11,748,000	8,544,000	12,206,000	14,647,000	10,985,000	15,105,000
	Lb. hr....	4369	6553	8010	5824	8320	9984	7490	10298
200	Lift, in....	0.06	0.09	0.11	0.07	0.10	0.12	0.08	0.11
	CH.......	7,253,000	10,879,000	13,296,000	9,670,000	13,814,000	16,580,000	12,433,000	17,095,000
	Lb. hr....	4946	7418	9068	6593	9420	11305	8475	11655
225	Lift, in....	0.06	0.09	0.11	0.07	0.10	0.12	0.08	0.11
	CH.......	8,097,000	12,146,000	14,845,000	10,796,000	15,423,000	18,507,000	13,881,000	19,086,000
	Lb. hr....	5521	8280	10120	7361	10514	12616	9465	13013
250	Lift, in....	0.06	0.09	0.11	0.07	0.10	0.12	0.08	0.11
	CH.......	8,942,000	13,412,000	16,393,000	11,922,000	17,031,000	20,438,000	15,328,000	21,076,000
	Lb. hr....	6097	9143	11175	8130	11614	13938	10448	14366
275	Lift, in....	0.06	0.09	0.11	0.07	0.10	0.12	0.08	0.11
	CH.......	9,786,000	14,679,000	17,941,000	13,048,000	18,640,000	22,368,000	16,776,000	23,067,000
	Lb. hr....	6672	10005	12233	8895	12707	15248	11438	15728
300	Lift, in....	0.06	0.09	0.11	0.07	0.10	0.12	0.08	0.11
	CH.......	10,630,000	15,946,000	19,489,000	14,174,000	20,249,000	24,298,000	18,224,000	25,058,000
	Lb. hr....	7248	10875	13290	9668	13807	16568	12428	17068

The Discharge capacity of a Flat Seat Valve of a given diameter with a given lift may be obtained by the discharge capacity given in the Table for a 45 deg. bevel seat valve of same diameter and same lift, by

275 Safety valve capacity may be checked in any one of three different ways, and if found sufficient, additional capacity need not be provided:

a By making an accumulation test, by shutting off all other steam discharge outlets from the boiler and forcing the fires to the maximum. The safety valve equipment shall be sufficient to prevent an excess pressure beyond six per cent as specified in Par. 270.

b By measuring the maximum amount of fuel that can be burned and computing the corresponding evaporative capacity upon the basis of the heating value of the fuel. See Appendix, Pars. 421 to 427.

c By determining the maximum evaporative capacity by measuring the feed water. The sum of the safety valve capacities marked on the valves, shall be equal to or greater than the maximum evaporative capacity of the boiler.

276 When two or more safety valves are used on a boiler, they may be either separate or twin valves made by mounting individual valves on Y-bases, or duplex, triplex or multiplex valves having two or more valves in the same body casing.

277 The safety valve or valves shall be connected to the boiler independent of any other steam connection, and attached as close as possible to the boiler, without any unnecessary intervening pipe or fitting. Every safety valve shall be connected so as to stand in an upright position, with spindle vertical, when possible.

278 Each safety valve shall have full sized direct connection to the boiler. No valve of any description shall be placed between the safety valve and the boiler, nor on the discharge pipe between the safety valve and the atmosphere. When a discharge pipe is used, it shall be not less than the full size of the valve, and shall be fitted with an open drain to prevent water from lodging in the upper part of the safety valve or in the pipe.

279 If a muffler is used on a safety valve it shall have sufficient outlet area to prevent back pressure from interfering with the proper operation and discharge capacity of the valve. The muffler plates or other devices shall be so constructed as to avoid any possibility of restriction of the steam passages due to deposit. When an elbow is placed on a safety valve discharge pipe, it shall be located close to the safety valve outlet or the pipe shall be securely anchored and supported. All safety valve discharges shall be so located or piped as to be carried

clear from running boards or working platforms used in controlling the main stop valves of boilers or steam headers.

280 When a boiler is fitted with two or more safety valves on one connection, this connection to the boiler shall have a cross-sectional area not less than the combined area of all of the safety valves with which it connects.

281 Safety valves shall operate without chattering and shall be set and adjusted as follows: To close after blowing down not more than 4 lb. on boilers carrying an allowed pressure less than 100 lb. per sq. in. gage. To close after blowing down not more than 6 lb. on boilers carrying pressures between 100 and 200 lb. per sq. in. gage inclusive. To close after blowing down not more than 8 lb. on boilers carrying over 200 lb. per sq. in. gage.

282 Each safety valve used on a boiler shall have a substantial lifting device, and shall have the spindle so attached that the valve disc can be lifted from its seat a distance not less than one-tenth of the nominal diameter of the valve, when there is no pressure on the boiler.

283 The seats and discs of safety valves shall be of non-ferrous material.

284 Springs used in safety valves shall not show a permanent set exceeding 1/32 in. ten minutes after being released from a cold compression test closing the spring solid.

285 The spring in a safety valve shall not be used for any pressure more than 10 per cent above or below that for which it was designed.

286 A safety valve over 3-in. size, used for pressures greater than 15 lb. per sq. in. gage, shall have a flanged inlet connection. The dimensions of the flanges shall conform to the American standard given in Tables 15 and 16 of the Appendix.

287 When the letters *A S M E Std* are plainly stamped or cast on the valve body this shall be a guarantee by the manufacturer that the valve conforms with the details of construction herein specified.

288 Every superheater shall have one or more safety valves near the outlet. The discharge capacity of the safety valve or valves on an attached superheater may be included in determining the number and sizes of the safety valves for the boiler, provided there are no intervening valves between the superheater safety valve and the boiler.

289 Every safety valve used on a superheater, discharging superheated steam, shall have a steel body with a flanged inlet connection,

and shall have the seat and disc of nickel composition or equivalent material, and the spring fully exposed outside of the valve casing so that it shall be protected from contact with the escaping steam.

290 Every boiler shall have proper outlet connections for the required safety valve or valves, independent of any other steam outlet connection or of any internal pipe in the steam space of the boiler, the area of opening to be at least equal to the aggregate area of all of the safety valves to be attached thereto.

Water and Steam Gages

291 *Water Glasses and Gage Cocks.* Each boiler shall have at least one water glass, the lowest visible part of which shall be not less than 2 in. above the lowest permissible water level.

292 No water glass connection shall be fitted with an automatic shut-off valve.

293 When shut-offs are used on the connections to a water column, they shall be either outside screw and yoke type gate valves or stop cocks with levers permanently fastened thereto, and such valves or cocks shall be locked or sealed *open.*

294 Each boiler shall have three or more gage cocks, located within the range of the visible length of the water glass, except when such boiler has two water glasses with independent connections to the boiler and located on the same horizontal line and not less than 2 ft. apart.

295 No outlet connections, except for damper regulator, feed-water regulator, drains or steam gages, shall be placed on the pipes connecting a water column to a boiler.

296 *Steam Gages.* Each boiler shall have a steam gage connected to the steam space or to the water column or its steam connection. The steam gage shall be connected to a syphon or equivalent device of sufficient capacity to keep the gage tube filled with water and so arranged that the gage cannot be shut off from the boiler except by a cock placed near the gage and provided with a tee or lever handle arranged to be parallel to the pipe in which it is located when the cock is open. Connections to gages shall be of brass, copper or bronze composition.

297 The dial of the steam gage shall be graduated to not less than 1½ times the maximum allowable working pressure on the boiler.

298 Each boiler shall be provided with a ¼-in. pipe size valved

connection for attaching a test gage when the boiler is in service, so that the accuracy of the boiler steam gage can be ascertained.

Fittings and Appliances

299 *Nozzles and Fittings.* All fittings shall conform to the American Standards given in Tables 15 or 16 of the Appendix Where the maximum allowable working pressure is less than 125 lb. per sq. in., Table 15 shall be used and where higher, Table 16.

300 The minimum number of threads that a pipe or fitting shall screw into a tapped hole shall correspond to the numerical values given for number of threads in Table 7.

301 *Stop Valves.* Each steam discharge outlet over 2 in. in diameter, except safety valve and superheater connections, shall be fitted with a stop valve or valves of the outside screw and yoke type, located as near the boiler as practicable.

302 The main stop valves of boilers shall be extra heavy when the maximum allowable working pressure exceeds 125 lb. per sq. in. The fittings between the boiler and such valve or valves shall be extra heavy, as specified in Table 16 of the Appendix.

303 When two or more boilers are connected to a common steam main, two stop valves, with an ample free blow drain between them, shall be placed in the steam connection between each boiler and the steam main. The discharge of this drain valve must be visible to the operator while manipulating the valve. The stop valves shall consist preferably of one automatic non-return valve (set next the boiler) and a second valve of the outside screw and yoke type; or, two valves of the outside screw and yoke type may be used.

304 When a stop valve is so located that water can accumulate, ample drains shall be provided.

305 *Steam Mains.* Provisions shall be made for the expansion and contraction of steam mains connected to boilers, by providing substantial anchorage at suitable points, so that there shall be no undue strain transmitted to the boiler. Steam reservoirs shall be used on steam mains when heavy pulsations of the steam currents cause vibration of the boiler shell plates.

306 Each superheater shall be fitted with a drain.

307 *Blow-off Piping.* The size of a surface blow-off pipe shall not exceed 1½ in., and it shall be carried through the shell or head with a brass or steel boiler bushing.

308 Each boiler shall have a bottom blow-off pipe, fitted with a valve or cock, in direct connection with the lowest water space practicable; the minimum size of pipe and fittings shall be 1 in. and the maximum size shall be 2½ in. Globe valves shall not be used on such connections.

309 A bottom blow-off cock shall have the plug held in place by a guard or gland. The end of the plug shall be distinctly marked in line with the passage.

310 The blow-off pipe or pipes shall be extra heavy from boiler to valve or valves, and shall run full size without reducers or bushings. All fittings between the boiler and valves shall be of steel.

311 When the maximum allowable working pressure exceeds 125 lb. per sq. in., the bottom blow-off pipe shall have two valves, or a valve and a cock, and such valves, or valve and cock, shall be extra heavy, except that on a boiler having multiple blow-off pipes, a single master valve may be placed on the common blow-off pipe from the boiler, in which case only one valve on each individual blow-off is required.

312 A bottom blow-off pipe when exposed to direct furnace heat shall be protected by fire-brick, a substantial cast-iron removable sleeve or a covering of non-conducting material.

313 An opening in the boiler setting for a blow-off pipe shall be arranged to provide for free expansion and contraction.

314 *Feed Piping.* The feed pipe of a boiler shall have an open end or ends. Wherever globe valves are used on feed piping, the inlet shall be under the disc of the valve.

315 The feedwater shall discharge at about three-fifths the length of a horizontal return tubular boiler from the front head (except a horizontal return tubular boiler equipped with an auxiliary feedwater heating and circulating device), above the central rows of tubes, when the diameter of the boiler exceeds 36 in. The feed pipe shall be carried through the head or shell near the front end with a brass or steel boiler bushing, and securely fastened inside the shell above the tubes.

316 Feedwater shall not discharge in a boiler close to riveted joints in the shell or to furnace sheets.

317 The feed pipe shall be provided with a check valve near the boiler and a valve or cock between the check valve and the boiler, and when two or more boilers are fed from a common source, there shall also be a globe valve on the branch to each boiler, between the check valve and the source of supply.

318 When a pump, inspirator or injector is required to supply feedwater to a boiler plant of over 50 h. p., more than one such appliance shall be provided.

319 *Lamphrey Fronts.* Each boiler fitted with a Lamphrey boiler furnace mouth protector, or similar appliance, having valves on the pipes connecting them to the boiler, shall have these valves locked or sealed *open*. Such valves when used, shall be of the straight-way type.

320 *Water Column Pipes.* The minimum size of pipes connecting the water column to a boiler shall be 1 in. Water-glass fittings or gage cocks may be connected direct to the boiler.

321 The water connections to the water column of a boiler shall be of brass and shall be provided with a cross to facilitate cleaning. Either the water column or this connection shall be fitted with a drain cock or drain valve with a suitable connection to the ashpit, or other safe point of waste. The water column blow-off pipe shall be at least ¾ in.

322 The steam connection to the water column of a horizontal return tubular boiler shall be taken from the top of the shell or the upper part of the head; the water connection shall be taken from a point not less than 6 in. below the center line of the shell.

SETTING

323 *Methods of Support.* A horizontal return tubular boiler over 78-in. in diameter shall be supported from steel lugs by the outside suspension type of setting, independent of the boiler side walls. The lugs shall be so designed that the load is properly distributed between the rivets attaching them to the shell and so that not more than two of these rivets come in the same longitudinal line on each lug. The distance girthwise of the boiler from the centers of the bottom rivets to the centers of the top rivets attaching the lugs shall be not less than 12 in. The other rivets used shall be spaced evenly between these points. If more than four lugs are used they shall be set in four pairs.

324 A horizontal return tubular boiler over 54 in., and up to and including 78 in. in diameter, shall be supported by the outside suspension type of setting, or at four points by not less than eight steel or cast-iron brackets set in pairs. A horizontal return tubular boiler up to and including 54 in. in diameter shall be supported by the outside suspension type of setting, or by not less than two steel or cast-iron brackets on each side.

325 Lugs or brackets, when used to support boilers, shall be properly fitted to the surfaces to which they are attached. The shearing stress on the rivets used for attaching the lugs or brackets shall not exceed 8 per cent of the strength given in Par. 16.

326 Wet-bottom stationary boilers shall have a space of not less than 12 in. between the bottom of the boiler and the floor line, with access for inspection.

327 *Access and Firing Doors.* The minimum size of an access door to be placed in a boiler setting shall be 12 × 16 in. or equivalent area, 11 in. to be the least dimension in any case.

328 A water tube boiler which is fired by hand shall have firing door or doors of the inward opening type unless such doors are provided with substantial latching devices to prevent them from being blown open by pressure on the furnace side.

Hydrostatic Tests

329 *Hydrostatic Pressure Tests.* After a boiler has been completed, it shall be subjected to a hydrostatic test of one and one-half times the maximum allowable working pressure. The pressure shall be under proper control so that in no case shall the required test pressure be exceeded by more than 6 per cent.

330 During a hydrostatic test, the safety valve or valves shall be removed or each valve disc shall be held to its seat by means of a testing clamp and not by screwing down the compression screw upon the spring.

Stamping

331 *Stamping of Boilers.* In laying out shell plates, furnace sheets and heads in the boiler shop, care shall be taken to leave at least one of the stamps, specified in Par. 36 of these Rules, so located as to be plainly visible when the boiler is completed; except that the tube sheets of a vertical fire-tube boiler and butt straps shall have at least a portion of such stamps visible sufficient for identification when the boiler is completed.

332 Each boiler shall conform in every detail to these Rules, and shall be distinctly stamped with the symbol as shown in Fig. 19, denoting that the boiler was constructed in accordance therewith. Each boiler shall also be stamped by the builder with a serial number and

with the builder's name either in full or abbreviated, as indicated in Fig. 20. The height of the letters and figures used in stamping shall be not less than ¼ in. and this stamp shall be placed directly below or alongside The American Society of Mechanical Engineers' stamp.

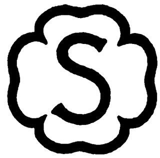

FIG. 19 OFFICIAL SYMBOL FOR STAMP TO DENOTE THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS UNIFORM STANDARD

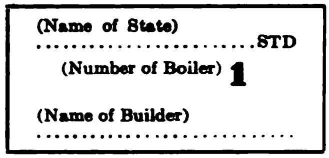

FIG. 20 FORM OF STAMP PROPOSED FOR THE BOILER MANUFACTURER

333 *Location of Stamps.* The location of stamps shall be as follows:

a On horizontal return tubular boilers—on the front head, above the central rows of tubes.

b On horizontal flue boilers—on the front head, above the flues.

c On traction, portable or stationary boilers of the locomotive type or Star water-tube boilers—on the furnace end, above the handhole.

d On vertical fire tube and vertical submerged tube boilers—on the shell above the fire door.

e On water-tube boilers, Babcock & Wilcox, Stirling, Heine and Robb-Mumford standard types—on a head above the manhole opening, preferably on the flanging of the manhole opening.

f On vertical boilers, Climax or Hazleton type—on the top head.

g On Cahall or Wickes vertical water tube boilers—on the upper drum, above the manhole opening.

h On Scotch marine boilers—on the front head, above the center or right-hand furnace.

i On Economic boilers—on the front head, above the central row of tubes.

j For other types and new designs—in a conspicuous location.

334 The American Society of Mechanical Engineers' standard stamp and the boiler builder's stamps shall not be covered by insulating or other material.

PART I—SECTION II

BOILERS USED EXCLUSIVELY FOR LOW PRESSURE STEAM AND HOT WATER HEATING AND HOT WATER SUPPLY

(THIS DOES NOT APPLY TO ECONOMIZERS OR FEED WATER HEATERS.)

Boiler Materials

335 The Rules for power boilers shall apply:

a To all steel plate *hot-water* boilers over 60 in. in diameter.

b To all steel plate *hot-water* boilers where the grate area exceeds 10 sq. ft. and the maximum allowable working pressure exceeds 50 lb. per sq. in.

c Under other conditions, the following rules shall apply.

336 Specifications are given in these Rules, Pars. 23 to 178, for the important materials used in the construction of boilers, and where given, the materials shall conform thereto.

337 Flange steel may be used entirely for the construction of steam heating boilers covered in this section, but in no case shall steel of less than ¼ in. in thickness, nor tube sheets or heads of less than 5/16 in. in thickness be used.

Maximum Allowable Working Pressure

338 The maximum allowable working pressure shall not exceed 15 lb. per sq. in. on a boiler built under these Rules to be used exclusively for low pressure steam heating.

339 A boiler to be used exclusively for low-pressure steam heating, may be constructed of cast-iron, or of cast-iron excepting connecting nipples and bolts, or wholly of steel or wrought-iron, or of steel and partially cast-iron, or of steel or wrought-iron with cast-iron mud rings, door frames and manhole flanges.

340 All steel plate, *hot-water* and *steam-heating* boilers shall have a factor of safety of not less than 5.

Boiler Joints

341 Longitudinal lap joints will be allowed on boilers to be used exclusively for low pressure *steam* heating, when the maximum allowable working pressure does not exceed 15 lb. per sq. in., and the diameter of the boiler shell does not exceed 60 in.

342 The longitudinal joints of a horizontal return tubular boiler if of the lap type, shall be not over 12 ft. in length.

343 In a *hot-water* boiler to be used excusively for heating buildings or hot water supply when the diameter does not exceed 60 in. and the grate area does not exceed 10 sq. ft., longitudinal lap joints will be allowed.

When the grate area exceeds 10 sq. ft. and the diameter of the boiler does not exceed 60 in. longitudinal lap joints will be allowed providing the maximum allowable working pressure does not exceed 50 lb. per sq. in.

344 *Protection of Joints.* When a boiler is built wholly or partially of steel and is used exclusively for low pressure *steam* heating, or when a *hot-water* boiler is used exclusively for heating buildings or for hot-water supply, it shall not be necessary to water jacket the rivets in the fire-box where one end of each rivet is exposed to the fire or direct radiant heat from the fire, provided any one of the following conditions is fulfilled:

a Where the ends of the rivets away from the fire are protected by means of natural drafts of cold air induced in the regular operation of the boiler;

b Where the ends of the rivets away from the fire are in the open air;

c Where the rivets are protected by the usual charges of fresh fuel, which is not burned in contact with the rivets.

Washout Holes

345 A boiler used for hot-water supply shall be provided with washout holes for the removal of any sediment that may accumulate therein.

Boiler Openings

346 *Flanged Connections.* Openings in boilers having flanged connections shall have the flanges conform to the American Standard

given in Tables 15 or 16 of the Appendix, for the corresponding pipe size, and shall have the corresponding drilling for bolts or studs.

Safety Valves

347 *Outlet Connections for Safety and Water Relief Valves.* Every boiler shall have proper outlet connections for the required safety, or water relief valve or valves, independent of any other connection outside of the boiler or any internal pipe in the boiler, the area of the opening to be at least equal to the aggregate area of all of the safety valves with which it connects. A screwed connection may be used for attaching a safety valve to a heating boiler. This rule applies to all sizes of safety valves.

348 *Safety Valves.* Each *steam* boiler shall be provided with one or more safety valves of the spring-pop type which cannot be adjusted to a higher pressure than 15 lb. per sq. in.

349 *Water Relief Valves.* Each *hot-water* boiler shall be provided with one or more water relief valves with open discharges having outlets in plain sight.

350 A *hot-water* boiler built for a maximum allowable working pressure of 30 lb. per sq. in. and used exclusively for heating buildings, or for hot-water supply, shall be provided with a water relief valve or valves, which cannot be adjusted for a pressure in excess of 30 lb. per sq. in.

351 No safety or water relief valve shall be smaller than 1 in. nor greater than 4½ in. nominal size.

352 When two or more safety or water relief valves are used on a boiler they may be single or twin valves.

353 Safety or water relief valves shall be connected to boilers independent of other connections and be attached directly or as close as possible to the boiler, without any intervening pipe or fittings, except the Y-base forming a part of the twin valve or the shortest possible connection. A safety or water relief valve shall not be connected to an internal pipe in the boiler. Safety valves shall be connected so as to stand upright, with the spindle vertical, when possible.

354 No shut-off of any description shall be placed between the safety or water relief valves and boilers, nor on discharge pipes between them and the atmosphere.

355 When a discharge pipe is used its area shall be not less than the area of the valve or aggregate area of the valves with which it

connects, and the discharge pipe shall be fitted with an open drain to prevent water from lodging in the upper part of the valve or in the pipe. When an elbow is placed on a safety or water relief valve discharge pipe, it shall be located close to the valve outlet or the pipe shall be securely anchored and supported. The safety or water relief valves shall be so located and piped that there will be no danger of scalding attendants.

356 Each safety valve used on a *steam* heating boiler shall have a substantial lifting device which shall be so connected to the disc that the latter can be lifted from its seat a distance of not less than

TABLE 9 ALLOWABLE SIZES OF SAFETY VALVES FOR HEATING BOILERS

Water Evaporated per Sq. Ft. of Grate Surface per Hr., Lb.		75	100	160	160	200	240
Maximum allowable Working Pressure, Lb. per Sq. In.		Zero to 25 Lb.	Over 25 to 50 Lb.	Over 50 to 100 Lb.	Over 100 to 150 Lb.	Over 150 to 200 Lb.	Over 200 Lb.
Diameter of Valve, In.	Area of Valve, Sq. In.	Area of Grate, Sq. Ft.					
1	0.7854	2.00	2.50	2.75	3.25	3.5	3.75
1¼	1.2272	3.25	4.00	4.25	5.00	5.5	5.75
1½	1.7671	4.50	5.50	6.00	7.25	8.0	8.50
2	3.1416	8.00	9.75	10.75	13.00	14.0	15.00
2½	4.9087	12.50	15.00	16.50	20.00	22.0	23.00
3	7.0686	17.75	21.50	24.00	29.00	31.5	33.25
3½	9.6211	24.00	29.50	32.50	39.50	43.0	45.25
4	12.5660	31.50	38.25	42.50	51.50	56.0	59.00
4½	15.9040	40.00	48.50	53.50	65.00	71.0	74.25

one-tenth of the nominal diameter of the seat when there is no pressure on the boiler. A relief valve used on a hot-water heating boiler need not have a lifting device.

357 Every safety valve or water relief valve shall have plainly stamped on the body or cast thereon the manufacturer's name or trade mark and the pressure at which it is set to blow. The seats and discs of safety or water relief valves shall be made of non-ferrous material.

358 The minimum size of safety or water relief valve or valves for each boiler shall be governed by the grate area of the boiler, as shown by Table 9.

When the conditions exceed those on which Table 9 is based, the following formula for bevel and flat seated valves shall be used:

$$A = \frac{W \times 70}{P} \times 11$$

in which

A = area of direct spring-loaded safety valve per square foot of grate surface, sq. in.

W = weight of water evaporated per square foot of grate surface per second, lb.

P = pressure (absolute) at which the safety valve is set to blow, lb. per sq. in.

359 *Double Grate Down Draft Boilers.* In determining the number and size of safety valves or water relief valves the grate area shall equal the area of the upper grate plus one-half of the area of the lower grate.

360 *Boilers Fired With Oil or Gas.* In determining the number and size of safety or water relief valve or valves for a boiler using gas or liquid fuel, 15 sq. ft. of heating surface shall be equivalent to one square foot of grate area. If the size of grate for use of coal is evident from the boiler design, such size may be the basis for the determination of the safety valve capacity.

Steam and Water Gages

361 *Steam Gages.* Each *steam* boiler shall have a steam gage connected to the steam space or to the water column or its steam connection. The steam gage shall be connected to a syphon or equivalent device of sufficient capacity to keep the gage tube filled with water and so arranged that the gage cannot be shut off from the boiler except by a cock placed near the gage and provided with a tee or lever handle arranged to be parallel to the pipe in which it is located when the cock is open. Connections to gages shall be of brass, copper or bronze composition. The dial of a steam gage for a *steam* heating boiler shall be graduated to not less than 30 lb.

362 *Pressure or Altitude Gages.* Each *hot-water* boiler shall have a gage connected in such a manner that it cannot be shut off from the boiler except by a cock with tee or lever handle, placed on the pipe near the gage. The handle of the cock shall be parallel to the pipe in which it is located when the cock is open. Connections to gages shall be made of brass, copper or bronze composition. The dial of

the pressure or altitude gage shall be graduated to not less than 1½ times the maximum allowable working pressure.

363 *Thermometers.* Each *hot-water* boiler shall have a thermometer so located and connected that it shall be easily readable when observing the water pressure or altitude. The thermometer shall be so located that it shall at all times indicate the temperature in deg. fahr., of the water in the boiler.

Fittings and Appliances

364 *Bottom Blow-off Pipes.* Each boiler shall have a blow-off pipe, fitted with a valve or cock, in direct connection with the lowest water space practicable.

365 *Damper Regulators.* When a pressure damper regulator is used, the boiler pressure pipe shall be connected to the steam space of the boiler.

366 *Water Glasses.* Each *steam* boiler shall have one or more water glasses.

367 *Gage Cocks.* Each *steam* boiler shall have two or more gage cocks located within the range of the visible length of the water glass.

368 *Water Column Pipes.* The minimum size of pipes connecting the water column of a boiler shall be 1 in. Water-glass fittings or gage cocks may be connected direct to the boiler. The steam connection to the water column of a horizontal return tubular boiler shall be taken from the top of shell or the upper part of the head; the water connection shall be taken from a point not less than 6 in. below the center line of the shell. No connections, except for damper regulator, drains or steam gages, shall be placed on the pipes connecting a water column to a boiler.

Methods of Setting

369 Wet-bottom steel plate boilers shall have a space of not less than 12 in. between the bottom of the boiler and the floor line with access for inspection.

370 *Access Doors.* The minimum size of access door used in boiler settings shall be 12 × 16 in. or equivalent area, the least dimension being 11 in.

371 The longitudinal joints of a horizontal return tubular boiler shall be located above the fire-line.

HYDROSTATIC TESTS

372 A shop test of 60 lb. per sq. in. hydrostatic pressure shall be applied to steel or cast-iron boilers or to the sections of cast-iron boilers which are used exclusively for low pressure *steam* heating.

373 *Hot-water* boilers for a maximum allowable working pressure not exceeding 30 lb. per sq. in. used exclusively for heating buildings or for hot-water supply, when constructed of cast-iron, or of cast-iron excepting the connecting nipples and bolts, shall be subjected to a shop test of 60 lb. per sq. in. hydrostatic pressure applied to the boiler or the sections thereof.

374 A maximum allowable working pressure in excess of 30 lb. per sq. in. will be allowed on a *hot-water* boiler constructed of cast-iron, or of cast-iron excepting the connecting nipples and bolts, used exclusively for heating buildings or for hot-water supply, provided such boilers or their sections have been subjected to a shop hydrostatic test of *two and one-half times* the actual working pressure.

375 Individual shop inspection shall be required only for boilers which come under the rules for power boilers.

STAMPING

376 Each plate of a completed boiler shall show a sufficient portion of the plate maker's stamp for identification.

377 *Name.* All boilers referred to in this section shall be plainly and permanently marked with the manufacturer's name and the maximum allowable working pressure.

PART II EXISTING INSTALLATIONS

Maximum Allowable Working Pressure

378 The maximum allowable working pressure on the shell of a boiler or drum shall be determined by the strength of the weakest course, computed from the thickness of the plate, the tensile strength of the plate, the efficiency of the longitudinal joint, the inside diameter of the course and the factor of safety allowed by these Rules.

$$\frac{TS \times t \times E}{R \times FS} = \text{maximum allowable working pressure, lb. per sq. in.}$$

where

TS = ultimate tensile strength of shell plates, lb. per sq. in.

t = thickness of shell plate, in weakest course, in.

E = efficiency of longitudinal joint, method of determining which is given in Par. 181, of these Rules

R = inside radius of the weakest course of the shell or drum, in.

FS = factor of safety allowed by these Rules

379 Boilers in service one year after these Rules become effective shall be operated with a factor of safety of at least 4 by the formula, Par. 378. Five years after these Rules become effective, the factor of safety shall be at least 4.5. In no case shall the maximum allowable working pressure on old boilers be increased, unless they are being operated at a lesser pressure than would be allowable for new boilers, in which case the changed pressure shall not exceed that allowable for new boilers of the same construction.

380 The age limit of a horizontal return tubular boiler having a longitudinal lap joint and carrying over 50 lb. pressure shall be 20 years, except that no lap joint boiler shall be discontinued from service solely on account of age until 5 years after these Rules become effective.

381 Second-hand boilers, by which are meant boilers where both the ownership and location are changed, shall have a factor of safety of at least 5½, by the formula Par. 378, one year after these Rules become effective, unless constructed in accordance with the Rules contained in Part I, when the factor shall be at least 5.

382 *Cast-Iron Headers and Mud Drums.* The maximum allowable working pressure on a water tube boiler, the tubes of which are secured to cast-iron or malleable iron headers, or which have cast-iron mud drums, shall not exceed 160 lb. per sq. in.

383 *Steam Heating Boilers.* The maximum allowable working pressure shall not exceed 15 lb. per sq. in. on a boiler used exclusively for low pressure *steam* heating.

384 No pressure shall be allowed on a boiler on which a crack is discovered along the longitudinal riveted joint.

Strength of Materials

385 *Tensile Strength.* When the tensile strength of steel or wrought-iron shell plates is *not* known, it shall be taken as 55,000 lb. per sq. in. for steel and 45,000 lb. for wrought-iron.

386 *Strength of Rivets in Shear.* In computing the ultimate strength of rivets in shear the following values in pounds per square inch of the cross-sectional area of the rivet shank shall be used:

Iron rivets in single shear	38,000
Iron rivets in double shear	76,000
Steel rivets in single shear	44,000
Steel rivets in double shear	88,000

The cross-sectional area shall be that of the rivet shank after driving.

387 *Crushing Strength of Mild Steel.* The resistance to crushing of mild steel shall be taken at 95,000 lb. per sq. in. of cross-sectional area.

TABLE 10 SIZES OF RIVETS BASED ON PLATE THICKNESS

Thickness of plate	1/4″	9/32″	5/16″	11/32″	3/8″	13/32″
Diameter of rivet after driving	11/16″	11/16″	3/4″	3/4″	13/16″	13/16″
Thickness of plate	7/16″	15/32″	1/2″	9/16″	5/8″	—
Diameter of rivet after driving	15/16″	15/16″	15/16″	1 1/16″	1 1/16″	—

388 *Rivets.* When the diameter of the rivet holes in the longitudinal joints of a boiler is *not* known, the diameter and cross-sectional area of rivets, after driving may be ascertained from Table 10, or by cutting out one rivet in the body of the joint.

Safety Valves for Power Boilers

389 The safety valve capacity of each boiler shall be such that the safety valve or valves will discharge all the steam that can be generated by the boiler without allowing the pressure to rise more than 6 per cent above the maximum allowable working pressure, or more than 6 per cent above the highest pressure to which any valve is set.

390 One or more safety valves on every boiler shall be set at or below the maximum allowable working pressure. The remaining valves may be set within a range of 3 per cent above the maximum allowable working pressure, but the range of setting of all of the valves on a boiler shall not exceed 10 per cent of the highest pressure to which any valve is set.

391 Safety valve capacity may be checked in any one of three different ways, and if found sufficient, additional capacity need not be provided:

a By making an accumulation test, by shutting off all other steam discharge outlets from the boiler and forcing the fires to the maximum. The safety valve equipment shall be sufficient to prevent an excess pressure beyond 6 per cent as specified in Par. 389.

b By measuring the maximum amount of fuel that can be burned and computing the corresponding evaporative capacity upon the basis of the heating value of the fuel. See Appendix, Pars. 421 to 427.

c By determining the maximum evaporative capacity by measuring the feedwater. The sum of the safety valve capacities shall be equal to or greater than the maximum evaporative capacity of the boiler.

392 In case either of the methods outlined in sections *b* or *c* of Par. 391 is employed, the safety valve capacities shall be taken at the maximum values given in Table 8 for spring loaded pop safety valves, or 0.66 times the maximum values given in Table 8, for lever safety valves.

393 When additional valve capacity is required, any valves added shall conform to the requirements in Part I of these Rules.

394 No valve of any description shall be placed between the safety valve and the boiler, nor on the discharge pipe between the safety valve and the atmosphere. When a discharge pipe is used, it

shall be not less than the full size of the valve, and the discharge pipe shall be fitted with an open drain to prevent water lodging in the upper part of the safety valve or in the pipe. If a muffler is used on a safety valve it shall have sufficient outlet area to prevent back pressure from interfering with the proper operation and discharge capacity of the valve. The muffler plates or other devices shall be so constructed as to avoid any possibility of restriction of the steam passages due to deposit. When an elbow is placed on a safety valve discharge pipe, it shall be located close to the safety valve outlet or the pipe shall be securely anchored and supported. All safety valve discharges shall be so located or piped as to be carried clear from running boards or working platforms used in controlling the main stop valves of boilers or steam headers.

Fittings and Appliances

395 *Water Glasses and Gage Cocks.* Each steam boiler shall have at least one water glass, the lowest visible part of which shall be not less than 2 in. above the lowest permissible water level.

396 Each boiler shall have three or more gage cocks, located within the range of the visible length of the water glass, when the maximum allowable working pressure exceeds 15 lb. per sq. in., except when such boiler has two water glasses with independent connections to the boiler, located on the same horizontal line and not less than 2 ft. apart.

397 No outlet connections, except for damper regulator, feed-water regulator, drains or steam gages, shall be placed on the pipes connecting a water column to a power boiler.

398 *Steam Gages.* Each steam boiler shall have a steam gage connected to the steam space or to the water column or to its steam connection. The steam gage shall be connected to a syphon or equivalent device of sufficient capacity to keep the gage tube filled with water and so arranged that the gage cannot be shut off from the boiler except by a cock placed near the gage and provided with a tee or lever handle arranged to be parallel to the pipe in which it is located when the cock is open. Connections to gages shall be of brass, copper or bronze composition.

399 *Stop Valves.* Each steam outlet from a power boiler (except safety valve connections) shall be fitted with a stop valve located as close as practicable to the boiler.

400 When a stop valve is so located that water can accumulate, ample drains shall be provided.

401 *Bottom Blow-Off Pipes.* Each boiler shall have a blow-off pipe fitted with a valve or cock, in direct connection with the lowest water space practicable.

402 When the maximum allowable working pressure exceeds 125 lb. per sq. in., the blow-off pipe shall be extra heavy from boiler to valve or valves, and shall run full size without reducers or bushings. All fittings between the boiler and valve shall be steel, extra heavy malleable iron or extra heavy cast-iron.

403 When the maximum allowable working pressure exceeds 125 lb. per sq. in., each bottom blow-off pipe shall be fitted with an extra heavy valve or cock. Preferably two (2) valves, or a valve and a cock should be used on each blow-off in which case such valves, or valve and cock, shall be extra heavy.

404 A bottom blow-off pipe when exposed to direct furnace heat, shall be protected from the products of combustion by fire-brick, a substantial cast-iron removable sleeve, or a covering of non-conducting material.

405 An opening in the boiler setting for a blow-off pipe shall be arranged to provide for free expansion and contraction.

406 *Feed Piping.* The feed pipe of a steam boiler operated at more than 15 lb. per sq. in. maximum allowable working pressure, shall be provided with a check valve near the boiler and a valve or cock between the check valve and the boiler, and when two or more boilers are fed from a common source, there shall also be a globe valve on the branch to each boiler, between the check valve and the source of supply. When a globe valve is used on a feed pipe, the inlet shall be under the disc of the valve.

407 *Lamphrey Fronts.* Each boiler fitted with a Lamphrey boiler furnace mouth protector, or similar appliance, having valves on the pipes connecting them to the boiler, shall have these valves locked or sealed *open.* Such valves, when used, shall be of the straightway type.

Hydrostatic Pressure Tests

408 *Test Pressure.* When a hydrostatic test is applied the required test pressure shall be one and one-half times the maximum allowable working pressure. The pressure shall be under proper control so that in no case shall the required test pressure be exceeded by more than 2 per cent.

409 During a hydrostatic test of a boiler, the safety valve or valves shall be removed or each valve disc shall be held to its seat by means of a testing clamp and not by screwing down the compression screw upon the spring.

APPENDIX

Efficiency of Joints

410 *Efficiency of Riveted Joints.* The ratio which the strength of a unit length of a riveted joint has to the same unit length of the solid plate is known as the efficiency of the joint and shall be calculated by the general method illustrated in the following examples:

TS = tensile strength stamped on plate, lb. per sq. in.
t = thickness of plate, in.
b = thickness of butt strap, in.
P = pitch of rivets, in., on row having greatest pitch
d = diameter of rivet after driving, in. = diameter of rivet hole

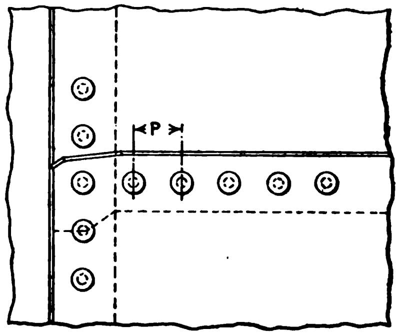

Fig. 21 Example of Lap Joint, Longitudinal or Circumferential, Single-Riveted

a = cross-sectional area of rivet after driving, sq. in.
s = shearing strength of rivet in single shear, lb. per sq. in., as given in Par. 16
S = shearing strength of rivet in double shear, lb. per sq. in., as given in Par. 16
c = crushing strength of mild steel, lb. per sq. in., as given in Par. 15
n = number of rivets in single shear in a unit length of joint
N = number of rivets in double shear in a unit length of joint.

411 *Example:* Lap joint, longitudinal or circumferential, single-riveted.

A = strength of solid plate = $P \times t \times TS$
B = strength of plate between rivet holes = $(P—d)t \times TS$
C = shearing strength of one rivet in single shear = $n \times s \times a$
D = crushing strength of plate in front of one rivet = $d \times t \times c$
Divide B, C or D (whichever is the least) by A, and the quotient will be the efficiency of a single-riveted lap joint as shown in Fig. 21.

TS = 55,000 lb. per sq. in.	c = 95,000 lb. per sq. in.
$t = \frac{1}{4}$ in. = 0.25 in.	$A = 1.625 \times 0.25 \times 55{,}000 = 22{,}343$
$P = 1\frac{5}{8}$ in. = 1.625 in.	$B = (1.625—0.6875)\ 0.25 \times 55{,}000 = 12{,}890$
$d = \frac{11}{16}$ in. = 0.6875 in.	$C = 1 \times 44{,}000 \times 0.3712 = 16{,}332$
a = 03.712 sq. in.	$D = 0.6875 \times 0.25 \times 95{,}000 = 16{,}328$
s = 44,000 lb. per sq. in.	

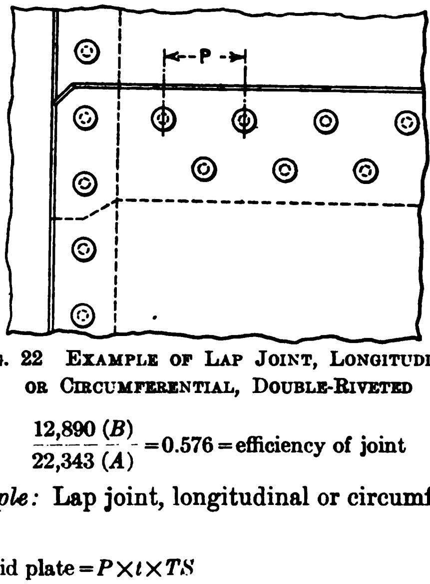

FIG. 22 EXAMPLE OF LAP JOINT, LONGITUDINAL OR CIRCUMFERENTIAL, DOUBLE-RIVETED

$$\frac{12{,}890\ (B)}{22{,}343\ (A)} = 0.576 = \text{efficiency of joint}$$

412 *Example:* Lap joint, longitudinal or circumferential, double-riveted.

A = strength of solid plate = $P \times t \times TS$
B = strength of plate between rivet holes = $(P—d)\ t \times TS$
C = shearing strength of two rivets in single shear = $n \times s \times a$
D = crushing strength of plate in front of two rivets = $n \times d \times t \times c$
Divide B, C or D (whichever is the least) by A, and the quotient will be the efficiency of a double-riveted lap joint, as shown in Fig. 22.

TS = 55,000 lb. per sq. in.	c = 95,000 lb. per sq. in.
$t = \frac{5}{16}$ in. = 0.3125 in.	$A = 2.875 \times 0.3125 \times 55{,}000 = 49{,}414$
$P = 2\frac{7}{8}$ in. = 2.875 in.	$B = (2.875—0.75)\ 0.3125 \times 55{,}000 = 36{,}523$
$d = \frac{3}{4}$ in. = 0.75 in.	$C = 2 \times 44{,}000 \times 0.4418 = 38{,}878$
a = 0.4418 sq. in.	$D = 2 \times 0.75 \times 0.3125 \times 95{,}000 = 44{,}531$
s = 44,000 lb. per sq. in.	

$$\frac{36{,}523\ (B)}{49{,}414\ (A)} = 0.739 = \text{efficiency of joint}$$

413 *Example:* Butt and double strap joint, double-riveted.

A = strength of solid plate = $P \times t \times TS$

B = strength of plate between rivet holes in the outer row = $(P-d)\ t \times TS$

C = shearing strength of two rivets in double shear, plus the shearing strength of one rivet in single shear = $N \times S \times a + n \times s \times a$

D = strength of plate between rivet holes in the second row, plus the shearing strength of one rivet in single shear in the outer row = $(P-2d)\ t \times TS + n \times s \times a$

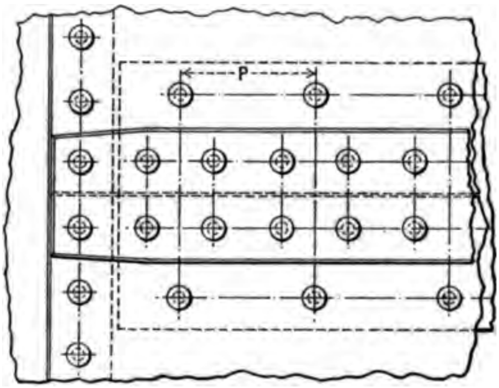

Fig. 23 Example of Butt and Double Strap Joint, Double-Riveted

E = strength of plate between rivet holes in the second row, plus the crushing strength of butt strap in front of one rivet in the outer row = $(P-2d)\ t \times TS + d \times b \times c$

F = crushing strength of plate in front of two rivets, plus the crushing strength of butt strap in front of one rivet = $N \times d \times t \times c + n \times d \times b \times c$

G = crushing strength of plate in front of two rivets, plus the shearing strength of one rivet in single shear = $N \times d \times t \times c + n \times s \times a$

H = strength of butt straps between rivet holes in the inner row = $(P-2d)\ 2b \times TS$. This method of failure is not possible for thicknesses of butt straps required by these Rules and the computation need only be made for old boilers in which thin butt straps have been used. For this reason this method of failure will not be considered in other joints.

Divide B, C, D, E, F, G or H (whichever is the least) by A, and the quotient will be the efficiency of a butt and double strap joint, double-riveted, as shown in Fig. 23.

$TS = 55{,}000$ lb. per sq. in.
$t = \frac{3}{8}$ in. $= 0.375$ in.
$b = \frac{5}{16}$ in. $= 0.3125$ in.
$P = 4\frac{7}{8}$ in. $= 4.875$ in.
$d = \frac{7}{8}$ in. $= 0.875$ in.

$a = 0.6013$ sq. in.
$s = 44{,}000$ lb. per sq. in.
$S = 88{,}000$ lb. per sq. in.
$c = 95{,}000$ lb. per sq. in.

Number of rivets in single shear in a unit length of joint = 1.
Number of rivets in double shear in a unit length of joint = 2.

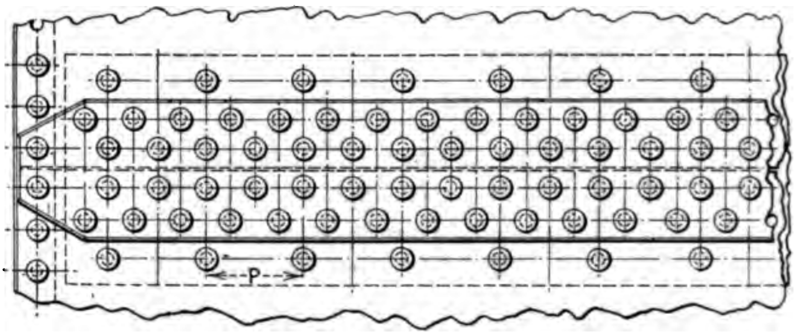

FIG. 24 EXAMPLE OF BUTT AND DOUBLE STRAP JOINT, TRIPLE-RIVETED

$A = 4.875 \times 0.375 \times 55{,}000 = 100{,}547$
$B = (4.875 - 0.875)\ 0.375 \times 55{,}000 = 82{,}500$
$C = 2 \times 88{,}000 \times 0.6013 + 1 \times 44{,}000 \times 0.6013 = 132{,}286$
$D = (4.875 - 2 \times 0.875)\ 0.375 \times 55{,}000 + 1 \times 44{,}000 \times 0.6013 = 90{,}910$
$E = (4.875 - 2 \times 0.875)\ 0.375 \times 55{,}000 + 0.875 \times 0.3125 \times 95{,}000 = 90{,}429$
$F = 2 \times 0.875 \times 0.375 \times 95{,}000 + 0.875 \times 0.3125 \times 95{,}000 = 88{,}320$
$G = 2 \times 0.875 \times 0.375 \times 95{,}000 + 1 \times 44{,}000 \times 0.6013 = 88{,}800$

$$\frac{82{,}500\ (B)}{100{,}547\ (A)} = 0.820 = \text{efficiency of joint}$$

414 *Example:* Butt and double strap joint, triple-riveted.

A = strength of solid plate $= P \times t \times TS$

B = strength of plate between rivet holes in the outer row $= (P - d)\ t \times TS$

C = shearing strength of four rivets in double shear, plus the shearing strength of one rivet in single shear $= N \times S \times a + n \times s \times a$

D = strength of plate between rivet holes in the second row, plus the shearing strength of one rivet in single shear in the outer row $= (P - 2d)\ t \times TS + n \times s \times a$

E = strength of plate between rivet holes in the second row, plus the crushing strength of butt strap in front of one rivet in the outer row = $(P—2d)\ t \times TS + d \times b \times c$

F = crushing strength of plate in front of four rivets, plus the crushing strength of butt strap in front of one rivet = $N \times d \times t \times c + n \times d \times b \times c$

G = crushing strength of plate in front of four rivets, plus the shearing strength of one rivet in single shear = $N \times d \times t \times c + n \times s \times a$

Divide B, C, D, E, F or G (whichever is the least) by A, and the quotient will be the efficiency of a butt and double strap joint, triple-riveted, as shown in Fig. 24.

TS = 55,000 lb. per sq. in.	a = 0.5185 sq. in.
t = $\frac{3}{8}$ in. = 0.375 in.	s = 44,000 lb. per sq. in.
b = $\frac{5}{16}$ in. = 0.3125 in.	S = 88,000 lb. per sq. in.
P = $6\frac{1}{2}$ in. = 6.5 in.	c = 95,000 lb. per sq. in.
d = $\frac{13}{16}$ in. = 0.8125 in.	

Number of rivets in single shear in a unit length of joint = 1.

Number of rivets in double shear in a unit length of joint = 4.

$A = 6.5 \times 0.375 \times 55{,}000 = 134{,}062$
$B = (6.5—0.8125)\ 0.375 \times 55{,}000 = 117{,}304$
$C = 4 \times 88{,}000 \times 0.5185 + 1 \times 44{,}000 \times 0.5185 = 205{,}326$
$D = (6.5—2 \times 0.8125)\ 0.375 \times 55{,}000 + 1 \times 44{,}000 \times 0.5185 = 123{,}360$
$E = (6.5—2 \times 0.8125)\ 0.375 \times 55{,}000 + 0.8125 \times 0.3125 \times 95{,}000 = 124{,}667$
$F = 4 \times 0.8125 \times 0.375 \times 95{,}000 + 1 \times 0.8125 \times 0.3125 \times 95{,}000 = 139{,}902$
$G = 4 \times 0.8125 \times 0.375 \times 95{,}000 + 1 \times 44{,}000 \times 0.5185 = 138{,}595$

$$\frac{117{,}304\ (B)}{134{,}062\ (A)} = 0.875 = \text{efficiency of joint}$$

415 *Example:* Butt and double strap joint, quadruple-riveted.

A = strength of solid plate = $P \times t \times TS$

B = strength of plate between rivet holes in the outer row = $(P—d)\ t \times TS$

C = shearing strength of eight rivets in double shear, plus the shearing strength of three rivets in single shear = $N \times S \times a + n \times s \times a$

D = strength of plate between rivet holes in the second row, plus the shearing strength of one rivet in single shear in the outer row = $(P—2d)\ t \times TS + 1 \times s \times a$

E = strength of plate between rivet holes in the third row, plus the shearing strength of two rivets in the second row in single shear and one rivet in single shear in the outer row = $(P—4d)\ t \times TS + n \times s \times a$

F = strength of plate between rivet holes in the second row, plus the crushing strength of butt strap in front of one rivet in the outer row = $(P—2d)\ t \times TS + d \times b \times c$

G = strength of plate between rivet holes in the third row, plus the crushing strength of butt strap in front of two rivets in the second row and one rivet in the outer row = $(P-4d)\ t \times TS + n \times d \times b \times c$

H = crushing strength of plate in front of eight rivets, plus the crushing strength of butt strap in front of three rivets = $N \times d \times t \times c + n \times d \times b \times c$

I = crushing strength of plate in front of eight rivets, plus the shearing strength of two rivets in the second row and one rivet in the outer row, in single shear = $N \times d \times t \times c + n \times s \times a$

Divide B, C, D, E, F, G, H or I (whichever is the least) by A, and the quotient will be the efficiency of a butt and double strap joint quadruple-riveted, as shown in Fig. 25.

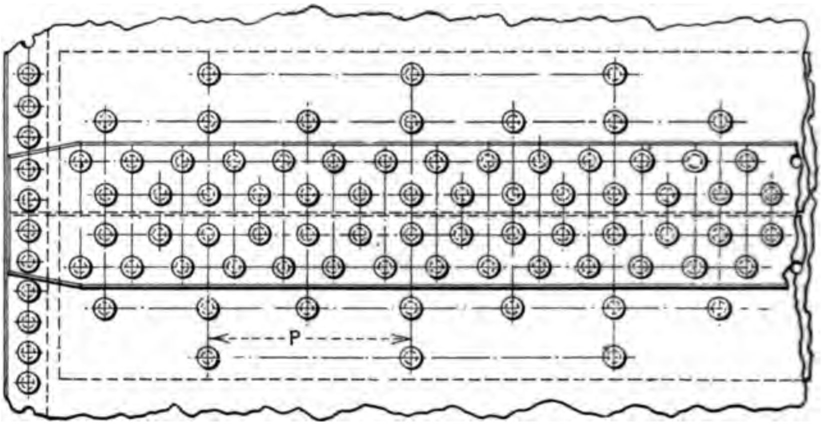

FIG. 25 EXAMPLE OF BUTT AND DOUBLE STRAP JOINT, QUADRUPLE-RIVETED

TS = 55,000 lb. per sq. in.	a = 0.6903 sq. in.
t = ½ in. = 0.5 in.	s = 44,000 lb. per sq. in.
b = $\frac{7}{16}$ in. = 0.4375 in.	S = 88,000 lb. per sq. in.
P = 15 in.	c = 95,000 lb. per sq. in.
d = $\frac{15}{16}$ in. = 0.9375 in.	

Number of rivets in single shear in a unit length of joint = 3.
Number of rivets in double shear in a unit length of joint = 8.

$A = 15 \times 0.5 \times 55{,}000 = 412{,}500$

$B = (15-0.9375)\ 0.5 \times 55{,}000 = 386{,}718$

$C = 8 \times 88{,}000 \times 0.6903 + 3 \times 44{,}000 \times 0.6903 = 577{,}090$

$D = (15-2 \times 0.9375)\ 0.5 \times 55{,}000 + 1 \times 44{,}000 \times 0.6903 = 391{,}310$

$E = (15-4 \times 0.9375)\ 0.5 \times 55{,}000 + 3 \times 44{,}000 \times 0.6903 = 400{,}494$

$F = (15-2 \times 0.9375)\ 0.5 \times 55{,}000 + 0.9375 \times 0.4375 \times 95{,}000 = 399{,}902$

$G = (15-4 \times 0.9375)\ 0.5 \times 55{,}000 + 3 \times 0.9375 \times 0.4375 \times 95{,}000 = 426{,}269$

$H = 8 \times 0.9375 \times 0.5 \times 95{,}000 + 3 \times 0.9375 \times 0.4375 \times 95{,}000 = 473{,}145$

$I = 8 \times 0.9375 \times 0.5 \times 95{,}000 + 3 \times 44{,}000 \times 0.6903 = 447{,}369$

$$\frac{386{,}718\ (B)}{412{,}500\ (A)} = 0.937 = \text{efficiency of joint}$$

416 *Example:* Butt and double strap joint, quintuple-riveted.

A = strength of solid plate $= P \times t \times TS$

B = strength of plate between rivet holes in the outer row $= (P-d)\ t \times TS$

C = shearing strength of 16 rivets in double shear, plus the shearing strength of seven rivets in single shear $= N \times S \times a + n \times s \times a$

D = strength of plate between rivet holes in the second row, plus the shearing strength of one rivet in single shear in the outer row $= (P-2d)\ t \times TS + 1 \times s \times a$

E = strength of plate between rivet holes in the third row, plus the shearing strength of two rivets in the second row in single shear and one rivet in single shear in the outer row $= (P-4d)\ t \times TS + 3 \times s \times a$

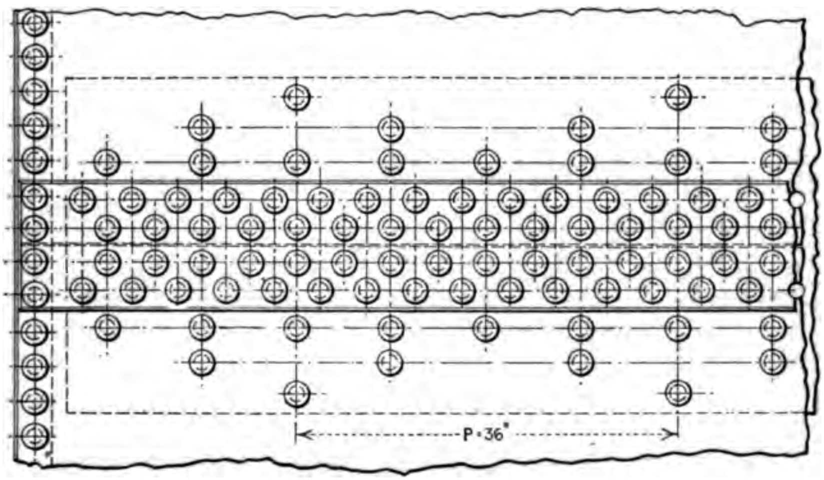

FIG. 26 EXAMPLE OF BUTT AND DOUBLE STRAP JOINT, QUINTUPLE-RIVETED

F = strength of plate between rivet holes in the fourth row, plus the shearing strength of four rivets in the third row, two rivets in the second row and one rivet in the outer row in single shear $= (P-8d)\ t \times TS + n \times s \times a$

G = strength of plate between rivet holes in the second row, plus the crushing strength of butt strap in front of one rivet in the outer row $= (P-2d)\ t \times TS + d \times b \times c$

H = strength of plate between rivet holes in the third row, plus the crushing strength of butt strap in front of two rivets in the second row and one rivet in the outer row $= (P-4d)\ t \times TS + 3 \times d \times b \times c$

I = strength of plate between rivet holes in the fourth row, plus the crushing strength of butt strap in front of four rivets in the third row, two rivets in the second row and one rivet in the outer row $= (P-8d)\ t \times TS + n \times d \times b \times c$

J = crushing strength of plate in front of 16 rivets, plus the crushing strength of butt strap in front of seven rivets $= N \times d \times t \times c + n \times d \times b \times c$.

K = crushing strength of plate in front of 16 rivets, plus the shearing strength of four rivets in the third row, two rivets in the second row and one rivet in the outer row in single shear $= N \times d \times t \times c + n \times s \times a$

Divide B, C, D, E, F, G, H, I, J or K (whichever is the least) by A, and the quotient will be the efficiency of a butt and double strap joint, quintuple-riveted, as shown in Fig. 26 or Fig. 27.

$TS = 55{,}000$ lb. per sq. in.
$t = \frac{3}{4}$ in. $= 0.75$ in.
$b = \frac{1}{2}$ in. $= 0.5$ in.
$P = 36$ in.
$d = 1\frac{5}{16}$ in. $= 1.3125$ in.

$a = 1.3529$ sq. in.
$s = 44{,}000$ lb. per sq. in.
$S = 88{,}000$ lb. per sq. in.
$c = 95{,}000$ lb. per sq. in.

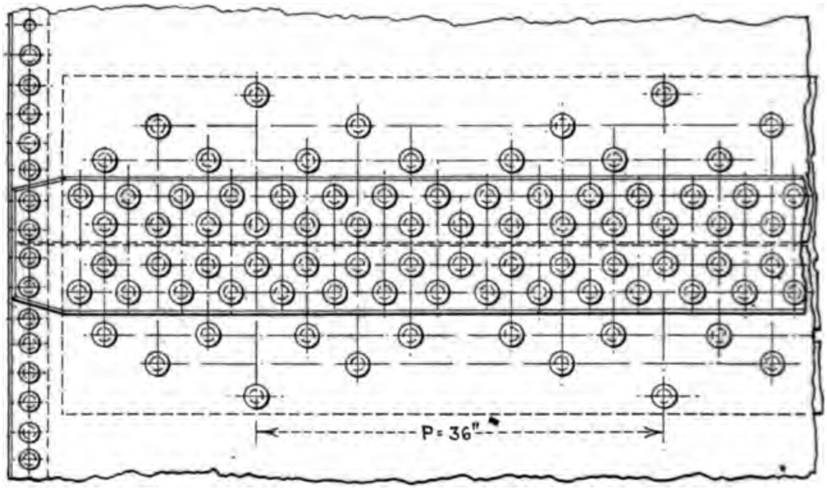

FIG. 27 EXAMPLE OF BUTT AND DOUBLE STRAP JOINT, QUINTUPLE-RIVETED

Number of rivets in single shear in a unit length of joint = 7.
Number of rivets in double shear in a unit length of joint = 16.

$A = 36 \times 0.75 \times 55{,}000 = 1{,}485{,}000$
$B = (36 - 1.3125)\ 0.75 \times 55{,}000 = 1{,}430{,}860$
$C = 16 \times 88{,}000 \times 1.3529 + 7 \times 44{,}000 \times 1.3529 = 2{,}321{,}576$
$D = (36 - 2 \times 1.3125)\ 0.75 \times 55{,}000 + 1 \times 44{,}000 \times 1.3529 = 1{,}436{,}246$
$E = (36 - 4 \times 1.3125)\ 0.75 \times 55{,}000 + 3 \times 44{,}000 \times 1.3529 = 1{,}447{,}020$
$F = (36 - 8 \times 1.3125)\ 0.75 \times 55{,}000 + 7 \times 44{,}000 \times 1.3529 = 1{,}468{,}568$
$G = (36 - 2 \times 1.3125)\ 0.75 \times 55{,}000 + 1.3125 \times 0.5 \times 95{,}000 = 1{,}439{,}064$
$H = (36 - 4 \times 1.3125)\ 0.75 \times 55{,}000 + 3 \times 1.3125 \times 0.5 \times 95{,}000 = 1{,}455{,}472$
$I = (36 - 8 \times 1.3125)\ 0.75 \times 55{,}000 + 7 \times 1.3125 \times 0.5 \times 95{,}000 = 1{,}488{,}141$
$J = 16 \times 1.3125 \times 0.75 \times 95{,}000 + 7 \times 1.3125 \times 0.5 \times 95{,}000 = 1{,}932{,}266$
$K = 16 \times 1.3125 \times 0.75 \times 95{,}000 + 7 \times 44{,}000 \times 1.3529 = 1{,}912{,}943$

$$\frac{1{,}430{,}860\ (B)}{1{,}485{,}000\ (A)} = 0.963 = \text{efficiency of joint}$$

417 Figs. 28 and 29 illustrate other joints that may be used. The butt and double strap joint with straps of equal width shown in Fig. 28 may be so designed that it will have an efficiency of from 82 to 84 per cent and the saw-tooth joint shown in Fig. 29 so that it will have an efficiency of from 92 to 94 per cent.

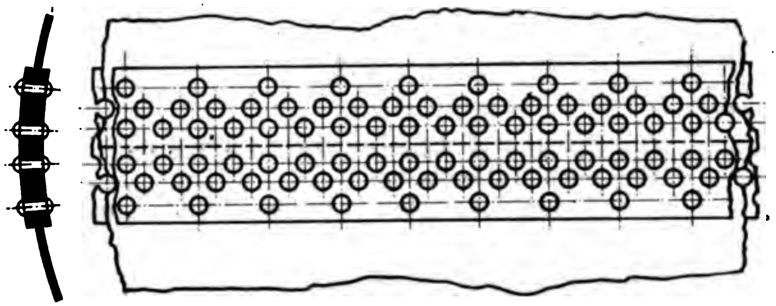

FIG. 28 ILLUSTRATION OF BUTT AND DOUBLE STRAP JOINT WITH STRAPS OF EQUAL WIDTH

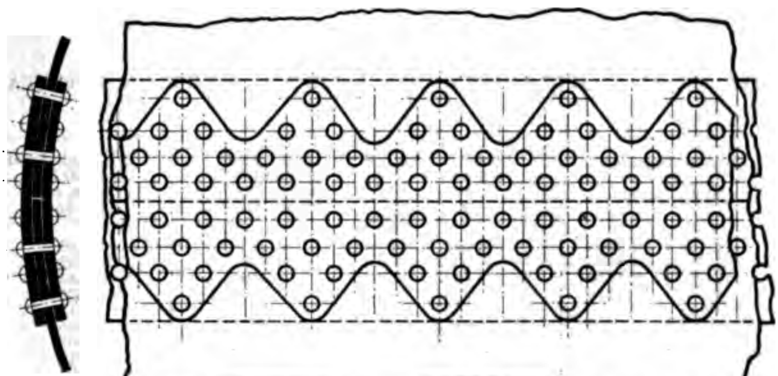

FIG. 29 ILLUSTRATION OF BUTT AND DOUBLE STRAP JOINT OF THE SAW-TOOTH TYPE

Braced and Stayed Surfaces

418 The allowable loads based on the net cross-sectional areas of staybolts with V-threads, are computed from the following formulae. The use of Whitworth threads with other pitches is permissible.

The formula for the diameter of a staybolt at the bottom of a V-thread is:

$$D - (P \times 1.732) = d$$

where

D = diameter of staybolt over the threads, in.
P = pitch of threads, in.
d = diameter of staybolt at bottom of threads, in.
1.732 = a constant

When U. S. threads are used, the formula becomes

$$D - (P \times 1.732 \times 0.75) = d$$

Tables 11 and 12 give the allowable loads on net cross-sectional areas for staybolts with V-threads, having 12 and 10 threads per inch.

TABLE 11. ALLOWABLE LOADS ON STAYBOLTS WITH V-THREADS, 12 THREADS PER INCH

Outside Diameter of Staybolts, In.		Diameter at Bottom of Thread, In.	Net Cross-Sectional Area (at Bottom of Thread), Sq. In.	Allowable Load at 7500 Lb. Stress, per Sq. In.
3/4	0.7500	0.6057	0.288	2160
13/16	0.8125	0.6682	0.351	2632
7/8	0.8750	0.7307	0.419	3142
15/16	0.9375	0.7932	0.494	3705
1	1.0000	0.8557	0.575	4312
1 1/16	1.0625	0.9182	0.662	4965
1 1/8	1.1250	0.9807	0.755	5662
1 3/16	1.1875	1.0432	0.855	6412
1 1/4	1.2500	1.1057	0.960	7200
1 5/16	1.3125	1.1682	1.072	8040
1 3/8	1.3750	1.2307	1.190	8925
1 7/16	1.4375	1.2932	1.313	9849
1 1/2	1.5000	1.3557	1.444	10830

TABLE 12. ALLOWABLE LOADS ON STAYBOLTS WITH V-THREADS, 10 THREADS PER INCH

Outside Diameter of Staybolts, In.		Diameter at Bottom of Thread, In.	Net Cross-Sectional Area (at Bottom of Thread), Sq. In.	Allowable Load at 7500 Lb. Stress per Sq. In.
1¼	1.2500	1.0768	0.911	6832
1 5/16	1.3125	1.1393	1.019	7642
1⅜	1.3750	1.2018	1.134	8505
1 7/16	1.4375	1.2643	1.255	9412
1½	1.5000	1.3268	1.382	10365
1 9/16	1.5625	1.3893	1.515	11362
1⅝	1.6250	1.4518	1.655	12412

419 Table 13 shows the allowable loads on net cross-sectional areas of round stays or braces.

TABLE 13. ALLOWABLE LOADS ON ROUND BRACES OR STAY RODS

Minimum Diameter of Circular Stay, In.		Net Cross-sectional Area of Stay, in Sq. In.	Allowable Stress, in Lb. per Sq. In., Net Cross-sectional Area		
			6000	8500	9500
			Allowable Load, in Lb., on Net Cross-sectional Area		
1	1.0000	0.7854	4712	6676	7462
1 1/16	1.0625	0.8866	5320	7536	8423
1⅛	1.1250	0.9940	5964	8449	9443
1 3/16	1.1875	1.1075	6645	9414	10521
1¼	1.2500	1.2272	7363	10431	11658
1 5/16	1.3125	1.3530	8118	11501	12854
1⅜	1.3750	1.4849	8909	12622	14107
1 7/16	1.4375	1.6230	9738	13796	15419
1½	1.5000	1.7671	10603	15020	16787
1 9/16	1.5625	1.9175	11505	16298	18216
1⅝	1.6250	2.0739	12443	17628	19702
1 11/16	1.6875	2.2365	13419	19010	21247
1¾	1.7500	2.4053	14432	20445	22852
1 13/16	1.8125	2.5802	15481	21932	24512
1⅞	1.8750	2.7612	16567	23470	26231
1 15/16	1.9375	2.9483	17690	25061	28009
2	2.0000	3.1416	18850	26704	29845
2⅛	2.1250	3.5466	21280	30147	33693
2¼	2.2500	3.9761	23857	33797	37773
2⅜	2.3750	4.4301	26580	37656	42086
2½	2.5000	4.9087	29452	41724	46632
2⅝	2.6250	5.4119	32471	46001	51413
2¾	2.7500	5.9396	35638	50487	56426
2⅞	2.8750	6.4918	38951	55181	61673
3	3.0000	7.0686	42412	60083	67152

420 Table 14 gives the net areas of segments of heads for use in computing stays.

TABLE 14. NET AREAS OF SEGMENTS OF HEADS

Height from Tubes to Shell, In.	Diameter of Boiler, In.												
	24	30	36	42	48	54	60	66	72	78	84	90	96
	Area to be stayed, Sq. In.												
8	28	33	37	40	43	47	51	53	55	58	60	63	65
8½	35	41	46	51	55	59	63	66	70	74	76	80	82
9	42	49	56	62	67	72	76	82	86	90	92	95	98
9½	50	58	66	70	80	86	91	96	101	105	111	116	119
10	57	68	77	85	93	99	106	112	117	123	129	132	137
10½	66	78	89	98	107	114	123	131	135	142	147	153	160
11	74	88	100	111	121	130	138	147	155	161	169	174	183
11½	83	99	112	124	137	146	156	165	173	181	189	196	204
12	91	109	125	139	151	163	174	184	194	203	213	219	230
12½	....	120	138	153	167	180	193	204	216	224	234	243	252
13	....	132	151	168	183	197	211	224	235	247	256	267	279
13½	....	143	164	183	200	216	230	246	258	270	282	293	302
14	....	155	178	199	217	234	250	266	280	294	305	319	331
14½	....	167	192	215	235	254	271	287	303	318	333	345	360
15	....	178	206	231	252	273	291	309	326	343	357	372	386
15½	....	....	220	247	271	291	312	332	350	368	382	400	417
16	....	....	235	263	289	312	334	355	374	394	411	423	443
16½	....	....	249	281	308	332	357	380	399	420	436	457	475
17	....	....	264	297	326	353	378	402	425	447	467	486	502
17½	....	....	....	314	345	374	400	426	449	471	494	516	536
18	....	....	....	331	365	396	424	450	476	500	520	543	564
18½	....	....	....	349	384	417	448	476	501	526	552	577	598
19	....	....	....	366	404	439	470	500	529	555	580	604	631
19½	....	....	....	384	424	461	496	528	558	584	613	641	663
20	....	....	....	401	444	483	519	552	583	613	642	667	699
20½	....	....	....	....	464	505	543	578	613	643	675	706	729
21	....	....	....	....	485	528	568	604	640	673	705	733	766
21½	....	....	....	....	505	551	594	632	669	703	739	766	797
22	....	....	....	....	526	574	618	658	697	734	769	800	835
22½	....	....	....	....	....	597	643	687	726	765	800	835	867
23	....	....	....	....	....	620	668	713	754	796	830	869	906
23½	....	....	....	....	....	642	695	740	784	827	866	904	945
24	....	....	....	....	....	667	719	768	814	859	897	939	978
24½	....	....	....	....	....	689	745	797	843	892	934	975	1018
25	....	....	....	....	....	714	771	825	875	922	966	1010	1051
25½	....	....	....	....	....	737	798	855	907	956	1003	1047	1092
26	....	....	....	....	....	761	824	882	936	987	1035	1083	1126
26½	....	....	....	....	....	....	850	909	968	1024	1073	1120	1167
27	....	....	....	....	....	....	877	939	998	1053	1106	1157	1202
27½	....	....	....	....	....	....	904	968	1030	1089	1145	1195	1243
28	....	....	....	....	....	....	930	997	1060	1120	1177	1232	1279
28½	....	....	....	....	....	....	....	1028	1092	1157	1211	1270	1321
29	....	....	....	....	....	....	....	1056	1123	1187	1248	1305	1360
29½	....	....	....	....	....	....	....	1084	1155	1221	1284	1347	1400
30	....	....	....	....	....	....	....	1115	1187	1255	1321	1382	1442
30½	....	....	....	....	....	....	....	....	1218	1290	1358	1424	1480
31	....	....	....	....	....	....	....	....	1252	1324	1394	1459	1523
31½	....	....	....	....	....	....	....	....	1286	1359	1433	1496	1561
32	....	....	....	....	....	....	....	....	1317	1394	1467	1538	1605
32½	....	....	....	....	....	....	....	....	....	1430	1508	1575	1650
33	....	....	....	....	....	....	....	....	....	1465	1542	1617	1687
33½	....	....	....	....	....	....	....	....	....	1500	1578	1655	1733
34	....	....	....	....	....	....	....	....	....	1536	1617	1695	1770
34½	....	....	....	....	....	....	....	....	....	....	1654	1735	1816
35	....	....	....	....	....	....	....	....	....	....	1692	1775	1856
35½	....	....	....	....	....	....	....	....	....	....	....	1810	1900
36	....	....	....	....	....	....	....	....	....	....	....	1857	1941
36½	....	....	....	....	....	....	....	....	....	....	....	....	1984
37	....	....	....	....	....	....	....	....	....	....	....	....	2026

Safety Valves

421 *Method of Computing Table 8.* The discharge capacity of a safety valve is expressed in equations 2 and 3 as the product of C and H. The discharge capacities are given in Table 8 for each valve size at the pressures shown and are calculated for various valve sizes, pressures and for three different lifts. The discharge capacities are proportional to the lifts, so that intermediate values may be obtained from the Table by interpolation.

C = total weight or volume of fuel of any kind burned per hour at time of maximum forcing, lb. or cu. ft.

H = the heat of combustion, B.t.u. per lb. or cu. ft. of fuel used.

D = diameter of valve seat, in.

L = vertical lift of valve disc, in., measured immediately after the sudden lift due to the pop.

P = absolute boiler pressure or gage pressure plus 14.7 lb. per sq. in.

1100 = the number of B.t.u. required to change a pound of feed water at 100 deg. fahr. into a pound of steam.

The boiler efficiency is assumed as 75 per cent.

The coefficient of discharge, in Napier's formula, is taken as 96 per cent.

$$\frac{C\times H\times 0.75}{1100\times 3600}=\frac{3.1416\times D\times L\times 0.707\times P\times 0.96}{70} \text{ for valve with 45-deg. seat.} \quad (1)$$

$$CH=160{,}856\times P\times D\times L \text{ for valve with bevel seat at 45 deg.} \quad (2)$$

$$CH=227{,}487\times P\times D\times L \text{ for valve with flat seat at 90 deg.} \quad (3)$$

Method of Checking the Safety Valve Capacity by Measuring the Maximum Amount of Fuel that can be Burned

422 The maximum weight of fuel that can be burned is determined by a test. The weight of steam generated per hour is found from the formula:

$$W=\frac{C\times H\times 0.75}{1100} \text{ where}$$

W = weight of steam generated per hour, lb.

C = total weight of fuel burned per hour at time of maximum forcing, lb.

H = the heat of combustion of the fuel, B.t.u. per lb. (see Par. 427).

The sum of the safety valve capacities marked on the valves as provided for in the Rules shall be equal to or greater than the maximum evaporative capacity of the boiler.

Table 8 may be used for determining the number of safety valves required as illustrated in the following examples:

423 *Example 1:* A boiler at the time of maximum forcing uses 2150 lb. of Illinois coal per hour of 12,100 B.t.u. per lb. Boiler pressure, 225 lb. per sq. in. gage.

$$2150 \times 12{,}100 = CH = 26{,}015{,}000$$

Table 8 shows that two 3½-in. bevel seated valves with 0.11 in. lift, or one 3-in. bevel seated valve with 0.10 in. lift and one 3½-in. bevel seated valve with 0.11 in. lift, would discharge the steam generated.

424 *Example 2:* Wood shavings of heat of combustion of 6400 B.t.u. per lb. are burned under a boiler at the maximum rate of 2000 lb. per hour. Boiler pressure, 100 lb. per sq. in. gage.

$$2000 \times 6400 = CH = 12{,}800{,}000$$

Table 8 shows that two 3½-in. bevel seated valves with 0.11 in. lift, or one 3-in. bevel seated valve with 0.08 in. lift and one 4-in. bevel seated valve with 0.12 in. lift, would discharge the steam generated.

425 *Example 3:* An oil-fired boiler at maximum forcing uses 1000 lb. of crude oil (Texas) per hour. Boiler pressure, 275 lb. per sq. in. gage.

$$1000 \times 18{,}500 = CH = 18{,}500{,}000$$

Table 8 shows that two 3½-in. bevel seated valves with 0.06 in. lift, or two 3-in. flat seated valves with 0.05 in. lift, or two 2½-in. flat seated valves with 0.06 in. lift, would discharge the steam generated.

426 *Example 4:* A boiler fired with natural gas consumes 3000 cu. ft. per hour. The working pressure is 150 lb. per sq. in. gage.

$$3000 \times 960 = CH = 2{,}880{,}000$$

Table 8 shows that two $1\frac{1}{4}$-in. bevel seated valves with 0.05 in. lift, or two 1-in. flat seated valves with 0.04 in. lift, would discharge the steam generated.

427 For the purpose of checking the safety valve capacity as described in Par. 422, the following values of heats of combustion of various fuels in B.t.u. per lb. or per cu. ft. may be used:

	B. t. u. per lb.
Semi-bituminous coal	14,500
Anthracite	13,700
Screenings	12,500
Coke	13,500
Wood, hard or soft, kiln dried	7,700
Wood, hard or soft, air dried	6,200
Wood shavings	6,400
Peat, air dried, 25 per cent moisture	7,500
Lignite	10,000
Kerosene	20,000
Petroleum, crude oil, Penn	20,700
Petroleum, crude oil, Texas	18,500

	B. t. u. per cu. ft.
Natural gas	960
Blast furnace gas	100
Producer gas	150
Water gas, uncarburetted	290

TABLE 15

AMERICAN STANDARD 125-LB. WORKING PRESSURE PER SQ. IN. STANDARD FLANGE FITTINGS, STRAIGHT SIZES (SEE FIG. 30)

	Size	1	1¼	1½	2	2½	3	3½	4	4½	5	6	7	8	9	10	12	14	15
A-A	Face to face	7	7½	8	9	10	11	12	13	14	15	16	17	18	20	22	24	28	29
A	Center to face	3½	3¾	4	4½	5	5½	6	6½	7	7½	8	8½	9	10	11	12	14	14½
B	Center to face of long radius ells	5	5½	6	6½	7	7¾	8½	9	9½	10¼	11½	12¾	14	15¼	16½	19	21½	22¾
C	Center to face of 45-deg. ells	1¾	2	2¼	2½	3	3	3½	4	4	4½	5	5½	5½	6	6½	7½	7½	8
D	Face to face laterals	7½	8	9	10½	12	13	14½	15	15½	17	18	20½	22	24	25½	30	33	34½
E	Center to face	5¾	6¼	7	8	9½	10	11½	12	12½	13½	14½	16½	17½	19½	20½	24½	27	28½
F	Center to face	1¾	1¾	2	2½	2½	3	3	3	3	3½	3½	4	4½	4½	5	5½	6	6
G	Face to face reducer	.....	.....	.....	.....	.....	6	6½	7	7½	8	9	10	11	11½	12	14	16	17
	Diameter of flange	4	4½	5	6	7	7½	8½	9	9¼	10	11	12½	13½	15	16	19	21	22¼
	Thickness of flange	7/16	½	9/16	⅝	11/16	¾	13/16	15/16	15/16	15/16	1	1 1/16	1⅛	1⅛	1 3/16	1¼	1⅜	1⅜
	Diameter of bolt circle	3	3⅜	3⅞	4¾	5½	6	7	7½	7¾	8½	9½	10¾	11¾	13¼	14¼	17	18¾	20
	No. of bolts	4	4	4	4	4	4	4	8	8	8	8	8	8	12	12	12	12	16
	Diameter of bolts	7/16	7/16	½	⅝	⅝	⅝	⅝	⅝	¾	¾	¾	¾	¾	¾	⅞	⅞	1	1
	Minimum metal thickness of body	7/16	7/16	7/16	7/16	7/16	7/16	7/16	½	½	½	9/16	⅝	⅝	11/16	¾	13/16	⅞	⅞

	Size	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48
A-A	Face to face	30	33	36	40	44	46	48	50	52	54	56	58	60	62	64	66	68
A	Center to face	15	16½	18	20	22	23	24	25	26	27	28	29	30	31	32	33	34
B	Center to face of long radius ells	24	26½	29	31½	34	36½	39	41½	44	46½	49	51½	54	56½	59	61½	64
C	Center to face of 45-deg. ells	8	8½	9½	10	11	13	14	15	16	17	18	19	20	21	22	23	24
D	Face to face laterals	36½	39	43	46	49½	53	56	59	.....	.....	.....	.....	.....	.....	.....	.....	.....
E	Center to face	30	32	35	37½	40½	44	46½	49	.....	.....	.....	.....	.....	.....	.....	.....	.....
F	Center to face	6½	7	8	8½	9	9	9½	10	.....	.....	.....	.....	.....	.....	.....	.....	.....
G	Face to face reducer	18	19	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48
	Diameter of flange	23½	25	27½	29½	32	34¼	36½	38¾	41¾	43¾	46	48¾	50¾	53	55¼	57¼	59½
	Thickness of flange	1 7/16	1 9/16	1 11/16	1 13/16	1⅞	2	2 1/16	2⅛	2¼	2 5/16	2⅜	2⅜	2½	2⅝	2⅝	2 11/16	2¾
	Diameter of bolt circle	21¼	22¾	25	27¼	29½	31¾	34	36	38½	40½	42¾	45¼	47¼	49½	51¾	53¾	56
	No. of bolts	16	16	20	20	20	24	28	28	28	32	32	32	36	36	40	40	44
	Diameter of bolts	1	1⅛	1⅛	1¼	1¼	1¼	1¼	1⅜	1½	1½	1½	1⅝	1⅝	1⅝	1⅝	1⅝	1⅝
	Minimum metal thickness of body	1	1 1/16	1⅛	1 3/16	1¼	1 5/16	1⅜	1 7/16	1½	1 9/16	1⅝	1 11/16	1¾	1 13/16	1⅞	1 15/16	2

Notes:—Figures given are for center to face and for face to face finished dimensions. Where necessary manufacturers will make suitable allowances in patterns before casting.

Laterals do not extend beyond the 30-in. size at the present time. Box wrench to be used on bolting for large sizes.

Square head bolts with hexagonal nuts are recommended. 1¾ in. diameter and larger stud with a nut at each end is satisfactory.

Hexagonal nuts for pipe sizes 1 in. to 46 in. can be conveniently pulled up with open wrenches of minimum design of heads. Hexagonal nuts for pipe sizes 48 in. to 100 in. can be conveniently pulled up with socket wrenches.

Flanges to be spot bored for nuts for sizes 32 in. to 100 in. inclusive.

AMERICAN STANDARD, 250-LB. WORKING PRESSURE PER SQ. IN., EXTRA HEAVY FLANGE FITTINGS, STRAIGHT SIZES (SEE FIG. 30)

	Size	1	1¼	1½	2	2½	3	3½	4	4½	5	6	7	8	9	10	12	14	15
A-A	Face to face	8	8½	9	10	11	12	13	14	15	16	17	18	20	21	23	26	30	31
A	Center to face	4	4¼	4½	5	5½	6	6½	7	7½	8	8½	9	10	10½	11½	13	15	15½
B	Center to face of long radius ells	5	5½	6	6½	7	7¾	8½	9	9½	10¼	11½	12¾	14	15¼	16½	19	21½	22¾
C	Center to face of 45-deg. ells	2	2½	2¾	3	3½	3½	4	4½	4½	5	5½	6	6	6½	7	8	8½	9
D	Face to face, laterals	8½	9½	11	11½	13	14	15½	16½	18	18½	21½	23½	25½	27½	29½	33½	37½	39½
E	Center to face, laterals	6½	7¼	8½	9	10½	11	12½	13½	14½	15	17½	19	20½	22½	24	27½	31	33
F	Center to face, laterals	2	2¼	2½	2½	2½	3	3	3	3½	3½	4	4½	5	5	5½	6	6½	6½
G	Face to face, reducer	...	...	...	...	...	6	6½	7	7½	8	9	10	11	11½	12	14	16	17
	Diameter of flange	4½	5	6	6½	7½	8¼	9	10	10½	11	12½	14	15	16¼	17½	20½	23	24½
	Thickness of flange	11/16	¾	13/16	⅞	1	1⅛	1 3/16	1¼	1 5/16	1⅜	1 7/16	1½	1⅝	1¾	1⅞	2	2⅛	2 3/16
	Diameter of bolt circle	3¼	3¾	4½	5	5⅞	6⅝	7¼	7⅞	8½	9¼	10⅝	11⅞	13	14	15¼	17¾	20¼	21½
	Number of bolts	4	4	4	4	4	8	8	8	8	8	12	12	12	12	16	16	20	20
	Diameter of bolts	½	½	⅝	⅝	¾	¾	¾	¾	¾	¾	¾	⅞	⅞	1	1	1⅛	1⅛	1¼
	Minimum metal thickness of body	½	½	½	½	9/16	9/16	9/16	⅝	⅝	11/16	¾	11/16	13/16	⅞	15/16	1	1⅛	1 3/16

	Size	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48
A-A	Face to face	33	36	39	41	45	48	52	55	58	61	65	68	71	74	78	81	84
A	Center to face	16½	18	19½	20½	22½	24	26	27½	29	30½	32½	34	35½	37	39	40½	42
B	Center to face of long radius ells	24	26½	29	31½	34	36½	39	41½	44	46½	49	51½	54	56½	59	61½	64
C	Center to face of 45-deg. ells	9½	10	10½	11	12	13	14	15	16	17	18	19	20	21	22	23	24
D	Face to face, laterals	42	45½	49	53	57½	...	...	...	...	...	...	...	...	...	...	...	...
E	Center to face, laterals	34½	37½	40½	43½	47½												
F	Center to face, laterals	7½	8	8½	9½	10	...	...	...	...	...	...	...	...	...	...	...	...
G	Face to face, reducer	18	19	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48
	Diameter of flange	25½	28	30½	33	36	38¼	40¾	43	45¼	47½	50	52¼	54½	57	59¼	61½	65
	Thickness of flange	2¼	2⅜	2½	2⅝	2¾	2 11/16	2 13/16	3	3⅛	3¼	3⅜	3 1/16	3 3/16	3 11/16	3¾	3⅞	4
	Diameter of bolt circle	22½	24¾	27	29¼	32	34½	37	39¼	41½	43½	46	48	50¼	52¾	55	57¼	60¾
	Number of bolts	20	24	24	24	24	28	28	28	28	28	32	32	36	36	36	40	40
	Diameter of bolts	1¼	1¼	1⅜	1½	1⅝	1⅝	1⅝	1¾	1⅞	1⅞	1⅞	1⅞	1⅞	1⅞	2	2	2
	Minimum metal thickness of body	1¼	1⅜	1½	1 9/16	1⅝	1 11/16	1⅞	2	2⅛	2¼	2⅜	2 1/16	2 3/16	2 11/16	2 11/16	2⅞	3

NOTES:—Figures given are for center to face and for face to face finished dimensions. Where necessary manufacturers will make suitable allowances in patterns before casting.
Laterals do not extend beyond the 24 in. size at the present time. Box wrench to be used on bolting for large sizes
Square head bolts with hexagonal nuts are recommended. 1⅜ in. diameter and larger stud with a nut at each end is satisfactory.
Hexagonal nuts for pipe sizes 1 in. to 16 in. can be conveniently pulled up with wrenches of minimum design of heads. Hexagonal nuts for pipe sizes 18 in. to 48 in. can be conveniently pulled up with socket wrenches.
Distance between inside edges of bolt holes and raised face to be in.
Flanges to be spot bored for nuts.
Thickness of flanges given in table includes raised face.

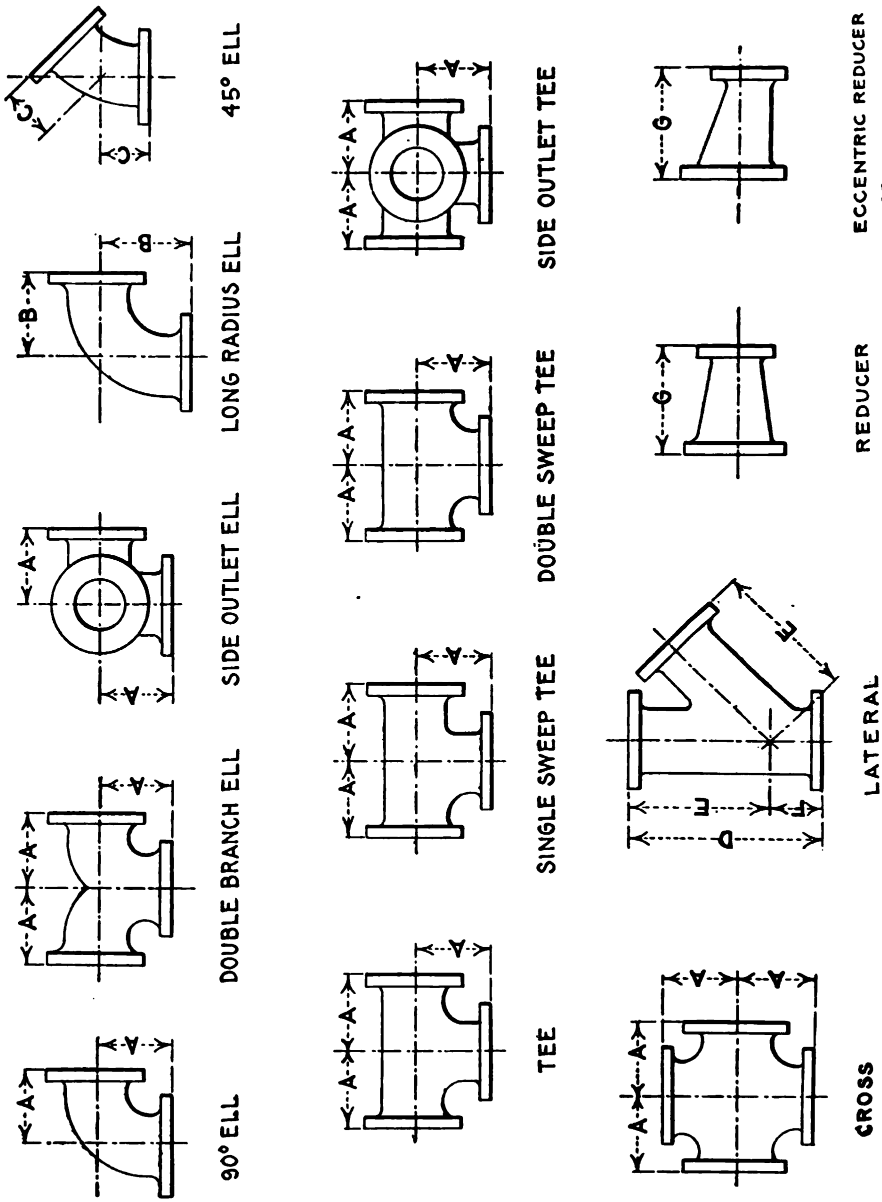

Fig. 80 Standard Types of Flange Fittings Dimensioned in Tables 15 and 16

Fusible Plugs

428 Fusible plugs, if used, shall be filled with tin with a melting point between 400 and 500 deg. fahr.

429 The least diameter of fusible metal shall be not less than ½ in., except for maximum allowable working pressures of over 175 lb. per sq. in. or when it is necessary to place a fusible plug in a tube, in which case the least diameter of fusible metal shall be not less than ⅜ in.

430 Each boiler may have one or more fusible plugs, located as follows:

a In Horizontal Return Tubular Boilers—in the rear head, not less than 2 in. above the upper row of tubes, the measurement to be taken from the line of the upper surface of tubes to the center of the plug, and projecting through the sheet not less than 1 in.

b In Horizontal Flue Boilers—in the rear head, on a line with the highest part of the boiler exposed to the products of combustion. and projecting through the sheet not less than 1 in.

c In Traction, Portable or Stationary Boilers of the Locomotive Type or Star Water Tube Boilers—in the highest part of the crown sheet, and projecting through the sheet not less than 1 in.

d In Vertical Fire-tube Boilers—in an outside tube, not less than one-third the length of the tube above the lower tube sheet.

e In Vertical Fire-tube Boilers, Corliss Type—in a tube, not less than one-third the length of the tube above the lower tube sheet.

f In Vertical Submerged Tube Boilers—in the upper tube sheet, and projecting through the sheet not less than 1 in.

g In Water-tube Boilers, Horizontal Drums, Babcock & Wilcox Type—in the upper drum, not less than 6 in. above the bottom of the drum, over the first pass of the products of combustion, and projecting through the sheet not less than 1 in.

h In Stirling Boilers, Standard Type—in the front side of the middle drum, not less than 4 in. above the bottom of the drum, and projecting through the sheet not less than 1 in.

i In Stirling Boilers, Superheater Type—in the front drum, not less than 6 in. above the bottom of the drum, exposed to the products of combustion, and projecting through the sheet not less than 1 in.

j In Water-tube Boilers, Heine Type—in the front course of the drum, not less than 6 in. above the bottom of the drum, and projecting through the sheet not less than 1 in.

k In Robb-Mumford Boilers, Standard Type—in the bottom of the steam and water drum, 24 in. from the center of the rear neck, and projecting through the sheet not less than 1 in.

l In Water-tube Boilers, Almy Type—in a tube or fitting exposed to the products of combustion.

m In Vertical Boilers, Climax or Hazelton Type—in a tube or center drum not less than one-half the height of the shell, measuring from the lowest circumferential seam.

n In Cahall Vertical Water-tube Boilers—in the inner sheet of the top drum, not less than 6 in. above the upper tube sheet, and projecting through the sheet not less than 1 in.

o In Wickes Vertical Water-tube Boilers—in the shell of the top drum and not less than 6 in. above the upper tube sheet, and projecting through the sheet not less than 1 in.; so located as to be at the front of the boiler and exposed to the first pass of the products of combustion.

p In Scotch Marine Type Boilers—in the combustion chamber top, and projecting through the sheet not less than 1 in.

q In Dry Back Scotch Type Boilers—in the rear head, not less than 2 in. above the upper row of tubes, and projecting through the sheet not less than 1 in.

r In Economic Type Boilers—in the rear head, above the upper row of tubes.

s In Cast-Iron Sectional Heating Boilers—in a section over and in direct contact with the products of combustion in the primary combustion chamber.

t In Water-tube Boilers, Worthington Type—in the front side of the steam and water drum, not less than 4 in. above the bottom of the drum, and projecting through the sheet not less than 1 in.

u For other types and new designs, fusible plugs shall be placed at the lowest permissible water level, in the direct path of the products of combustion, as near the primary combustion chamber as possible.

No. 1470

NECROLOGY

CHARLES F. BAKER

Charles F. Baker was born at Shoreham, Vt., January 22, 1855, and in his boyhood moved with his parents to Wisconsin. He received his technical training at the University of Illinois, and his first work was with the E. P. Allis Company of Milwaukee. During his service with the company Mr. Baker had charge of some of their largest work, including the pumping engines for Allegheny City and the blowing engines for the Edgar Thompson Steel Works at Braddock, Pa. He left the Allis Company to take charge of the installation and operation of the steam plant of the C. A. Pillsbury & Company flour mill at Minneapolis.

In 1893, Mr. Baker entered the employ of the West End Street Railway Company of Boston, now the Boston Elevated Company, and ultimately became superintendent of motive power and machinery in charge of all power plants and car shops. This work included the maintenance, inspection and design of rolling stock, shops and power stations and under his supervision the East Boston, Charlestown, Dorchester and Harvard Square power stations were built. In 1905, Mr. Baker entered the employ of the Brooklyn Rapid Transit Company as superintendent of power and machinery, and while there had charge of the reconstruction of the Kent Avenue Station. He then went to Baltimore as superintendent of power and construction of the local street railway, and later became associated with the Hudson and Manhattan Company as superintendent of equipment of the power station and substations.

Later Mr. Baker joined the forces of the Bay State Street Railway in Massachusetts in charge of new construction and power plant reconstruction. During this period and until the time of his death on May 21, 1914, Mr. Baker, who had meantime removed to New York to promote a very effective cooling system for generators, was engaged in private consulting engineering practice with special reference to power station economies.

Mr. Baker was a member of the New England Street Railway

Club. In 1904 he was elected president of the American Railway Mechanical and Electrical Association and was also the past president of the New England Steam Railroad Club of Boston.

CHARLES HAZELTINE BASSHOR

Charles Hazeltine Basshor was born in Baltimore, Md., May 30, 1871, and died at his home near Cambridge, Md., August 22, 1914. He was educated at private schools in Baltimore. His shop experience and apprenticeship was served under his father, Thomas C. Basshor. Upon his father's death he succeeded him as head of the Thomas C. Basshor Company of Baltimore, and continued the business until about two years ago, when he retired.

Mr. Basshor was a member of the Engineers' Club of New York, the Maryland Club, the Kennels, the Green Spring Hunt Club, the Baltimore Country Club, and the Cambridge Yacht Club.

EMIL C. BOERNER

Emil C. Boerner, consulting mechanical engineer for Russell, Burdsall & Ward Bolt and Nut Company, died in Port Chester, N. Y., on May 27, 1914, after an illness of some months' duration.

Mr. Boerner was born in Germany on May 23, 1843, and came to the United States at the age of fifteen. His first connection was as an apprentice to Russell, Burdsall & Ward, and at the time of his death he had served the company for fifty years. When he first entered their employ their only plant was situated at Pemberwick and was operated on comparatively small lines. After a number of years spent in the upper shop, he severed his connection to go into partnership with George C. Mertz in the wood planing business. Upon the dissolution of this firm, Mr. Boerner went to Providence, R. I., as a machinist, but after a brief time returned to Port Chester to his early employers.

Mr. Boerner was a designer of automatic bolt and nut machinery.

FRANK L. BUSEY

Frank L. Busey was born in Urbana, Ill., on August 28, 1872, and was graduated from the University of Illinois in 1895 with the degree of B.S., receiving also the degree of M.E. in 1898. He was employed in various engineering capacities in Chicago from 1895 to 1900, and in 1905 removed to Seattle, Wash., to enter the office of a consulting engineer. He returned to Urbana in 1906 as first assistant in the engineering experiment station of the University, resigning in 1911 to become assistant chief engineer for the Buffalo Forge Company, Buffalo, N. Y., which position he held at the time of his death.

Mr. Busey was a frequent contributor to the engineering magazines, writing for the most part on his special subjects of heating and ventilating. He had just completed a handbook on fan system apparatus, under the direction of Willis H. Carrier, which was in the printer's hands when his death occurred at the Battle Creek Sanitarium on June 7, 1914.

CHARLES H. CORBETT

Charles H. Corbett was born in Buffalo, N. Y., on March 19, 1842, and was educated in the schools of that city. In 1858 he entered the employ of the Rogers Locomotive Works, Paterson, N. J., as an apprentice. His work was in the shop and drawing room, and during the latter part of the construction of the U. S. ironclad steamer Keokuk he was employed as assistant superintendent. In 1863 he identified himself with the Continental Iron Works of Brooklyn, of which he was a vice-president at the time of his death on January 14, 1914, working up from the position of draftsman to chief draftsman. He had a prominent part in the plans for the construction of various gas works throughout the East, notably at Boston, Worcester, Salem, Mass., Providence, R. I., and the various gas works of New York now merged in the Consolidated Gas Company. When the Continental Works was incorporated in 1887 he was made second vice-president.

He served the Society as Manager from 1901 to 1904.

EDWIN M. CORYELL

Edwin M. Coryell was born in Brooklyn, N. Y., September 25, 1847, and was educated in the public schools there. After three years as apprentice and draftsman, in 1869 he started out for himself as mechanical engineer, patent attorney and draftsman in New Haven, Conn. Two years later he secured employment at the Bessemer Steel Works, Troy, N. Y., where he came under the personal direction of Alexander L. Holley and was fellow draftsman with Allen Sterling. He served as draftsman at the Providence Steam Engine Works as well as on the Brooklyn Bridge, and from 1878 to 1879 was draftsman with the New York Gas Light Company. For the last 34 years Mr. Coryell had been connected with the A. S. Cameron Steam Pump

Works, first as draftsman, then as salesman, assistant superintendent, superintendent and finally as consulting engineer. During that time he invented more than 200 patented devices for pumps and other machinery. He died suddenly on March 23, 1914.

GEORGE A. DOUGHTY

George A. Doughty, who died on March 8, 1914, was born in Brooklyn, N. Y., on April 2, 1878, and was educated in the public schools, Brooklyn Polytechnic Institute, and Stevens Institute of Technology. In 1898 he entered the drafting room of the Logan Iron Works, becoming secretary of the company in 1909, which position he held at the time of his death.

He has been identified largely with the design, fabrication and erection of shields and caissons, and with general foundation work in connection with the building of subways and tunnels.

WILLIAM R. ECKART

William R. Eckart was born in Chillicothe, Ohio, June 17, 1841. His relatives were pioneers in the settlement of that part of the State, but in 1842 his family moved to Cleveland, where his father had large shipping interests on the Great Lakes. His early education began in private schools, but from the time he was twelve years old his school days were divided between the public schools of Chillicothe and Cleveland. Later, he took a special course in mathematics at the St. Clair Street Academy, Cleveland, with the view of becoming a civil engineer.

In the early fifties his father removed to Zanesville to engage in the operation of a flour mill, operated by water power, and after the installation of some improved water-wheels, Mr. Eckart received the opportunity to serve an apprenticeship in the works of Griffith, Ebert and Wedge, which in those days, had a high reputation for general mill and steamboat work; this was a welcome opportunity as the fascination of steamboat work had taken hold of his ambition while traveling on the Ohio and Mississippi Rivers. In his apprenticeship he was fortunate in having the friendship and guidance of Mr. Wedge, who found the time to show him how to improve upon his work after he had thought it "good enough."

Mr. Eckart's river experience aroused a desire for naval life, and in June, 1861, he took an examination before the Board of Engineers. On July 30, when he was twenty years of age, he was appointed Third

Assistant Engineer in the navy and was ordered at once to join the fleet of naval vessels on the Pacific coast. On July 10, 1864, Mr. Eckart resigned from the navy on account of ill health and took up his residence in San Francisco, where he began work in the drawing room of H. J. Booth and Company. While with this company, he made the design and drawings for the first California built locomotive. He remained with this company until February, 1869, when he received an appointment as draftsman in the Steam Engineering Department at Mare Island Navy Yard. He was afterwards made foreman machinist and later was promoted to superintendent of steam machinery through B. F. Isherwood's recommendation.

In 1871, Mr. Eckart left the Navy Yard to enter into partnership with Prescott, Scheidel & Company, at the Marysville Foundry. The firm name was later changed to Booth and Eckart. It was while there that Mr. Eckart contracted for, designed and built the steam Meteor for the Carson Lumber Company, with a guaranteed speed of 21 miles per hour; this steamer was used on Lake Tahoe and was probably the fastest boat of her size known at that date.

In 1876, Mr. Eckart was recalled by the Prescott, Scott & Company, who were the successors to H. J. Booth and Company, to superintend the construction and assist in designing and erecting some pumping machinery for the Comstock Lode. About this time he moved to Virginia City to become consulting engineer to the "Bonanza Firm" that owned or controlled nearly all of the "North End" Mines. During this time he was manager of the Fulton Foundry, Virginia City. In 1878, he was appointed U. S. Deputy Mineral Surveyor for the State of Nevada. While still a resident at Virginia City he designed and built, in connection with W. I. Sakeld, a noted millwright at that time, the Bulwer Standard Mill, at Bodie, which was one of the largest pan mills for working ore that had been built at that time.

During the early part of 1880, Mr. Eckart was appointed a member of the U. S. Geological Survey under Clarence King and was given charge of investigating and reporting upon the mechanical appliances of the Comstock Lode. On this work, which was really a labor of love, he spent nearly two years collecting data, testing pumps, engines and hoists, and making drawings for the Government of all the machinery on the Comstock. The finest instruments procurable in the United States and Europe were used in the various investigations of efficiency.

In 1881, Mr. Eckart removed to San Francisco and opened offices there as a consulting and constructing engineer, and during the following eight or ten years some of the largest and most important mining plants were designed and constructed under his supervision. The pumping engines for the Ontario Mine, with perhaps the largest Cornish pumps for deep mining ever built in the United States, were constructed from his designs during this period. In 1881, he began for Haggan and Tevis, plans for all of the Anaconda Works, hoists and reduction works, and during the next seven years, all their mining work and mills were designed by him.

In 1883, The Union Iron Works, formerly Prescott, Scott & Company, was changed to an incorporated company and Mr. Eckart was retained as consulting engineer in matters pertaining to the propelling power of the Government vessels built by that company. He was present at and assisted in conducting nearly all the preliminary and government trials of these vessels.

In 1899, he was appointed consulting engineer to the Standard Electric Company and afterward became the resident construction engineer for all their hydraulic works, including storage, reservoir, ditches, dams, flumes, pipe lines and power house installations. This was the first or among the first of the long distance, high-potential-transmission, hydraulic plants projected.

Mr. Eckart was a member of the American Society of Civil Engineers, The Institution of Mechanical Engineers, The Society of Naval Architects and Marine Engineers and an Associate Member of the Institute of Naval Architects. He was Vice-President of this Society from 1883 to 1886.

Mr. Eckart died at the home of his son, in Palo Alto, Cal., on December 8, 1914, after a very successful engineering career covering a period of fifty years' practice on the Pacific coast, which, as he once said, was due "to a studious life surrounded by an extensive collected engineering library of American and foreign books and the appreciative assistance of associated engineers, together with the encouragement and loyalty of employers."

QUIMBY N. EVANS

Quimby N. Evans was born August 15, 1845, at Lovell, Me., and had a common school education at Freyburg, Mass. He served an apprenticeship with the Pitkin Brothers, steamfitters, at Hartford, Conn., and later entered the Walworth Manufacturing Company and then the Walker & Pratt Company, in Boston, Mass. He left the latter company to become chief engineer at the Boylston Hotel.

In 1880, Mr. Evans formed a partnership with Frederick Tudor, under the name of Tudor & Company, and engaged in the steamfitting business, and in 1881 entered into a partnership with Mr. Joslyn, as Q. N. Evans & Company of Boston and New York. Several years later Mr. Evans entered the Otis Elevator Company of New York as superintendent of construction, but in 1885, he again returned to the steamfitting business, forming the corporation known as the Q. N. Evans Construction Company. This concern was maintained under that name until 1895, when the present firm of Evans, Almirall & Company was formed.

During his early connection with the Q. N. Evans Construction Company, they designed and installed the heating and ventilating systems in the Leake and Watts Orphan Asylum of New York, the Criminal Court House of New York, and the English and Latin School, and also the heating and ventilating plant in the original capitol building in Albany, N. Y.

Mr. Evans was a member of the Montauk Club of Brooklyn, N. Y. He died on July 7, 1914.

HENRY SELBY HAYWARD

Henry Selby Hayward was born at Brooklyn, N. Y., on September 19, 1845. His parents moved to Elizabeth, N. J., in 1852, and he was educated at Rev. David H. Pierson's school in that city. In 1862, he entered the Novelty Iron Works in New York City and served a four years' apprenticeship in marine construction work and engineering. In July 1866, he entered the service of the Pacific Mail Steamship Company and made a voyage on the Steamship "Montana" through the Strait of Magellan to San Francisco. On several other long trips during the years 1866 to 1872, he filled positions as 2nd and 1st assistant and acting chief engineer. For about four years, he was detailed to service on branch lines on a steamer plying between ports in Japan, China and the Siberian Coast.

In April, 1873, he entered the service of the Pennsylvania Railroad Company as machinist in the Altoona shops. In 1874, he was detailed for special duty on the United Railroad of N. J. Division as Assistant Road Foreman of Engines. He was appointed, in 1875, Assistant Superintendent of Motive Power of this division, to which the marine department was added in 1881. In 1882, he was appointed Superintendent of Motive Power of this same division and also of the West Jersey Railroad in 1883, and of the Camden and Atlantic R. R. including the ferries and floating equipment on the Delaware River in 1884. He had supervision of the motive power and marine equipment of the New York, Philadelphia and Norfolk Railroad from January 1, 1890, until his death.

During the 80's, he took out patents on several inventions, including an interior check valve on a locomotive boiler, a car journal box and a cut off valve for a beam engine. This cut off valve was adopted by practically all the ferries in New York harbor.

Mr. Hayward was one of the oldest members of the Society having been elected in 1882. He was also a member of the Society of Naval Architects and Marine Engineers, the Engineers' Club of New York, the Engineers' Club of Philadelphia and the New York Railroad Club. He died December 14, 1914.

AXEL H. HELANDER

Axel H. Helander was born in Vingaken, Sweden, in 1864, but came to America as a boy and spent most of his life in Pittsburgh. From July 1, 1906, to September 30, 1912, Mr. Helander was connected with the engineering department of the Mesta Machine Company after which he was with the William Tod Company, of Youngstown, Ohio, as second vice-president and general sales manager. Mr. Helander was the designer and inventor of many important engineering devices, chief among which might be listed the Helander condenser. He died at his home in Youngstown on October 17, 1914.

RICHARD HENDERSON

Captain Richard Henderson, who died at Salisbury, N. C., on February 24, 1914, was born in that city on August 23, 1855. After education in private schools he entered the U. S. Naval Academy in 1872, and continued in the service until he was fifty years old. During his active service he was attached to the Essex, Nipsic, Shenandoah and the Torpedo Station at Newport, R. I., was assistant lighthouse inspector, instructor of ordnance at the Navy Yard in Washington, professor of physics in the North Carolina College of Agriculture and Mechanic Arts at Raleigh, N. C., from 1894 to 1895, was the executive officer on the Indiana during the Spanish War. In 1899-1901, he served as a member of the Board of Inspection and Survey on the trial boards of the new battleships and torpedo boats. In 1901, he had charge of the entire electric plant of the battleship Illinois, and from 1902-1904, was the executive officer on the U. S. S. Alabama.

After his retirement from the navy he returned to Salisbury and interested himself in the activities of the community.

THOMAS HILL

Thomas Hill, vice-president of the Electric Wheel Works, died at his home in Quincy, Ill., on May 27, 1914, after a long illness. Mr. Hill was a native of England, where he was born in Newton, Wales, on May 3, 1840. He came to the United States at the age of 21, locating at first in St. Louis, where he remained during the Civil War, working on government boats in the river. In 1866, he removed to Quincy and entered the employ of the Smith-Robertson Company. Here he rapidly advanced to an interest in the concern, which became known as the Smith-Hill Elevator Company. As Mr. Hill had made a number of improvements on elevators and held patent rights, the company dropped all machine work and devoted itself entirely to the manufacture of elevators.

When the Otis Elevator Company absorbed the Smith-Hill Company, Mr. Hill went to Chicago, but remained only two years. He became interested during that time in an engine and formed the Quincy Engine Company, acting as president of the concern. At the same time the Ellington Manufacturing Company and the Electric Wheel Company were formed and Mr. Hill was made president of the former and vice-president of the latter.

WALTER LEE HILL

Walter Lee Hill was born May 18, 1859, in Methuen, Mass., and was educated in Boston. In 1886, he entered the employ of John P. Squire & Company, and with Mr. Louis Block installed the first large direct expansion refrigerating system. In 1899, he put through the Eastern Cold Storage Company of Boston, of which he served as treasurer and manager until 1908. He became cold storage expert for the Worcester Cold Storage and Warehouse Company in 1906, and managed this concern for three years.

Since 1908, he had acted as a consulting engineer on refrigerating matters. He was an associate member of the American Society of Refrigerating Engineers, a member of the Engineers Club of New York and the Algonquin Club of Boston. He died August 16, 1914.

M. L. JENKINS

M. L. Jenkins was born February 26, 1865, at Walworth, Wis. He received his education at Delavan, Wis., and served an apprenticeship as toolmaker with the Wilson Sewing Machine Company, Chicago, Ill. This experience was followed by brief periods as machinist with such companies as the Chicago Steam Engine Works, Chicago Die & Machine Works, A. H. Andrews & Company, and Wheeler & Tappan. In 1881, he was made foreman of the last named concern and two years later was promoted to superintendent, in which position he was in charge of all design. In 1891, Mr. Jenkins was made superintendent of the Gardner Steam Pump Company of Quincy, Ill., and in this connection designed and built a line of duplex steam pumps. In 1893, he became superintendent of Fairbanks, Morse & Company, Beloit, Wis., where he engaged in the manufacture of gas and gasolene engines, steam pumps, hoisting engines and power transmitting machinery. He was for a time shop superintendent of Allis-Chalmers Company, Milwaukee, Wis., and in 1905, became associated with the Buda Company, Harvey, Ill., in the capacity of superintendent and general manager. His inventions and developments during this period covered miscellaneous gas engines for automobiles, commercial cars, and railroad motor cars, as well as miscellaneous types of operating mechanism used in connection with them, such as transmissions, etc., and the designing of original ideas as worked out by him in connection with tools for accuracy in production work and manufacturing. He died March 2, 1914.

WALTER LAIDLAW

Walter Laidlaw was born in Scotland in 1849, and in his youth served an apprenticeship of four and one-half years as machinist with James Sheil, maker of machinery for the manufacture of Scotch-Tweed engines, water wheels, shafting and gearing. This course was supplemented by one and one-half years' service as an "imperial erector" with Caird & Company, shipbuilders and engineers, Greenoch, Scotland, in which position he was engaged in the erection of first-class ocean steamships. He next entered the engineering department of Trinity House, a body which has official charge of the lighthouses of Great Britain. He served as engineer and chief engineer for ten years and worked in this most interesting period of lighthouse development shoulder to shoulder, first with Prof. Michael Faraday, who was scientific advisor to Trinity House, and later with his successor, Professor Tyndall; he also enjoyed the acquaintance and occasional coöperation of Lord Kelvin in some of these developments. While in this service he drew the specifications and purchased the first direct-acting generator ever used for lighting, which he installed and for a while operated in the lighthouse at Lizard Point, where it is still in satisfactory use as an auxiliary.

Mr. Laidlaw came to this country in May 1881, and entered the employment of the Lane & Bodley Company of Cincinnati. After two years with this company, he accepted a position as constructing engineer with the Procter & Gamble Company of Cincinnati, where he designed and constructed their extensive new factories at Ivorydale, near Cincinnati. Mr. Laidlaw remained in charge of this work until 1887, and had the satisfaction of bringing to completion one of the most complete manufacturing plants in this country.

In 1887, with the completion of the Ivorydale plant, Mr. Laidlaw assisted in organizing the Laidlaw & Dunn Company, afterwards the Laidlaw-Dunn-Gordon Company of Cincinnati, manufacturers of steam pumping and hydraulic machinery. With the formation of the International Steam Pump Company in 1899, Mr. Laidlaw was continued as manager of the Cincinnati plant. In 1908, he became general manager of the Snow Steam Pump Works at Buffalo, N. Y., and in 1909, a member of the executive committee of the International Steam Pump Company, making his headquarters at the head office, New York City. Shortly afterwards, he became secretary, and later director, of the International Steam Pump Company, and vice-president of the Laidlaw-Dunn-Gordon Company, positions he retained until the time of his death, March 25, 1914.

During the latter part of his life Mr. Laidlaw realized the full development of his engineering abilities, and became greatly interested in the technical education and advancement of young men. It was largely through his efforts that the Ohio Mechanics Institute was placed upon a solid basis and began its successful expansion. He served at one time as president of the institute and recently stated that one of the most pleasant memories of his life was his privilege, in that capacity, of awarding the diplomas to the young graduates in whom he had taken so much interest, and seeing them started upon their life work.

Mr. Laidlaw was manager of the Society from 1905 to 1908, and was a member of the Engineers Club of Cincinnati, Engineers Club of New York, Manufacturers Club of Cincinnati, Cincinnati Chamber of Commerce, and of the Board of Managers of the Society for the

Promotion of Industrial Education. He was a man of widely varied interests and activities, but bringing to all of them a degree of calm and far-seeing judgment and tolerance and a breadth of ideas which will be as much missed among his associates as his characteristics of high personal integrity and invariable kindliness and helpfulness of disposition.

EDWARD B. LINSLEY

Edward B. Linsley, manager of the Sheffield Car Company of Three Rivers, Mich., was born July 27, 1847, at Henrietta, N. Y., and died at Three Rivers on February 9, 1914. He was educated in the public schools of Lyons, Ia., and Kalamazoo, Mich. In 1881, he helped to form the Sheffield Car Company and held the position of treasurer in it until his death. He became general manager in 1902. Although Mr. Linsley had no actual shop experience, his close association with the factory gave him a wide insight into mechanical matters and he had patented a number of devices used on the company's small railroad cars.

JOHN DOWNING LOGAN

John D. Logan died at his home in Hillsdale, N. Y., on March 15, 1914. Mr. Logan was born on January 14, 1863, in Brooklyn, N. Y., and was educated in the public schools of Brooklyn. For a time he attended the Polytechnic Institute of that city and was graduated from Columbia College in 1884. He served his apprenticeship with John Roach & Sons, shipbuilders, at Chester, Pa., and in 1885, entered the Logan Iron Works in Brooklyn, of which he was for many years secretary and superintendent.

Mr. Logan was regarded as one of the most shrewd and intelligent of engineers, and was frequently sought out to solve some very difficult problem. He made many improvements in steel working machines, which, however, he never patented. He was responsible for the simplification and improving of the shields used in the tunnels on both the North and East Rivers.

Mr. Logan was also secretary of the Logan Real Estate Company, and was a member of the Illuminating Engineers Society.

EDWARD DANIEL MEIER

In the death of Col. Edward Daniel Meier on December 15, 1914, after several months of illness, the engineering profession lost one of its most honored members. He was president and chief engineer of the Heine Safety Boiler Company, president of The American Society of Mechanical Engineers in 1911, and for 20 years was one of the most active workers in the Society. He enjoyed an unusually wide circle of friends, as evidenced by the presentation at the Pittsburgh meeting of the Society of an engrossed testimonial by a large number of his fellow members in celebration of his seventieth birthday.

He was born in St. Louis, Mo., May 30, 1841. At the close of a course at Washington University, St. Louis, in 1858, he spent four years in Germany at the Royal Polytechnic College in Hanover, this being followed by an apprenticeship at Mason's Locomotive Works, Taunton, N. J. In 1863, he enlisted in the Grey Reserves, the Thirty-Second Pennsylvania, which was attached to the Army of the Potomac until after the Battle of Gettysburg. He subsequently served in the Second Massachusetts Battery, also in the United States Engineer Corps, and finally became lieutenant in the First Louisiana Cavalry, seeing much active service, and on May 30, 1865, receiving the surrender of Lieutenant-General John B. Hood and staff.

At the close of the war he entered the Rogers Locomotive Works, at Paterson, N. J., remaining one year. From 1867 to 1870, he was associated with the Kansas Pacific Railway, first as assistant superintendent of machinery, keeping open its Western communications when the bridges were swept away, designing, building and operating a mill for sawing, planing and turning the soft magnesian limestones by machinery, designing machine and car shops, etc., and subsequently becoming superintendent of machinery. He resigned to become chief engineer of the Illinois Patent Coke Company, leaving there in 1872, to assume the secretaryship of the Meier Iron Company and to build its blast furnaces. From 1873 to 1875, he directed the machinery department of the St. Louis Interstate Fair. During this time he became actively interested in the St. Louis cotton industry and was associated with the St. Louis Cotton Factory and with the Peper Hydraulic Cotton Press, for both of which he designed machinery for compressing cotton. In 1884, he organized the Heine Safety Boiler Company for the development in the United States of the water-tube boiler of that name, and continued as its president and chief engineer to the time of his death. He was also responsible for the introduction of the Diesel motor into the United States and until 1908 was engineer-in-chief and treasurer of the American Diesel Engine Company. One of his most important accomplishments was

Promotion of Industrial Education. He was a man of widely varied interests and activities, but bringing to all of them a degree of calm and far-seeing judgment and tolerance and a breadth of ideas which will be as much missed among his associates as his characteristics of high personal integrity and invariable kindliness and helpfulness of disposition.

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In the death of Col. Edward Daniel Meier on December 15, 1914, after several months of illness, the engineering profession lost one of its most honored members. He was president and chief engineer of the Heine Safety Boiler Company, president of The American Society of Mechanical Engineers in 1911, and for 20 years was one of the most active workers in the Society. He enjoyed an unusually wide circle of friends, as evidenced by the presentation at the Pittsburgh meeting of the Society of an engrossed testimonial by a large number of his fellow members in celebration of his seventieth birthday.

He was born in St. Louis, Mo., May 30, 1841. At the close of a course at Washington University, St. Louis, in 1858, he spent four years in Germany at the Royal Polytechnic College in Hanover, this being followed by an apprenticeship at Mason's Locomotive Works, Taunton, N. J. In 1863, he enlisted in the Grey Reserves, the Thirty-Second Pennsylvania, which was attached to the Army of the Potomac until after the Battle of Gettysburg. He subsequently served in the Second Massachusetts Battery, also in the United States Engineer Corps, and finally became lieutenant in the First Louisiana Cavalry, seeing much active service, and on May 30, 1865, receiving the surrender of Lieutenant-General John B. Hood and staff.

At the close of the war he entered the Rogers Locomotive Works, at Paterson, N. J., remaining one year. From 1867 to 1870, he was associated with the Kansas Pacific Railway, first as assistant superintendent of machinery, keeping open its Western communications when the bridges were swept away, designing, building and operating a mill for sawing, planing and turning the soft magnesian limestones by machinery, designing machine and car shops, etc., and subsequently becoming superintendent of machinery. He resigned to become chief engineer of the Illinois Patent Coke Company, leaving there in 1872, to assume the secretaryship of the Meier Iron Company and to build its blast furnaces. From 1873 to 1875, he directed the machinery department of the St. Louis Interstate Fair. During this time he became actively interested in the St. Louis cotton industry and was associated with the St. Louis Cotton Factory and with the Peper Hydraulic Cotton Press, for both of which he designed machinery for compressing cotton. In 1884, he organized the Heine Safety Boiler Company for the development in the United States of the water-tube boiler of that name, and continued as its president and chief engineer to the time of his death. He was also responsible for the introduction of the Diesel motor into the United States and until 1908 was engineer-in-chief and treasurer of the American Diesel Engine Company. One of his most important accomplishments was the design and installation of 10,000 h.p. boilers in the power house of the new Grand Central Terminal, New York.

Colonel Meier was lieutenant-colonel and later colonel of the First Regiment of the Missouri National Guard, serving about ten years, and was a member of the Grand Army of the Republic and of the Loyal Legion. He had been active in a number of professional organizations, serving in 1881-1884 as treasurer of the St. Louis Engineers Club, in 1889-1890 as its president, and as secretary of the American Boiler Manufacturers Association. It was in the latter capacity that he drew up the Uniform American Boiler Specifications of 1898. He had been president of that organization and also of the Machinery and Metal Trades Association.

In The American Society of Mechanical Engineers, which he joined in 1891, he was active on many committees. He served as Manager from 1895 to 1898, twice as Vice-President, from 1898 to 1900 and from 1909 to 1910, and as President in 1911. At the time of his death he was a member of the committee of the Society appointed to formulate Standard Specifications for Steam Boilers, which had its inception largely through his efforts.

A source of the greatest satisfaction to Colonel Meier, and a delightful memory to his many friends, was his connection with the remarkable tour through Germany in the summer of 1913, at the invitation of the Verein deutscher Ingenieure. Colonel Meier was chairman of the committee having all the arrangements in charge, to a considerable extent was conductor of the party and many times was its spokesman. He often addressed his audience in German and his intimate knowledge of German history and accomplishment and his thorough appreciation of the industrial ideals of the nation added materially to the value and pleasure of the trip to the large number of engineers and guests who constituted the party.

DAVID N. MELVIN

David N. Melvin, for forty years superintendent and general manager of the American Linoleum Manufacturing Company of Staten Island, died in Miami, Florida, on January 27, 1914. He was born in Glasgow, Scotland, on July 21, 1840, and was graduated from the Andersonian University of Glasgow in 1860. For several years he was employed by Crawhall & Campbell, as engineer and draftsman, and later designed fireproof buildings and machinery for sugar refining mills in Scotland, Cuba and the West Indies. He afterwards purchased an interest in a paper mill near Oxford, England, which he operated until the abolition of the British tariff on paper made the business unprofitable.

Shortly after his arrival in America in 1867, he obtained a patent for an improved sectional safety steam boiler and later an automatic furnace door and a high-pressure engine. He also formed a connection with T. A. Weston of Buffalo, inventor of the differential chain pulley, and subsequently engaged in the erection of large buildings in the Michigan lumber region. In 1873 he became associated with Frederick Walton, the inventor of linoleum, and erected an extensive plant at Long Neck, S. I., which has grown to be one of the largest of its kind. In 1888, when the Walton patents expired, Mr. Melvin invented what is known as inlaid linoleum, and later wood inlaid, which have since been extensively manufactured under his patents.

Mr. Melvin was a member of the American Society of Civil Engineers, of the St. Andrews Society, and of the Richmond County Automobile Society, of which he for some years acted as secretary.

CHARLES A. MOORE

Charles A. Moore, president of Manning, Maxwell and Moore, Inc., New York, was born at Sparta, N. Y., in 1846. When he was 12 years old, he went to Lynn, Mass., to live with an uncle and receive his education. In 1862, he enlisted in the United States Navy and served until the end of the Civil War.

Fifteen years of his early business life were spent in and about Boston. During this time, he was connected with the Ashcroft Manufacturing Company and the Consolidated Safety Valve Company in the manufacture of steam specialities.

Mr. Moore later came to New York to be with H. S. Manning & Company. In 1881, the firm name was changed to Manning, Maxwell and Moore. At Mr. Maxwell's death in 1895, the business was left in the hands of Messrs. Manning and Moore. Mr. Manning retired in 1905.

In his busy years, Mr. Moore was very active in Republican politics. He was president of the American Protective Tariff League, and one of the founders and for ten years president of the Montauk Club in Brooklyn, N. Y., a member of the New York Chamber of Commerce, and the National Association of Manufacturers and several other societies and clubs. Mr. Moore died on December 8, 1914.

J. WEIDMAN MURRAY

J. Weidman Murray was born October 17, 1850, at Union Forge, Pa., and received his education in the public schools. He served as an apprentice and later entered the drawing room of the Weimer Machine Works of Lebanon, Pa., and was subsequently in the employ of the Tennessee Coal, Iron & Railroad Company at Birmingham, Ala., as superintendent of the machine shop. He resigned this position in 1901, to become manager of the Pittsburgh office of the Allis-Chalmers Company, and retained this position up to the time of his death on July 17, 1914.

GEORGE W. NISTLE

George W. Nistle, who died on May 27, 1914, was born at Williamsburg, N. Y., on May 20, 1854, and received his education in the public schools. He became an apprentice with the Erie Railroad Company in Jersey City in 1870, and was employed in the drawing room of the Long Island Railroad in Long Island City, from 1880-1882. He entered the repair shops of the New York Elevated Railroad in 1882, and was subsequently with the Simpson Manufacturing Company as superintendent from 1884-1886. He operated the power plant for the Pullman Company in Chicago from 1886 to 1888, and was consulting engineer to the Chicago branch of the T. H. Electric Company, in its operating department. Subsequently he became mechanical engineer in the Chicago office of B. W. Payne & Sons, to the Wainwright Company, chief engineer for S. P. Conn, in charge of Worlds Fair Installations, and chief engineer of the Board of South Park Commissioners of Chicago. At the time of his death he was secretary to the Illinois Engineering Company.

ALFRED NOBLE

There passed away on April 19, 1914, in New York City, Alfred Noble, an esteemed member of our council and a man whose loss will be deeply felt and deplored not only by the engineering profession of which he was one of the most distinguished members, but by everyone who had the good fortune to know him.

He had a very interesting career, and the story of his life, if adequately written, would be typical of that of many of the great men and builders of this nation.

He was born August 7, 1844, at Livonia, Wayne County, Michigan, where his parents resided on a farm. His early education was received in the district school of his native place, and during his spare time he worked on the farm.

In 1862, when only 18 years of age, he enlisted in the Civil War in the 26th Michigan Volunteer Infantry. From that time until 1865, he served in the Army of the Potomac, taking part in all of the hard and desperately fought battles which that army engaged in against Lee and Stonewall Jackson. At Gettysburg his regiment lost a very large percentage of its numbers. At Chancellorsville, it was by the merest accident that his brigade was not captured by Stonewall Jackson's men, but he was lucky in serving through the war without being wounded, and was mustered out of the service in June 1865, with the rank of sergeant. He then prepared to enter the University of Michigan, and in 1867, became a sophomore, graduating in 1870, with the degree of C.E. He received the degree of LL. D. from his alma mater in 1895, also from the University of Wisconsin in 1904.

From 1868 to 1870, he was assistant engineer on river and harbor work on the Great Lakes. From 1870 to 1872, he was in charge of improvements on St. Mary's Falls Canal and St. Mary's River. During this time the first great masonry lock at the Soult, then by far the largest canal lock in the world, was built. On completion of this work he became resident engineer on the construction of an important bridge at Shreveport, La., over the Red River.

From 1883 to 1886, he was general assistant engineer on the Northern Pacific Railroad, and from 1886 to 1887, resident engineer on the construction of the Washington Bridge over the Harlem River, at that time the largest arch bridge in existence.

From 1887 to 1894, he was resident engineer on the construction of several very large and important bridges over the Mississippi at Memphis and Alton, over the Missouri at Bellefontaine and Leavenworth, over the Ohio at Cairo.

He was appointed a member of the Nicaragua Canal Board by President Cleveland in 1895. This board visited Central America and examined the route of the Nicaragua Canal and also the Panama Canal and then returned to the United States, completing its work November 1, 1895.

In June 1899, he was appointed by President McKinley a member of the Isthmian Canal Commission, which was charged with the selection of the best canal route across the American isthmus, and it has been substantially on the route selected by this commission that the Panama Canal has been constructed. While on this commission, Mr.

Noble with his colleagues visited Europe to examine the existing canals there, and the data which the French Canal Company had in Paris, and also made several trips to Central America to examine more fully the various canal routes.

In 1905, he was appointed by President Roosevelt a member of the International Board of Engineers, to recommend whether the Panama Canal should be constructed as a sea level or a lock canal. This board consisted of thirteen members, of whom five were nominated by foreign governors. Mr. Noble was one of the minority of five Americans who recommended the adoption of the lock plan. Their views were adopted by the Government and the canal has been built in accordance with their recommendations. In March 1907, he was one of the three appointed by President Roosevelt to visit the Panama Canal to investigate the conditions regarding the foundations of some of the principal structures. This duty was completed in a few weeks. He was obliged to decline a similar appointment two years later.

From the very inception of the plan by this country to build an Isthmian Canal, and from the commencement of the preliminary investigations and surveys, to the adoption of the final plan and the beginning of the actual construction of the Panama Canal, Mr. Noble was continuously identified with the project and deserves as much credit for the solution of the engineering problems as any other one who has been connected with this great work.

In July 1897, he was appointed by President McKinley a member of the United States Board of Engineers on Deep Water Ways, which made surveys and estimates of cost for a ship canal from the Great Lakes to deep water in the Hudson River.

In November 1901, the city authorities of Galveston, Texas, appointed Alfred Noble along with Henry C. Ripley and General Robert, as a board of engineers to devise a plan for protecting the city and suburbs from future inundation. They recommended the building of a solid concrete wall over three miles long and seventeen feet in height above mean low water, the raising of the city grade, and the making of an embankment adjacent to the wall; the whole to cost about three and a half million dollars, which plan has since been carried into effect.

From 1902 to 1909, Mr. Noble was chief engineer of the East River Division of the New York extension of the Pennsylvania Railroad, and was in entire charge of this most difficult piece of work, involving as it did, a very accurate survey across Manhattan, and the construction of the foundations of the Pennsylvania Station, of the land tunnels, and of the East River tunnels which were very troublesome.

Since 1909, he has been engaged in general practice as a consulting engineer, the firm name being Noble and Woodard. Probably the most important work dealt with was in relation to the dry docks built for the United States Government near Honolulu. He was also for a time consulting engineer to the Quebec Bridge Board, also consulting engineer for the Board of Water Supply, New York City, and for the Public Service Commission of the First District of the State of New York.

He was a past-president of the Western Society of Engineers, the American Society of Civil Engineers, and the American Institute of Consulting Engineers. He was elected to the Council of this Society in 1912 and had served several years on the Library Committee.

In 1910, he was awarded the John Fritz Medal for notable achievements as a civil engineer, and in the same year was elected an honorary member of the Institution of Civil Engineers of Great Britain, a distinction which no other American has had. In 1912, he received the Elliott Cresson Medal of The Franklin Institute in recognition of his distinguished achievements in the field of civil engineering.

Mr. Noble was deeply interested in anything affecting the status of the engineering profession. His unfailing good humor, his kindliness and sweetness of disposition, his sound common sense and good judgment, his youthful mentality, his quick and very sure perception, and his modesty, invariably impressed his colleagues with whom he worked on many committees, and commissions in which he was so active.

He possessed a combination of strength, gentleness, tact and discernment rarely met with. He was universally respected by all who had any business dealings with him. The plain workman, the man with the pick and shovel, the contractor under him, the highly trained technical engineer, or the president of a great corporation, all appreciated the nobility, simplicity, and rugged honesty of his character. His personality was such as to evoke the faithful and enthusiastic loyalty of his subordinates, and the deep, strong, and lasting affection of all those who were honored with his friendship.

At the funeral services on the evening of April 21, the Society was represented by Jesse M. Smith, Past-President and Member of the Council; Leonard Waldo, Chairman, and E. G. Spilsbury of the Library Committee, Charles Whiting Baker, Rudolph Hering, J

Waldo Smith, C. M. Wales, W. L. Saunders, and Calvin W. Rice, Secretary.

WALTER AMBROSE PEARSON

Walter Ambrose Pearson was born in Putnam, Conn., on July 3, 1869, and died in New York on January 25, 1914. He was educated at Tufts College, Mass., where he was graduated in 1890 with the degree of B.A. Immediately afterward he entered the employ of the West End Street Railway Company of Boston, which was then going through the early stages of electric railway development. Mr. Pearson was employed first as a station operator.

In 1893, Mr. Pearson went to Brooklyn, N. Y., to take charge of the electric installation of the Brooklyn Heights Railroad Company, as electrical engineer, and in 1896, undertook similar work for the Metropolitan Street Railway Company of New York. Here he was active in the development of the Lenox Avenue underground electric system, the first to be developed in this country. In 1906, he went to Niagara Falls for the Electric Development Company of Ontario, in charge of the electrical installation and construction of this company's power house at Niagara Falls.

In 1910, Mr. Pearson went to Rio de Janeiro, Brazil, remaining for two years as assistant general manager of the Rio de Janeiro Tramway, Light and Power Company. Poor health due to climatic conditions forced his return and he became associated with the banking house of Bertron, Griscom & Company as consulting engineer, with which he was connected at the time of his death.

He was a member of the American Institute of Electrical Engineers, the New York Railroad Club, and the Engineers Club of New York, and was prominent in Masonic circles.

RODNEY C. PENNEY

Rodney C. Penney was born in East Addington, Me., on November 11, 1853, and was educated in the schools and the Eastern Maine Conference Seminary of Bucksport, Me. His first shop experience was with his father at St. Johns, N. B., and his apprenticeship was served in the shop of the Bangor & Piscataquis R. R. of Oldtown, Me., also under his father who was master mechanic of the railroad. He served for a short time as locomotive engineer on the Bangor & Katahdin Iron Works of Brownsville, Me., and in 1885, became general manager of the Mouson, Me., Slate Company. Twelve years later he came to

Bangor as general manager of the Hinckley Engineering Iron Works, and during this time was instrumental in consolidating his firm with the Bangor Foundry & Machine Company, under its present name of the Union Iron Works.

With several others he then formed the Penobscot Machinery Company of which he became president and manager. At the time of his death he was acting as Eastern representative and mechanical engineer of the Dodge Manufacturing Company.

Mr. Penney served for a short time in the Senate of the Maine Legislature.

FRANKLIN PHILLIPS

Franklin Phillips, president of Hewes & Phillips Iron Works of Newark, N. J., died in that city on February 9, 1914, after a brief illness. He was born in Newark in 1857, and was a son of John M. Phillips, founder of the Hewes & Phillips Company.

He was educated in the public schools and at Stevens Institute of Technology and Cornell University, graduating from the last in 1878, and immediately entering his father's firm, in which he was active up to the time of his death.

Mr. Phillips had a broad reputation as a steam and hydraulic engineer and was frequently called into consultation by eminent engineers in relation to large engineering projects. He was president of the New Jersey Foundrymen's Association and was actively interested in all civic movements that had for their object the prosperity and up-building of his city and state. He was a member of the Newark Board of Trade and of the Essex Club and was quartermaster sergeant of the Essex Cavalry Troop and had been major and inspector of small arms of the New Jersey Second Regiment of Infantry.

WILLIAM BLEECKER POTTER

William Bleecker Potter, founder and manager of the St. Louis Sampling & Testing Works and one of the best known mining engineers and metallurgists in the United States, died at his home in St. Louis, on July 14, 1914.

Mr. Potter was born in Schenectady, N. Y., March 23, 1846, and received his A.B. degree at Columbia in 1866, his A.M. in 1869, and his E.M. in the School of Mines, Columbia, in 1869. After his graduation he studied for a time in Germany. He acted as assistant in geology at Columbia from 1869 to 1871, and was an assistant in geological survey in Ohio.

In 1871, he was appointed professor of mining and metallurgy in Washington University, the year in which this chair was founded, and remained at the head of the department, which had a phenomenal growth, until 1893. The department was abandoned after his resignation.

He founded the St. Louis Sampling & Testing Works in 1886, as a metallurgical and chemical laboratory for the benefit of the students of Washington University.

In 1889, he was placed on the board of the Missouri Geological Survey and served until 1893. He was an assistant in geological survey in Missouri from 1872 to 1874, engineer of the Pilot Knob Iron Company, 1874 to 1878, metallurgist for the Vulcan Iron & Steel Works, 1876 to 1878, and chief engineer of the Iron Mountain Mining Company from 1882 to 1893.

Mr. Potter was widely known both as a practising and consulting engineer. He was a past-president of the American Institute of Mining Engineers and of the St. Louis Engineers' Club, and a member of the Mining and Metallurgical Society of America, and a corresponding member of the New York Academy of Science, Wisconsin Academy of Science and National Geographic Society.

He received the honorary degree of Sc.D. from Columbia University in 1904, in recognition of his services in the field of mining and metallurgy.

EDWARD PUCHTA

Edward Puchta was born October 15, 1870, in Washington, Mo., and received his education in the public schools and at Washington University, from which he was graduated with the degree of M.E. in 1892. In 1894, he entered the service of the Western Electric Company in Chicago as draftsman. From 1897 to 1899, he was employed by the Diesel Motor Company of America, as assistant engineer, under the supervision of Col. E. D. Meier, spending the first four months of his time abroad supervising the construction of engines being made for them in Germany.

In 1899, he returned to the Western Electric Company as chief draftsman, becoming in 1901, assistant superintendent of the Chicago shops. He held this position until 1913, when he was appointed assistant superintendent in charge of the employment and welfare work for the Hawthorne Works of that company, continuing in this work until the time of his death on February 25, 1914.

CHARLES W. RICHARDS

Charles W. Richards was born December 4, 1867, in New York City and received his education in the public schools. He served his apprenticeship with Joseph Edwards & Company of New York. In 1887, he entered the employ of Henry R. Worthington & Company, as machinist, and was subsequently connected with the Boston Heating Company as assistant engineer, with the United Electric Traction Company as construction engineer, with the Cumner-Richards Company, in Boston, electric construction business, with the Consolidated Electric Car Lighting Company as general manager, with Stone & Webster, in electric railroad construction, with the sales department of Chase-Shawmut Company and that of the Simplex Electric Heating Company, with the Boylston Manufacturing Company as superintendent, and with the Stevens-Duryea Company of Chicopee Falls, Mass., as superintendent. At the time of his death he was manager of the Driggs-Seabury Ordnance Corporation of Sharon, Pa.

Mr. Richards was a member of the Society of Automobile Engineers, and had served on the board of directors of the Connecticut Valley Metal Trades Association.

HENRY K. ROWELL

Henry K. Rowell was born June 1, 1870, at Charlestown, Mass., and after completing his education in the public schools, entered the office of E. A. Buss, mill engineer, in Boston. He was subsequently connected with Lockwood, Greene & Company, and during the last eight years with Charles T. Main. Mr. Rowell's experience in mill work was very extensive and he was responsible for the organization and construction of many well-known plants, including the textile plant of the Edwards Manufacturing Company, Augusta, Me., the textile plant of the Pepperell Manufacturing Company, Biddeford, Me., the woolen weave mill of S. Slater & Sons, Inc., Webster, Mass., and many others.

Mr. Rowell made studies, reports and valuations on many mills and wrote a number of monographs, one of which, Organization of the Carding Department in Cotton Mills, read before the National Association of Cotton Manufacturers in 1911, deserves special mention.

He died at his home in Waltham, Mass., on August 9, 1914.

GEORGE C. SCHOFF

George C. Schoff was born in Annapolis, Md., on September 28, 1867, and was educated at St. Johns College and at the University of Arkansas, Fayetteville, from which he received the degree of C.E. in 1889. After his graduation he remained at this institution as an instructor and assistant professor for several years.

In 1893, he became associated with J. M. Witham of Philadelphia, consulting engineer, as first assistant, resigning in 1895, to enter the Philadelphia sales office of the Babcock & Wilcox Company, where he remained until the time of his death, January 21, 1914. He represented the company in the design of a number of large power plants throughout eastern Pennsylvania, Maryland and Virginia.

Mr. Schoff was a member of the Union League Club of Philadelphia.

M. W. SEWALL

M. W. Sewall, who died at his home in New York on May 27, 1914, was born in Brownville, Me., on August 2, 1852, and received his technical education in the Maine State College of Agriculture and the Mechanic Arts, graduating in 1875, with honors. In the following year he entered the employ of The Baldwin Locomotive Works in Philadelphia. In 1878, he became head draftsman for the Edge Moor Iron Company, and had subsequent experience as draftsman and superintendent of erection on machine and boiler shop tools, for Hilles & Jones of Wilmington, Del., and in designing, erecting and fitting up the new shops of the Yale & Towne Manufacturing Company. In 1884, he became assistant engineer of the Pneumatic Dynamite Gun Company of New York, where he had charge of the erection of guns on board the U. S. S. Vesuvius. He was also for a short time with the Cable Road of New York, where he had charge of designs of winding machinery.

At the time of his death he had been in the employ of the Babcock & Wilcox Company, New York, for 22 years, having had general supervision of the drafting room for the earlier part of this period, and devoting his time of late to experimental work on chain grate stokers, furnace design, and improvements in boiler settings. He had made a number of inventions in this field.

Mr. Sewall was esteemed by all who know him for his conscientious spirit, upright character and gentleness. He was unselfish in imparting the results of his experiments to others and was ever ready to lend a helping hand to those about him.

SIDNEY LEROY SMITH

Sidney Leroy Smith, who was born in Boston, Mass., March 29, 1838, died in the same city on May 25, 1914. He was graduated from Dartmouth College with the B.S. degree, and his first position was as resident engineer in charge of the construction of a railroad between Sheboygan and Fond du Lac, Wis. In 1861, he entered the engineer corps of the United States Navy, continuing in the service after the close of the war. At the time of his resignation in 1884, he was acting as assistant engineer. From 1894 to 1897, Mr. Smith was superintendent of the Roxbury Carpet Company, Boston, Mass.

Mr. Smith was a member of the American Society of Naval Engineers and of the Loyal Legion.

ALBERT STEARNS

Albert Stearns was born in Rindge, N. H., December 20, 1833. When 21 years of age he was appointed to serve on the metropolitan police force in Brooklyn, N. Y., and six years later received the rank of sergeant. At the outbreak of the Civil War, he temporarily resigned this position to organize Company I of the 131st Regiment, New York Volunteers. He served with distinction throughout the war: while in Louisiana, as provost marshal and judge, also as sheriff, Department of the Gulf; and as military street commissioner in Savannah, Ga. His labors there were commended by Gen. William T. Sherman in his published report of May 9, 1865. He was slightly wounded at the battle of Cedar Creek and was brevetted a major for bravery in action. Major Stearns was the author of a book, Reminiscences of the Late War, which gives an entertaining account of the years spent in his country's service. At the conclusion of the war he was offered the rank of captain in the metropolitan police force, a position he retained until 1870. In that year he became connected with Church & Company, Syracuse, N. Y., manufacturers of bicarbonate of soda, and for 33 years served them as superintendent of factories and chemical works, as inventor of labor-saving devices and machines, and also as purchasing agent and confidential advisor. After the consolidation of Church & Company with the John Dwight Company, chemical manufacturers, Mr. Stearns became superintendent of the new concern, the Church & Dwight Company. This position he held for 17 years. He retired from active work in April, 1913, and returned to Brooklyn, N. Y. He died April 21, 1914.

JOHN CHRISTIAN HENRY STUT

John Christian Henry Stut was born in Germany on January 11, 1851, and was educated in public and private schools. He served his apprenticeship in Germany and in 1870, came to the United States, entering the Union Iron Works in San Francisco as a draftsman. He also served an apprenticeship with several firms in the same city. He designed the plans for the American Sugar Refinery in that city in 1885, and acted as constructing engineer for the Cable Railroad, during his association with the Omnibus Cable Company. He was also associated with the Presidio & Ferries Railroad of San Francisco and the California Street Cable Railroad as constructing engineer, and designed the plans for the Alameda Sugar Company at Alvarado, Cal.

At the time of his death, Mr. Stut had for a number of years conducted a private consulting business, specializing in cable and electric roads, sugar refineries, etc.

WARREN H. TAYLOR

Warren H. Taylor, one of the best bank lock and fine lock experts in the country, and superintendent of the bank-lock department of Yale & Towne Manufacturing Company, died at his home in Stamford, Conn., on June 11, 1914. Mr. Taylor was born in Winchendon, Mass., February 17, 1846, and was educated in public and private schools. He served an apprenticeship as a machinist with his uncle in Milford, N. H.

When the Civil War broke out Mr. Taylor, though quite young, enlisted in a New Hampshire regiment, but was prevented by illness from going into service. Upon his recovery he returned to his trade of machinist, entering the employ of a sewing machine company at Winchendon, where he remained a year and a half. Subsequently he worked for the Smith & Wesson Arms Company, Springfield, Mass., the Remington Arms Company, Ilion, N. Y., for a lock company founded by Linus Yale's father at Newport, N. Y., and for Linus Yale, Jr., at Shelburne Falls, Mass., with the company which has since become the Yale & Towne Manufacturing Company of Stamford. In the spring of 1868, Mr. Taylor went with Mr. Yale to Stamford and was with the firm until the time of his death. The many inventions and patents which have been issued to him in conjunction with the manufacture of their products, numbering over 200, are universally known.

During his many years of service with the company he was associated with about every branch its operations cover. It is an interesting fact that at the beginning of his service he was associated with the bank-lock department and at the end he was the head of the department. During about ten years he acted as general superintendent of the company. Most of Mr. Taylor's inventions had to do with pin locks, but he made a number of important inventions in connection with post office lock boxes which have been used by the United States Government.

Mr. Taylor took an active interest in public affairs and was a member of the Board of Appropriation and Apportionment. He was one of the charter members of the Board of Trade. He was a member of the Stamford Yacht Club, the Democratic Club of New York, and the Reform Club of New York.

ALFRED P. TRAUTWEIN

Alfred P. Trautwein, vice-president of the American Welding Company, Carbondale, Pa., died at his home in that city on August 5, 1914. He was born in New York City on October 10, 1857, and was graduated from Stevens Institute of Technology in 1876. In the same year he entered the employ of the Continental Iron Works, Brooklyn, as mechanical draftsman and engineer, engaged in the construction of coal and water gas works, fuel gas plants, ice making and refrigerating machinery and marine construction. In 1889, he removed to Carbondale and entered the Hendrick Manufacturing Company as superintendent and consulting engineer. Ten years later he organized the Carbondale Machine Company and was president for a number of years. He also organized the Carbondale Supply Company, the Carbondale Chemical Company, now known as the Carbondale Calcium Company, the American Welding Company, and the Carbondale Instrument Company. He was also one of the reorganizers of the Consolidated Telephone Company and until recently was one of its directors. At one time he acted as president of the American Acid and Alkali Company of Bradford, Pa., and was a former director of the Buffalo Cold Storage Company, Buffalo, N. Y. Mr. Trautwein was also one of the organizers and until a short time ago one of the directors of the Pioneer Dime Bank. During the past three years he had devoted the greater part of his time to the Barium Products Company of Scranton, Pa., of which he was president. He was a director in the Carbondale Machine Company and the American Welding Company at the time of his death.

Mr. Trautwein first pointed out the advantages of the anthracite coal region for the silk industry, and it was through his persistent efforts that the chain of Klots Mills was located in the region of Carbondale. This was followed in turn by the Empire Silk Company, and Mr. Trautwein was himself one of the organizers of the Carbondale Knitting Company. He did much throughout the valley to develop its industrial interests, and while he never took an active part in politics he was always ready and willing to lend financial and moral support to every movement instituted for the welfare of the community.

He served Stevens Institute in the capacity of alumni trustee from 1887 to 1890, and was a member of the Engineers Club of New York, the Manufacturers Club of Scranton, the Engineers Club of Scranton, and the Drug Trade Club of New York.

MAX JULIUS ULRICH

Max Julius Ulrich, designer in the oil engine department of the De La Vergne Machine Company, died July 27, 1914, after a three days' illness.

Mr. Ulrich was born at Halle, Germany, February 8, 1856. He was educated at the Royal Technical Institute at Halle and graduated from the Polytechnic Institute at Karlsruhe. He served an apprenticeship to Emil Stahrer at Leipzig from 1870 to 1873, and from 1873 to 1874, was spent in the drawing room of W. Uhland at Leipzig. He later spent a year in shop experience with Sachsenberg Brothers, Rosslau, in building mining machinery, and from 1879 to 1881, was designer for Messrs. Haddick & Roethe, pump-builders at Weissenfels, Germany.

After this, he came to the United States, and in 1882, became superintendent and mechanical engineer of the Ulrich Engine Company of Florence, Massachusetts, where he remained until 1894. During this time he invented a cut-off motion for duplex steam pumps which was patented in the United States, England and Germany. From 1892 to 1894, he served also as designer for the Deane Steam Pump Company, at Holyoke, Massachusetts. In 1894, he became chief draftsman of the Deane Company and held this position, with the exception of three years' absence, until 1901. During the period from 1900 to 1902, he also wrote two courses for the International Correspondence Schools in hydraulics and pumping machinery design.

In 1902, he came to New York as chief draftsman for the Alberger Condenser Company, which position he retained until 1912. His first undertaking here was the designing of the condensers installed in the 59th Street Power Station of the New York Subway, by the Alberger Company.

On December 15, 1912, he became designer in the oil engine department of the De La Vergne Machine Company, and held this position at the time of his death.

Mr. Ulrich was a member of the Verein deutscher Ingenieure and was a prominent Mason.

WILLIAM DE HERTBURN WASHINGTON

William De Hertburn Washington was born June 29, 1863, and died August 30, 1914, in Hanover County, Virginia. He received his early education at private schools and at the Maryland Agricultural College, where he took a special course in mathematics with a view to entering the United States Naval Academy. He changed his plans, however, and at the age of sixteen began work on an engineering corps of the Canal and Iron Railway. He was afterwards assistant resident engineer on the construction of the West Virginia Central & Pittsburgh Railway, and later in the office of the Atlantic & Pacific Ship Canal Company. He entered the employ of C. W. Hathaway & Company as a designer of special machinery, and designed many original mechanical devices, including steam engines, air separators, methods of hydraulic sheet piling, and a system of sinking caissons hydraulically, which has been successfully used in many of the large buildings in New York City.

At the time of his death, Mr. Washington was president of the Hydraulic Construction Company, New York, which has engineered and constructed many important industrial plants in the United States. He was appointed by Governor Sulzer as consulting engineer to the Highway Commission of the State of New York, and was a delegate to the Third International Road Congress. He was a member of the American Society of Civil Engineers, the American Institute of Mining Engineers, and a fellow of the National Geographical Society.

GEORGE WESTINGHOUSE

George Westinghouse, Past-President and Honorary Member of the Society, died in New York on March 12, after an illness of several months. He was born at Central Bridge, N. Y., October 6, 1846. A few years later his father, who was a manufacturer of agricultural machinery, moved to Schenectady, where the boy attended the public schools and outside of school hours and during vacations studied mechanics and learned to handle machinery at his father's shop.

When the Civil War came on the patriotic ardor which filled the youth of the country drew young Westinghouse into the volunteer army. Although he was under the age for enlistment, his size and strength were such that he was admitted to the service, first joining the cavalry. In December 1864, he became an assistant engineer in the navy serving in that capacity until August 1865.

After the war he returned to Schenectady and entered Union College, but this was a classical institution and the bent of young Westinghouse was in the direction of mathematics and engineering. Acting upon the advice of the president of the college, who felt that such latent ability should be given an unrestricted opportunity for growth, he left before graduation and started seriously upon his career in engineering.

Putting the president's advice into practice, he took out his first patent. He had seen a crew of railroad men tediously working to replace a derailed car on the tracks and thought their primitive methods were wasting time. He invented a simple device for the operation and undertook to sell it to the railroads.

On one of his journeys "frog selling," as he has called it, he was close to a collision of trains. The brakemen, tugging at their handbrake wheels, did their best, but the best of handbrakes were primitive affairs, and in emergencies almost useless. He conceived the idea of instantly braking an entire train with some form of power apparatus controlled by the locomotive engineer. In a year or so, after much experiment, he was satisfied that he had made a practical design, but he was without capital to manufacture the equipment of even a single train and to get the invention tried. He went to Pittsburgh, where he obtained encouragement enough to begin in a small way. He patented the air brake in 1867.

The first train to which this brake was applied ran on a line west from Pittsburgh and on what is now a portion of the Pennsylvania Railroad. During the trial trip a collision with a loaded team stuck on a grade crossing was prevented. This practical illustration of the utility of the invention led to the adoption of the brake. Mr. Westinghouse, retaining the control of his invention, undertook to manufacture it and organized the Westinghouse Air Brake Company, establishing at Pittsburgh the business which subsequently became the nucleus of the many industries associated with his name. He later applied compressed air to switching and signalling and utilized electricity in this connection. From this grew the Union Switch and Signal Company.

His introduction of electricity into switch and signal work led him far into electrical experiment and he devoted his energies to a cause in which few then believed, the adoption of the alternating current for lighting and power, in which he had to meet and overcome almost fanatical opposition, which in many states sought legislation against the use of the alternating current as dangerous to the public welfare. In 1885, he acquired the patents of Gaulard & Gibbs, and having undertaken a comprehensive study of the distribution and utilization of electrical currents in a large way, he personally devised apparatus and methods for the work, and gathered around him a group of men who were to become experts in the new electrical art. He also organized the electrical company which bears his name and undertook the development and manufacture of the induction motor which made practical the utilization of the alternating current for power purposes.

The Westinghouse Machine Company was established by Mr. Westinghouse in the 80's for the manufacture of high-speed steam engines, and at this plant has come in succession the construction of large steam engines, gas engines and steam turbines.

Following the discovery of natural gas in the Pittsburgh region, Mr. Westinghouse devised a system for controlling the flow and for conveying the gas over long distances through pipe lines, thus supplying fuel to the homes and factories of Pittsburgh. He took up the study of the gas engine, and for ten years conducted a series of exhaustive experiments in this line, at the end of that time putting into commercial use a gas engine of large power for electric generating.

Mr. Westinghouse introduced the Parsons steam-turbine into this country, adding to it improvements and developments of his own, and others carried out under his supervision. The reduction gearing for driving the propeller shaft of a ship by means of a steam turbine was developed at the Machine Company's Works, with the coöperation of the late Admiral Melville and John H. Macalpine. Very recently, also, the Westinghouse air spring for motor vehicles was brought out.

It is impracticable to enumerate here the inventions which Mr. Westinghouse had personally made or those which his staff have brought forth under his supervision. As a result of this work and enterprise, there have grown thirty corporations of which he was president at one time, employing 50,000 men, with works at Wilmerding, East Pittsburgh, Swissvale and Trafford City, Pa.; at Hamilton, Canada; London and Manchester, England; Havre, France; Vardo, Italy; and at Vienna and St. Petersburg.

Mr. Westinghouse made many visits to Europe in connection with his inventions and industries. There as in his own country he won the friendship of the foremost men of his time and the high esteem of the engineering profession. He has been decorated by the French Republic and by the sovereigns of Italy and Belgium; and he was the second recipient of the John Fritz Medal "for the invention and development of the air-brake," Lord Kelvin, his friend of many years, having been the first. The Königliche Technische Hochschule of Berlin bestowed upon him the degree of Doctor of Engineering; and his own college, Union, gave him the degree of Ph.D. The Edison Gold Medal was presented to him in 1912, for his "meritorious achievement in connection with the development of the alternating system for light and power." In 1913, the Grashof Medal of the Verein deutscher Ingenieure, the highest honor in the gift of the engineering profession of Germany, was awarded to Mr. Westinghouse on the occasion of the official visit to Germany of the American Society of Mechanical Engineers, and accompanying the medal was a certificate which read: "To George Westinghouse, who opened up new fields by his invention of the automatic railway brake, successfully fought for the introduction of the alternating current in the United States, and did useful work in the designing of high-speed machinery."

Besides his honorary membership in The American Society of Mechanical Engineers, Mr. Westinghouse was one of the two honorary members of the American Association for the Advancement of Science and an honorary member of the National Electric Light Association.

Mr. Westinghouse was two months under 21 when he married Marguerite Erskine Walker, who with a son, George Westinghouse, Jr., survives him. She was his sympathetic and understanding companion throughout his whole career.

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NOTE

1 Names of authors and discussors, also deceased members preceding an obituary notice, are in caps and small caps. A discussor is distinguished from the author of a paper by (*D*), placed after the name of the paper.

2 Titles of papers, where placed after the name of the author, and appearing in their exact form, are in italic. Papers are indexed not under their title but under their subject matter.

3 The Society is not responsible as a body for the statement of facts or opinions in the papers and discussions.