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CONTENTS.

REGULAR MEETING, NEW YORK, SEPTEMBER 26, 1902.

REGULAR MEETING, NEW YORK, NOVEMBER, 21, 1902.

VARIABLE SPEED MOTOR CONTROL.

REGULAR MEETING, NEW YORK, DECEMBER 19, 1902.

BRAKING AND TRACTION BRAKES.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

New York, September 26, 1902.

The 168th meeting was held this date at 12 West 31st Street, and was called to order by Past-President Steinmetz, at 8:50 P M.

Past-President Steinmetz:—Gentlemen, the meeting is called to order. The first item of business on the program of this evening, which it is my pleasure to execute, is the introduction to you of our new President, my friend Mr. Charles F. Scott. It is really unnecessary to introduce him, as Mr. Scott is very well known to you, not only by his reputation in engineering work but also by the very active part he has taken in the meetings as a member, and in the work of the Committees of the Board of Directors, to which he has belonged for a number of years. I take very great pleasure in relinquishing the Chair in favor of Mr. Scott.

[President Scott then read an address on "Proposed Developments of the Institute." See page 3.]

President Scott:—It has been my good fortune to have been associated in my professional work with a very able and congenial corps of associates. One man who has produced a great deal of good work has been of a rather quiet, retiring disposition. He has let his work speak for itself. But I am sure that all of those who, together with myself, have been co-workers with him will join me in saying that whatever of success and whatever of reputation Westinghouse machines may have, is due to him, both directly and indirectly, as the electrical engineers who are in the machine design work of the company have been trained up as his disciples. One the latest pieces of his work we are here this evening to have presented to us by the gentleman himself, and I take great pleasure in introducing him—Mr. B. G. Lamme.

[Mr. Lamme read his paper, entitled "Washington, Baltimore and Annapolis Single Phase Railway." See page 15.]

An address delivered at the 168th Meeting of the American Institute of Electrical Engineers, New York, September 26th, 1902.

PROPOSED DEVELOPMENTS OF THE INSTITUTE.

An address

By Chas. F. Scott, *President.*

Gentlemen:—To-day your newly-elected officers enter upon their duties, and another year begins. Before entering upon the routine of our regular work, let us pause to consider the functions of our Institute, its present status and its future possibilities.

The position occupied by the electrical engineer is unique. The science which underlies his work is most fascinating and most fruitful. Its applications are not confined to a limited field. There is scarcely a branch of human activity that has not received its quickening touch. So rapidly have electrical novelites become commercial necessities and simple experiments evolved great systems that a new branch of engineering has been developed in a score of years. The scope of the electrical engineering profession has developed from trivial beginnings until it includes works of the greatest diversity and magnitude and far-reaching consequences, in industrial, commercial and social life. This development has been the result not of mere chance, but of a combination of favoring conditions. Faraday and Maxwell laid the foundations of electrical science and the general mechanical, industrial and scientific evolution of the nineteenth century gave the necessary opportunity and impetus to its commercial application. Electricity is usually a means, an agency, and is not in itself an end. In order that electricity may be applied, there must be that to which it can be applied. The electric motor, for example, would be of little consequence if there were no field for it—if there were no machine-shops or mills, no elevators or street cars. It is because the steam engine has for a century been training men to use mechanical power, and because the existing methods of transmitting and distributing power have such fixed and narrow limitations, that the electrical system has so quickly taken its place between engine and lathe, between the waterfall and the loom. It is because the science of electrochemistry was advancing that the dynamo found a place in electrochemical industries and, in turn, cheap electrical energy has accelerated electrochemical development. It is notable that the greater part of the power developed at Niagara Falls is used in electrochemical and allied processes, in the manufacture of aluminium, carborundum, sodium, chlorine, caustic soda, calcium carbide, phosphorous, graphite and barium hydrate; while in almost every case even the discovery of the process itself, as well as the development of the industry, has occurred since the work upon the power plant was begun.

It is a hackneyed theme—the infancy of electricity; and yet to obtain a just view of his position the electrical engineer must realize how brief compared with other branches of engineering is the experience upon which his work is based. Even the man who has been called the "Father of Electrical Engineering," whose theoretical and mechanical skill made possible the suceess of the ocean cable, is still a vigorous worker, and quite recently the INSTITUTE was privileged to tender him a reception. I refer, of course, to our distinguished Honorary Member, Lord Kelvin. It is not yet twenty-seven years, the age required for full membership in the INSTITUTE, since the Centennial Exposition gave an impetus to electrical invention and the telephone was made public. It was not until 1884, the year of the Philadelphia International Electrical Exposition, that measures were taken for establishing a national organization among electrical men, and the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS was established. Its first President, Dr. Norvin Green, and half of its vice-presidents and managers were identified with the telegraph. The practical electricians of those days were telegraph men, but now a new generation has arisen to whom the click of the sounder is unintelligible.

The past fifty years and notably the past decade have witnessed a general development of such magnitude that it marks an epoch in the World's history. And in this development, electricity has been foremost. I will not attempt to recount and catalogue what has been accomplished, in how many ways electricity has proven useful, the various purposes for which it is employed in industrial and manufacturing enterprises, nor to what extent the telephone, telegraph and cable have affected domestic, commercial, social and national life; I will not mention the results which the railway motor in city, suburban and interurban service is effecting in the cheapening of travel and the redistribution of population; I will not dwell upon the far-reaching effects in the economic world of an agent which makes possible the combination of formerly diverse interests by operating in one great system local and interurban railways, mills, shops, elevators, street lighting and indoor illumination; nor will I even attempt to sum up all these achievements and estimate by how much the results of human activity are increased through the agency of electricity. The point I do make is the rapid growth and the magnitude of the work and the far-reaching responsibilities which have so quickly devolved upon the electrical profession.

Consider for a moment the financial aspect. It is estimated that the total investment in electrical applications outside of telegraphy and telephony at the time this INSTITUTE was founded, did not exceed $1,000,000. At the present time the estimated capitalization of electrical applications in the United States approximates $4,000,000,000. In other words, electricity represents a value about one-third as great as that represented by the investment in our steam railway systems. Speaking generally, this enormous expansion has been made possible by the electrical engineer, and furthermore the successful outcome of these investments depends upon his work. Even these figures do not fully measure the vast responsibilities which are entrusted to the electrical engineer, since they take no account of the importance of his work in the many industries and enterprises which use electrical apparatus in a merely subsidiary or auxiliary way.

The work which the future has in store for the electrical engineer seems even greater. Scarcely a plan for future progress is proposed either by the practical and conservative business man, manufacturer or engineer, or by the sanguine promoter or the imaginative writer who portrays an Utopian civilization, which does not involve some application of electricity.

We are now at a time of general prosperity. Will this continue? Is prosperity a normal condition, or are successions of prosperity and depression inevitable? Continued prosperity requires high efficiency. Effort must not be wasted or dissipated.

The ordinary activities and functions of industrial and commercial life must be efficiently performed, and energy must not be lost through great undertakings which fail in the execution, or accomplish no useful result. Imagine the results had the hundreds of millions of pounds expended by England on the South African war been devoted to the development of the country, by establishing electrical railways and lighting and power plants. Consider what a drain upon the resources of a country both in wealth and in men, are a large standing army and navy. Even granting that wars have been necessary factors in the world's history, and that on the whole they have been beneficial, nevertheless they indicate how vast are the forces which have directly retarded rather than advanced material prosperity. There is no doubt but that the forces at hand are ample to maintain a constantly increasing condition of prosperity if they be wisely directed. A grave responsibility rests upon the intelligent, the wealthy and the directing classes.

As a factor in maintaining prosperity, the work of the electrical engineer is of great consequence. Applied electricity so increases the efficiency of industrial and commercial life that a given expenditure of energy can produce greater results in less time. The electrical engineer is called upon to advise and direct in many large undertakings and upon the soundness of his judgment depends success or failure. Since electricity occupies so vital a place in the affairs of the present, and will be an increasing element in those of the future, the electrical engineer must be an important agent in avoiding depression and maintaining prosperity.

If we were to consider further the indirect as well as the direct relations of the electrical engineer to industrial and commercial and social interests we would be more deeply impressed with the responsibility of his part in the world's work In a profession where there are so many workers, where the majority of them are young men, where their work is so closely connected with scientific investigation and with what is being done in allied professions, when the rate of advance is so great in scientific discovery, in invention, in application to processes which are new and to undertakings of increasing value, and particularly in a country which is recognized as foremost in electrical development, there is a unique field for a national organization such as the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS. In a profession whose interests are so diversified and so extended, workers should be brought together. They should have a common meeting place. Here discoveries may be announced, inventions described, engineering schemes criticized and new undertakings presented and discussed. Here the student and professor, the investigator, the inventor, the manufacturer, the operator and the consulting engineer may meet upon common ground. The engineer who is tempted to ridicule scientific work finds that it is the foundation upon which his own work rests. The professor who regards slightly the work of the designing or constructing engineer may find that his own cherished formulæ are derived from the rules and contain the constants which the practical man has determined for himself. Association leads to mutual understanding, it curbs eccentricity and one-sided development, and promotes symmetrical advancement.

It is the function of the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS to bring individual workers into a common unity, to join them in a community of interest—a fraternity which is called the electrical engineering profession. It should place the profession of electrical engineering above suspicion of corruption and chicanery and should call for high standards of dignity and honorable accomplishment. It should discountenance the spirit of blind partisanship and of depreciation of others' efforts among those who are divided by commercial interests, whether they represent competitors or buyer and seller. While each has his individual interests, there is a general interest which is common to all. All share in that which discredits the profession as well as in that which elevates and advances it.

It is the function of the INSTITUTE to bring together continually the diversified achievements of many workers, which taken altogether constitute a single total of accomplishment—a total which is called progress. It should discriminate between that which is substantial and that which is not. It should place the stamp of recognition and approval upon all that is meritorious and marks an advance in the art.

It is the function of the INSTITUTE to take the lead in such measures as will promote the general interests of the profession and the efficiency of electrical work.

In the past the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS has represented the profession and advanced its interests in various ways:

It has taken a prominent part in establishing uniform insurance rules in a National Code.

It has been conspicuous in representing American engineers at international expositions and international congresses both in America and abroad. In the same connection it has been active in establishing international standards, and through its advocacy the name Henry, in honor of an American electrician, has secured a place in the list of electrical units.

It prepared in 1890 the standard wiring table for lighting and power purposes, which has been of great service in standardizing electrical calculations.

It has established a code of standardization covering names, definitions, methods of rating, tests and the like, which is of the greatest service in unifying and simplifying electrical practice.

It has established through the generosity of a few individuals a library which in historic value is unequaled.

It has brought electricians together in annual conventions and in monthly meetings, it has stimulated activity through papers and discussions which have dealt with vital problems, it has developed in eighteen Volumes of TRANSACTIONS a panoramic history of American Electrical Engineering.

Let us now turn our attention to the future and consider the specific ways in which the work of the INSTITUTE may be advanced during the coming year:

1. The membership should be increased. The power and influence of the INSTITUTE is dependent upon the number, character and activity of its members. There are many engineers eligible to membership who are not members, because they do not fully appreciate the scope and the work of the INSTITUTE. There are many electrical workers who would become worthy associate members if they realized the value of connection with the INSTITUTE.

Is it not the privilege and the duty of an electrical engineer to give his best support to the INSTITUTE which stands for the highest interests of his profession? Are not the advantages which connection with the INSTITUTE affords such that no progressive engineer can afford to be without them? If these things are so, then it rests upon the present members to build up the INSTITUTE by making its work known to those who should become members.

During the past year the membership increased 25 per cent. and reached 1,546. This is less than one-half the membership in the British Institution of Electrical Engineers. If AMERICAN INSTITUTE membership bore the same relation to the kilowatt capacity of the electrical power-stations of the country as does that of the British Institution, our membership should be 25,000.

There are to-day cities in which are located engineering schools and large electrical interests, which have but three or four members. Five States east of the Mississippi River have but one or two members each, and there are three of the New England States that have but three members each.

2. Papers and discussions should be contributed from a larger proportion of the membership. The transactions of the INSTITUTE should be a record of the advance in electrical work, and should contain only that which is of material value to the advancement of the art. I submit that even their present high standard does not adequately represent American electrical progress. If it is true that our papers do not fully present the advance thought and best achievements of the time, it is simply because our advance workers do not contribute more.

Material may be presented in formal papers, in original communications or in discussion. Some subjects do not provoke general discussion; others depend for their value upon the experience or the opinions of a large number of members. While the INSTITUTE is not as a body responsible for the statements or the opinions of its members, there is nevertheless an obligation resting upon its members not to leave unchallenged any inaccurate and misleading statements.

Our last volume shows that 5 per cent. of the membership took part in the meetings, and that 2 per cent. furnished papers. Of these papers 10 per cent. came from miscellaneous sources, 20 per cent. came from college professors, 25 per cent. from operating and consulting engineers, and 45 per cent. from engineers connected with manufacturing companies.

These figures indicate that electrical matters are advancing so fast that even the teachers in the great technical schools fall behind the pace, because the problems come first to the manufacturer. To the manufacturing companies must be given credit for substantially advancing scientific investigation as well as practical development.

Further examination of the last annual volume shows that although one-fourth of the members reside in New York and the monthly meetings are held there, yet only one-fifth of the papers were presented by New York members. The INSTITUTE is national in its scope, and there should be united effort throughout the entire membership to increase the quantity as well as the quality and the usefulness of its published proceedings.

3. Local meetings of the INSTITUTE in various cities will broaden the interest in its work and generally extend its benefits. Some local organizations have been formed, but this department of our work should be greatly extended. While such organizations should be conducted in harmony with the general methods and purposes of the INSTITUTE, synchronizing as far as practicable with its general meetings, they should also become "self-exciting" centers of local electrical activity. There is so much material available and there are so many subjects of local and general interest that a small amount of well-directed effort in organization will produce great results.

4. Universities and technical schools with electrical engineering departments may organize local meetings of the INSTITUTE which would be of benefit to both instructors and students in keeping them in touch with the most recent developments and practice in electrical work. Meetings may be under the direction of the professor of electrical engineering and may be conducted in various ways to conform best to the local conditions. Local INSTITUTE members may join with the school meetings. A school should be the natural center for engineers of its vicinity. It supplies a suitable meeting place, and the discussion of INSTITUTE papers by engineers, instructors and students should be of benefit to all. In the thesis work of students the INSTITUTE may be helpful also in recognizing and publishing in abstract or in full, theses which are noteworthy. This would give an impetus to the preparation of theses and wholesome rivalry among different institutions, and would add to the value of our Transactions.

The proper education of the engineer is a problem to which various solutions are offered. All however, will doubtless agree that the profession has already reached a stage and is advancing so rapidly that the purely "practical man" cannot hope to maintain himself in the front rank. The rate at which development is progressing demands a thorough grounding in fundamental principles, in order to impart the power for grasping and meeting new conditions. My predecessor spoke truly when he said that the primary aim of the educational institution should be to give the young engineer "a thorough understanding of the fundamental principles of electrical engineering and allied sciences, and a good knowledge of the methods of dealing with engineering problems." The best education is that in which theoretical training in fundamental principles predominates. The true function of practical work in a broad engineering education is not to produce skilled workmen or full-fledged engineers, but it is to supplement theoretical work, making it definite and certain, so that the student may properly assimilate the instruction which he receives. Again, a student should not make his mind a storehouse of facts, but he should learn where facts and information can be obtained, and how to use them.

The principal purpose for bringing the work of the INSTITUTE directly to the student is to enable him to keep in touch with actual things and give him a definite idea of the kinds of work which lie before him, and for which he is preparing. Fortunate will it be if we can lead him to see that in the development of an electrical engineer there should be something besides technical training—that logical thinking and clear expression and general culture are indispensable in a profession that is closely related to so many departments of science and engineering as well as industrial and commercial and social activity, and that he must be a broad man with a broad educational foundation, who would aspire to the fullest usefulness and success.

5. The collection of engineering data and the establishment of standard practice in electrical engineering is one of the important functions of the INSTITUTE. The present years are formative years. Electrical engineering is crystallizing. Electrical theory and laws and electrical measurements are more definite than those relating to the allied professions; for example, compare the accuracy in the predetermination of the efficiency of a dynamo with that of an engine, or the ease and precision of measurement of dynamo output by a wattmeter with that of an engine by a mechanical dynamometer or brake. Electrical engineering practice, however, is now being established. The apparatus and the methods, both in detail and in general, which characterize present work are radically different from those of five or ten years ago. It is of the highest importance to the profession that definitions and principles and laws pertaining to engineering practice should be determined and adopted as rapidly as circumstances will permit. General investigations should be made in various lines of electrical engineering work, not primarily for the purpose of devising theoretical standards or undertaking original investigation, but for the purpose of determining what is best in present practice, and of formulating and crystallizing it into what may be recognized as standard practice.

We must not fail to realize the value of standards. An English engineer in a distant part of the British Empire in specifying the apparatus for a large electrical railway, strongly recommended that American standard apparatus be purchased as "England has no standard." In Europe to-day there is a confusion of systems and frequencies and voltages, and a wide diversity in types of construction. Many foreign engineers pride themselves on devising that which is novel, instead of adapting that which is standard. American engineers are not divided by nationality and by language as are those of Europe; they have that unity in which there is strength; they appreciate the advantage of adhering to standard practice; they realize that the manufacture of dynamos and motors, as well as of shoes and clocks, of engines and bridges will be cheaper and quicker if made in quantity.

Do you realize the relative magnitude of American electrical work? The United States with only one-fifth the population of Great Britain and Europe has two and one-third times the kilowatt capacity in power-stations, and three and one-half times the mileage of electric railways. The power-houses in operation and under contract in New York City would replace all the central stations for lighting and power in Great Britain or in Germany; they would operate all the electric railways of Great Britain and Europe combined; one alone would be sufficient for the railways of Germany and the output of a single generator would run all the railways of Switzerland.* Although some foreign engineers are still in doubt as to the practicability of the rotary converter, yet the output of American rotary converters is sufficient to operate all the railways in Great Britain and Europe combined. American designs, methods and practice are being introduced into half-a-dozen factories in foreign countries. Electrical progress and leadership can be promoted by this INSTITUTE, as it draws together and unites the efforts of electrical workers and as it aids in establishing the standards for the future. Standards are not to prevent progress, but they are to make definite the steps already taken and they are the foundation for advancement.

* See "Some Comparative Approximate Figures of Electric Light, Power and Traction Systems in European Countries and in the United States of America at the Present Day," Philip Dawson, *Engineering Magazine*, February, 1902, page 712.

6. Our library merits a cordial support. The policy decided upon by the Library Committee is to place upon our shelves every book relating to electricity in the English language, and every book of any value in the French, German and other languages. Let all who are able, coöperate in this important work of building up a complete reference library.

Through good fortune and the generous assistance of Dr. S. S. Wheeler we have the Latimer Clark library as a foundation. Mr. Carnegie's kindly contribution has enabled the library to be catalogued and otherwise made useful. Various members, notably Messrs. Mailloux, Hutchinson, Wetzler, Arnold, Keith, Caldwell, Jenks, Fish and Clarke, as well as the American Bell Telephone Co., The New York Electrical Society, and others, have contributed valuable sets of books, such as the proceedings of scientific societies, the records in patent litigation and the like. At least one member has provided by his will that a part of his technical library shall pass to the INSTITUTE and another is proposing an endowment for the future continuation of the sets which he has presented.

The preceding sentence was written yesterday. I am authorized by the Board of Directors to state the contents of a letter received to-day from Mr. W. D. Weaver, the Chairman of the Library Committee—to whose efficient services the development of the Library is due. This letter reports the receipt of a check from Mr. Mailloux to be used as an endowment for continuing subscriptions to several of the valuable sets which he has presented to the Library. Among the books, a thousand or more, which he has presented, are some rare series, some of which have been secured at considerable cost, others by rare good fortune. Our Library is already assuming a high rank among electrical libraries, and even among general technical libraries.

7. Permanent quarters for the INSTITUTE should be an object of plans and anticipations. An organization which is so closely connected with so many vital interests of such vast commercial value and which possesses such possibilities for promoting the best interests of the profession should not be hampered for want of the most convenient accomodations. Personal acquaintance and social intercourse are influential factors in unity of sentiment and of action. Our library is all but inaccessible in its present cramped quarters which do not permit normal growth.

8. Coöperation with similar institutions in other countries will

be mutually beneficial in various ways. In certain lines they may learn from us, but there is a great deal that we can learn from them.

In addition to general coöperation such as is promoted by international congresses, much is to be gained in less formal ways. For example, different institutions may at times discuss the same subject. Again, they may do a great service to electrical progress by harmonious working in the adoption of standards. The members of one institution may broaden their outlook by becoming members of other bodies. It is the hope and expectation of our INSTITUTE to have as its guest, within the next few years, the Institution of Electrical Engineers of Great Britain. The scope of our profession is world-wide. Let us welcome this coming opportunity to extend our acquaintance and broaden our ideas.

In conclusion, I have realized the responsibilities which rest upon the President of this INSTITUTE, and it was with reluctance and misgiving that I yielded to some urgent friends and consented to become a candidate. I fully appreciate the confidence you have expressed by your votes and I now ask your coöperation in continuing the high standard of work attained during the past year under my honored predecessor, whose able and enthusiastic efforts have awakened the INSTITUTE to new activity and usefulness.

The outlook is propitious. The Board of Directors at its meeting this afternoon authorized the appointment of a Committee on Membership, also a Committee on Local Organization with authority to make immediate arrangements for the holding of local meetings. This Committee also has under its direction the proposed INSTITUTE meetings in connection with technical schools. A Committee on Theses was provided for to consider the relations of the INSTITUTE to this branch of student work. A Transmission Committee was provided for to collect data with respect to present practice in high tension transmission, particularly with reference to the construction of transmission lines and to formulate this data for the use of electrical engineers. It was recognized that this branch of engineering is advancing rapidly and that it merits special attention from the INSTITUTE in order that the best elements of present practice may be set forth. The standing Committees of the INSTITUTE are taking up their work with renewed vigor.

If, my fellow-members, the objects of INSTITUTE endeavor which I have outlined are worth while, each of us can well afford to do his part towards realizing them.

A paper presented at the 168th Meeting of the American Institute of Electrical Engineers New York, September 26th, 1902.

WASHINGTON, BALTIMORE AND ANNAPOLIS SINGLE-PHASE RAILWAY.

BY B. G. LAMME.

The Washington, Baltimore and Annapolis Railway is a new high-speed electric line extending from the suburbs of Washington to Baltimore, a distance of about 31 miles, with a branch from Annapolis Junction to Annapolis, a distance of about 15 miles. The overhead trolley will be used, and schedule speeds of over 40 miles per hour are to be attained. This road is to be the scene of the first commercial operation of an entirely new system of electric traction.

The special feature of this system is the use of single-phase alternating current in generators, transmission lines, trolley, car equipment and motors. It constitutes a wide departure from present types of railway apparatus, and while retaining the best characteristics of the present standard D. C. motor system, the use of alternating current makes it possible to avoid many of the bad features.

The standard D. C. railway equipment possesses several characteristics which fit it especially for railway service. These characteristics have been of sufficient importance to overbalance many defects in the system. In fact, a far greater amount of effort and engineering skill has been required for overcoming or neutralizing the defects, than for developing the good features possessed by the system. By far the most important characteristic possessed by the D. C. system is found in the type of motor used on the car. The D. C. railway motor is in all cases a series-wound machine. The series motor is normally a variable field machine and it is this feature which has adapted the motor especially to railway service. Shunt-wound motors have been tried and abandoned. All manner of combinations of shunt, series and separate excitation have been devised and found wanting, and in many cases the real cause of failure was not recognized by those responsible for the various combinations. They all missed to a greater or less extent the variable-field feature of the straight series motor. It is true that a variable field can be obtained with shunt or separate excitation, but not without controlling or regulating devices, and the variation is not inherently automatic, as in the series motor. Polyphase and single-phase induction motors do not possess the variable field feature at all, as they are essentially constant-field machines. They are equivalent to direct current shunt or separately excited motors, with constant field strength, which have been unable to compete successfully with the series motor. The variable field of the series motor makes it automatically adjustable for load and speed conditions. It also enables the series motor to develop large torques without proportionately increased currents. The automatically varying field is accompanied by corresponding variations in the counter e.m.f. of the armature, until the speed can adjust itself to the new field conditions. This feature is of great assistance in reducing current fluctuations, with a small number of steps in the regulating rheostat. Any increase in current, as resistance is cut out, is accompanied by a momentary increase in the counter e.m.f., thus limiting the current increase to a less value than in the case of a constant field motor.

Next to the type of motor, the greatest advantage possessed by the D. C. system lies in the use of a single current or circuit, thus permitting the use of one trolley wire. The advantages of the single trolley are so well-known that it is unnecessary to discuss them. For third rail construction, the use of single current is of even greater importance than in the case of the overhead trolley. It is seen, therefore, that it is not to the direct current that credit should be given for the great success of the present railway system, but to the series type of motor and the fact that up to the present time no suitable single-phase A. C. motor has been presented.

Some of the undesirable features of the D. C. railway system should also be considered. The speed control is inefficient. A nominally constant voltage is supplied to the car, and speed control is obtained by applying variable voltage to the motor terminals. This variation is produced by the use of resistance in series with the motors, with a loss proportional to the voltage taken up by the resistance. By means of the series-parallel arrangement, the equivalent of two voltages is obtainable at the motor terminals without the use of resistance. Therefore, with series-parallel control, there are two efficient speeds with any given torque, and with multiple control there is but one efficient speed with a given torque. All other speeds are obtained through rheostatic loss, and the greater the reduction from either of the two speeds, series or parallel, the lower will be the efficiency of the equipment. At start, the rheostatic losses are always relatively large, as practically all the voltage of the line is taken up in the rheostat. For heavy railroad service, where operation for long periods at other than full and half speeds may be necessary, the rheostatic loss will be a very serious matter.

The controlling devices themselves are also a source of trouble. An extraordinary amount of time and skill has been expended in the perfecting of this apparatus. The difficulties increase with the power to be handled. The controller is a part of the equipment which is subjected to much more than ordinary mechanical wear and tear, and it can go wrong at any one of many points. The larger the equipment to be controlled, the more places are to be found in the controller which can give trouble. The best that can be said of the railway controller is that it is a necessary evil.

Another limitation of the D. C. system is the trolley voltage. Five hundred volts is common at the car and 650 volts is very unusual. By far the larger number of the railway equipments in service to-day are unsuited for operation at 600 volts, and 700 volts in normal operation would be unsafe for practically all. The maximum permissible trolley voltage is dependent upon inherent limitations in the design of motors and controllers. The disadvantages of low voltage appear in the extra cost of copper and in the difficulty of collecting current. In heavy railroad work the current to be handled becomes enormous at usual voltages. A 2400 H.P. electric locomotive, for example, will require between 3000 and 4000 amperes at normal rated power and probably 6000 to 8000 amperes at times. With the overhead trolley these currents are too heavy to be collected in the ordinary manner, and it is a serious problem with any form of trolley or third rail system which can be used. It is evident that for heavy service, comparable with that of large steam railways, a much higher voltage than used in our present D. C. system is essential, and the use of higher voltage is destined to come, provided it is not attended by complications which more than overbalance the benefits obtained.

A further disadvantage of the D. C. system is the destructive action known as electrolysis. This may not be of great importance in interurban lines, chiefly because there is nothing to be injured by it. In city work its dangers are well-known, and very expensive constructions are now used to eliminate or minimize its effects.

From the above statements it is evident that an A. C. railway system, to equal the D. C., should possess the two principal features of the D. C. system, viz: A single supply circuit and the variable field motor, and to be an improvement upon the D. C. system, the A. C. should avoid some of the more important disadvantages incident to the present D. C. railway apparatus.

The system must, therefore, be single-phase. The importance of using single-phase for railway work is well known. The difficulties and complications of the trolley construction are such that several A. C. systems have been planned on the basis of single-phase supplied to the car, with converting apparatus on the car to transform to direct current, in order that the standard type of railway motors may be used. Such plans are attempts to obtain the two most valuable features of the present D. C. system. The polyphase railway system, used on a few European roads, employs three currents, and therefore does not meet the above requirement.

The motor for the A. C. railway service should have the variable speed characteristics of the series D. C. motor. The polyphase motor is not suitable, as it is essentially a constant field machine, and does not possess any true variable speed characteristics. Therefore it lacks both of the good features of the D. C. railway system. A new type of motor must, therefore, be furnished, as none of the alternating current motors in commercial use is adapted for the speed and torque requirements of first-class railway service. Assuming that such a motor is obtainable for operation on a single-phase circuit, the next step to consider is whether the use of alternating instead of direct current on the car, will allow some of the disadvantageous features of the A. D. system to be avoided.

The D. C. limits of voltage are at once removed, as transformers can be used for changing from any desired trolley voltage to any convenient motor voltage. Electrolytic troubles practically disappear. As transformers can be used, variations in supply voltage are easily obtainable. As the motor is assumed to have the characteristics of the direct-current series motor, speed control without rheostatic loss is practicable when voltage control is obtained. This combination, therefore, allows the motor to operate at relatively good efficiency at any speed within the range of voltage obtained. If the voltage be varied over a sufficiently wide range, the speed range may be carried from the maximum desired down to zero, and therefore, down to starting conditions. With such an arrangement no rheostat need be used under any conditions, and the lower the speed at which the motor is operated, the less the power required from the line. The least power is required at start, as the motor is doing no work and there is no rheostatic loss. The losses at start are only these in the motor and transforming apparatus, the total being less than when running at full speed with an equal torque. Such a system, therefore, permits maximum economy in power consumed by motor and control. This economy in control is not possible with the polyphase railway motor, as this motor is the equivalent of the D. C. shunt motor, with which the rheostatic loss is even greater than with the series motor.

The use of alternating current on the car allows voltage control to be obtained in several ways. In one method a transformer is arranged with a large number of leads carried to a dial or controller drum. The Stillwell regulator is a well-known example of this type of voltage control. This method of regulation is suitable for small equipments with moderate currents to be handled. The controller will be subject to some sparking, as in the case of D. C. apparatus, and therefore becomes less satisfactory as the car equipment is increased in capacity. Another method of control available with alternating current is entirely nonsparking, there being no make-and-break contacts. This controller is the so-called " induction regulator," which is a transformer with the primary and secondary windings on separate cores. The voltage in the secondary winding is varied by shifting its angular position in relation to the primary. With this type of voltage controller, very large currents can be handled, and it is especially suitable for heavy equipments, such as locomotives. It is thus seen that there is one method of control, available with alternating current, which avoids the inherent troubles of the D. C. controller. The induction regulator is primarily a transformer, and all wear and tear is confined to the supports which carry the rotor. Therefore the objectionable controller of the standard D. C. system can be eliminated, provided a suitable A. C. motor can be obtained. This ideal type of controller is not applicable to the polyphase railway motor, in which speed control can be obtained only through rheostatic loss. The polyphase control system is even more complicated than the D. C., as there must be a rheostat for each motor, and two or three circuits in each rheostat. It is thus apparent that by the use of single-phase alternating current with an A. C. motor having the characteristics of the D. C. series motor, the best features of the D. C. system can be obtained, and at the same time many of its disadvantages can be avoided.

This portion of the problem therefore resolves itself into the construction of a single-phase motor having the characteristics of the D. C. series motor. There are several types of single phase A. C. motors which have the series characteristics. One type is similar in general construction to a D. C. motor, but with its magnetic circuit laminated throughout, and with such proportions that it can successfully commutate alternating current. Such a motor is a plain series motor, and can be operated on either alternating or direct current and will have the same torque characteristics in either case. Another type of motor is similar in general construction to the above, but the circuits are arranged in a different manner. The field is connected directly across the supply circuit, with proper control appliances in series with it. The armature is short-circuited on itself across the brushes, and the brushes are set at an angle of approximately 45° from the ordinary neutral point. The first of these two types of motors is the one best adapted for operation in large units.

This is the type of motor which is to be used on the Washington Baltimore and Annapolis Railway. Several motors have been built and tested with very satisfactory results, both on the testing stand and under a car. The results were so favorable that the system was proposed to the Cleveland Construction Company, representing the Washington, Baltimore and Annapolis Railway, and after investigation by their engineers, it was adopted. A description of the apparatus to be used on this road will illustrate the system to good advantage.

Single-phase alternating current will be suppled to the car at a frequency of 16⅔ cycles per second, or 2,000 alternations per minute. The current from the overhead trolley wire is normally fed in by one trolley at approximately 1,000 volts. Within the limits of the District of Columbia two trolleys are employed, as by Act of Congress the use of rails as conductors is prohibited in this District, presumably on account of electrolysis. In this case the trouble, of course, will not exist, but the contracting company has been unable to obtain permission for the grounded circuit.

The alternating current to the car is carried through a main switch or circuit breaker on the car, to an auto-transformer connected between the trolley and the return circuit. At approximately 300 volts from the ground terminal a lead is brought out from the auto-transformer and passes through the regulator to one terminal of the motors. For starting and controlling the speed, an induction regulator is used with its secondary winding in series with the motors. This secondary circuit of the regulator can be made either to add to, or substract from the transformer voltage, thus raising or lowering the voltage

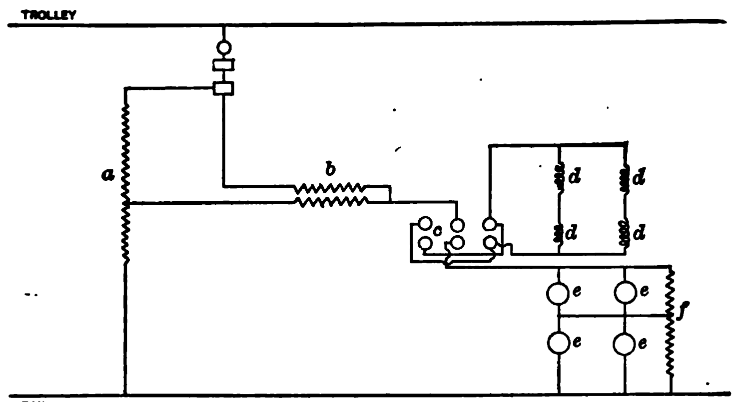


FIG. 1.—*a.* Auto-Transformer. *b.* Induction Regulator. *c.* Reversing Switch. *d.* Field of Motors. *e.* Armature of Motors. *f.* Equalizing Transformer.

supplied to the motors. The regulator therefore does double duty. The controller for D. C. motors merely lowers the voltage supplied to the motors but cannot raise it, but an A. C. regulator can be connected for an intermediate voltage, and can either raise or lower the motor voltage. In this way the regulator can be made relatively small, as it handles only the variable element of the voltage and the maximum voltage in the secondary winding is but half of the total variation required.

In the equipments in question, the range of voltage at the motor is to be varied from approximately 200 volts up to 400 volts or slightly higher. The transformer on the car will supply 315 volts, and the secondary circuit of the regulator will be wound to generate slightly more than 100 volts when turned to the position of its maximum voltage. This voltage of the regulator is about one-fourth of that of the motors at full voltage. The regulator can consequently be made relatively small, in comparison with the motor capacity of the equipment. It has been found unnecessary to use much lower than 200 volts in this installation, as this allows a comparatively low running speed, and approximately 200 volts will be necessary to start with the required torque. The greater part of this voltage is necessary to overcome the e.m.f. of self-induction in the motor windings, which is dependent upon the current through the motor and is independent of the speed of the armature.

There will be four motors of 100 H.P. on each car. The full rated voltage of each motor is approximately 220 volts. The motors are arranged in two pairs, each consisting of two armatures in series, and two fields in series, and the two pairs are connected in parallel. The motors are connected permanently in this manner. Since voltage control is used, there is no necessity for series parallel operation, as with D. C. motors. To ensure equal voltage to the armatures in series, a balancing or equalizing action is obtained by the use of a small auto-transformer connected permanently across the two armatures in series with its middle point connected between them. The fields are arranged in two pairs, with two fields in series and two pairs in multiple. This parallels the fields independently of the armatures, which was formerly the practice with D. C. motors. It was a defective arrangement with such motors, as equal currents in the field did not ensure equal field strengths in the motors, and the armatures connected in parallel therefore would be operating in fields of unequal strength, with unequal armature currents as a direct result. With alternating currents in the fields, the case is different. The voltage across the fields is dependent upon the field strengths, and the current supplied to the fields naturally divides itself for equal magnetic strengths. The chief advantage in paralleling the fields and armatures independently is, that one reversing switch may serve for the four motors and one balancing transformer may be used across the two pairs of armatures. The ordinary D. C. arrangement of armatures in series with their own fields can be used, with a greater number of switches and connections.

The general arrangement of the auto-transformer, regulator, motors, etc., is shown in Fig. 1.

The induction regulator or controller, resembles an induction motor in general appearance and construction. The primary winding is placed on the rotor, and the secondary or low voltage winding on the stator. The rotor also has a second winding which is permanently short-circuited on itself. The function of this short-circuited winding is to neutralize the self-induction of the secondary winding as it passes from the magnetic influence of the primary. The regulator is wound for two poles, and therefore is operated through 180° in producing the full range of voltage for the motors. One end of the primary winding of the regulator is connected to the trolley, and the other to a point between the regulator and the motors. It thus receives a variable voltage as the controller is rotated. There are several advantages in this arrangement of the primary in this particular case. First, the regulator is worked at a higher induction at start, and at lower induction when running, the running position being used in these equipments for much longer periods than required for starting. Second, when the motors are operating at full voltage the current in the primary of the regulator passes through the motors but not through the auto-transformer or the secondary of the regulator. This allows considerable reduction in the size of auto-transformer and regulator.

The motors on the car are all of the straight series type. The armature and fields being connected in series, the entire current of the field passes through the armature as in ordinary series D. C. motors. The motor has eight poles, and the speed is approximately 700 revolutions at 220 volts. The general construction is similar to that of a D. C. motor, but the field core is laminated throughout, this being necessary on account of the alternating magnetic field. There are eight field-coils wound with copper strap, and all connected permanently in parallel. The parallel arrangement of field-coils assists in equalizing the field strength in the different poles, due to the balancing action of alternating circuits in parallel. This arrangement is not really necessary, but it possesses some advantages and therefore has been used. With equal magnetic strength in the poles, the magnetic pull is equalized even with the armature out of center.

The armature is similar in general construction to that of a D. C. motor. The fundamental difficulty in the operation of a commutator type of motor, on single-phase alternating current lies in the sparking at the brushes. The working current passing through the motor should be practically no more difficult to commutate than an equal direct current, and it is not this current which gives trouble. The real source of trouble is found in a local or secondary current set up in any coil, the two ends of which are momentarily short-circuited by a brush. This coil encloses the alternating magnetic field, and thus becomes a secondary circuit of which the field-coil forms the primary. In

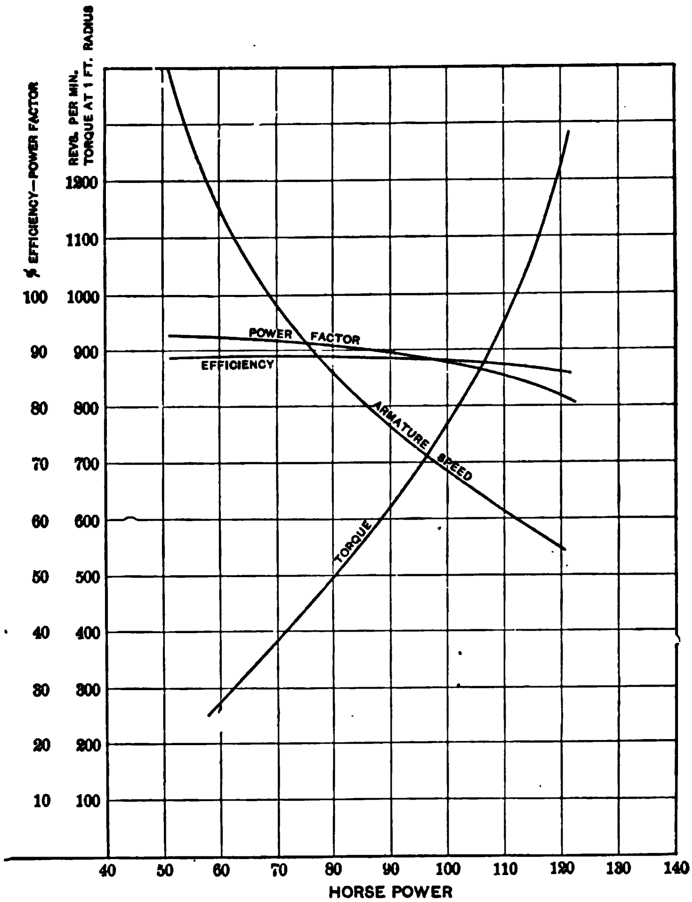


FIG. 2.—Westinghouse Alternating Current Railway Motor. No. 91.—Single-Phase.—220 Volts.

the motors of the Washington, Baltimore and Annapolis Railway, this commutation difficulty has been overcome by so constructing the motor that the secondary or short-circuit current in the armature coil is small, and the commutating conditions so nearly perfect that the combined working and secondary currents can be commutated without sparking. This condition being obtained, the motor operates like a D. C. machine and will give no more trouble at the commutator than ordinary D. C. railway motors. Experience covering a considerable period in the operation of motors of 100 h.p. capacity indicates that no trouble need be feared at the commutator.

An extended series of tests were made with these motors at at the Westinghouse shops at East Pittsburg, both in the testing room and under a car. Fig. 2 shows curves of the speed, torque, efficiency and power factor plotted from data from brake tests.

It should be noted that the efficiency is good, being very nearly equal to that of high-class D. C. motors. The power factor, as shown in these curves, is highest at light loads and decreases with the load. This is due to the fact that the power developed increases approximately in proportion to the current, while the wattless component of the input increases practically as the square of the current. The curve indicates that the average power factor will be very good. The calculation for the W. B. and A. Railway show that the average power factor of the motors will be approximately 86 per cent.

The average efficiency of these equipments will be much higher during starting and accelerating than that of corresponding D. C. equipments, as rheostatic losses are avoided. When running at normal full speed, however, the efficiency will be slightly less than with D. C. This is due to the fact that the A. C. motor efficiency is slightly lower than the D. C., and in addition there are small losses in the transformer and the regulator. The A. C. equipments are somewhat heavier than the D. C., thus requiring some extra power, both in accelerating and at full speed. Therefore, for infrequent stops the D. C. car equipment is more efficient than the A. C., but for frequent stops the A. C. shows the better efficiency. Tests on the East Pittsburg track verified this conclusion. But the better efficiency of the D. C. equipment with infrequent stops is offset with the A. C. by decreased loss in the trolley wire, by reason of the higher voltage used, and by the elimination of the rotary converter losses. The resultant efficiency for the system will therefore be equal to or better than that of the D. C.

In the W. B. and A. Railway contract the guarantee given by the Westinghouse Electric and Mfg. Co. states that the efficiency of the system shall be equal to that of the D. C. system with rotary converter substations.

There is one loss in the A. C. system which is relatively much higher than in the D. C. This is the loss in the rail return. Tests have shown that at 2,000 alternations it is three to four times as great as with an equal direct current. This would be a serious matter in cases where the D. C. rail loss is high. But the higher A. C. trolley voltage reduces the current so much, that the A. C. rail loss is practically the same as with direct current at usual voltages. In many city railways the D. C. rail loss is made very low, not to lessen waste of power, but in order to reduce electrolysis. In such cases the A. C. rail loss could be higher than D. C., thus decreasing the cost of return conductors. More numerous transformer substations, with copper feeders connected to the rails at short intervals will enable the rail loss to be reduced to any extent desired.

As a frequency of 2,000 alternations per minute is used, the lighting of the cars and the substations was at first considered to be a serious difficulty, due to the very disagreeable winking of ordinary incandescent lamps at this frequency. Two methods of overcoming the winking were tried, both of which were successful. One method was by the use of split phase. A two-phase induction motor was run on a single-phase 2,000 alternating circuit, and current was taken from the unconnected primary circuit of the motor. This current was, of course, at approximately 90° from the current of the supply circuit. A two-phase circuit was thus obtained on the car. Currents from the two phases were put through ordinary incandescent lamps, placed close together. The resulting illumination a few feet distant from the lamps showed about the same winking as is noticed with 3,000 alts. With two filaments in one lamp the winking disappears entirely. A three-phase arrangement would work in the same way.

A much simpler method was tried which worked equally well. This consisted in the use of very low-voltage lamps. Low voltage at the lamp terminals allows the use of a thick filament with considerable heat inertia. Tests were made on lamps of this type at a frequency of 2,000 alts., and the light appeared to be as steady as that from the ordinary high-frequency incandescent lamp. The low voltage is not objectionable in this case, as a number of lamps can be run in a series, as in ordinary street railway practice, and any voltage desired can readily be obtained, as alternating current is used on the car.

There will be an air compressor, driven by a series A. C. motor, on each car, for supplying air to the brakes and for operating the driving mechanism of the controller. The details of this mechanism are not sufficiently near to completion to permit a description of it. The method used will be one which readily allows operation on the multiple-unit system.

The generating station contains some interesting electrical features, but there is no great departure from usual A. C. practice. There will be three 1,500 K.W. single-phase alternators. These are 24-pole machines operating at 83 revolutions and wound for 15,000 volts at the terminals. They are of the rotating field type, with laminated magnetic circuits and field-coils of strap on edge. The field-coils are held on the poles by copper supports, which serve also as dampers to assist in the parallel running. The armatures are of the usual slotted type. The armature coils are placed in partially closed slots. There are four coils per pole. The proportions of these machines are such that good inherent regulation is obtained without saturation of the magnetic circuit. The rise in potential with non-inductive load thrown off will be approximately 4 per cent. An alternative estimate was furnished for the generators proposing 20,000 volts instead of 15,000. The simplicity of the type of winding used, and the low frequency, are both favorable for the use of very high voltage on the generator. As 15,000 volts was considered amply high for the service, the engineers for the railway considered it inadvisable to adopt a higher voltage.

There are to be two exciters, each of 100 K.W. capacity at 250 revolutions. The exciters are wound for 125 volts normal. The armature of each exciter has, in addition to the commutator, two collector rings, so that single-phase alternating current can be delivered. It is the intention to use the exciters as alternators for supplying current to the system for lighting when the large generators are shut down at night.

The main station switchboard comprises three generator panels, one load panel, and three feeder panels. High-tension oil-break switches are to be provided, operated by means of controlling apparatus on the panels. The switches, bus-bars and all high-tension apparatus will be in brick compartments separate from the board. In each generator circuit there are two non-automatic oil-break switches in series; and on each feeder circuit there are two overload time-limit oil-break switches in series. The two oil-break switches in series on the same circuit can be closed separately and then opened to test the switches without closing the circuit. With the switches in the closed position they are both operated at the same time by the controlling apparatus, to ensure opening of the circuit, and to put less strain on the switches although either one is capable of opening the load.

There will be nine transformer substations distributed along the railway line. Each station will contain two 250 K.W. oil-cooled lowering transformers, supplying approximately 1,000 volts to the trolley system. Two transformers are used in each station so that in case of accident to one transformer the station will not be entirely crippled.

It is the intention of the railway company to operate a D. C. road already equipped with the direct-current system. The present D. C. car equipments are to be retained, but the current will be supplied from a rotary converter substation fed from the main system of the W. B. and A. Railway. As this system is single-phase, it is necessary that single-phase rotaries be used in the substations. There are to be two 200 K.W. 550-volt rotary converters. These are 4-pole, 500-revolution machines. The general construction of these machines is very similar to that of the Westinghouse polyphase rotary converters. The armature resembles that of a polyphase rotary except in the number of collector rings, and in certain details of the proportions made necessary by reason of the use of single-phase. The commutating proportions are so perfect that any reactions due to the use of single-phase will result in no injurious effect. The field construction is similar to that of a polyphase rotary. The laminated field-poles are provided with dampers of the "grid" or "cage" type, a form used at present in the Westinghouse polyphase rotary converters. The dampers serve to prevent hunting, as in the polyphase machines, and also to damp out pulsations due to single-phase currents in the armature. The damper acts to a certain extent as a second phase. Each rotary converter is started and brought to synchronous speed by a small series A. C. motor on the end of the shaft. The voltage at the motor terminals can be adjusted either by loops from the lowering transformer or by resistance in series with the motor, so that true synchronous speed can be given to the rotary converter, before throwing it on the A. C. line.

From the preceding description of this system and the apparatus used on it, some conclusions may be drawn as to the various fields where it can be applied to advantage. It is evident that a good field for it will be on interurban long-distance lines such as the W. B. and A. Railway. On such railways, high trolley voltage and the absence of converter substations are very important factors.

For heavy railroading also, this system possesses many ideal features. It allows efficient operation of large equipments at practically any speed and any torque, and also avoids the controller troubles which are ever present with large direct current equipments. It also permits the use of high trolley voltage, thus reducing the current to be collected. In this class of service the advantages of this A. C. system are so great that it is possible that heavy railroading will prove to be the special field for it.

For general city work, this system may not find a field for some time to come, as the limitations in the present system are not so great that there will be any urgent necessity for making a change. It is probable that at first it will be applied to new railways, or in changing over steam roads rather than in replacing existing city equipments. One difficulty with which the new system will have to contend, is due to the fact that the A. C. equipments cannot conveniently operate on existing D.C. city lines, as is the present practice where interurban lines run into the cities. It will be preferable for it to have its own lines throughout, unless very considerable complication is permitted. When the A. C. system applied to interurban and steam railways finally becomes of predominant importance, it is probable that the existing D. C. railways will gradually be changed to A. C. as a matter of convenience in tying the various lines together.

As was stated above, A. C. equipments cannot conveniently be operated on direct current lines. It does not follow, however, that the motor will not operate on direct current. On the contrary, the motor is a first-class direct current machine, and if supplied with suitable control apparatus and proper voltage it will operate very well on the D. C. lines. This would require that the motors be connected normally in series, as the voltage per motor is low. A complete set of D. C. control apparatus would be needed when the A. C. equipment is to be run on direct current, and considerable switching apparatus would be necessary for disconnecting all the A. C. control system and connecting in the D. C. The complication of such a system may be sufficient to prevent its use, at least for some time to come.

In some cities, very strict laws are in force in regard to the voltage variations in various parts of the track system. The permissible variations are so small in some cases that an enormous amount of copper is used for return conductors; and in some cases special boosters are used in the return circuits to avoid large differences of potential between the various parts of the track system. The object in limiting the conditions in this manner is to avoid troubles from electrolysis. The A. C. system will, of course, remedy this.

For city work, it is probable that voltages of 500 or 600 would be employed instead of 1,000 or higher. The transformers and controllers can be designed to be readily changed from full to half voltage, so that low voltage can be used on one part of the line and high voltage on another. As the car equipments of such railways are usually of small capacity, it is probable that speed control will be obtained by means of a transformer with a large number of leads carried out to a control drum, rather than by means of the induction regulator, as the latter device is much more expensive in small units. This is chiefly a question of cost, and if the advantages of the induction regulator are found to over-weigh the objection of high first cost, then it will be used even on small equipments.

In the W. B. and A. Railway, the generators are wound for single-phase. In the case of large power-stations with many feeders, the generators may be wound for three-phase, with single-phase circuits carried out to the transformer substation; or three-phase transmission may be used, with the transformers connected in such a manner as will give a fairly well-balanced three-phase load.

There are many arrangements and combinations of apparatus made possible by the use of alternating current in the car equipments, which have not been mentioned, as it is impracticable to give a full description of all that can be done. But enough has been presented to outline the apparatus and to indicate the possibilities of this new system which is soon to see the test of commercial service.

PITTSBURG, Sept. 19, 1902.

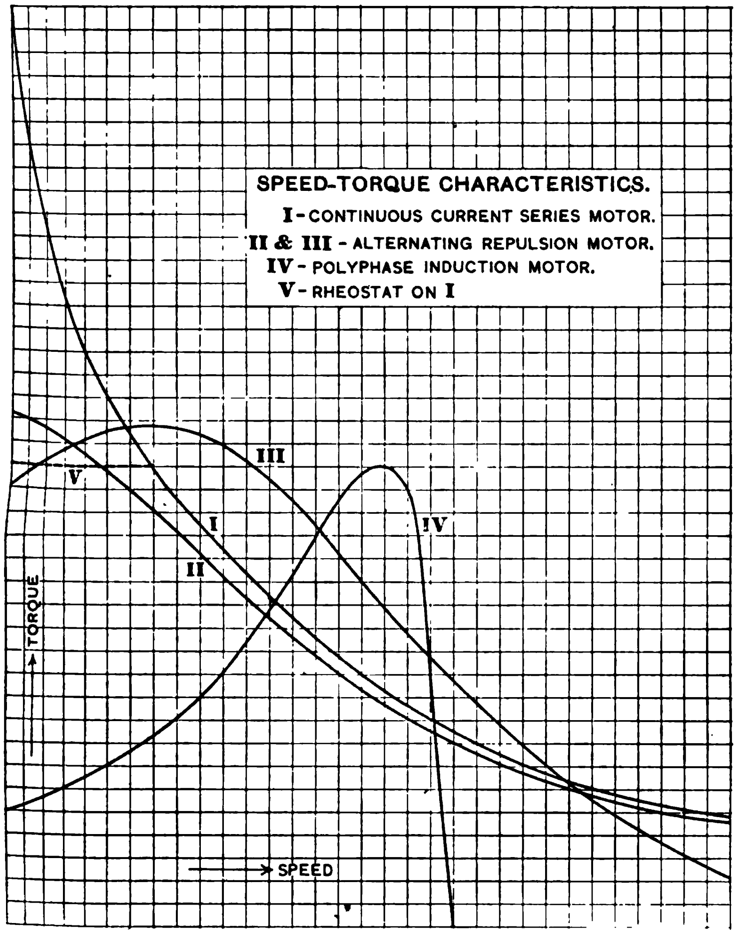
Discussion.

President Scott:—The subject is open for discussion. The papers have been in the hands of some of the members for the last day or two, and there may be some who are already prepared. The Secretary has given me a list of a few members who may be called upon. We will extend the courtesy of the floor to Mr. Steinmetz, if he will please to accept it.

Mr. Charles P. Steinmetz:—I have read with very great interest and listened to Mr. Lamme's very interesting paper, and I believe we can congratulate ourselves that he has agreed to make public first before the Institute a description of this railway system.

It is encouraging to me that, in spite of all that has been said in past years, American engineering is still in advance. That is, while in Europe, motors which we know are not suitable to the purpose are being applied to railroad work, our engineers have attacked the problem from what I consider the only proper side, namely, the development of motors which are adapted to that work, in their speed-torque characteristics. Now, during the last few years our friends abroad have become very enthusiastic over polyphase induction motor railroading, so much so that the American press has been affected. We have been told over and over again how unprogressive we are, and that we should take cognizance of the work done by our European friends. President Scott has to a certain extent dissipated this, by showing the relative proportions of European and American electrical engineering. I may say, however, that those American engineers in whose hands were placed the destinies of large engineering manufacturing companies, went over the field in 1894–95, experimentally and theoretically, and they very completely satisfied themselves that there is no more in the polyphase induction motor for railway work than there is in the continuous current shunt motor; and since that time they have over and over again, when the enthusiasm became too high, gone over the same field, and reached the same conclusions. I believe we can congratulate ourselves then that here is published the record of some work done in the direction of developing apparatus, giving the proper characteristics for alternating current railway work. I must confess, however, that I have been somewhat disappointed in reading this paper, by seeing that after all this new motor is nothing but our old friend the continuous current series motor adapted to alternating currents by laminating the field. Now, I remember this type of motor very well because I was asssociated with Mr. Eickemeyer in 1891 and 1892, and we spent a very great deal of time in building alternating current series motors, investigating their behavior, and trying to cure them of their inherent vicious defects. The principal defect was the serious inductive sparking at the commutator, due to the short-circuited armature coil becoming a short circuited secondary with the field of the motor as primary. We did not attain satisfactory results, and I hope Mr. Lamme will succeed better than we did. I believe there is some chance for it, because it was ten years ago that we did our work, and in ten years engineering here in this country has advanced a great deal, and furthermore, we at that time worked with somewhat higher frequencies than 16 cycles which are feasible now. We found that although such a series motor inherently has a very poor power factor, we have to run it at very high speed. I am gratified to see that Mr. Lamme operates his 16-cycle motor with a speed corresponding to the frequency of rotation of something like 47 cycles, nearly three times synchronous speed; therefore, we get a good power factor.

I must confess I really expect more from Prof. Elihu Thomson's repulsion motor, in which the main current does not pass through the armature, but the armature is short-circuited upon itself through the brushes, which are shifted against the lines of polarization. Now, if you consider the problem of the alternating current motor in its derviation from the continuous current motor, you will find that by natural steps the continuous shunt motor, by adaptation to alternating currents, leads to the polyphase induction motor, and by gradual steps you are led from the continuous series motor to the alternating repulsion motor, which gives a speed-torque characteristic, very closely resembling that of the continuous series motor. You know the speed-torque characteristic of the polyphase induction motor is this, a fairly low torque in starting, gradually increasing with speed to maximum, then decreasing to zero at a definitive speed, the speed of synchronism. You may improve the starting torque by shifting the point of maximum torque, by inserting resistance in the armature and wasting the power corresponding to the difference in speed of the motor without resistance, and with resistance. Now the continuous current series motor gives a speed-torque curve something like that, starting with a definite torque also at zero speed, and decreasing gradually, first fast and then slower, with increase of speed, never reaching zero, but continuously decreasing theoretically. Probably it reaches zero when this torque reaches the friction torque. Now this is not practical in railroading, because such starting torque is beyond the torque which will slip the wheels. If we take the alternating current repulsion motor, we find the torque turning over and reaching a finite point, that is, when you come to lower speeds, the reactance of the motor begins to be noticeable, and limits the current and torque. In general you see a torque characteristic similar to that of the series motor, with rheostatic control in starting, represented by Prof. Thomson's repulsion motor without any rheostat. Now it was this alternating current single-phase repulsion motor, which I was thinking of when in some previous discussions on alternating current railroading, I mentioned the inferiority of the induction motor, and stated that alternating current railroading will become feasible only when the single-phase motor is developed, giving characteristics of the series motor, that is, starting with maximum torque and giving a torque decreasing with the increase of speed.



MR. RALPH D. MERSHON:—This paper is certainly an extremely interesting one. The development of an alternating current system of traction has long been a " consummation devoutly to be wished," and apparently the consummation is with us. I am sure that we will all watch the performance of this road with a great deal of interest, because in this case, as in most other cases, the proof of the pudding will be in the eating. Although in this case we have apparently reached the development desired, by means of a single-phase series motor, I have not by any means lost hope for the induction motor. Not the induction motor which has been used up to date, because, as has been stated this evening and many times before, the characteristics of the induction motor as we know it to-day are those of the shunt motor, and it has the inherent defects accompanying rheostatic control; but an induction motor of somewhat different characteristics. I feel rather confident, almost confident enough to predict, that the time will come when the induction motor for variable speed work will be a motor which will, just as truly as the motor which has been described—and perhaps more efficiently—develop power at speeds below the maximum speed, in proportion to the power taken from the supply circuit. In other words, that we will be able to graduate the speed of the motor, not by means of a rheostat and thereby lose power in proportion to the difference between the full speed of the motor and the speed at which you are operating, but by means enabling us to take from the alternating current circuit, power which will be in amount closely proportioned to that which the motor develops.

I should like very much to have the author, if he will, speak a little more of the elements of design involved in accomplishing some of the results which have been attained. I should like to know the means taken to reduce the secondary sparking spoken of, and I should like also to hear from him in regard to the methods of design by which the high power factors were obtained. I am inclined to think that this was due not only to the facts mentioned by Mr. Steinmetz, that is, the high speed relative to the frequency speed of the motor, but also to the number of poles which is greater than that used in direct current practice, and I should like to ask also if the power factor results might not be considerably bettered by increasing the number of poles.

PRESIDENT SCOTT:—If Mr. Lamme will kindly make note of these points we will give him an opportunity at the end of the discussion to reply, We have with us this evening from the middle West a man whom you have just elected to the Council, who is the representative of the electrical interests in the coming St. Louis Exposition, and who has in the past year conducted some extended tests on an extensive interurban railway in Indiana—Prof. Goldsborough.

PROF. W. E. GOLDSBOROUGH:—I doubt if there is any engineer in America who has been more confident than myself, that some day we would run our railways by the alternating current. I was once so bold, a number of years ago, as to say at one of the conventions of the National Electric Light Association, when the Wagner single-phase motor was having rather a hard time, that I had a great deal of confidence in the single-phase problem surviving, and I still feel that in the end we will develop a motor which will be applicable to the railway, and which will be the single-phase alternating current motor, without the defects of the direct current railway motor. Just what that solution will be, I am not prepared to say, because I don't know, but I think the engineers in the great factories of America, who are working on this problem, will eventually evolve something that will perform the work as I have outlined it. We are now just entering upon a new field in electric railway work. For a long time we were confronted by numerous systems for the application of direct current, and I presume during the next five or six years we will be confronted by numerous systems for applying the alternating current. In a few years from now, however, we will hear of "the standard single-phase alternating current railway equipment," and by that time there will be but one system in evidence. What that one system will be I do not believe any man here to-night knows. When that day comes I think we will have entered upon a great railway era in America. We will probably see all our trunk lines equipped with electricity. I doubt very much if that will take place prior to the time that the single-phase system is perfected for electric railway service, and I believe when that day comes that we will all be a great deal happier than we are now. The American people are essentially a traveling people, and how much pleasanter and cleaner and more delightful it will be to ride in electrically propelled trunk line trains than to be covered up with soot and cinders from our present locomotives.

I do not know that I ought to say anything that is derogatory to the steam railway problem, while under the roof of the American Society of Mechanical Engineers, yet I am certain that in this coming work, which we all foresee, the mechanical engineers will join with us in wishing it God speed, because nothing that will promote engineering from the electrical standpoint will do anything but promote engineering from the mechanical standpoint. The day is coming when the engineer will not be either electrical or mechanical; no man will be an engineer who has not a complete grasp of both sides of the profession.

It is a great pleasure for me this evening to have contributed to the discussion of the paper, and I think we all owe a vote of thanks to Mr. Lamme and Mr. Arnold and other of our engnieers who have been courageous enough to start out in this new field and *do something.*

PRESIDENT SCOTT:—Mr. Lamme has presented his paper and received the thanks of Prof. Goldsborough. Prof. Goldsborough has extended his thanks to Mr. Arnold, also, before Mr. Arnold has told us what he has developed. Mr. Arnold, by the way, is a new member of the Council, and is on the Committee on Papers for next year. He promises to do some active work in the Chicago local organization

MR. BION J. ARNOLD:—I have some photographs and drawings here in an envelope, but I do not think I will show them to-night. I came prepared to disclose additional information regarding my single-phase alternating current system provided Mr.

Lamme should show photographs or anything which would enable one to gather a comprehensive idea of his system, but he did not show us enough, and until he tells us more I think I will say nothing more about my system, as some months ago I announced the principles upon which it is built.

I do not mean by this action any disrespect to the INSTITUTE, but I would like to defer what I may say in regard to my work until a suitable time, so that I may say it in a proper way, or at any rate until I can get it so shaped that I can give full and complete information.

I did not see Mr. Lamme's paper until a short time before entering this meeting, but thinking possibly he would give more complete data or show photographs of accomplished work, I came prepared to show what I have done. I am very much interested in the development of his system, and wish to express my appreciation of his work, as I am glad to see him come out and stand for the single-phase alternating current motor for railway work. Still more pleased am I to see him, representing, as he does, a large manufacturing company in this country, come out and stand for it, for but one year ago it was not only difficult to get representatives of his company to do it, but they took a very decided stand against it and in favor of the direct current motor.

I think that my sentiments on this question are pretty well-known and can easily be ascertained by reading the records of the INSTITUTE for the last three years. I advocated the alternating current motor at the joint meeting of the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS and the British Institution of Electrical Engineers at Paris in 1900; again, and against considerable opposition, at the annual convention of this INSTITUTE at Buffalo in 1901, and again last June at the Great Barrington convention, when, as is known, I announced the principles of the system that I have developed, and of which in the course of sixty or ninety days, I hope to present full details to this INSTITUTE, together with drawings and photographs of the full working system, and it is because I do not wish to spoil that paper that I hesitate about showing what I have here to night.

Now, there is one point in Mr. Lamme's paper which I am quite sure he will correct, if he thinks I am right. Rather, I would say that I do not know whether he personally intends to make the point or not, although the statement is definitely made in the preliminary articles, relating to this road, which recently appeared in the technical papers. That is, the conclusion to be gathered from his paper that this road between Washington and Baltimore is the *first single-phase railway in this country*.

In a modest and mild though emphatic way, I must resent that statement, because in December, 1899, or early in 1900, I took a contract to build complete 60 miles of railroad and use single-phase motors upon it. That road has been located, graded, bridged, and equipped under my direction, under my own engineers and construction force, and 20 miles of it is now being operated with steam locomotives.

The trucks, cars and some of the motors are nearly ready to run, as can be shown by the photographs which I have with me and I believe that this road, when it runs, is entitled to be known as the first road equipped with single-phase motors.

Now, with this correction in Mr. Lamme's paper I have no further criticism to make, for I concur with him in his belief in the advantages of the alternating current road as described in the paper, many of which I have, from time to time, pointed out, as evidenced by the records.

I think that the essence of his paper is summed up in one paragraph, in which he says that he has succeeded in making an alternating current, single-phase motor operate in starting under load by means of a commutator, *without sparking*. If Mr. Lamme accomplished this successfully, he is entitled to great credit, and I have no doubt that he has largely accomplished it since he says so, on his experimental motor, but he has not done it yet on the scale he hopes when he gets his railway running, and if he does it efficiently on a large scale with motors of the size he speaks of operating under the varying conditions of railway work, he will deserve all the credit we can give him.

I do not know that I have another word to say on the subject, and I will, therefore, ask you to excuse me from giving any further information regarding my own system until I can present it in the proper way, and be in position to answer all questions fully and frankly.

DR. W. S. FRANKLIN:—There is one idea that has impressed me very much in listening to the paper, and that is the fact that we are going back to such old-style and well-known apparatus. It is a curious fact, I think, that early alternating current work began with such high frequencies. I think the reason of that, no doubt, is that the earlier electrical engineers worked with toy apparatus, which was necessarily driven at enormously high speed to get any output, and along with that went, of course, the necessity of high frequency. There has been a remarkable drop in frequencies in the last ten years, and the question in my mind is whether we may not see still greater drop in the future. The tendency to low frequency, of course, has been to get rid of inductance troubles, and at the same time to permit of the use of enormously large units.

PRESIDENT SCOTT:—We have with us this evening a gentleman who has been in other parts of the country, and in other countries, for a number of years. He was at one time an engineer on the Pacific coast. For the last few years he has been an engineer in charge of important transmission work in Mexico. Although he is not now connected with the INSTITUTE, he assures me that he soon will be—Mr. Norman Rowe.

MR. NORMAN ROWE:—You certainly surprise me, Mr. Scott, in calling upon me this evening, as I had no idea of taking part in the discussion. I think those men, however, who have been with the Westinghouse Company, who know Mr. Lamme and his work, appreciate the fact that when Mr. Lamme says that he has got a motor which will develop 100 horse power, a single-phase motor that will run without sparking, and is good in all other respects, that he has there the elements of a system which will undoubtedly revolutionize street railway work, and will open a vast field in the future for trunk and interurban work. I do not care to say anything more than this. Others of you may think that possibly it is an experiment. But I know it is more than experiment; I know it is a reality.

PRESIDENT SCOTT:—It just occurs to me, gentlemen, that although this is a New York meeting of the INSTITUTE, so far there has not been a New York member who has had the floor. We want to come around to New York, and we will call on our good old friend, Mr. Mailloux.

MR. C. O. MAILLOUX:—I was wondering after Mr. Arnold spoke whether I would have an opportunity to say something, because on all occasions when the case of alternating versus direct current for railroad work has been discussed, it has happened that somehow or other, Mr. Arnold and I, good friends as we are, have differed somewhat. We still differ. There has been something said about the manner in which Amercians have been criticized for their apathy towards the alternating current system and I think that I may personally accept the responsibility for a great deal of that apathy. If you look over the TRANSACTIONS —Mr. Arnold having called attention to the TRANSACTIONS in regard to what he said, I cannot help following suit—you will find that I have been one of the skeptical engineers, who have been slow to believe in the possibilities of the alternating current system in railroad work. You will find that at a previous meeting, notwithstanding the papers by two able European engineers, both members of this INSTITUTE, which papers were calculated to show us what wonderful things the alternating system was doing in Europe, I still wished to remain unconvinced. Now, the reasons which I advanced still substantially exist. I said then that the alternating current system must undergo a great deal of development before it can hope to contend with the direct current. I admit that, this evening, we have before us the perspective of some important steps in a direction that may give us an opening towards a satisfactory solution of the problem of railway operation by means of the alternating current. In all discussions thus far but little if any attention has been paid to the single-phase, alternating current system. We have always had the polyphase system, with the induction motor especially, as the solution suggested, more, perhaps, because that is the only method which seems to have been thought of and utilized by European engineers in the many installations which they have made of alternating current railroad systems. It is certain that if we do away with one of the two leading conductors, that will remove a serious objection which hitherto could be urged against the alternating current system. The system proposed to-night is one which opens that perspective, and promises that feature. It still has to accomplish a great deal; it proposes to do it by presenting a motor which will have the characteristics and the working qualities of a series direct-current motor; in fact, it is nothing but a series direct current motor adapted for alternating currents. Unfortunately, the paper does not tell us very much about the manner in which the author proposes to obviate the inherent defects of such a motor. In reading the paper carefully, I failed to note that the author introduces any radically new feature, and I concluded that so far as the paper discloses ideas, one is led to suspect that he depends more upon features of design and proportion than upon original ideas, either in manipulation or control. Now we do not know, of course, what merit there may be in this; only practical experience can tell us. Mr. Lamme's friends, who seem to be here in numbers, assure us of his ability to cope with this subject. We all know and admit his reputation as a designer, therefore we may feel warranted in hoping that he has indeed found a satisfactory solution. I cannot at the same time feel quite as enthusiastic about it as either Mr. Lamme's friends, or as Mr. Arnold. I do think that it pays to be slightly conservative. I have started out to be conservative on this question, and I am going to remain so, so as to be consistent, at least. I believe that we have before us a beautiful perspective, but whether it will be a reality is something that only time will tell us, and can tell us. I am more inclined to take Prof. Goldsborough's view. I think that he takes a practical, sensible view of the entire situation when he says that some years will elapse before an alternating current railroad system can become as much standardized as the direct current railroad system, and that no one here, this evening, would be able to tell us what will be the standard alternating railroad system. There is a great deal of truth in that "conservative" statement. I also think the remarks of our Past-President, Mr. Steinmetz, are extremely suggestive, as they point out other methods which appear to be really more promising than those which are outlined in the paper. I can speak impartially because I am not interested on either side. I am very much in the attitude of one who is looking at a contest without caring much which side wins, or whether any side wins. I am perfectly willing that both sides should win. I still believe what I said the last time we had occasion to discuss this question, when I took the conservative view, namely, that there is a great deal of good work that is being done to-day, and that will be done for some time with direct current apparatus, for the simple reason that "it is better to be sure than to be sorry." It is better to stick to the evils that we know of, than to fly to others that we know not of, and while I have a great deal more faith in the alternating current system than I had before I heard Mr. Lamme's paper, yet I am still conservative. I think it would be very interesting indeed to get the results, and I am inclined to wait for them before I become unduly enthusiastic. I hope that Mr. Lamme, or his colleagues, may be induced to give us some actual results as a sort of supplement to this paper, a year, it may be, after the road has been completed. In the meantime I would not advise those who have electric railroads to build where the conditions are first rate for direct current motors—such conditions as I have outlined in my previous discussion—namely, where you have high speed work and many stops, to wait for new systems, but to use direct current motors. It may be that these can also be improved. It may be that stimulated by the forthcoming competition of the alternating current motor, our good friends who have been directing their time to the direct current motor may also find some way of making them do a little better than they are doing now.

PRESIDENT SCOTT:—Are there any others who desire to take part in the discussion?

MR. JOSEPH SACHS:—Assuming that both sides will win, which is probably a reasonable assumption, the matter of detail is a question that will arouse a little attention, if not from the strictly scientific end, at least from the man who runs the road. I have been very much interested recently in the matter of satisfactory suspension apparatus for high potential railway wires, and am very anxious to hear from Mr. Lamme what method he has adopted for suspending the 1,000-volt wire for the railway system that he speaks of. Whether he has stuck to the old methods of insulation, or whether he has adopted something else.

MR. WILLIAM C. GOTSHALL:—When Mr. Arnold began to speak, I became very much interested. I was really afraid that he was going to give away some salient point of some new system. When Mr. Mailloux spoke, I became even more interested, and, if anything, more alarmed, for I feared Mr. Mailloux was going to give away something relating to a system which is being developed in connection with an electrically operated high-speed railroad, which I have something to do with. Mr. Mailloux is eminently qualified to speak of the alternating current system referred to in Mr. Lamme's paper, or, in fact, upon any alternating current system. Mr. Mailloux and I spent about a year trying to find out whether the alternating current could be used on a certain railroad. The results of our conclusions were that we would have to use direct current.

On arriving here this evening, I discovered a gentleman from the Middle West with whom it was my good fortune to be associated about nine or ten years ago in St. Louis. We were both interested in developing the business of a large alternating current station, and in connection therewith spent considerable time in an attempt to develop a single-phase alternating current motor. We found that the motor was entirely applicable for very small powers, that is, for fan purposes. Incidentally, we learned a good deal about the single-phase alternating current motor, all of which knowledge is possessed by the gentleman to whom I refer. This gentleman, I believe, knows as much about alternating currents as anybody in the country, and I would like to have the Chair call upon Mr. Herbert A. Wagner to add to this discussion by stating some of his experiences with the single-phase alternating current motor.

PRESIDENT SCOTT:—The suggestion is most appropriate—Mr. Wagner.

MR. HERBERT A. WAGNER:—After such an introduction I hardly know what to say. I have had some experience with alternating current motors, and it gives me the greatest pleasure to see a dream, which I have had for years, about to be realized in the form of a successful alternating current, single,-phase railway motor. I have always been an advocate of single-phase alternating current motors, and spent a great many years in experimenting to develop such motors, with some measure of success, for stationary work. My experiences during years of experiment in that line could hardly be told in a few minutes. Some of them were very discouraging. Most of them, in fact. I happen to know that Mr. Lamme has not experimented with such a motor for a few months only. I think I remember many years ago in Pittsburg, in the early nineties, probably, of seeing a street railway motor mounted on trucks, and some brake tests being made. I was told that the motor or motors—there were two, I believe—were single-phase alternating motors with commutators, the motors being very similar to the direct-current railway motors then being made by the Westinghouse Company, adapted to the use of alternating currents. I did not know what success was achieved with those motors at that time, but I did know that they were not put into commercial use for some reason or other.

With Mr. Steinmetz I think that there is also a future, a very promising future, for the type of motor known as the Thomson repulsion motor. I have experimented to a great extent with that class of motor myself. I know that the sparking, especially at low frequencies, can be overcome, and I have no doubt that that motor can be developed, in time, for street railway work. I am also pleased to see the introduction of single-phase, rotary converters. I think some years ago in a paper read before the National Electric Light Association, I made the statement that there would be on the market before many years a single-phase rotary converter, and that the design of such a machine ought not to be much more difficult than that of the polyphase, although the output would of course be somewhat less for a given amount of material. I should like to ask Mr. Lamme about some of the details of the construction of his motor, particularly with reference to the air gap; whether it is not necessary in order to obtain his high power factor to use a very small air gap; also, I should like to know if the field of the motor is constructed with the ordinary polar projections of the direct current motor, or whether it is a ring provided with slots into which the windings are placed, and if so, whether the field winding is a distributed winding or a concentrated single coil winding.

MR. ELIAS E. RIES:—At previous meetings of this INSTITUTE a number of papers were read and more or less discussion indulged in with reference to the operation of railways, particularly trunk line railways, by means of alternating currents, and on all of those occasions, as the TRANSACTIONS will show, I have uniformly been one of the foremost advocates of the alternating current motor for that class of work. One peculiarity of the installation now proposed is the fact that it happens to take place on the line between Baltimore and Washington—Baltimore being the city in which I formerly lived—and I remember that some years ago, I think it was in 1893 or 1894, there was a movement on foot to build what was called at that time a " Boulevard Electric Railway " between those two cities, over what was then a record distance, the proposed road being about forty miles long.

I had previously given considerable study to the question of applying alternating currents to operate long distance electric railways, having taken out the first patents ever granted on this subject, which as a result of my experiments in this direction, I applied for as early as 1887.

When this boulevard road was proposed, it was the intention of its projectors to operate it by means of the direct current, using a three wire transmission system with a difference of potential of about 1,000 volts between the two outside wires. I felt satisfied however, that this road, if built, could not be operated with any commercial success upon that plan, and that a system of transmission and distribution involving the use of a high tension alternating current transmission line with either static or rotary converter sub-stations was the only feasible one.

I finally proposed a method for operating that line by means of a single phase, alternating current system. I figured out the details, and in many respects they were substantially similar to what we have listened to to-night. That is to say, I proposed using a 5,000 volt alternating current transmission circuit supplying energy at high tension to about eight converter stations, using, preferably, static transformers to transform the primary voltage to a low secondary or working pressure of about 500 volts, and also using a series motor with laminated fields. I likewise designed and recommended as an alternative type, a constantly running synchronous motor, provided with a variable pressure friction clutch mechanism for starting and controlling the speed of the car. There were a good many difficulties, however, in the way, that being at a very early stage of the art, and I therefore did not succeed in making much of an impression upon the experts employed by the road, which it subsequently turned out, was never completed. In view of my own experience I am very much pleased to learn to-night from Mr. Lamme's paper that he has gone so thoroughly into the details of the single-phase alternating current railway system that I then proposed, particularly in the matter of regulation and adjustment of the car motor conditions, which from the experiments he has made, lead him to believe that a single-phase motor, on the plan of the old series motor, is apt to be productive of good results.

In September, 1896, I believe, a paper on the same subject was read before this INSTITUTE by Dr. Louis Duncan, with whom I was in consultation at the time of this proposed Baltimore equipment, and in the discussion following the reading of that paper I also took an active stand in regard to the advisability of using alternating current single-phase motors as soon as a commercially practicable motor—better than those with which I have experimented—was forthcoming or was put upon the market by the large electrical manufacturers. I might say that I have always taken an active interest in the matter, as I was one of the pioneers in the art of operating railways by means of alternating high-tension transmission currents, that are converted at intervals along the line of way by means of suitable apparatus into low-tension working currents which are then fed to the car motors. For that reason, among others, I am very glad to see that the matter is receiving the attention that it is at this time. There have been a good many skeptics among our members in the past, as has been stated here to-night, but I was never one of them; I always felt confident that the time would come shortly when my early ambitions and faith in this method of operation would be realized and when we would see the single-phase alternating current system, with its manifest advantages over the direct-current system, taking first rank in matters of railway operation.

PRESIDENT SCOTT:—If there are no others who care to take part in the discussion, we will give the floor to Mr. Lamme.

MR. LAMME:—I have only a few comments to make. Some doubt has been expressed in regard to the sucecss of A. C. single-phase motors of 100 h.p. size, which is that to be used on the Washington, Baltimore and Annapolis Railway. It is stated in the paper that motors of this size have been tested. The engineers of the Cleveland Construction Company selected the 100 h.p. size because they had actually seen them in operation in the factory.

Several speakers have referred to this as a proposed system, but we wish to call attention to the fact that it is not simply a scheme, but a system which is so far advanced that the contract has been taken and the apparatus is being manufactured. It is not something which we hope to do, but something which we are doing.

In the discussion this evening, reference has been made to the repulsion motor, which is the type in which the field is connected across the line and the armature brushes are short-circuited on themselves and set at an angle to the ordinary neutral point. This type is mentioned on page 1236 in the August and September number of the TRANSACTIONS. The opinion has been expressed by several speakers that the repulsion type of motor is better suited than the straight series motor for the service proposed. We have investigated both types of motots and consider that the repulsion type is not so suitable as the straight series. There are some very serious disadvantages with the repulsion type of motor in this class of service. The construction is more complicated as the reversal of the direction of rotation is not so easily accomplished as in the plain series motor. Analysis of the motor shows that there are other important objections which will count heavily against it. According to our calculations, the repulsion motor will be larger and heavier for same output. It appears, therefore, that the series motor is the more suitable one for railway work.

Some questions have been asked in regard to the high power factor obtained with the motors to be used on this railway system, and it has been suggested that the large number of poles and the low frequency had something to do with the good power factor. In answer it may be stated that the frequency, of course, will have considerable to do with the power factor of the motor but there are many other points entering into the construction that have an effect on the power factor. There are so many of these points that no one of them should be credited with any great gain. The entire proportions of the motor have to do with the results obtained as regards power factor. With a 4-pole motor a good power factor can be obtained—with a 12-pole motor perhaps slightly better can be gotten. It is probable that the 4-pole motor would be so nearly like the 12-pole in many features that it would be difficult to note the difference, but in some particular points either one would show some advantage over the other. The number of poles chosen was that which appeared to give the best average results.

The opinion has been expressed this evening that we are practically going back to an old, well-known type of motor. Looking at the motor as a whole, it may appear to some that there is nothing new, but nevertheless here is a plant which will be put in operation with a type of motor which some consider to be old, but which accomplishes a result that has not been attained before. That fact indicates that there must be some features in this apparatus which have not been utilized before.

Some reference has been made to the single-phase rotaries. One reason why single-phase rotaries have not been used heretofore has been due to the fact that there has been comparatively few occasions where their use was necessary. Rotaries have been called for principally in connection with polyphase plants.

Polyphase rotaries, of course, possess some advantages over single-phase; but the difficulties of construction of the single-phase rotaries are not great, and where there has been occasion for such machines, and supply conditions have been suitable, it has been the practice of the Westinghouse Company to bid on them. Polyphase rotaries have been frequently operated single-phase for temporary purposes. There are cases where they have been operated single-phase for several weeks at a time with satisfactory results.

Mr. Arnold has called attention to the fact that this is not the first example of the single-phase railway. So far as I know, this is the first example in which the scheme of operation is a purely electrical one. If there are other roads ahead of this one, of course this road cannot have the credit of being the first.

MR. MERSHON:—Mr. President, Mr. Lamme has omitted answering some of the most interesting questions, the question of sparkless commutation, the question of air gap and the question of type of field winding, are not only of great interest from the designer's standpoint, but of great interest from the practical standpoint. It is to be regretted that Mr. Lamme cannot see his way clear to give us fuller details.

MR. STEINMETZ:—Before you conclude, I should move a vote of thanks to Mr. Mailloux for his contribution to the library, which establishes a precedent in supplying us not only with books, but also with an endowment to take care of the further issues of those periodicals.

The motion was carried.

PRESIDENT SCOTT:—Mr. Mailloux has the thanks of this INSTITUTE.

MR. MAILLOUX:—I rose primarily to speak on the paper. Having been honored by the kind vote of the gentlemen present, I would first make a few remarks on this subject. I am more than repaid by your generous appreciation. I thank you. I know that there are many who can do at least as well, and many very much better. I hope they will all do it, and all do it immediately. We have a society that has been growing very fast. It has had a brilliant past, but it has and should have a much more brilliant future. Let us all help to make it brilliant. As the President stated, we ought to have—and figures will not lie—25,000 members. I hope we will get them. One of the ways of getting them is to get a fine library, and a fine building. This meeting, with its overflowing attendance, has shown the necessity for a fine and large building. We cannot accommodate the members in a building of this size. We ought to have one twice as large. I hope you will all go home and think about it, gentlemen, and that your thoughts will bear fruit.

Now about the paper. Generally, I want to state that the reason why some consulting engineers like myself are skeptical and conservative is, possibly, because those who are interested in designing and introducing alternating current systems are mysterious and uncommunicative about them. I must state that while I am skeptical, I have never been lacking in openness to conviction. I think you will find in all the discussion wherein I have participated, that I have always manifested a disposition to accept progress and welcome it. I have stated in previous discussions that there are many cases for which I was desirous of finding an alternating current system. I would gladly welcome it, and I am very glad to see progress evidenced this evening. At the same time I must say that I would be better satisfied if we could get more complete and satisfactory technical information as to the features whereby the mysterious and wonderful results enumerated are to be obtained. I have previously stated that there did not seem to be anything radically new in the paper which could account for these results, and that they must be accounted for, if at all, by certain peculiarities of design and proportion, and it seems to me that we are missing the heart of this discussion, as Mr. Mershon has intimated, when we fail to elicit information as to those very important points.

PRESIDENT SCOTT:—Mr. Lamme may have the floor again.

MR. LAMME:—The information which has been asked for in regard to the constructional features of the machine will probably be given at a later date. At present there are good reasons why it is not desired to give some of that information. When the proper time comes the whole of it may be given.

MR. WAGNER:—I asked one of my questions, with reference to the air-gap, as having a bearing on the mechanical construction and operation of such a motor. If the air-gap has to be very small, it is a mechanical question as to how often the bearings will have to be renewed to prevent the armature from brushing the field. Such questions, engineering questions like that, I thought might be answered. There was one other question that I wished to ask. Of course if Mr. Lamme prefers not to answer, very well. I want to know if the motor can be reversed without resetting the brushes; that is, can a position be found for the brushes which is equally good for either direction of operation. I do not wish to pry into any details of electrical design which may not be fully covered or protected at this time.

MR. LAMME:—The question has been asked in regard to the air gap on the motors for the Washington, Baltimore and Annapolis Railway. The clearance over the armature in these motors is practically the same as that between the pole piece and the bands in ordinary D. C. railway motors. The question has also been asked whether it is necessary to shift the brushes of these motors when the direction of rotation is to be reversed. In answer, it may be stated that the brushes are on the true neutral point as in D. C. railway motors and the brushes are not shifted when the direction of rotation is changed.

MR. P. K. STERN:—I believe that I understood Mr. Lamme to say the brushes were set in a position 45° from the neutral point.

PRESIDENT SCOTT:—The reference is to another type of motor, I think. If there is nothing further, gentlemen, the motion to adjourn is in order. [ADJOURNED.]

PITTSBURG LOCAL MEETING.

MINUTES OF MEETING HELD FOR THE ORGANIZATION OF A LOCAL BRANCH OF THE AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS, AT PITTSBURG, PA.

In accordance with the suggestion made by President C. F. Scott in his presidential address and on invitation from the Electric Club, Mr. C. W. Rice, Chairman of the Institute Committee on Local Organization, called a meeting for the organization of a local section of the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS in Pittsburg, to be held in the Lecture Hall of The Electric Club, Monday evening, Oct. 13th.

The meeting was called to order by Mr. C. W. Rice.

Mr. Rice was elected Chairman of the evening and Mr. C. E. Skinner, Temporary Secretary.

The following resolution was adopted:

Resolved, That a committee of five (of which the present Chairman shall be one), be appointed to call a second meeting, to provide a programme therefor, and to propose a plan for a permanent organization.

The Chair appointed Mr. P. M. Lincoln, Prof. S. M. Kintner, Mr. F. B. Erwin, Mr. J. S. Peck and Mr. Calvin W. Rice.

Chairman Rice gave a short talk on the desirability of those engaged in electrical pursuits becoming members of the INSTITUTE and read sections of the Constitution, giving the requirements of membership and the initiation fees and dues.

Mr. Scott, President of the INSTITUTE, was then called upon to read his address entitled, Proposed Developments of the INSTITUTE, which was delivered on his inauguration as President at the general meeting of the INSTITUTE in New York, September 26, 1902. Mr. Scott elaborated those points which were of special local interest.

Chairman Rice then called upon Mr. P. M. Lincoln to read Mr. Lamme's paper entitled " Washington, Baltimore & Annapolis Single-Phase Railway." Mr. Lincoln abstracted Mr. Lamme's paper, giving the more important parts. In conclusion, Mr. Lincoln called attention to the fact that Mr. C. P. Steinmetz, at the New York meeting, agreed in practically all engineering points presented in Mr. Lamme's paper. Mr. Lincoln stated that the extra losses in the rails are not really serious, as these can be reduced by increasing the voltage of the circuit, thereby reducing current. He stated that the extra losses in the rails are caused by the so-called " skin effect " when magnetic materials are used as conductors. Measurements made on the Manhattan Railway showed, under certain conditions, an increase in the line loss of about 400 per cent. when magnetic material was used on the circuit over that of non-magnetic material.

Chairman Rice then called for questions on the paper of the evening. These questions were answered by Mr. Lincoln.

Q. Why is the power factor variable?

A. For the reason that the inductive element of the input to the motors at any given current is a constant, whereas the power element is proportional to the speed. It is evident, therefore, that the ratio of these two quantities—which is the power factor—will increase with increasing voltage and therefore increasing power output.

Q. What is the power factor of the motor when starting?

A. From 30 to 35.

Q. Why are motors connected in series parallel instead of all in series?

A. Chiefly to reduce the voltage across the motors and therefore to reduce the strains on the insulation of the armatures.

Q. How is the induction regulator operated?

A. By air pressure.

Q. Why is the primary of the regulator connected in series with the motors?

A. To reduce current in the regulator and auto-transformer and therefore make them smaller.

Q. Why are the fields of the motors connected in separate circuits instead of directly in series with the armatures?

A. In order to enable the motors to be reversed by a single switch.

Q. Why are balancing coils used across the motor armatures?

A. In order to make use of static friction. With this arrangement it is not possible to slip the wheels to which one motor is connected without slipping all, and maximum tractive effort is therefore available.

At this point Chairman Rice called on Mr. N. W. Storer for a few remarks.

Mr. Storer stated that during the last few months, as the exponent of the D. C. railway system, he had been the recipient of much advice and many pitying glances, implying that he would soon be out of a job and had received many offers of new positions as the D. C. railway motor was sure to become a thing of the past. He said that in spite of this, the D. C. railway motor was still doing business and as far as he could see would continue to do so for some time to come. He also said that he welcomed the advent of the new A. C. railway motor as it solved one of the difficult problems in connection with railway work, viz., the long distance railway lines. With D. C. railway motors it is not practical to use more than 600 volts across the motor, or 700 volts on the line, on account of the liability to flashing at the commutator. He said he was particularly gratified to find that when the A. C. motor was to be adopted, the designers were compelled to use the old D. C. motor. There would be some disadvantages in the new system which did not occur in the old, one of these being the increased weight necessary, consisting of transformers and other apparatus on the car. Mr. Storer closed by saying that he was very glad to extend the right hand of fellowship to the new system.

Mr. Scott spoke of the fact that in the beginning there was a wide difference between the appearance of alternating and direct current machines, but that these differences have gradually become less, until at present there is a very close similarity, so much similarity that it is sometimes very difficult to distinguish one from the other during construction in the factory; and that it is notable that after so many attempts at alternating current railway work, the present motor is remarkably similar to the old direc-current series wound motors. He said that the paper by Mr. Lamme was more than a statement of a new motor; it was a broad statement of a complete new system, indicating how many things are required in the development of such a system, and how many things must be worked together in order to produce an operating system. If, for instance, the drop in the rails should happen to be several times greater than it is with the alternating current at the frequency selected, the present scheme might not be feasible. Mr. Scott referred to his introduction of Mr. Lamme at the New York meeting, where he said that Mr. Lamme had had to do either directly or indirectly with the development and success of practically all the machinery manufactured by the Westinghouse Company.

Chairman Rice asked that the members be perfectly free in giving to Mr. Lincoln, Chairman of the Committee of Permanent Organization, any ideas they might have in regard to such an organization.

A count of the INSTITUTE members present showed a total of 19, with approximately 120 Club members and guests.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

NEW YORK, October 24, 1902.

The meeting was called to order by President Scott at 8.30 P. M.

THE PRESIDENT:—The Chairman of the Reception Committee, Mr. T. Commerford Martin, has some remarks to make.

MR. MARTIN:—At the request of Mr. Scott, I have a great deal of pleasure in reporting to the members of the INSTITUTE, the work which has been done by members who were selected to coöperate with members of the other three national engineering societies, with regard to the founding of the John Fritz medal for achievement in the industrial arts and sciences. This movement had its inception last spring. This is Mr. John Fritz's eightieth year, and it was proposed to signalize that interesting event by the foundation of this medal, Mr. Fritz being, as many of you gentlemen know, the oldest living iron master and engineer in this country connected with the great underlying arts of the production of iron and steel. A general committee was formed. Its first meeting was held in these rooms, and that meeting was attended by your Chairman of Committee on Papers, Mr. Calvin W. Rice, by the Secretary, Mr. Pope, by Mr. William Maver, Jr., and by myself. Mr. Rice, as you know, has been called away from New York to assume very important duties. Our esteemed Secretary, Mr. Pope, had other pressing engagements, and I seemed to be the only member left of the Committee who had any leisure. The various committees of the General Committee were formed, and I have much pleasure and pride in reporting that we have raised a fund, to which the electrical engineers have contributed largely and liberally, of $6,000. The John Fritz medal to-day is an assured fact. We have paid out about $1,500 to Mr. Victor D. Brenner, an American sculptor, for the execution of the medal, and we have enough left in hand to provide a fund of about $150 a year, which will allow of the presentation of a gold medal every year of the value of about $100. It is proposed that the medal shall be awarded by a select committee of four members from each of the four national engineering bodies, four from the electricals, four from the mining, four from the mechanicals, and four from the civils. Should any society fail to coöperate in any given year, it is still proposed that the award of the medal shall take place if anybody is found deserving; and the remaining three or remaining two societies will constitute the necessary committee and executive body to award the medal. As far as I am aware at the present time, there is not the slightest doubt as to the coöperation of the four national engineering bodies in this very interesting and important movement. I believe it is the first time we have ever coöperated in anything of the kind, and that it should have achieved such an instantaneous success is an augury of the best character with regard to our mutual working together and coöperation in the future. I think it is necessary for the success of each of the four national bodies, that they should stand together rather than stand apart. So far as our own INSTITUTE is concerned, I understand that the following gentlemen will represent this INSTITUTE on the committee or council which is to award the medal. I presume it will be awarded within one year from the present time. The members of that committee are Mr. Charles F. Scott, Mr. Charles P. Steinmetz, Mr. Carl Hering and Dr. A. E. Kennelly. I am sure you will agree with me that no more appropriate selection could possibly be made.

Having achieved the first part of our purpose in the foundation of the medal and in having it executed by the best artistic skill that we could command in America, the next thing to do was to celebrate the event in fitting fashion. The John Fritz Medal banquet will be held in this city at the Waldorf-Astoria next Friday night, Hallowe'en, and the indications are that it will be one of the memorable banquets in this city. There are already subscriptions to the dinner for about 450, and as we are still a week away from the event, I think it is safe to say that we shall have at least 500 or 600 ladies and gentlemen present upon that occasion The representation of the INSTITUTE there is excellent and could hardly be better, but we are naturally desirous that the electricals should show up as strongly as they can on that occasion, and if any of you gentlemen wish to be present, I would like personally, in view of the honor which has been conferred upon me of making me a member of the Dinner Committee, to ask you to be present upon that occasion and to help hold up my hands. I want to see the electricals as strongly in this movement as possible, and I live in hopes of seeing the John Fritz medal conferred upon some of the members of the INSTITUTE, upon some of the gentlemen whom I have the honor to see before me at the present time.

The subscriptions to the John Fritz Banquet will be received by Mr. J. C. Kafer, the President of the Engineers' Club, at the Club, not later than Wednesday next, and from present indications, we shall have to close the list a great deal earlier. Personally, I feel the utmost pride and pleasure in the success of this first joint movement amongst the National engineering bodies of this country, and I live in hopes, also, of seeing medals like the John Fritz medal founded in our own SOCIETY.

THE PRESIDENT:—Mr. Martin is not only a member of the Dinner Committee, but he has the position to which he is entitled by proved ability. He is chairman of that committee. The Board of Directors of the INSTITUTE decided this afternoon that the INSTITUTE should be represented on the Board of Award of the John Fritz medal, by the three most recent past presidents, and by the present president. It is the intention each year to appoint the incoming president as a member of the Board of Award, there being one change each year.

The subject of the meeting this evening is " Photometry and Illumination."

A paper read at the 169th Meeting of the American Institute of Electrical Engineers, New York, October 24th, 1908.

PHOTOMETRY AND ILLUMINATION.

INTRODUCTION BY PRESIDENT SCOTT.

It is difficult for us whose streets and houses are illuminated almost as well by night as by day to realize that it was only a trifle over a century ago when inventors began to make improvements upon the primitive lamp which had done service for many thousands of years. The fuel for lamps was principally solid or fixed oils until the advent of mineral oils within the past fifty years. The general change from candle-sticks to lamp chimneys was in the days of our fathers and mothers. Gas lighting became common in London in 1816. The electric lighting on a commercial scale has come about with the easy recollection of all of us. It was the demand for illumination and the development of electric lighting which gave the electrical industry its great impetus and it is still one of the most important branches of electrical work. If time permitted, it would be interesting to study the influence of artificial illumination as a factor in civilization, to note its effect upon domestic affairs, social customs and industrial activity.

Light as a commercial product must be measured. Although it is one of the most common commodities and has been for years sold daily to millions of customers, yet there is scarcely any commodity in which the standards and methods of measurement are so inadequate. Gas is sold by volume and not by the quantity of illumination produced. Electricity is sold by the quantity of current or of energy, which is probably quite satisfactory to the central station. When, however, the measurement of the light itself is considered, the methods and the standards are inadequate and often illogical; for example, the candle power of an arc lamp has been so unscientifically stated that as a makeshift it is often designated by the watts consumed irrespective of the actual quantity of light or of the difference in the quality of light from various lamps.

Although the measurement of the invisible, intangible, subtle flow of electricity is effected with the greatest degree of refinement and precision by instruments which are the embodiment of simplicity in design, construction and operation and the electrical units of measurement are among the most definite physical standards, yet the measurement of light and of illumination is one for which the standards are not simple and convenient and for which the methods of measurement are difficult and inconvenient, and unsatisfactory and inadequate. Peculiar difficulties are inherent in the problem, as it involves physiological as well as physical elements. The only purpose of illumination is the production of a certain effect upon the nerves of the retina, and popularly speaking, it is the amount of this effect which is termed the intensity of the illumination. The color and character of the light, as well as its quantity, are elements of the first importance both objectively when considered in a physical and in a scientific sense and also subjectively in their relation to vision. These effects are by no means the same with different individuals nor are they constant with the same individual.

In discussing the operation of incandescent lamps on low frequency alternating current, the late Prof. Rowland once remarked that the proper test would be to have an old lady use the light for reading and see whether it hurt her eyes. At first this suggestion seemed rather out of place, but I rather think that the leading physicist of America was not far wrong when he proposed the physiological rather than the physical test to determine the suitability of a source of light.

In a scientific sense the quantity of the energy which is luminous and which is capable of affecting the retina is the important element when determining the efficiency of a source of light. This luminous energy is quite small compared to the heat energy which is wasted energy so far as the eye is concerned. In a physical measurement of the efficiency of illumination the total quantity of light emitted is the only quantity to be considered. In determining this it is necessary to obtain the total radiation and it is for this purpose that the mean spherical or the average candle power in all directions is measured. In general, it is not total illumination which is of practical consequence; it is effectiveness in illumination which is wanted, and not so many total candle power or so many watts consumed. Effective illumination involves quantity of light, color of light, distribution of light and the canons of adequate and acceptable illumination are physiological as well as physical. Two sources of illumination which emit the same aggregate quantity of light cannot be placed upon a commercial parity if one of them throws a greater proportion of its light up when the illumination should be downward or vice versa; nor if one gives yellow light which is less effective than the white light of the other; nor if one emits its light from a single intense source, whereas the other may send its light forth from numerous points or an extended area.

It is well to study carefully and make intelligent use of the physical methods of measurement. Such methods are certainly useful in comparing different lights of the same kind or order and they greatly assist one who is experimenting to increase the efficiency of a given type of lamp. But in our study of the standards to be used in the measurement of light and the methods and apparatus which are suitable it is fitting that we should have in mind the general problem of illumination. We must recognize that although electric lighting is of prime importance in contributing to the general welfare and in its commercial aspects, nevertheless, all of our present methods of producing electric illumination require an exorbitant expenditure of energy for the production of a given quantity of light on account of the large amount of waste heat; also that the present methods of supplying light usually give a distribution which is uneven, ineffective and unsatisfactory; and also that the present methods of measurement, although susceptible of a fair degree of physical precision do not adequately measure what is of first importance, namely, the effectiveness of illumination.

A paper read at the 169th Meeting of the American Institute of Electrical Engineers, New York, October 24th, 1902.

AN INTEGRATING PHOTOMETER FOR GLOW LAMPS AND SOURCES OF LIKE INTENSITY.

BY CHARLES P. MATTHEWS.

In a previous paper[1], I have described an equipment designed for the photometric study of arc lamps. The most valuable feature of this equipment lies in its ability to yield a value of the mean spherical luminous intensity from a single photometer setting. It is the purpose of this paper to describe an apparatus possessing this same valuable feature, and several others worthy of note, when used for the photometry of the incandescent lamp and other sources of the same order of brightness.

Designed especially for incandescent lamp measurements, the apparatus has several functions and might have been styled a "universal glow lamp photometer." It is capable of use for all photometric measurements on the glow lamp that do not lie in the province of spectro-photometry. To particularize, it may be used as follows:

(1.) As a simple photometer for any unidirectional measurements, such as occur in standardizations, ratings and candle-power distributions.

(2.) As an integrating instrument for the direct determination of mean horizontal, mean spherical, mean hemispherical or mean zonular candle-power.

(3.) As an integrating instrument for the direct determination of the *spherical reduction factor*; that is, the ratio—mean spherical: mean horizontal candle-power.

1. TRANSACTIONS, xviii, 1901.

THE IMPORTANCE OF THE MEAN SPHERICAL VALUE.

The fact has long been recognized[2] that the only strictly fair basis for the comparison of incandescent lamps, is that of the total flux of light emitted, a quantity proportional to the mean spherical candle-power. It is possible by altering the configuration of the filament to concentrate luminous flux in particular solid angles at the expense of flux in other angles. Hence, two lamps of equal rated candle-power may yield total light flux in quite different amounts. On the other hand, if two lamps have initially the same mean spherical candle-power, their relative value is determined simply by their power consumption and sustained candle-power. The vexed question of what is the most useful light may well be left to the purchaser, who can select the type of filament best adapted to his own needs. The question is comparable to that which asks: What is the best diet for man?

EXISTING METHODS FOR THE DETERMINATION OF THE MEAN SPHERICAL VALUE.

Of the methods in use in the determination of the mean spherical candle-power, the most accurate is that in which measurements are made at equal angular intervals through 180° in a plane passing through the axis of symmetry of the filament, the lamp being rotated meanwhile about this axis. From the readings so obtained, the mean spherical value may be found either by formula or the graphical construction known as the Rousseau diagram.[3]

The method employed in the Franklin Institute tests of 1884 involves the mean of 38 candle-power values taken in such directions at to give a nearly uniform space distribution. The mean of these values is the result sought.

Both of the foregoing methods involve a large number of readings—so large, in fact, that their application to the practical rating or extended study of lamps is out of the question.

A third method consists in the use of the spherical reduction factor appropriate to the type of filament under consideration. Unfortunately, this factor is not a constant for any given type

2. In 1897 a committee of the INSTITUTE reported as follows: (Transactions, page 90.) "Although incandescent lamps are at present rated by their horizontal candle-power, yet, since the only true criterion of the total quantity of light emitted by a lamp is its mean spherical candle-power, we recommend that the rating of lamps should be based upon their mean spherical candle-power so far as is commercially practicable."

3. TRANSACTIONS, September, 1901.

of lamp. With some types, the method yields a good result; with others the variations are such as to render the results only roughly approximate. A disadvantage is the large and increasing number of types on the market and the necessity for determining and keeping account of the corresponding constants.

Liebenthal found as the result of an extended series of measurements that the mean of the intensities taken at 51.8° north polar distance and 51.8° south polar distance on a spinning lamp is a value approximating the mean spherical intensity regardless of the type of lamp. The errors resulting from the application of this method range from −.1% to + 3.9%. This is probably the most accurate of the simpler approximative methods.

THEORY AND DESCRIPTION OF THE APPARATUS.

From what has been said, it would appear that there is need of a photometer capable of giving the mean spherical candle-power of an incandescent lamp with the ease and celerity obtainable in the ordinary photometric measurement. With this need in mind, I have designed and had constructed the apparatus decribed below.

The theoretical basis of the design is the approximate equation for the mean spherical intensity

$$I_{ms} = \frac{\pi}{2n} \sum_{0}^{\pi} I_\theta \sin\theta \qquad (1)$$

wherein I_θ is the intensity of a ray making an angle θ with a vertical passing through the light center and n the number of terms in the summation. In order that equation (1) may apply to a glow lamp, it is necessary to spin the lamp precisely as is commonly done in determining mean horizontal candle-power.

To see how equation (1) may be made the basis of an integrating photometer, let us consider a source of lights (Fig. 1), and a photometer screen P whose plane extended contains the effective light center of S. We will hereafter denote the center of the photometer screen by p and the effective light center by q. For convenience we will further assume that p and q lie in the same horizontal plane to which the plane of P is normal, and we will call the line $p\,q$ the axis of the system. Now consider two mirrors whose planes are vertical and make an angle of 90° with each other. Let the centers of these mirrors, designated by a and b, come into the horizontal plane in such positions that the lines $q\,a$ and $p\,b$ are equal and respectively normal to the axis of the system. Let a' and b' be the centers of a second pair of mirrors occupying a position such as would be found by swinging a and b, without mutual displacement, upward about $q\,p$ as an axis until $q\,a$ makes the acute angle θ with the vertical. Having thus located a' and b' angularly, we may now assume that some radial movement of this pair of mirrors is possible. The eye placed at p will see virtual images of the source in horizontal and θ aspects respectively. The images s' and s'' may be regarded as producing jointly an illumination on the photometer screen of

$$i_0 + i_\theta = \frac{K_0 I_0}{d^2_0} + \frac{C\, K_\theta\, I_\theta}{d^2_\theta} \qquad (2)$$

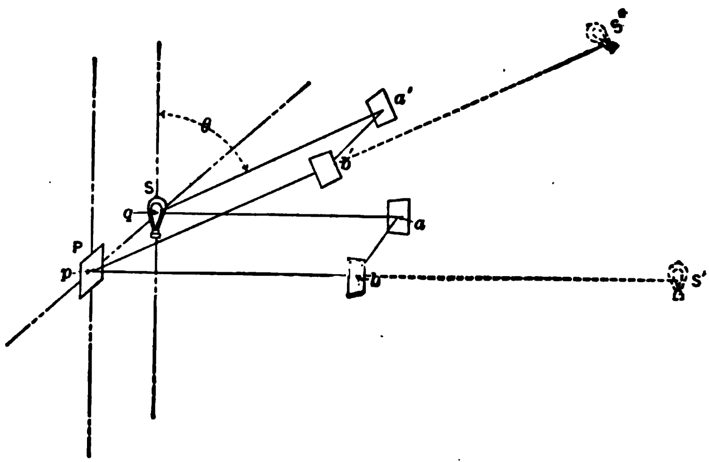


FIG. 1.

where K_0 and K_θ are the reflection co-efficients of the pairs of mirrors, d_0, d_θ, the distances from source to screen by way of the mirrors and C a factor varying with the incidence of the light upon the photometer screen P. Now if n pairs of mirrors be placed similarly to a, b and a', b', but spaced at equal angular intervals of $\Delta\,\theta$ such that $n\,\Delta\,\theta = \pi$, we shall have as the resulting illumination

$$\sum_0^\pi (i) = \sum_0^\pi \frac{C\, K_\theta\, I_\theta}{d^2_\theta} \qquad (3)$$

If by radial adjustment of the mirror pairs we make

$$\frac{C\, K_\theta}{d^2_\theta} = \frac{K_0 \sin\theta}{d^2_0} \qquad (4)$$

then

$$\sum_0^\pi (i) = \frac{K_0}{d_0^2} \sum_0^\pi I \sin \theta \qquad (5)$$

That is to say, the total illumination of the screen is proportional to the mean spherical intensity of the source. (See equation 1.) To evaluate this intensity, it is necessary merely to balance this illumination against that due to a source of known intensity at a known distance.

Fig. 2 shows the disposition of twelve pairs of mirrors, m_1, m_2, etc., in order to produce the desired results. If the illumination of a given surface varied exactly as the cosine of the incidence of

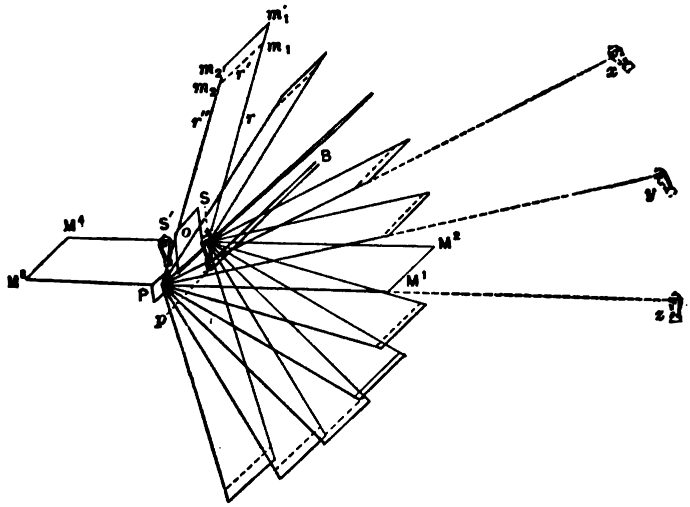


FIG. 2.

the light upon that surface, and if all mirrors used were of equal reflecting power, then there would be no need of radial adjustment of the mirror pairs, for in such case $S\ C = \sin \theta$ and $K_\theta = K_0$. But the so-called cosine law is only approximately true and mirrors vary in reflecting power, hence it is necessary to compensate for discrepancies in C and K_θ by slight changes in d_θ. The extent to which this correction is of importance depends, of course, upon the nature of the photometer screen. The plaster of Paris surface of the Lummer-Brodhun screen obeys the cosine law with exactness up to an incidence of 50°, but beyond this point a divergence of increasing magnitude occurs (Fig. 3). Hence, for the Lummer-Brodhun screen the only adjustment of mirrors necessary is that to overcome variations in their reflection co-efficients except for angles greater than 50°. With mirrors cut from one sheet of glass, the correction for variation in reflecting power is often negligible. With the Bunsen screen, correction must be made for all angles of incidence. For example, the second curve in Fig. 3 is the result of measurements made upon ordinary draughting paper from which the Bunsen screen is often made. Here the departure from the cosine relation is noticeable from the very beginning and becomes as high as 15% at 75° incidence. The third curve in the same figure shows the results obtained with ordinary glazed writing paper. The cosine relation is not even roughly approximate is this case.

Fig. 2 also shows the method of balancing the illumination

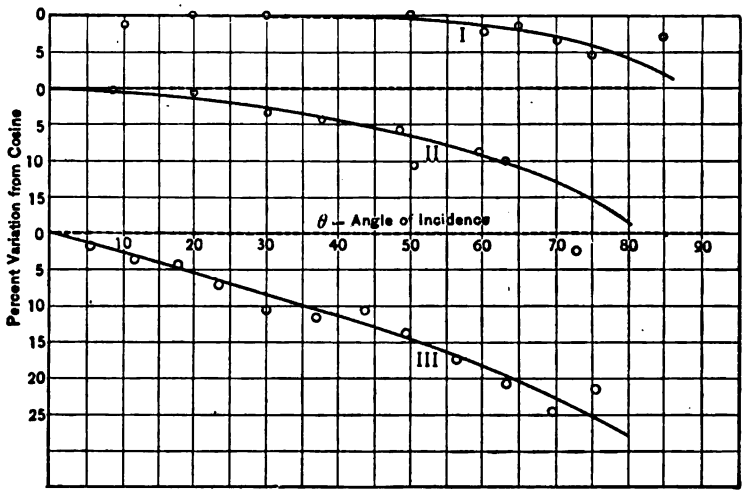


FIG. 3.

Per cent. variation from cosine relation for different screens.
I.—Lummer-Brodhun screen.
II.—Unglazed paper.
III.—Glazed paper.

produced by the series of images due to the circular system of mirrors. Mirrors M_1, M_2, M_3, M_4 are cut from one piece of glass just as are the mirrors in the ordinary Bunsen photometer. It is not essential that the other mirrors of the system should have the same coefficient, since, as already explained, the initial adjustment corrects for failure of the cosine relaton and inequalities in the mirror coefficients at the same time. With the standard at s′ separated from s, the source to be tested, by an opaque screen, a balance in the illumination is obtained by moving M_3 and M_4. The method of doing this will be better understood by reference to Fig. 4, which shows in elevation and plan the essential elements of the apparatus. To the right of these figures is seen the mirror system, each pair of mirrors being capable of a certain amount of radial movement for purposes of the initial adjustment of the instrument. S is the lamp to be tested, mounted upon a rotator, S′ is a standardized glow lamp. The mirrors M_3 and M_3, rigidly connected, may be moved along the bar by means of a rack and pinion conveniently under control of the observer at the photometer P. The photometer is fixed and hence the operation of making a setting is more convenient than that which obtains with the ordinary sliding form. As the design is based upon the approximate equation (1) and not upon the integral form, some error arises from this cause. With eleven pairs of mirrors the error is negligible for all practical purposes.

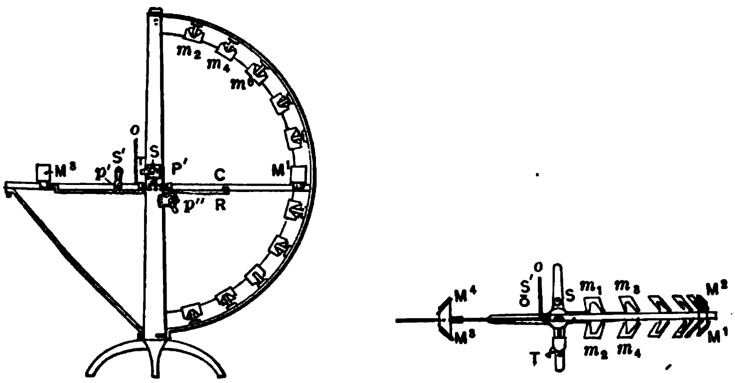


FIG. 4.

Fig. 5 shows a photograph of the finished apparatus with all screens removed in order that the details of construction may be better seen. This particular instrument is fitted with a Lummer-Brodhun photometer screen. Each mirror bracket is provided with two pins. These pins extend through the frame of the ring radially. By means of this construction, each mirror pair may have independent radial adjustment.

We will now consider in detail the different operations to which the instrument readily lends itself.

OPERATION 1.—MEASUREMENT OF MEAN HORIZONTAL CANDLE POWER.

In this operation the apparatus is used as a simple photometer. Hence, all mirrors except the four horizontal ones are covered by black screens suitably provided for the purpose. The right pair of mirrors (Fig. 4) is connected at C to the sliding rod carrying the rack. The lamp S to be tested is mounted in the rotator

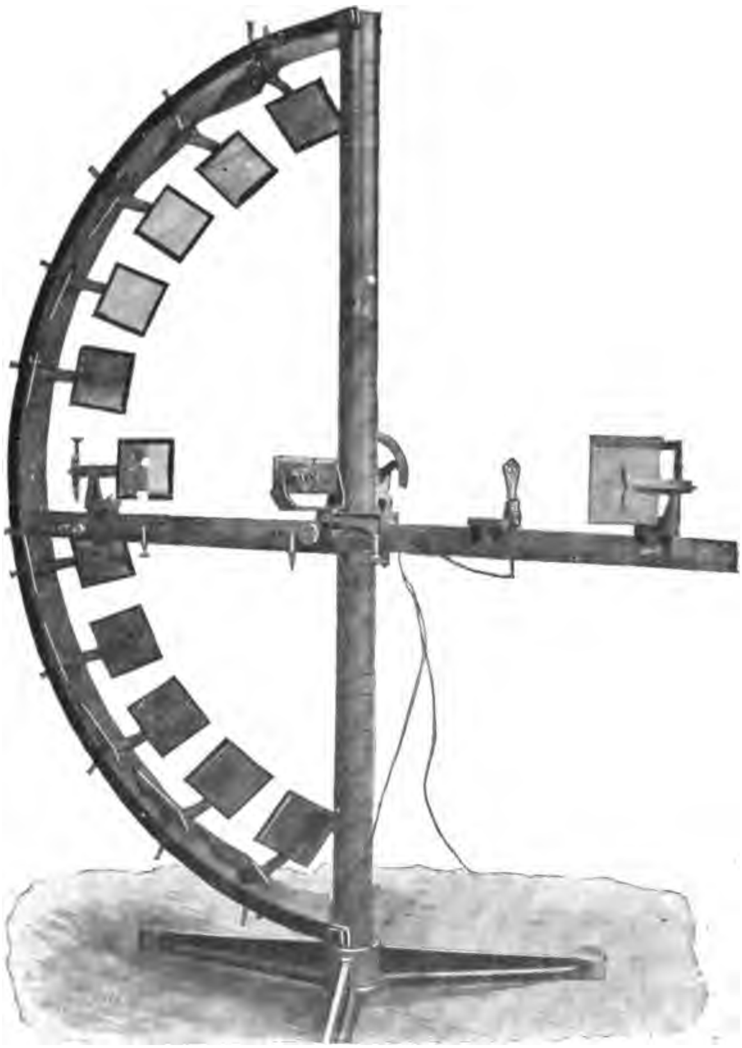


FIG. 5.

and driven at a speed of say 180 r. p. m., and a standardized incandescent lamp, of intensity I_s is placed in a suitable holder, at S′. The rod R may be moved by the hand for a rough adjustment, and the pinion P″ used only for the final setting. Since a displacement d of the mirror pairs means a change in the light paths of $2d$, the moving rod is graduated in divisions one-half the unit (centimetres) in which the light paths are conveniently measured. A reading R means that the distance from S′ to the screen by way of the mirrors M_3, M_4, is R centimetres. If, now the total photometric distance between the sources is 300 *c m*, we have for the intensity I of the light under test

$$I_s = \left[\frac{300 - R}{R}\right]^2 I_{s'} \quad (6)$$

$$= T_1 I_{s'} \quad (7)$$

where T_1 is the value of the expression in brackets and stands for "tabulated value corresponding to the reading *R*." When the apparatus is used with a standard of always the same intensity, it is a simple matter to make the instrument direct reading.

Obviously, the mean intensity in any north or south polar zone may be found by clamping the arm of the rotator at the proper angle and spinning the lamp, readings being taken as for the mean horizontal measurement. The mean horizontal candle-power of a flame source must be found by taking the horizontal distribution step-wise since it is impracticable to rotate such a source. Equation (7) is applicable in such measurements.

Operation 2.—Distribution of Candle-Power in Vertical Planes.

The distribution of intensity of an incandescent lamp in any vertical plane is obtained with the apparatus arranged as described under Operation 1. The arm of the rotator is merely tilted about a horizontal axis so as to bring any desired aspect of the lamp toward the photometer screen. From equation (7) the different intensities are easily found.

The vertical distribution of candle-power from a flame source cannot be obtained by tilting the arm of the support. The following method is available in such cases: Mount the burner vertically at S, Disconnect the mirrors M_1, M_2 from the movable rod and push them to their place at the extreme right (Fig. 4). Now with a standard of the same order of brightness as the source to be testeu, make a setting. The horizontal intensity is given by

$$I_0 = \left[\frac{200}{R}\right]^2 I_s \quad (8)$$

$$= T_2 I_{s'} \quad (9)$$

where T_2 is the tabulated value of the expression in brackets corresponding to the reading R.

To obtain the intensity of the source in a direction of θ_0 to the vertical, the horizontal and θ mirrors should both be used. This prevents the limit of the bar being reached by mirrors M_3, M_4. The intensity is given by

$$I_\theta = \frac{T_2 I_{s'} - I_0}{\sin\theta} \qquad (10)$$

where I_0 is the intensity found in the horizontal measurement

OPERATION 3. STANDARDIZATION OF GLOW LAMPS.

For this operation the lamp s is removed and a horizontal circular plate mounted in place of the lamp. This plate is ruled with concentric circles which facilitate the centering on the amyl-acetate lamp or other primary standard. The lamp to be standardized is mounted at s′. With all mirrors screened except the horizontal ones, and with M_1 M_2 attached to the bar, settings are made as usual. The value of s′ is given by

$$I_{s'} = \frac{1}{T_1} \qquad (11)$$

if the standard is unity.

OPERATION 4. MEASUREMENT OF MEAN SPHERICAL INTENSITY.

(*a*) *Glow Lamp.*—The lamp to be tested is mounted in the rotator and driven at a speed of about 180 r. p. m. Mirrors M_1 M_2 are detached from the movable rod and pushed to the extreme right, in which position they may be considered a part of the system of eleven mirror pairs. With a standardized lamp at s′, a setting in made in the manner already described. If R is the reading, we have

$$I_{ms} = T_3 I_{s'} \qquad (12)$$

where T_3 is a tabulated value corresponding to the setting R and $I_{s'}$, the intensity of the standard as heretofore. Thus the operation has all the simplicity of any photometric measurement.

The intensity of the standard used should be approximately that of the lamp to be tested. For example, if a 16 c.p. lamp is to be tested, a standard of not less than 16 c.p. is best. With such a standard, the range of possible measurement depends upon the limit of travel of the mirrors M_3 M_4. A 16 c.p. lamp will serve as a standard for the measurement of mean spherical intensities ranging from 2 to about 25 c.p., when the limit of travel is about one metre. It is best to substitute a 32 c.p. standard for intensities much greater than 16 c.p.

(*b*) *Flames.*—To obtain the mean spherical intensity of a flame or of any source that cannot be rotated, it is necessary to repeat Operation 4 at equal angular intervals on the horizontal circle. The mean of the results may then be taken.

Operation 5. Direct Measurement of the Spherical Reduction Factor.

If the standard s′ and the opaque screen o be removed, it is clear from the figure that the left side of the photometer screen will be illumined by the horizontal rays of the lamp s. In fact, if s be rotated, we will have on the right side of the photometer screen an illumination proportional to the mean spherical intensity of s and on the left side of the screen an illumination proportional to the mean horizontal intensity of the same source. Under these conditions the photometer setting yields the spherical reduction factor. In other words, the mean spherical intensity is measured against the mean horizontal intensity as a standard. The reduction factor is given by

$$f = T_s \tag{13}$$

As the removal of the standard s′ lengthens the distance from source to screen, it is necessary to add a constant to the reading. This is provided for by a second reading point marked R F. All readings for Operation 5 must be taken at this reference mark.

Operation 6. To Check the Horizontal Mirror Constants.

As before stated, it is essential that the four mirrors attached to the movable bar should have the same constant. To ascertain if this condition exists, remove the opaque screen and the lamp s′ as in Operation 5. Connect the horizontal mirrors to the moving rod and, screening all other mirrors, take reversed photometer readings on a rotating lamp s. If the mirror coefficients are equal the mean reading will be 150, indicating equal light paths on each side of the photometer screen. Here again the R F reading mark must be used.

Operation 7. To Check the Adjustment of the Circular Mirror System.

In case of any doubt as to the accuracy of the initial adjustment of the photometer, or in case of the substitution of a new screen, it may be necessary to readjust the mirrors of the half ring. This operation is best performed as follows: Mount at s a 32 nominal c.p. lamp, and at s′ an 8 c.p. lamp, the latter being in circuit with a rheostat capable of continuous variation. With mirrors M_1 and M_2 free from the moving rod, and with all other mirrors on the half-ring screened set R equal to 100 c.m. Now, while maintaining the 32 c.p. lamp at constant voltage, vary the voltage impressed on the 8 c.p. lamp until the photometer shows equal illuminaton. Note voltage on 8 c.p. lamp. Repeat measurements with reversed photometer. The lamp should finally be maintained at the mean voltage so found. Under these conditions the two lamps have a candle-power ratio of 4:1. Next tilt the lamp holder to an angle of 15°. Uncover the corresponding mirrors ($\theta = 75°$ or $\theta = 105°$) and cover the horizontal ones. Under these conditions we have the same aspect of the lamp toward the photometer, but with the light incident at 15°. Set the bar at

$$R_{15} = \frac{R_0}{\sqrt{\cos 15°}} \tag{14}$$

Adjust the 15° mirrors radially until an equality of illumination is obtained, then secure them by means of the set screw. This operation may be repeated until all the mirrors have been adjusted.

In conclusion, I would acknowledge my indebtedness to Messrs. D. M. Lynch and E. D. Fristoe for their painstaking labor in construction a preliminary form of this apparatus. I am also indebted to Mr. C. R. Dooley, Assistant in Electrical Engineering at Purdue University, for assistance.

A paper presented at the 169th Meeting of the American Institute of Electrical Engineers, at New York, October 24th, 1902.

DISTRIBUTED LIGHTING.

BY DOUGLASS BURNETT, B.S.

The papers of Messrs. Bell[1], Doane[2] and Ryan[3] presented this year to the INSTITUTE, direct attention to the possibility of reducing the general considerations which they propound to a more scientific and exact basis than has yet appeared.

Commercially speaking, the instances are few in which the raw material is the finished product; and the higher the civilization, the greater the number of developing steps and the greater the efficiency of each.

The necessity of manipulating sources of light to practical ends has been realized for many centuries and the early developments are illustrated in the Tissot paintings, which show a number of ancient lamps grouped on super-posed trays.

Photometric studies have been concerned with sources of light, their production, comparison and standardization, their intensity quality and characteristics; and with the instrument for measuring their candle power, both total and intrinsic, as well as with simple formulas for theoretical cases of light distribution.

Most experiments have been made in rooms or enclosed spaces from which practical conditions have been excluded as much as possible, the walls being plain and made non-reflecting by dead-black surfacing, and scientific refinements have so far been applied that even the atmosphere in which the standard flames have been burned has been replaced by one of pure oxygen.

I wish to direct thought to the necessity of determining—not the conditions existing at the prime source of light, but those existing at the illuminated surfaces with which we are constantly concerned in daily life.

No light may ever be used until it impinges upon something, for, unless interrupted, light will continue along a straight line indefinitely. Distributed sources of light and diffusing surfaces are always present in actual lighting. The percentage of time which one spends and of work which one does in direct sunlight in city life is very small; artificial lights should be and are usually so screened or arranged as to take advantage of the diffusion and minimize the glare in one way or another. These results are secured by applying more or less ornamental shades to naked flames, by frosting incandescent lamps or surrounding them with diffusing screens and directing shades and by enclosing arc lamps and gas lamps of high intensity in translucent globes.

These processes are carried to an extreme in cases of "concealed lighting," where all the lamps are hidden from view behind solid cornices or translucent materials. In New York City there are several excellent instances of halls or rooms lighted entirely in this manner, using incandescent lamps.

The indications are that such methods may be applied to a greater extent than heretofore in the event of developments in vacuum tube or gas tube lighting. This type of lamp should lend itself particularly to diffused lighting effects, owing to the greater area of the source of light and its correspondingly decreased intrinsic brilliancy; the result would be a decrease in the spotting effect, which has been difficult to eliminate with incandescent lamps, owing to the brightness of the wall surface in the immediate neighborhood of the lamps. The optical efficiency is also high, being as much as 32 per cent. for Geissler tubes, compared with 5 per cent. to 10 per cent. for incandescent, and 15 to 25 per cent. for arc lamps.

It would be interesting to compare the intrinsic brilliancy of the light of such tubes with that of other lights; the figures are for an arc crater 6,400 candle power per square centimeter[5], for a Nernst glower about 100[6], for an incandescent filament about 40 and for an Argand gas flame .3 candle power per square centimeter. In connection with these figures it may be said that the arc lamp is much too dazzling for exposed use ordinarily and even with the incandescent lamp the after-image is quite prominent. It is seen that the development of lights of high intrinsic brilliancy renders increasingly important the study of the distribution and diffusion of their light.

The inverse square law for determining the amount of illumination on any surface is based on the conception that the light from an isolated source radiating into space decreases in proportion to the areas of concentric spheres. In practice the amount of illumination is greater than would be determined by this law, but is less than that obtained from a non-divergent beam, such as that from a searchlight projector, in which case were it not for the intervention of dust, fog or other obscuring particles, the illumination upon a standard reflecting surface would be the same at any point in the beam within an infinite distance.

The increase of the illumination upon a lighted surface due to diffusion from reflecting surfaces near the source of light, reaches a maximum represented by the expression $\frac{1}{1-f}$[8] where f represents the reflecting coefficient and is the fraction showing the percentage of reflected to the incident light. If f equals 95 per per cent., the multiplication would be twenty times. Some actual tests of this effect are needed, though reflection coefficients have been measured.[9] In consequence of this multiplying power, diffusing surfaces are therefore a positive aid in distributing illumination.

The illumination apparent upon a surface is, according to Fechner's law, proportional to the logarithm of the actual lighting stimulus reflected from the surface.

The distribution of illumination along a surface with reflecting power of f per cent., from a lamp of intensity I candle power, located at a normal distance of h feet from the surface, throwing rays of light at angles θ with the surface, the rays reaching points x feet distant from the foot of the normal, is determined by the formula

$$e = \frac{f\,I \sin\,\theta}{h^2 + x^2}$$

"e" is to be measured in luxes or candle feet. In this connection question may be raised as to the desirability of calling the lighting effect of one lux on a unit surface, otherwise called a lumen, one " ray " or one " beam " of light, just as in connection with the magnetic field we use the term " line of force."

It is therefore possible in some measure to calculate the distribution of lighting along an illuminated surface, though the problem becomes further complicated when a second reflecting surface is introduced and it may be at present considered impracticable to determine with any fair degree of accuracy the actual illumination in a room.

It seems, however, quite possible actually to measure this lighting effect.

In several instances such curves of illumination have been plotted [10], but are usually based upon the assumption that there is no reflcetion or diffusion. In others, the mistake has been made of plotting the candle power of the light incident upon the surface, with the result of exaggerating the apparent lighting effect.

A fundamental law in this connection is that illuminations from independent sources may be arithmetically added to determine resultant illumination.

An error, which I think has always been made, is in connection with the plotting of the space intensity curves of incandescent, arc, Nernst and other lamps. The impression they convey would much more nearly accord with what actually occurs if the curves showed–not the intensity of light in the various directions, but the lines along which the lighting is equal at any point. Such curves may be called "isophotals," and while they are of the same general shape as intensity curves, their dimensions are as the square root of the radii.

A theoretical set of such curves has been published by Weber.[11]

The tendency of enclosing an arc, for instance, either in the interior gas globe or more particularly in the outer diffusing globe, is to make such an isophotal curve approach more nearly a circle, which effect is further enhanced by the diffusion from a neighboring ceiling; thus tending towards the desired result of a flat curve, indicating uniform illumination.[12]

Arc lamps for the lighting of country roads should be such as throw their lighting downward; whereas in the lighting of city streets, lined with buildings, such lamps should be used as will throw an amount of light on the walls for diffusion purposes as will not be objectionable to the occupants.

A number of photometers for determining the intensity of sources of light have been devised, while few instruments, notably those of Weber[13] and of Houston and Kennelly[14] for the measurement of illumination on a surface have been described; and in each of these the lighting was not measured directly, but was adjusted by means of screens or by means of the weakening of visual power, and then compared with a standard amount of illumination. The nearest approach to attempt such a measurement has been made, I believe, by Hutchinson[15], in connection with the lighting of the Congressional Library at Washington, but in this case a simple photometer with a Bunsen grease-spot disc was used, one side being exposed to the illumination of the room, the other to an adjustable standard of light—in this case a 16 candle-power lamp, but in that case the candle-power was measured and the illumination estimated from the known distance of the group of lights, no allowance being made for diffusion; and all measurements were made in a single position.

The Bunsen, the Lummer-Brodhun, and other standard photometers operate with varying and indeterminate amounts of lighting on the surfaces to be compared; and any one of them is in essence a luminometer rather than a photometer, since the candle power is deduced by the application of the mathematical formula instead of measured or compared directly.

The author has devised an instrument arranged so as to expose a standard white surface to the ordinary lighting of a room, the amount of which is not varied. The position of a small incandescent lamp in reference to a similar and adjoining surface is, however, adjusted in order to secure within commercial limits an equal illumination, the position of this standard lamp being indicated on a graduated scale in terms not of distance but directly in terms of the number of luxes. Other observers[16] have stated that the use of small incandescent lamps is quite permissible for such purposes for several hundred consecutive observations. The only precaution necessary in the use of such an instrument would be to shield the eyes from light other than that reflected from the two standard surfaces, and to shield each respectively from the other source of light.

It may be of interest at some future date to plot the space candle-power curves from a standard open arc without enclosing globe, the space candle-power curves of an enclosed lamp of the same watt consumption with the diffusing globes used in practice, the isophotals from the latter lamp, the theoretical illumination from the open arc along a horizontal surface without diffusion and the actual illumination curves from the lamp with the enclosing and diffusing globes in a room under normal operating conditions.

In addition to the case cited there have been but few instances where the amount of illumination on a surface has been measured or calculated, notable among which may be mentioned a test of the lighting of the streets of Paris.[17]

Our methods of expressing illumination have been in terms of the number of standard lamps such as those of 16 candle-power 50 watts per hundred or thousand square feet of surface. Bell[18] has expressed an opinion that 5 candle-power per square inch is a maximum for interior lighting; Cohn[19] has given 10 meter candles as the hygienic minimum and 50 meter candles as the value of daylight; and Wybauw[20] has given 15 to 25 meter candles as necessary to fluent reading, or one meter candle for street lighting. Possibly practical requirements may hereafter be more clearly specified by the assistance of some such instrument as has been suggested in this paper.

REFERENCES.

1. Methods of illumination, Am. Inst. Elec. Engrs., Jan. 3, 1902.
2. Some Common Faults in Exterior Illumination, Am. Inst. Elec. Engrs., Jan. 3, 1902.
3. Street Illumination and Units of Light, Am. Inst. Elec. Engrs., Jan 3, 1902.
4. Palaz, Industrial Photometry, p. 264.
5. Palaz, Ibid., p. 318.
6. The Standard 50 c.p. 220 volt glower is 25 mm. long and 0.63 mm. diameter: Wurts, Am. Inst. Elec. Engrs., Aug. 23, 1901.
7. Palaz, Industrial Photometry, p. 258.
8. Palaz, Ibid., p. 298.
9. Palaz, Ibid., p. 318: W. E. Sumpner, Phil. Mag., February, 1893.
10. Palaz, Ibid., p. 285.

Bell, Electrical World and Engineer, Vol. XXXVII., No. 14, p. 553.
Utzinger, Zeit f. Beleucht., March 20, 1899.

11. Weber, Kurven zur Berechnung der von kunstlichen Lichtquellen indizirien Helligkeit, E. T. Z., 1885.
12. Utzinger, Z. f. B., March 20, 1899.
13. Meinrich, Am. Inst. Elec. Engrs., May 15, 1894.
14. Houston R. Kennelly, Nat'l Elec. Lt. Assn., Feb. 20, 1895.
15. Hutchinson, Elec. Engr., N. Y. ,Vol. XXIV., No. 496, p. 425.
16. Heinrich, Am. Inst. Elec. Engrs., May 15, 1894.
17. Palaz, Ibid., p. 292.
18. Bell, Methods of Illumination, A. I. E. E., Jan. 3, 1902.
19. Utzinger, Z. f. B., March 20, 1899.
20. Mesure et repartition de l'eclairement, Bull, de la Soc. Belge d'Electr 1885.

A paper presented at the 169th Meeting of the American Institute of Electrical Engineers, New York, October 24, 1902.

SOME METHODS OF PHOTOMETRY AS APPLIED TO INCANDESCENT LAMPS.

BY J. T. MARSHALL.

For fifteen years or more the Edison General Electric Company and its predecessor, the Edison Lamp Company, have tested lamps for voltage on a so-called sliding scale photometer. This type of photometer is an adaptation of the ordinary form of a Bunsen grease spot photometer, by which the voltage of the lamp at rated candle-power is determined from the candle-power it gives at a given voltage.

If two lamps of the same candle-power and voltage be placed one at each end of the photometer and the same voltage be applied to them, they will give the same candle-power and the photometer screen will balance at the middle of the photometer. If the two lamps are of different voltages, they will give different candle-powers and the screen will balance at some other point than the middle of the photometer. The relative candle-power of the two lamps, as indicated by the point at which the screen balances, will determine their relative voltage. The voltage of one lamp being known, the voltage of the other lamp may be read directly from a scale on the photometer made to suit the lamp.

The sliding scale photometer does not require a volt-meter—an advantage which, before the introduction of reliable dead-beat volt meters, was more apparent than at present. This type of photometer has a further advantage, in that its readings are not materially affected by changes of several volts in the line—for the reason that these changes similarly affect both lamps, and do not alter the balancing point of the screen.

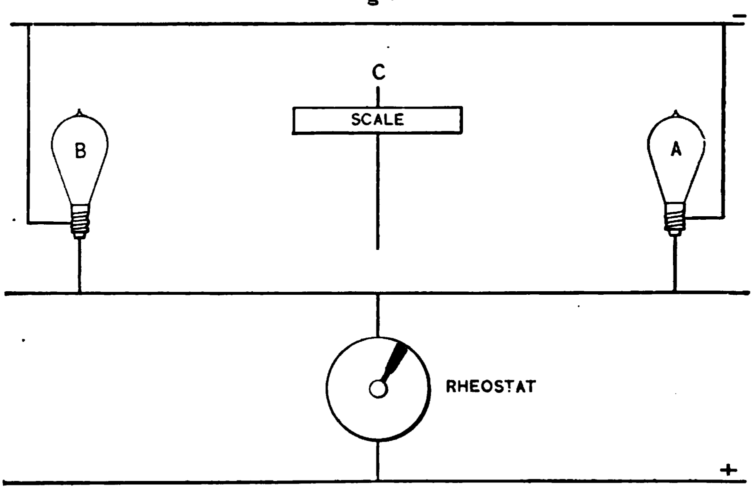
Fig. 1 is a simple diagram showing the electrical connections of a photometer.

A is the working standard, or lamp of known voltage. B is the lamp to be tested, and C is the movable screen, the position of which at the balancing point indicates the voltage of the lamp B. The volt scale is made by a combination of the curves of the candle-power scale of a Bunsen photometer and a curve showing the change of candle-power due to change of voltage.

Fig. 2 is a curve of a candle-power scale of a Bunsen photometer. It is derived from the formula:

$$\frac{100}{x^2} = \frac{y}{(100 - x)^2}$$

Fig. 1

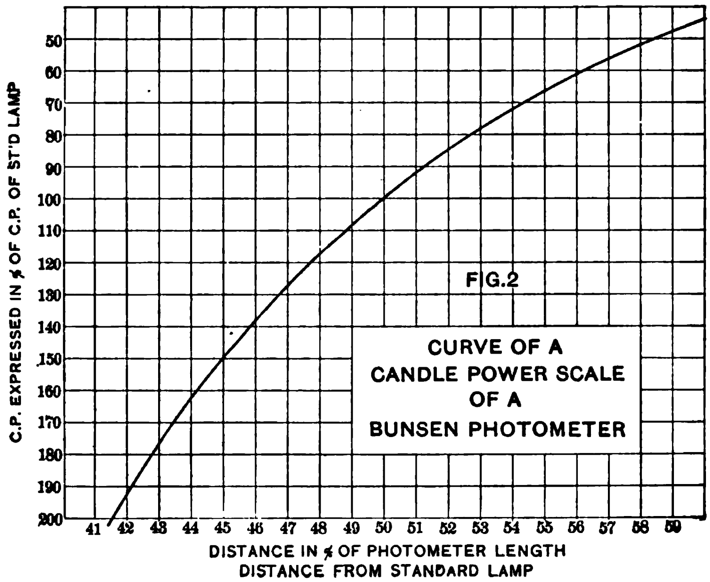


x is the distance of the screen from the standard lamp, expressed in per cents. of the photometer length, and y is the candle-power expressed in per cents. of the candle-power of the standard lamp.

Fig. 3 is a curve showing the change of candle-power due to change of voltage. The candle-powers and voltages are expressed in per cents. of the candle-power and voltages at 3.1 w.p.c.

Fig. 4 is a curve of the volt scale of a sliding scale photometer. The voltages are expressed in per cents. of the voltage of the standard lamp, and the distances from the standard lamp in per cents. of the photometer length. This curve is derived from the curves of Figs. 2 and 3.

For instance: A lamp with a voltage 105 per cent. of the voltage of the standard lamp will, when burned at the voltage of the standard, be burning at 95.24 per cent. of its true voltage. In Fig. 3 the percentage candle-power corresponding to 95.24 per cent. voltage is 71.2 per cent., and in Fig. 2, the per cent. distance corresponding to 71.2 per cent is 54.28 per cent; so that the distance corresponding to 105 per cent. volts is 54.28 per cent. The



projection of the integral per cent. volt points of the curve on the length scale gives the volt scale.

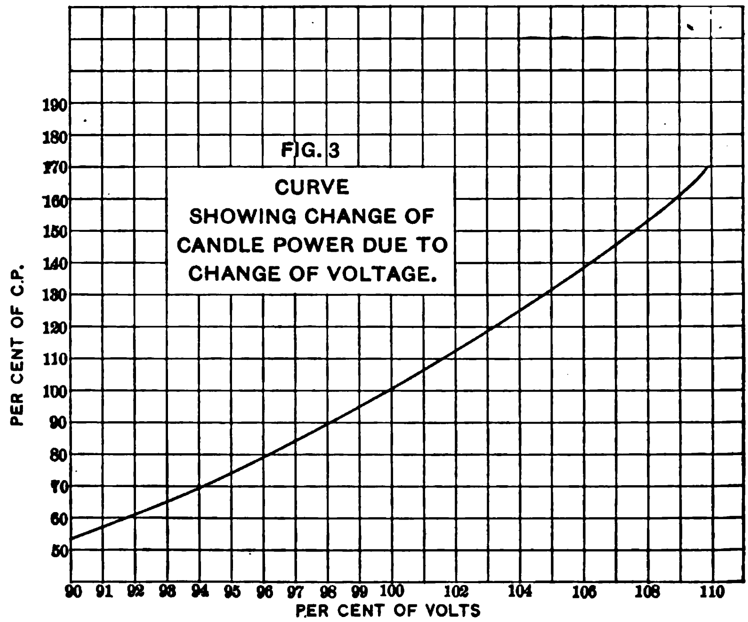
The length of the volt divisions for any length photometer and voltage of standard lamp will be directly as the length of the photometer, and inversely as the voltage of the standard lamp.

There is a source of error in the use of the sliding scale photometer, in that the curve in Fig. 3 is not the same for all lamps. This difference is due to the fact that the law of change of resistance of filaments with change of temperature or candle-power varies—depending on how much of the filament is base carbon and how much is treatment.

Fig. 5 shows change of candle-power due to change of voltage for lamps made with filaments of only base carbon, and filaments which have been treated respectively to 75, 50, 37½ and 25 per cent. of the resistance of the base carbon. The voltages and candle-powers are expressed in per cents. of the voltage and candle-power at 3.1 w.p.c.

Fig. 6 shows the volt scales derived from each of the curves referred to in Fig. 5.

The curves of Figs. 3 and 4 are derived from the lamps treated to 37½ per cent. of the initial resistance. This is about an average treatment.



It will be seen in general that the volt scale is contracted more and more as the treatment on the filament thickens. If any one of these scales is used for reading variously treated filaments, it will be necessary to restrict the readings to a few volts either side of the middle point.

These scales were derived from a few lamps, made and measured since I was asked to prepare this paper. Measurements made on a larger number of lamps would probably modify these scales somewhat. The scale actually in use at our factory is shown on Fig. 6 by round dots.

In using the sliding scale photometer it is the practice to select a scale whose middle voltage is very nearly the average voltage of the lamps to be tested; to select for a working standard a well-seasoned lamp of the same candle-power as the lamps to be tested and of a slightly lower voltage than the middle point of the scale; to have a few ohms resistance in series with the working standard, so that its candle-power may be reduced or slightly changed; to read only a few volts either side of the middle point

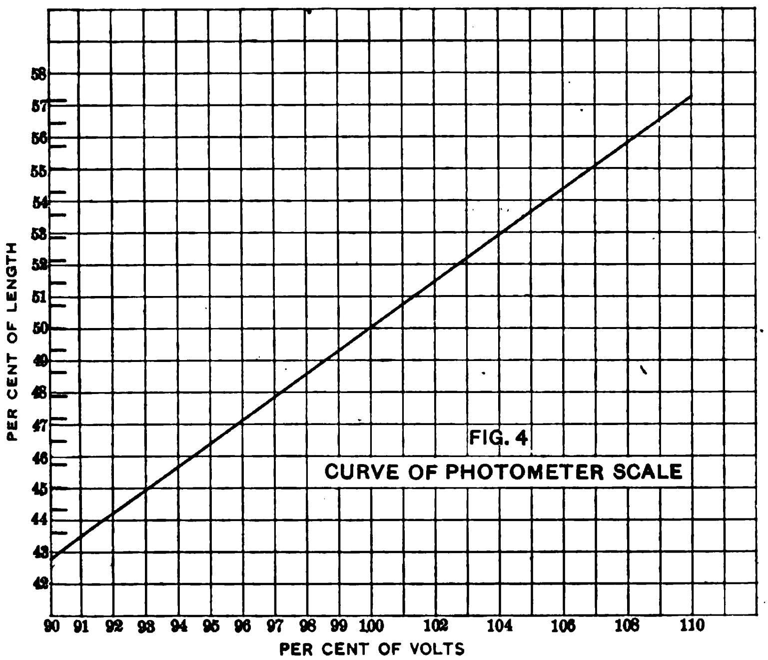


FIG. 4
CURVE OF PHOTOMETER SCALE

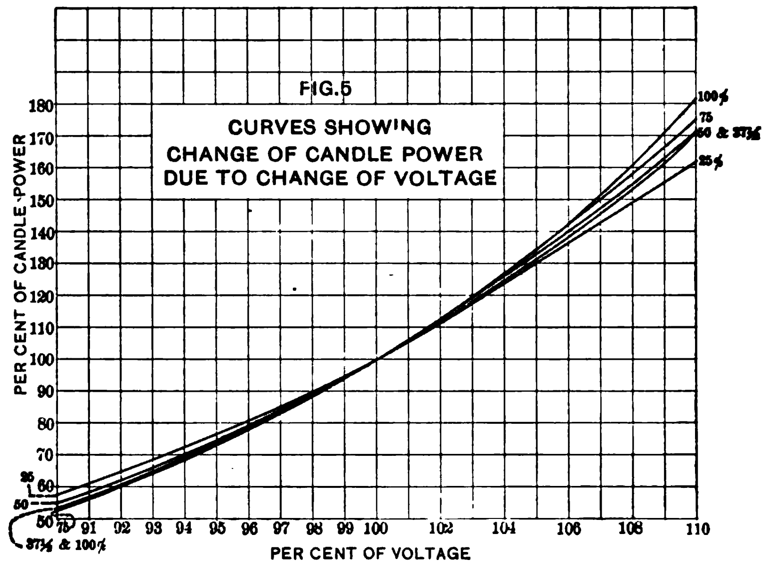
of the scale, and to keep the voltage of the line nearly the same as the middle point of the scale.

The photometer is set with a few lamps like those to be tested. They are first carefully seasoned and tested for voltage on a standard photometer, and kept for reference lamps. One of them is placed on the working end of the photometer, the screen is placed on the scale at the voltage marked on the reference lamp and the working standard is brought to a candle-power which balances the screen. The other reference lamps are then placed successively on the working end and their voltage read on the scale by moving the screen. If the observed voltage averages the same as those marked on the reference lamps, the photometer is correctly set.

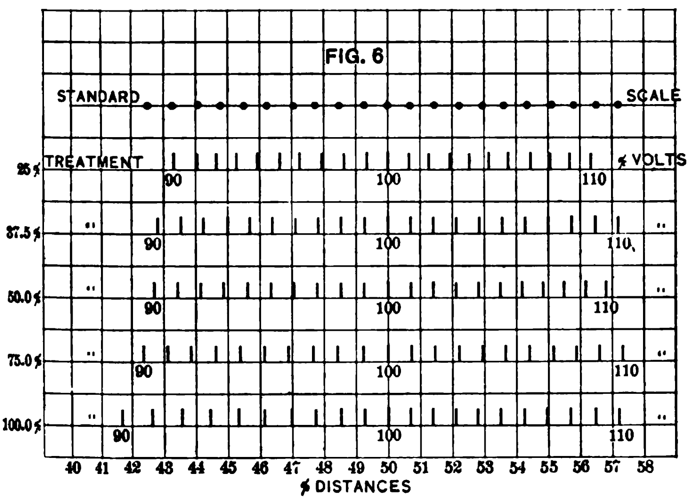
Attention has been called to the fact that the curves of candle-power and voltage are different for differently treated filaments. It is interesting to note that if curves were made showing the change of candle-power with w.p.c., they would be coincident for all the filaments of Fig. 5.

A brief account of the invention and early use of the sliding scale photometer may be interesting.

Some time in the early eighties, Mr. William Holzer, then



Superintendent of the Edison Lamp Company, sent to the life test photometer room several thousand 16 candle-power lamps, from which he asked us to select all that were above 115 volts. I began with the usual method of bringing the lamps up to candle-power and reading the volts with a Thompson galvanometer. Then it occurred to me that I could put in a standard lamp of 115 volts, connect it in multiple with the other lamp, and that all the lamps that were less than 16 candles would be more than 115 volts. The varying candle-powers of the successive lamps put on the photometer suggested the making of the volt scale; and, recalling that Mr. J. W. Howell had in his table drawer curves like those in Figs. 2 and 3, I made a scale like that in Fig. 4, and the next day tested 1,500 lamps in four hours, something heretofore unprecendented in lamp testing. We were then making so few lamps that it did not seem worth while to change our regular photometer room to this method, particularly as the photometer required resetting for every different candle-power lamp. Mr. F. R. Upton, then General Manager of the lamp company, advised me to patent the invention, but I thought a publication of the method would only cause our competitors to appropriate it without compensation, and therefore did not do so. Soon afterwards, I was sent to our Canadian factory to put the lamp testing apparatus in order. I there found that the engine

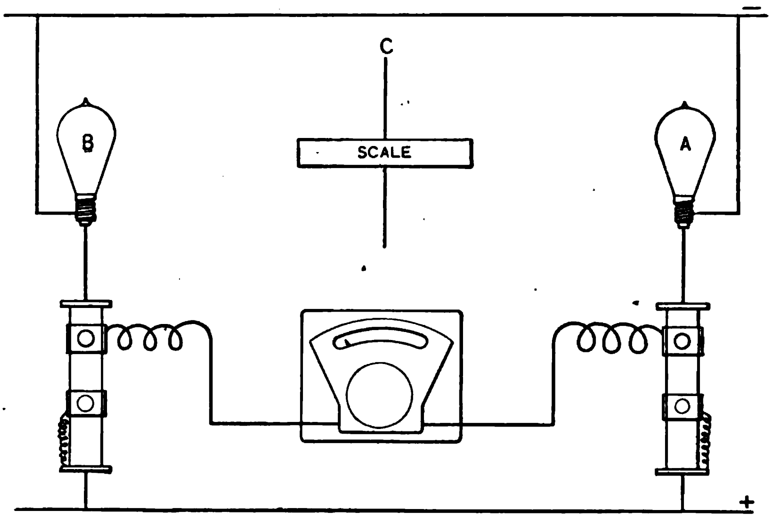


regulation was so bad that the best way to obtain steady voltage was to turn the engine throttle while watching the voltmeter. I found that I could duplicate my results better with the sliding scale photometer, letting the engine race, than by trying to control it and read volts with a voltmeter. I therefore installed the sliding scale photometer and made up a full set of reference lamps After this had been running for a year we commenced to install them in the Harrison factory, and are still using them.

We are using for inspection purposes a photometer connected as per Fig. 7. We call this the differential photometer.

The voltmeter reads the difference in voltage of the two lamps, and has its point of no difference at the middle of the scale, which is marked with the voltage of the standard lamp. The scale is calibrated only a few volts either side of the middle point so that it is very open. One terminal of the voltmeter can be slid along the resistance in series with the standard lamp, so as to make the voltmeter read the voltage of the reference lamp used in setting the photometer. The advantage of this type of photometer over the sliding scale photometer for inspection is, that by changing the position of the screen it can be used with the same setting for lamps of all candle-powers, that come

Fig. 7



in the range of the voltage of the meter. The advantage over a standard photometer which reads the total voltage of the lamp, is that a more open scale can be used and changes in the voltage of the line produce smaller errors. For instance, if the standard lamp and the test lamp are the same voltage, a change in the line will make no change in the reading. But suppose that the test lamp is 100 volts, and that the line drops 10 per cent.; then the 10 volts difference will appear as 9 volts, and the lamp will read 109 volts instead of 110 volts, an error of less than 1 per cent., due to change of 10 per cent. in the line.

Our method of inspection with this photometer is to bring the test lamp to the volts marked on it and read the candle-power.

In this way a few lamps are inspected from about a third of all trays of lamps tested.

Mr. J. W. Howell first used the differential photometer as a means of testing lamps for volts, some time in 1897. We are now experimenting with it again for that purpose, and may possibly substitute it for the sliding scale photometer as a means of overcoming the error due to the different volt curves of differently treated lamps.

We are also experimenting on a photometer, using alternating current in a transformer having single volt steps. The test lamp will be brought to its rated candle-power by connecting it to the proper step, and its volts will be shown by the number of steps between the connections of the test lamp and the standard lamp. This method will have the triple advantage of dispensing with a voltmeter, overcoming the errors of the sliding scale photometer, and reading all lamps with one setting of the photometer. This method was suggested by Mr. H. B. Coolidge, of the Lamp Testing Bureau.

A paper presented at the 160th Meeting of the American Institute of Electrical Engineers New York, Oct. 24th, 1902.

THE COMMERCIAL ACCURACY OF PHOTOMETRICAL MEASUREMENTS.

BY CLAYTON H. SHARP.

The term "commercial accuracy" has a significance which recognizes the fact that for the practical purposes of the engineer and the manager, measurements, tests and computations of all sorts need not be carried out to the highest degree of refinement. This is because variations in working conditions are so large that they mask the effect of ultra refinements in the subject matter of the test, or because the residue neglected in making rougher tests is not sufficiently large to make it pay to expend on its determination the necessary time and money.

It would ,for example, be superfluous to check the accuracy of a switch-board instrument to one-tenth per cent. (0.1%), or to determine the dielectric losses in a cable to a similar degree of accuracy. It is not possible to fix any value for the limits of error within which tests or measurements may be taken as commercially accurate, since their limits vary widely with the conditions of the test. In the case of the switchboard instrument cited above, one-half of one per cent. may be taken as the allowable limit, while in the case of the cable ten per cent. error would not be excessive. A recording watt-hour meter is considered as commercially accurate if it registers correctly within two per cent.

It is probable that in almost any test involving the making of more than one measurement under conditions of fluctuating voltage or current such as nearly always prevail in practice, the result can be considered as commercially accurate if it is within 2 per cent. This value of 2 per cent. may consequently be taken as a kind of general value for the limit of commercial accuracy.

It is the purpose of this paper to inquire whether photometrical measurements conform in general to the requirements of commercial accuracy; that is, whether they stand on equal or nearly equal footing in this regard with other electro-technical measurements. The excuse for presenting this inquiry is the fact that there seems to be a widespread feeling that such is not the case. The idea is sometimes expressed that photometrical measurements are subject to an uncertainty and unreliability all their own, and that their results are often worthy of little confidence. It is undoubtedly true that a certain amount of skill and practice is required to make good photometrical measurements and that certain precautions must be taken, the neglect of which will vitiate such measurements. But it is the business of a photometrist to have such skill and to be familiar with such precautions, just as it is the business of the alternating current engineer to understand the conditions of his work and the pitfalls which are liable to entrap him. The fact that many bad photometrical measurements have been made by persons not sufficiently familiar with the nature of the work, does not argue that this class of measurements is *per se* unreliable.

Photometrical measurements may be divided into three general classes, corresponding to similar classes in electro-technical measurements in general. For these classes, different degrees of accuracy are to be expected. The first class includes those measurements in which the primary standard or unit of luminous intensity is used to calibrate secondary standards of the same. This is similar to the calibration of secondary standards of resistance from a mercury ohm, and like the latter, the results are involved in the uncertainty connected with the production of the primary standard.

The second class comprises the calibration of working secondary standards by reference to the original secondary standards. This is the class of work which can be carried out to the highest degree of accuracy. The third class includes commercial measurements of sources of light by reference to working secondary standards, and corresponds to ordinary electrical testing where direct reading instruments are used and no effort is made toward great refinement. Speed is an important factor in this kind of work.

In order to ascertain if a good commercial accuracy is attainable in photometrical work of these three classes, series of experiments have been carried out in the Lamp Testing Bureau as outlined below.

In testing the accuracy of work of the first class, starting out, that is, from a primary standard, two Hefner amylacetate lamps and one Harcourt ten-candle power pentane lamp were repeatedly compared with invariable incandescent lamp standards.

The Hefner lamps used were manufactured by different German makers, but both bore the stamp of the Reichsanstalt, the one No. 242, dated 1896, and the other, No. 937, dated 1901. These lamps were not identical in all their dimensions. One of them was supplied with a woven wick, the other with a wick of loose strands. The pentane lamp was made by the American Meter Company. The proper burning fluid was used for all the lamps. These lamps represent the best types of primary photometrical standards in use to-day. The proper precautions in their use were taken and the necessary corrections for atmospheric humidity were applied. It was assumed that the pentane lamp required the same percentage correction for humidity as the amylacetate lamp, since the true value for its correction has not been determined by experiment. The measurements were carried out chiefly by Miss Leiter and Miss Merriman who, while both college graduates and trained in laboratory methods, had had no previous experience in handling these lamps. Carried out under these conditions, it is safe to assume that the results obtained can be duplicated anywhere where atmospheric conditions are not excessively bad. The results are contained in Tables I and II.

Inspecting the column of Table I, where the differences between the lamps are given, it will be seen that in two cases these reached the excessive value of 5.2 per cent. and 3.9 per cent., indicating that one of the lamps was not burning under normal conditions. The mean difference between the lamps was but 1.2 per cent. in a series of fourteen measurements made on ten different days. The mean deviation of the values uncorrected for humidity from the mean of all was 1.7 per cent. for both lamps, while the corrected values differed only 1.1 per cent and 1.0 per cent. on the average. The greatest deviation of a single measurement from the mean of all was but 4.8 per cent., but this occurred when the indications of the lamp disagreed by 5.2 per cent., and in any practical case this measurement would have to be rejected. If the mean indication of the pair of lamps is

TABLE I.

HEFNER LAMP MEASUREMENTS.

Date	C.P. uncorrected for humidity		C.P. corrected for humidity.		Difference between the lamps.	Amount of humidity correction.	Deviation from mean of all uncorrected.		Deviation from mean of all corrected.		Deviations of mean of pairs from mean of all.
1902	No. 242	No. 937.	No 242.	No. 937.			No. 242.	No. 937.	No. 242.	No. 937.	
Oct. 8	.880	.860	.903	.883	2.2%	2.7%	−0.5%	−2.6%	+1.3%	−0.7%	+0.3%
" 9	.834	.867	.856	.889	3.9%	2.5%	−6.1%	−1.8%	−3.4%	−0.1%	−1.7%
" 10	.889	.880	.898	.889	1.0%	1.0%	+0.4%	−0.3%	+0.8%	−0.1%	+0.3%
" 10	.894	.893	.905	.903	0.1%	1.2%	+1.0%	+1.1%	+0.5%	+0.3%	+1.4%
" 11	.881	.883	.898	.900	0.2%	2.0%	−0.4%	0.0%	+0.8%	+1.0%	+0.1%
" 13	.888	.841	.889	.842	5.2%	0.2%	+0.3%	−4.7%	−0.1%	−4.8%	−2.5%
" 14	.882	.891	.890	.899	1.0%	1.0%	−0.3%	+0.9%	0.0%	+0.9%	+0.5%
" 14	.866	.881	.879	.894	1.7%	1.5%	−2.1%	−0.4%	−1.1%	+0.4%	−0.3%
" 15	.860	.860	.868	.868	0.0%	1.0%	−2.9%	−2.6%	−2.2%	−2.2%	−2.2%
" 16	.886	.887	.886	.887	0.1%	0.0%	+0.1%	+0.4%	−0.4%	−0.3%	−0.4%
" 16	.894	.887	.894	.887	0.7%	1.5%	+1.0%	+0.4%	+0.4%	−0.3%	0.0%
" 17	.917	.907	.910	.900	1.0%	−0.75%	+3.6%	+2.7%	+2.0%	+1.0%	+1.5%
" 17	.913	.912	.906	.905	0.1%	−0.75%	+3.1%	+3.2%	+1.6%	+1.5%	+1.5%
" 18	.905	.906	.905	.906	0.1%	0.0%	+2.2%	+2.6%	+1.5%	+1.6%	+1.6%
Mean	.885	.883	.892	.889	1.2%	1.1%	±1.7%	±1.7%	±1.1%	±1.0%	±1.0%

taken as representing a measurement, the mean deviation was 1.0 per cent., and the maximum 2.5 per cent.

The secondary standard lamps to which these measurements go for the value of the British candle power are the progeny of lamps standardized at the Reichsanstalt over ten years ago, using the ratio I Hefner unit = 0.88 c. p. At that time the correction for humidity had not been determined by the Reichsanstalt authorities. We find now that in terms of these secondary standards the Hefner uncorrected, equals 0.884 c. p., a deviation of less than one-half of 1 per cent.

The pentane lamp used was known to be an imperfect one, not giving its full 10 c. p., hence too much stress should not be laid upon the low value which it shows. The results in Table II. indicate that it is at least as consistent with itself as the Hefner. The maximum deviation from the mean was 4.8 per cent. for the uncorrected readings and 4.05 per cent. for the corrected ones. The mean deviations were 1.4 per cent. and 1.1 per cent. respectively, or substantially the same as for the Hefner. It is a fair conclusion from the foregoing that it is feasible to determine luminous intensities absolutely with reference directly to a primary standard with a degree of accuracy falling within the general limit ascribed above to commercial accuracy.

TABLE II.

PENTANE LAMP MEASUREMENTS.

Date	C.P. uncorrected for humidity.	C.P. corrected for humidity.	Amount of humidity correction.	Deviation from mean of all, uncorrected.	Deviation from mean of all, corrected.
1902					
Oct 8	9.20	9.44	2.7%	—1.2%	+0.4%
" 9	9.00	9.22	2.5%	—3.3%	—1.8%
" 9	9.20	9.43	2.5%	—1.2%	+0.3%
" 10	9.31	9.40	1.0%	0.0%	0.0%
" 10	9.15	9.24	1.0%	—1.7%	—1.7%
" 11	9.33	9.51	2.0%	+0.2%	+1.1%
" 14	9.30	9.39	1.0%	+0.1%	—0.1%
" 14	9.33	9.46	1.5%	+0.2%	+0.6%
" 15	9.11	9.02	1.0%	—2.1%	—4.0%
" 16	9.37	9.37	0.0%	+0.6%	—0.3%
" 16	9.27	9.42	1.5%	—0.4%	+0.2%
" 17	9.67	9.60	—0.75%	+3.0%	+2.1%
" 17	9.76	9.68	—0.75%	+4.8%	+2.9%
" 18	9.40	9.40	0.0%	+0.9%	0.0%
Mean....	9.31	9.40	2.2%	±1.4%	±1.1%

The results of measurements coming under the second class, namely, the copying of incandescent lamp secondary standards, are shown in Table III. In it are given various determinations of the voltage at which each of 10 lamps gives 16 c. p. The measurements were made by two different photometer operators on different days, as shown, and have been simply abstracted from the ordinary records of the Lamp Testing Bureau.

TABLE III.

STANDARD LAMP MEASUREMENTS.

Lamp.	E.F. Sept. 25.	M.E.P. Oct. 1.	E.F. Sept. 30.	M.E.P. Oct. 8.	E.F. Oct. 14.	Mean.	Mean deviation from mean.
	Volts.	Volts.	Volts.	Volts.	Volts.	Volts.	
1	108.40	108.43	108.19	108.39	108.37	108.4	0.06%
2	108.75	108.79	108.62	108.91	108.80	108.8	0.06%
3	109.05	108.96	108.82	109.04	109.02	109.0	0.04%
4	109.79	109.82	109.75	109.89	109.86	109.8	0.04%
5	107.82	107.80	107.68	107.75	107.64	107.7	0.04%
6	108.77	108.61	108.61	108.63	108.60	108.6	0.04%
7		108.16	107.96	107.82	107.96	108.0	0.07%
8	110.01	109.90	109.85	109.98	109.91	109.9	0.06%
9	108.50	108.42	108.41	108.52	108.42	108.5	0.05%
10	109.00	108.98	109.00	108.83	108.97	109.0	0.02%

The greatest mean deviation from the mean for any lamp is 0.07 per cent. in voltage, which corresponds to about 0.05 c.p. The final results may be taken as certainly correct within narrower limits than this value. The closeness with which photometrical measurements can be made under these conditions is such as to task the capabilities of the best direct reading voltmeter. The voltmeter acutally used in making these was a Weston laboratory standard. Certainly, for commercial purposes, copies of photometric standards need not be made any more accurately than this table shows that it is possible to make them.

As showing what may be and is done in strictly commercial measurements, class three, the results in Table IV. are of interest. Ten lamps were measured at marked volts on four different photometers by four different photometer teams, under strictly commercial conditions. Each photometer was turning out some 500 lamps a day, measured just as these ten were. Each value given represents a single photometer setting.

The greatest deviation of a single measurement from the mean of the four was 2.5 per cent. The mean of the maximum deviations is but 0.4 per cent. It is particularly important to note that the results obtained by different operators on different photometers are in substantial agreement. The deviations of the candle-power of the individual lamps from 16 are to be

TABLE IV

COMMERCIAL MEASUREMENTS.

Lamp No.	C.P. Photom. No. 1.	C.P. Photom. No. 2.	C.P. Photom. No. 3.	C.P. Photom. No. 4.	Maximum Deviation.
1	16.5	16.4	16.3	16.4	0.6%
2	16.2	16.2	16.2	16.1	0.5%
3	16.3	16.4	16.2	16.4	0.8%
4	16.0	16.15	16.0	15.9	0.6%
5	15.9	16.0	16.0	15.9	0.3%
6	16.6	16.9	16.4	16.2	2.5%
7	16.1	16.2	16.3	16.2	0.6%
8	16.2	16.1	16.0	16.0	0.8%
9	16.3	16.2	16.1	16.1	0.8%
10	15.9	15.9	16.1	16.0	0.8%
Mean....	16.20	16.25	16.16	16.12	0.4%

ascribed to the fact that these lamps were marked to integral voltages only.

When photometrical measurements are made on sources of light such as the electric arc, the limits of allowable error must be considerably extended. The difficulties of arc-light photometry have often been ascribed to the difference in color which exists between the light of the arc and that of the comparison source. This is undoubtedly a real and a serious difficulty, but it is not an unsurmountable one. The great trouble in arc-light photometry has been that photometrists have been trying to ascribe a constant value to a varying quantity, namely, the luminous intensity of the arc in a given direction. Just as soon as a rational endeavor is made to measure some moderately constant luminous element of the arc, such as its total luminous flux or its mean spherical intensity, good, consistent results can be obtained, as the experiments of Professor Matthews have amply demonstrated.

The points which it has been the purpose of this paper to emphasize may be summarized as follows:

1. There are primary standards of luminous intensity, which, whatever may be their shortcomings from the point of view of the physicist, are sufficiently accurate for commercial purposes.

2. These standards can be copied with as high a degree of accuracy as is desired.

3. Rapid photometrical measurements can be made with all the accuracy required for commercial purposes.

4. In the case in which photometrical measurements are in the worst repute, namely, in the photometry of the arc, the chief fault lies with the varying nature of the quantity which it is sought to measure rather than with available methods of measuring the same.

Discussion.

Mr. Burnett, after reading his paper, continued as follows: I should like to show the arrangement of these "isophotal" curves, suggested in this paper. If we have here (referring to blackboard), a source of light, the customary method of plotting out its action has been to draw a curve on any arbitrary scale, showing the relative intensity in various directions in a vertical plane. My suggestion is that we consider the actual illumination throughout a plane of the space lighted and indicate the various curves of 1, 2, 3, etc.; or 10, 20, 30, etc., candle meters, the chart would be drawn to a scale of so many feet to the inch. The radial dimensions of these curves will be found to vary as the square root of the intensity of the light source in the corresponding direction, and all the of "isophotal" curves will be found to have the same general shape as the single light intensity curve as I now show, except as changed by shadows and diffusion. It would be at least interesting, if not of actual value, to proceed to chart out these curves in real instances. The only set that I have seen are those of Weber, which are referred to in my paper.

Having then mapped out the illumination throughout a vertical plane, we may show on our chart a surface upon which the light impinges, and draw a curve showing the distribution of the lighting in candle meters along a line of that surface intersected by the plane. A study of this sort of curves will show that the distribution of the lighting is much more uniform than a curve showing the intensity of the light in the various directions, radiating toward corresponding points of the surface.

From these rough curves which I have indicated, we make the deduction, as pointed out by Ryan, that the direction of the maximum intensity is different from and higher than the direction of maximum illumination.

As I show here, my instrument compares the normal lighting of the room falling upon this surface with the lighting on a similar and adjoining surface created by an adjustable lamp, suitable shades being provided to avoid interference between the lights and with the normal size of the pupil of the eye. Such an instrument would measure the illumination at the various points of a room and would furnish data for the construction of such a curve as I have indicated.

The President:—Gentlemen, we have been presented with an exceptionally excellent array of luminous material, and the general subject is now open for discussion. We have with us this evening Prof. Nichols, a recognized authority on the subject before us. Prof. Nichols will open the discussion.

Prof. Edward L. Nichols:—Mr. President and Gentlemen: I came to-night to listen rather than to say anything, but I should like to express my admiration for the very admirable and ingenious manner in which Mr. Matthews has worked out the problem of rapid measurements of the mean spherical candle power, both of the arc lamp and of the incandescent lamp. While it is true, of course, that the use to which a lamp is to be put, as the Chairman has stated in his introductory remarks, determines the question as to the direction in which the light shall flow, there can never be any other general method, I think, of comparing light-giving sources, except that of the mean spherical candle power. Whatever methods we use for our convenience or for special purposes, should after all be referred back to this, and the only reason why it has not come into general use, has, I take it, been that it has hitherto been most laborious and uncertain. Mr. Matthews has shown us how this can now be accomplished rapidly, and I am sure that he deserves the highest thanks of all interested in photometry for his labors in this field.

I should also like to say that I feel very strongly the point that the second reader, Mr. Burnett, made in his paper, with reference to the importance of the study of illumination as distinct from the mere photometric measurements of sources of light. We see growing indications everywhere of a realization of the importance of this side of our subject. I might say that we have in the laboratory at Cornell University made a step toward the practical study of these problems, by setting aside a room for the study of illumination. Dr. Sharp, who read a paper to-night, is the originator of that plan, and the room which he devised is being used. It is a room shaped something like this one, although not quite so large. The walls and ceiling can be draped in any desired way, so that the wall surface can be changed, using white, colored or black draperies. These draperies can be moved aside, and the walls, when the test is an important one, can be kalsomined or painted or coated with any desired pigment, and the floor can likewise be treated. The method which is employed and which I think is likely to yield important results, consists in dividing off the floor into squares of one metre and placing upon the floor at various points, a small white card the illumination upon which is determined in various positions by means of the Weber photometer. There are other devices for doing this, but this was the one that happened to be at our command and it works very well. The same piece of cardboard can then be placed on a movable stand at any desired height above the floor, and the illumination can be explored at a distance of one metre above the floor, two metres above the floor, and so on in detail. Thus the light field of the room can be plotted in detail, very much as one might study the magnetic field of a region, and maps can be made of the same. The lighting of the room is likewise capable of adjustment at will; that is to say, you can use as many lamps of a given kind as may be desired and those can be gropped as may be desired, in a central cluster, or around the walls or in any way, and the resulting illumination can be compared. I think that this is a line of work which will be very instructive to those who have occasion to deal with artificial lighting, and it is certain that it ought to be carried on, not only in closed spaces of this kind, but likewise out of doors, since the question of the best method of street lighting is almost as important as the best method of lighting rooms. The fact has already been pointed out that our newer sources of artificial light are all too bright to be good for the eye, and I think there is no doubt but what the future of lighting as a fine art will consist, in a great measure, in placing the lamps where they themselves will not be seen, and getting the light from them in such directions and such quantity as may be most desirable for the work in question.

We are in the study of illumination only upon the threshold of exactitude. Dr. Sharp has pointed out that photometric measurements are capable of a considerable degree of precision, but photometry is only the beginning of the science of the study of illumination.

Mr. Francis R. Upton:—The method of testing lamps by a comparison with a lamp in the same circuit, was one that solved many a hard difficulty that was met with in the early days of making incandescent lamps. The fact that Dr. Nichols was the first photometrist of incandescent lamps, is interesting, especially as he has followed that out for so many years. What he describes to-night regarding the study of illumination, is most important. What the light itself tests is nothing. It is what it does. That is what the public are looking at. There is one point about illumination that I have never seen mentioned; that is, the effect of the mass of light in New York City, and the mass of light in Newark, upon the clouds reflected back upon the landscape. At Orange at night, this is now so great that on a cloudy night, all the trees, all the houses, can be distinctly distinguished by the light from the clouds. This illumination is such that in New York harbor on any dark night you can see all the boats on the river and even the waves. I remember distinctly that when the question of putting arc lights on the piers or along the water front was discussed, it was thought that they would interfere with navigation. Now, the arc lights are so many, and the general illumination is so great that navigation is much aided.

The President:—It is rather surprising to note that although clouds in the day time obscure the general illumination, clouds at night contribute to the illumination of the surrounding country. Mr. L. B. Marks has given a good deal of attention to this general subject.

Mr. L. B. Marks: The photometer of Prof. Matthews was brought to my attention about six months ago, and I at once became very much interested in the method of operation which was described to you by him this evening.

I find on looking over some of the literature relative to the subject of photometry, that in 1897, as I believe Prof. Matthews mentioned, the American Institute of Electrical Engineers made the following recommendation as to the candle-power rating of incandescent lamps. The Committee on Units and Standards reports: "Although incandescent lamps are at present rated by their horizontal candle-power, yet, since the only true criterion of the total quantity of light emitted by a lamp, is its mean spherical candle-power, we recommend that the rating of lamps should be based upon their mean spherical power so far as is commercially practicable."

Again, at the Great Barrington Convention of the INSTITUTE this year, a Committee further reported on the same subject in these words: "It is customary in industrial practice at the present time, to rate incandescent lamps upon the basis of their mean horizontal candle-power; but in comparing sources of light in which the relative distribution of luminosity differs considerably, the comparison should be based upon the total quantity of light or total flux of light emitted by each source."

The Committee appointed by the National Electric Light Association to investigate this question reported in 1902 in substance, that while in theory the mean spherical candle-power should be the final test for luminous radiation of incandescent lamps or other lamps, until such candle-power can be determined by a more correct and precise process than is now commercially available, it is best to depend upon the mean horizontal candle-power, etc.

In other words, it may be said that up to the present time we have had no means of commercially determining the mean spherical candle-power of incandescent lamps, that is, of making this measurement with the same accuracy and facility as now obtain in making horizontal candle-power measurements. Prof. Matthews shows us a practical way of obtaining the spherical measurement, and it is for this reason that his integrating photometer appeals to me most strongly.

My friend, Dr. Nichols, has long urged that the mean spherical candle-power unit is the only rational basis for rating incandescent lamps. Curiously, there has been great opposition to the adoption of this rating. At the meeting at Great Barrington, a distinguished representative of one of our leading electric light companies, took the ground that such a rating would be inexpedient for the reason that the people had been educated up to a 16 candle-power standard and that the lighting company would suffer if the lamps were sold on the basis of their mean spherical candle-power, which is really only about 13 c.p.

In this connection, I am reminded of our early experience in enclosed arc lighting. When the enclosed arc lamp first came out it was said that lamps of this type couldn't compete with open arcs because the maximum candle-power of the former was only about half that of the latter, for lamps consuming the same amount of energy. People had been educated up to the 2,000 c.p. standard of the open arc and it was contended that the lower rating of the enclosed arc would seriously handicap its introduction. This contention, it is true, was not without some foundation for it took a few years to convince the people that the so-called 2,000 c.p. lamp was not giving them any more light than the 250 c.p. (mean spherical) lamp.

Now, we have an analogous situation with regard to the incandescent lamp. It is contended that the introduction of the spherical rating will seriously handicap the lamp companies, because the so-called 16 c.p. lamp will be rated at only about 13 c.p. But the spherical rating must come. It is the only true standard by which incandescent lamps can be properly compared, and its adoption will surely benefit the lamp companies as well as the lamp users.

Prof. Matthews has shown you how the instrument may be used for measuring the spherical reduction factor of the lamp, that is, the ratio of the mean spherical candle-power to the mean horizontal candle-power. This measurement is of considerable importance. I may say that some of the large lighting companies now specify in their contracts with the lamp manufacturing companies, that the reduction factor of the lamps supplied, must fall within certain narrow and specified limits. The direct measurement of this reduction factor has heretofore been impossible, but Prof. Matthews, as you have seen, has solved the problem in a very simple way.

It is quite as possible and practicable to rate a lamp according to its flux as according to its horizontal candle-power, and as Prof. Matthews has pointed out, the scale of his photometer may be calibrated either in lumens or in spherical c.p., so that the direct measurement of the total flux may be made with as great accuracy and celerity at the measurement of the horizontal c.p.

In ordinary measurements, as you know, it is necessary to slide the photometer carriage along the bar to obtain a setting. In the instrument we have before us, the photometer disc is fixed. Those who have had experience in making photometric measurements will appreciate the value of this improvement.

It also occurs to me that for making candle-power measurements of the Nernst lamp, in which case it is particularly important to measure the mean hemispherical intensity below the horizontal, an instrument of this kind will be very serviceable.

From a scientific point of view, the ingenious method by which Prof. Matthews has solved the question of the inequalities in the cosine law, is of extreme interest. Kennelly has also grappled with this very problem, and has attempted to solve the question by another method. The results of his efforts are quite well known. Prof. Matthews, however, attacks the subject from an entirely new and original standpoint. By a simple radial adjustment of the mirrors, he corrects not only for error in the cosine law, but also at the same time, for any difference in the coefficient of reflection of the mirrors. What is particularly interesting to me, as one who will be apt to use the instrument commercially, is the fact that the mirrors being once set, need no further adjustment. For the solution of these various qestions, I think Prof. Matthews deserves great credit.

MR. W. S. HOWELL:—The Lamp Testing Bureau some months ago tested one of Dr. Matthews' photometers, and found that its results checked very closely against results obtained by standard methods, so closely indeed, that we are now building one. We intend to use it for spherical measurements.

MR. F. S. SMITH:—Personally, I have been very much interested in Prof. Matthews' instrument, and I think that lamp makers are as much indebted to him as lamp users. I think that everyone who has gone into the matter at all, has appreciated that the existing methods of measuring incandescent lamps have been very unsatisfactory, and that the rating, in line with those measurements, has not been such as could be adapted to the various types. There was a paper here some little time ago which brought out that question very forcibly, and Prof. Matthew's instrument certainly reduces to a very simple matter, the question of the proper determination of the real value of a lamp.

THE PRESIDENT:—We have with us this evening, a gentleman who is the Physicist of the National Bureau of Standards, and is now a member of our Standardization Committee. He is here to-day to meet with that Committee—Dr. Rosa.

DD. EDWARD B. ROSA:—Mr. President, I cannot speak authoritatively on the subject of photometry. I can say, however, that I have listened with great pleasure to the papers that have been given; to the description of this very ingenious and practical photometer and to the account of the very satisfactory accuracy which has been attained in the Lamp Testing Bureau in their photometric work. I hope it will not be long before the Bureau of Standards will be able to contribute something to the subject of photometry. As soon as the new buildings of the Bureau are completed and equipped, work on that line will, I hope, be pushed with commendable energy, but at present, equipment is very moderate. We shall hope in the very near future, as I say, to take up photometry, and to be able to supply photometric standards wherever they are required.

THE PRESIDENT:—The subject is open for discussion, gentlemen. We will be glad to hear from any others. Mr. Rice.

MR. CALVIN W. RICE:—Mr. President, I take considerable pleasure in congratulating Prof. Matthews to-night. I think it is three years ago that I visited him in his laboratory to see the apparatus on which he was then working. There is no doubt of the satisfaction he had in showing me what he had then, and I think it must be the greatest satisfaction to him to be here to-night with the perfected device. I am not sure, but I think he was hoping to present this last June at Great Barrington, and was disappointed. Am I right? And therefore it is the added plea-u-e of finally succeeding. The remarks that Prof. Nichols made to-night are very interesting. I have a written communication from Mr. A. J. Wurts—and, if possible, I would like to have the Secretary give him credit for the communication—suggesting the Room Photometer. In substance, it was just as Prof. Nichols outlined, as a practical commercial photometer for comparing illumination. If I might interject a request to every gentleman who will give remarks to-night, speaking as a member of the National Electric Light Association Committee on Standards, it will be a great help to the art if some one would suggest a satisfactory primary standard, something more permanent, something more definite, if I am correct in using that expression. We are still in need of an acceptable universal standard, and if anyone could suggest an acceptable universal standard that could be reproduced, I think it would be a great help to the art, and I hope that some one to-night in his remarks, would suggest something for the physicist to employ and develop.

THE PRESIDENT:—While Prof. Matthews was speaking, I recalled the very pleasant hour that I spent with him in his laboratory several years ago, and I was struck then with the thoroughness with which he entered into this work, and his paper this evening has shown how fully this work has been carried out, and how every detail seemingly has been elaborated so that he has a very complete instrument.

I notice Mr. W. J. Hammer. Mr. Hammer has given general attention to this subject.

MR. WILLIAM J. HAMMER:—I am afraid I cannot contribute very much to this subject, Mr. President. I think the suggestion that Dr. Nichols made, and which Mr. Burnett, Mr. Upton and others echoed regarding what the public wants in the way of illumination in any given area is an exceedingly important one, and an idea occurred to me which may not be a practicable one now, but which a little later Cornell University or the Bureau in Washington might be able to carry out, *i. e.*, that in such a room as Prof. Sharp arranged at Cornell, the illumination might be studied by placing selenium cells around the room. We know that all parts of a room have been studied in connection with ventilation and heating problems by placing thermometers in all parts of the room and subsequently plotting the curve showing the circulation of air and variation in temperature.

While I am somewhat familiar with the character of that remarkable substance "selenium," and the manner in which it varies its resistance when exposed to a varying amount of light and also the difficulty often experienced in getting the same results twice from the same selenium cell, and of making it so that it would remain constant, still I believe that we shall ultimately be able by means of such selenium cells to study and plot out curves showing the varying degrees of luminosity in all parts of a room.

I had the pleasure during my recent trip abroad of seeing some very interesting work which had been done by Mr. Ernest

Ruhmer and his father in making the selenium cell much more constant and reliable, and I was very much impressed with the future possibilities of it, after witnessing the very interesting demonstrations made at the Ruhmer laboratory in Berlin.

THE PRESIDENT:—Are there others who desire to take part in the discussion?

MR. MARKS:—I understand that Dr. Stratton, of the National Bureau of Standards, is present.

DR. STRATTON:—I can do no more than say what others have said, that I am very much interested in the papers of the evening, especially that of Dr. Matthews upon his new photometer. As to the work of the National Bureau of Standards, Dr. Rosa has stated our position very well. We hope to be in a position to help you in the very near future and to report actual progress rather than plans. It has given me great pleasure to meet with you this evening.

THE PRESIDENT:—I will now call upon the readers of papers for any further remarks they may have and name them in reverse order—Dr. Sharp.

DR. SHARP:—Mr. President, I wish to speak on just one point, that is, with reference to the suggestion of Mr. Rice about standards. I think it would be very desirable indeed to have a better standard, and I would like if Mr. Rice would state specifically what objection he has to the incandescent lamp as a secondary standard of light. Those who have used incandescent lamps in that way, and their name is legion, have found them very satisfactory, I think, for most purposes of photometry; and it would be hard to imagine anything which will more perfectly fulfill the requirements of a source of light, reproducible anywhere and constant if properly used for a limited amount of use, than the incandescent lamp. I hardly think that it is a fair thing—I don't know that Mr. Rice intended to do anything of the kind—to cast aspersions on the incandescent lamp as a standard, without finding fault with it in a specific manner.

MR. RICE:—I would like to remark that I referred to the primary standards of candle power and not to the secondary standards.

MR. MARSHALL:—Mr. President, I have nothing further to add. It is often said that imitation is the sincerest flattery, and I wish to state that this photometer of Dr. Matthews, has been brought to the attention of the lamp works at Harrison, and that we have thought so favorably of it, that we have obtained permission from Prof. Matthews to build such a photometer, and that we are now building one.

THE PRESIDENT:—You intimated in your paper that it was not necessary to get such permission.

MR. BURNETT:—I am very glad to know that Dr. Nichols has undertaken to investigate these questions at Cornell and I was surprised that we had not heard from him along that line before now.

The Weber photometer, which he is using, is a thoroughly developed instrument, but its objection is that it chokes off the light which impinges upon the surface, the lighting of which is to be measured, and adjusts it so as to bring it down to the lighting from a standard lamp on a surface at a fixed distance. The same difficulty, if it can properly be called a difficulty, exists with the Houston and Kennelly luminometer. In that instrument the light falls upon a surface of glass, is transmitted through it and is then choked off in a similar way so as to give an illumination equivalent to that of a small standard lamp at a fixed distance.

The object of such an instrument should be not in any way to vary the light which has fallen upon the surface, but to compare our standards with the light and thus get a direct measurement or comparison. I think I can say, without any show of egotism, but purely in the way of reference, that the instrument which I have suggested involves the desirable feature of Prof. Matthews' instrument, that the position of the photometer surfaces by which the lights are compared is not varied and does not require any adjustment of the position of one's head in taking the measurement.

THE PRESIDENT:—I think I may state in a word a résumé of the remarks which have been made upon Prof. Matthews' paper —that he has given us something of exceptional interest and value, his results show careful scientific work, and the embodiment of this work in an instrument which is of practical utility. It is well worked out. He has given us something which is valuable and useful, an advance is made in the art of measurement, and he has also given us an account of his work which is also of particular interest, as it shows an evolution. It is an instance of interesting personal work which has had a very happy outcome in successful results. Prof. Matthews.

PROF. MATTHEWS:—I do not think ,Mr. President, that I have much more to say. I wish to express my hearty appreciation of Dr. Sharp's paper, because I think that photometry and photometric measurements have long been under a cloud. This is partly due to the fact that anybody thinks he can make photometric measurements, if he cannot do anything else—an opinion which is not true. The basis of photometry is a very simple thing, but the practice of it takes skill and experience, and therefore I was very glad to have brought up here some discussion which shows what can be done in good commercial photometry.

Of the many kind remarks that have been made regarding my own work, I wish to express my appreciation. I have put a good many years of work on photometric subjects. I think perhaps the remarks this evening will be inclined to increase the mean spherical radius of my head, if I am at all susceptible.

However, I thank you very much for the kind reception you have given me.

On motion, the meeting adjourned at 10.45 P. M.

[COMMUNICATED AFTER ADJOURNMENT BY EDWARD P. THOMPSON.]

Having followed the invention underlying Prof. Matthews' new photometer, through the United States and foreign Patent Offices, and having been unable to attend the meeting, I take pleasure in adding my commendation of the valuable experimental and practical work obtained by the author of the paper. It may not be amiss to add something about the actual novelty of the device considered as an invention. This may best be accomplished by quoting one of the claims granted by the United States Patent Office as an award for his ingenuity.

"In an apparatus for measuring candle power, the combination with the support for the light to be tested, of a photometer screen, and mirrors so fixed as to illuminate said screen proportionally to the mean spherical candle power of said light, said mirrors remaining stationary during the operation of measuring the light."

This is one of the twenty-three claims granted by the Patent Office. It serves to show that Prof. Matthews has originated a new type of photometer, and the members will no doubt greatly appreciate his services in providing an instrument which will so readily save time and tedious calculation.

I have also examined complete drawings of Mr. Burnett's photometer for measuring illumination in terms of the number of luxes instead of in terms of distance. The device as practially carried out is exceedingly simple, and without movable parts. There is nothing to get out of order.

CRITICISM ON THE MEAN SPHERICAL CANDLE POWER AS A STANDARD FOR ILLUMINATION.

[COMMUNICATED AFTER DISCUSSION BY ALEXANDER J. WURTS.]

The mean spherical candle power is unquestionably the present accepted standard of light, but in reviewing a subject of this kind, it often is instructive to consider whether we may not be somewhat biased by a practice, rule or standard which has ceased to be either useful or practical. The question arises as to whether we wish to continue this standard as our guide. Does the so-called standard meet with our approval? Does the mean spherical candle power, as a standard, measure that which we desire to have measured? In the opinion of the writer, it fails to do so and it would seem that something which more nearly meets our present needs should be devised.

In years gone by, when the incandescent lamp was practically the only electric lamp in commercial use, and later, even after the arc lamp had been introduced, the photometric determination of candle power served a purpose and gave a nominal rating to these lamps, but the great difference in candle power between the arc and incandescent was such that comparison between them on a basis of mean spherical candle power was of small consequence. With the advent, however, of new illuminants, the question of fair comparison becomes at once a matter of considerable practical importance.

In the laboratory, the photometer has proved itself a valuable guide in determining the relative life and efficiency of illuminants under varying conditions. If there were only one kind of illuminant to be considered, then units differing slightly in candle power could be easily and satisfactorily compared with this instrument, either by direct measurement or by the mean spherical candle power method; but with illuminants differing widely in candle power, quality and distribution of light, neither the direct measurement on the photometer nor the mean spherical candle measurement offer a fair basis of comparison, because two lights having the same mean spherical candle power might differ widely in quality and distribution of light or effective illuminating power. For example, let us consider two lights exactly the same in every respect except that one throws all its light upward, whereas the other throws it all downward. Both have the same mean spherical candle power, but obviously not the same effective illuminating power for a given purpose. Take for further illustration the various well-known electric lights—the incandescent, the arc, the Nernst, the Hewitt and the Bremer. These all differ widely in both quality and effective illuminating powers for a given set of conditions, and as above shown, cannot be consistently compared by the standard of mean spherical candle power.

It follows logically and as a matter of fact that a user of light never, it may be said, inquires about the mean spherical candle power of an illuminant; the only use he makes of a photometer is to test with it some guarantee of candle power which may have been furnished with his lamps. The practical user in negotiating for this or that illuminant is more interested in the effective illuminating power of the lamp in question than he is in the mean spherical candle power, and by effective illumination is meant that amount of light which is reflected to the eye from the objects it is desired to see. The total light flux is of no consequence to the dry goods man or his customers, to the hotel keeper or his guests, except in as far as upward or horizontal rays may be reflected from ceiling and walls. Interest centers rather in (1) the quality of the light; (2) the effective illuminating power; and (3) cost of maintaining the illumination. If this last statement be correct, may not the comparison of various illuminants as to the three points involved be more practically and satisfactorily determined in some other way than by the mean spherical candle power method; that is, by a method which does not place on an equal footing a sphere of soft white light and a search light, assuming that both have the same mean spherical candle power.

Having thus criticised the mean spherical candle power method of comparing lights, your attention is called to a rather old photometer or means for comparing different illuminants which seems to be worthy of more attention than it has yet received and one which also seems to be capable of considerable development. The photometer in mind provides a means for comparing the effective illuminating powers of various illuminants and involves every characteristic, advantage and disadvantage which may be found in any particular class of illuminants. This method has been used from time to time in a crude way, by placing different kinds of illuminants in the same room and noting the illumination, but could not this idea be carried out on a more practical and elaborate scale by providing two rooms exactly alike in every respect, that is, in dimensions, color and furniture, and then by locating standardized units of light, such as 16 c.p. incandescent lamps, in one room, comparing the effective illuminating power of these lamps as a standard with the effective illuminating power of any other lamp or lamps arranged in the other room in any manner whatsoever which will produce the best results—namely, the most effective illumination with the particular kind of lamp. For example, suppose it be desired to illuminate a dry goods store, the chief points to be considered being the illumination of goods on the counters and on the shelves back of the counters, also boxes and their labels above the shelves to a height of eight feet above the floor. Question: For a given expenditure of energy, can this illumination be obtained more effectively with this or with that lamp. In making such comparison of effective illumination, it would seem proper not to make any restrictions whatever as to the position or distribution of the units. Both the lamps to be used as standard and the lamps to be compared with the standard should be located and distributed to the best possible advantage with reference to effective illumination.

With the two-room photometer above described, it would be a simple matter for the observer to place himself in a position commanding a good view of the two rooms for purposes of comparison. The illumination of the standard room might be easily varied by using a considerable number of small units and the wattmeter readings would of course give the relative efficiencies for equal effective illuminating power. Comparisons of this kind have been made by the writer, not, however, in such an elaborate manner as above described, but if the various illuminants now in the field could be thus authoritatively compared with reference to effective illuminating power and the results tabulated and given to the public, users of artificial light would have before them a reasonable and practicable means of determining the best illuminant for a given set of conditions.

Pittsburg Branch, Meeting November 10, 1902.

The meeting was called to order by Mr. P. M. Lincoln, Chairman of the Temporary Committee, who read the committee's report. This report advised the election of a committee consisting of a Chairman, a Secretary and three other members, to have charge of the preparation of programs, calling of meetings, etc.

The report was adopted, and the following Permanent Committee was elected: Mr. P. M. Lincoln, *Chairman;* Mr. J. S. Peck, *Secretary;* Mr. H. W. Fisher; Prof. S. M. Kintner; Mr. C. W. Rice.

Prof. Kintner read a paper, giving a resumé of the papers presented at the New York meeting of the A. I. E. E.

Mr. C. F. Scott gave a resumé of the discussion at the New York meeting; also an extremely interesting description of the John Fritz dinner given in New York on November 7th, as well as a brief account of the work of Mr. Fritz and of the founding of the John Fritz medal.

Mr. A. J. Wurts gave a talk on illumination in general, with particular reference to the Nernst lamp. Attention was called to the fact that no illuminant has ever been discarded; candles, oil-lamps, gas and incandescent lamps are all in extensive use. The custom of rating lamps according to mean spherical candle power instead of by effective illumination was severely criticized. The great flexibility in the size of the Nernst lamp was pointed out. It was predicted that the Nernst lamp will have a great influence on street lighting as well as on interior illumination. Mr. Wurts then read a copy of the communication sent by him to the New York meeting.

Mr. R. H. Henderson gave a description of the Bremer flame arc lamp. Attention was called to the fact that the arc lamp was the earliest form of the electric lamp, and that a great amount of experimental work has been done on methods for holding carbons in proper position. The Bremer lamp is strictly a German invention, and no American improvements have been made upon it. The carbons are manufactured according to a secret process, and only in Germany. The most striking features of the Bremer lamp are the composition of the carbons, their position in the lamp, and the fact that the arc is drawn out fan-shaped by means of a magnet placed around the arc. When the carbons are heated, mineral vapors are given off, which become luminous, and give the arc the peculiar flaming appearance as well as its yellow color. The two carbons are nearly parallel, converging at an angle of about 20°. The arc is started by means of a starting device, which short circuits the ends of the two carbons. The arc is prevented from traveling up between the carbons by means of the magnets which surround the carbon points and hold the arc in position, as well as spreading it out fan shaped. Tests have shown the Bremer lamp to be over three times as economical as the ordinary arc lamp.

Lamps were exhibited and explained in detail.

Dr. von Reckinghausen read the accompanying discription of the Cooper-Hewitt lamp. Several lamps were shown in operation, and were frequently referred to by the speaker.

Mr. P. M. Lincoln then talked for a few minutes on the acetylene gas lamp. Attention was called to the fact that although the acetylene light is not an electric light, it is an indirect production of electricity, inasmuch as the electric furnace is the only method yet devised for producing calcium carbide from which the acetylene gas is made. The cost of producing acetylene gas was briefly discussed. The values given are approximately as follows: 1 kw. hour will produce 250 candle-power hours by incandescent lamp, 500 candle power by Nernst lamp, 1,000 candle-power by arc lamp, 2,000 candle-power by Cooper-Hewitt lamp, and 110 candle-power by acetylene. In the production of calcium carbides, however, an electric plant may be operated at full load for 24 hours per day, while the ordinary lighting station does not ordinarily deliver more power than is equivalent to full load for two hours per day. A 25 candle-power acetylene lamp was exhibited, and it was stated that the cost of operating this lamp was not more than one cent per hour.

The following discussion then took place:

Q. Can the Cooper-Hewitt lamp be operated in any position?

A. Yes; provided it is arranged for the position in which it is to operate.

Q. What is the pressure in the Cooper-Hewitt lamp?

A. 2 mm. of mercury when operating. Almost absolute vacuum when cold.

Q. What is the range in size of the Cooper-Hewitt lamp?

A. The smallest size made up to the present time is approximately 20 inches long, giving about 180 candle-power. The longest about 20 feet, giving approximately 3,000 candle-power.

Mr. Edward Bennett called attention to the statement made by the President of the INSTITUTE at the New York meeting to the effect that " quality " of light was of great importance and said that it could not be brought out too strongly. Mr. Bennett discussed at some length the question of the different kinds of light, and the effect of their quality on the human eye.

Mr. N. W. Storer expressed his sympathy for Mr. Wurts in his contention against mean spherical candle-power as a unit of measure, as he was conducting a similar campaign with reference to the one-hour-horse-power rating of street car motors;

but as a horse power rating is demanded by the commercial conditions, so a candle-power rating would also be demanded.

Mr. Wurts stated that the candle power rating does not fill the commercial want, as it is not a unit of measure of effective illumination.

Mr. F. W. Jones stated that from large experience in lighting buildings he was convinced that mean spherical candle power rating was in no way satisfactory, but that effective illumination was the thing demanded.

An animated discussion then took place between Messrs. Wurts, Kintner and Storer, with respect to the necessity of maintaining the candle power rating.

Thirty INSTITUTE men and about 175 visitors were in attendance.

THE COOPER-HEWITT LAMP.—CONTRIBUTION BY DR. M. VON RECKLINGHAUSEN, READ AT PITTSBURG MEETING.

The artificial illuminants which we now use are all based on the principle of the incandescence of solid bodies due to high temperatures. In most illuminants this incandescent body is carbon. For instance, in the incandescent and the arc lamp. It is also carbon in the ordinary gas or kerosene flame. In the latter two the solid carbon is produced in a very fine state, through decomposition of the hydrocarbons at high temperature.

The Cooper-Hewitt lamp, which I have the pleasure of showing you to-night, is the first high candle power illuminant not based on an incandescent solid, but on an incandescent gas. This incandescence takes place under the influence of the electric current. Many attempts have been made to produce light by means of the action of electric currents passing through gases or vapors, especially when the latter were under low tension. I recall the Geissler tubes and the Moore vacuum tubes. With very few exceptions these methods were based on electric currents of entirely different type from the kinds we use commercially. The earlier workers in this field rarely succeeded in getting high candle powers. None of them went so far as to introduce their illuminants into commercial use.

The particular type of Cooper-Hewitt lamp I am showing you is the mercury vapor lamp. The mercury vapor is enclosed in glass tubes, and when the lamps are cold there is practically a vacuum in the tubes. When they are running normally the pressure is about 2 millimeters. The electrodes we use are mercury as negative and mercury or iron as positive. The connections of the electrodes are made of platinum wires sealed into the ends of the tubes. The lamps, as you see them, are running on the ordinary D. C. street current of 120 volts, and they consume about 3 amperes each. The voltage across the terminals is about 80, and the candle power is, as nearly as we can measure, 700.

You will see readily that this means an extremely high efficiency; as a matter of fact, we get about ten times the light from the same amount of energy that we get in incandescent lamps. Lamps of about the same type are in continual use in our factory, where they have been for several months, and show little or no depreciation.

We have made lamps of other shapes and dimensions. We find that the voltage is proportional to the length under otherwise similar conditions. The main difference in conductivity between these lamps, and metallic conductors is that an increase of current within certain limits will not be accompanied by an increase of voltage. I suppose you have seen that there is a certain peculiarity about the way I started the lamps. When they are put right on the line voltage no current will pass through them. We have to make them conductors first. This we do by means of a single discharge of very high voltage, upon the passage of which the lamp becomes a very good conductor, and a low pressure will permit heavy current to continue. If we put this type of lamp on an ordinary alternating current circuit, we have to start it at every alternation, which would practically mean running it continually on the very high starting potential. To pass 2 amperes through the lamp we would have to use about 4,000 volts, while the lamp runs on D. C. at about 100 volts. The seat of reluctance to starting seems to be in the negative electrode, and this reluctance is overcome as described, though when starting the lamp we considerably increase the effect of the high potential kick, by using what we call a starting band; that is, a metal strip outside the negative electrode, connected by a wire to the positive electrode.

A peculiar phenomenon can be seen at the point where the the current leaves the negative electrode and goes over to the vapor. A very brilliant spot of light marks this space on the mercury surface and causes a certain amount of flickering near the negative electrode, We can prevent this by having a small wire projecting out from the surface of the mercury. To this wire the light spot will attach itself. Above this light spot for about an inch there is a fairly dark space in the tube, and then the light-giving column starts. There are also other very interesting phenomena noticeable near the negative electrode, especially under the influence of a magnetic field. One of the most striking features of the mercury vapor lamp, as you will notice, is the strange color and the strange way that things look within the range of the lamp. This color is peculiar to the kind of vapor. We have been making lamps with other gases than mercury, giving other colors; but as we had to take certain disadvantages in exchange, we preferred, for the time being, to stick to mercury vapor as our conducting gas.

It is only natural that many people who see this lamp for the first time ask why we don't use colored glass to get some red into the light. A simple look at the lamp through red glass, or observation of the spectrum of the lamp, shows that we cannot get red rays from an illuminant that does not send out any. The result of using a red glass is to kill every part of a spectrum except red. It means, in our case, hiding the light entirely. Another way which one might propose to obviate the ghastly effect of the mercury light is to use red reflectors, but you will readily believe that this is just as hopeless as using red glass or globes. There is still one way, which we have tried, as you will see, with some success; that is, using a fluorescent screen, coated in a peculiar way, or else silk dyed in a certain way. The peculiar dye which we have used in these cases has the property of fluorescing red under the influence of the mercury light; that is, it transforms some of the wave lengths into red waves. Still, we think that without these artificial means of improving the color there is quite a large field for these lamps, especially where color is of no account. One very interesting feature of the Cooper-Hewitt lamp is its actinic power. Its effect on photographic plates is extremely strong, and the lamp is on this account useful in photographic studios, and especially for printing purposes. We have been taking photographs with the Cooper-Hewitt light with about 1-30th the exposure that is required with an arc light consuming the same amount of current.

I would also mention one more extremely important fact. We find that the Cooper-Hewitt light is far less tiring to the eyes than any other kind of illuminant. This is not only our own experience, but it is also confirmed by our mechanics and draughtsmen and other people who have been using it continuously for some time.

Everyone knows what a great strain on the eyes is draughting and other delicate work in artificial light. It seems that we have found in the Cooper-Hewitt lamp an illuminant which will do away with these troubles.

A paper read at the 170th Meeting of the American Institute of Electrical Engineers, New York, November 21, 1902.

VARIABLE SPEED MOTOR CONTROL.

INTRODUCTION BY PRESIDENT SCOTT.

The applications of electricity lead to the revolution of old methods, as well as to the evolution of new ones. Electrical apparatus not only replaces that which it supersedes and performs the work more efficiently, but it also broadens the field and leads to developments which were impossible by former methods. For example, the electric light does not simply replace indoor lamps and flickering street lights, but it has revolutionized the whole art and practice of illumination. The first railway motors were made to have a little greater power than the horses or mules which they replaced, but electric cars have increased in size and in speed, they have extended out from the city to the suburbs, they connect adjacent towns, and in a dozen years great systems have developed which have little in common with the horse cars. The electric crane has been the prime factor in modernizing the methods of manufacturing where heavy work is to be turned out. The electric distribution of power to the machines in a factory not only accomplishes more effectively the service which other systems of power distribution had accomplished, but it is capable of other things as well. Because volts and amperes are more easily measured than speed and torque, the power consumption of tools may now be definitely known. The electric motor affords an effective means of securing speed variation.

The revolution of old methods and the evolution of new ones are both taking place in the machine shop through the application of the electric motor to the driving of tools. Plenty of power effectively applied with a speed control which is wide and flexible, together with new kinds of cutting tools and heavier machines in which to use them, make possible an increase of output which seems almost incredible.

In a sense, speed variation is a purely mechanical matter. The two factors which determine mechanical work are speed and torque. The relations between speed and torque may be varied in definite ratios by means of belts and pulleys or by gearing. There is, however, no general mechanical solution of the mechanical problem of speed variation, or variable speed control. There are devices by which either of several fixed ratios may be selected; for example, common cone pulleys which allow the shifting of a belt from one pair of pulleys to another having different diameters, or the counterpart of this, several sets of gears, either one of which may be selected at will. There are indeed a number of mechanical variable speed devices by which the speed ratio may be changed by very small increments. Many of these devices are quite successful over a certain limited range of speed variation or of power capacity. In general, those which are satisfactory over a fairly wide range are limited in the amount of power which they can transmit.

On the other hand, speed variation by the electric motor can be so successfully effected that it is quite common to think that the whole problem of speed control should properly be turned over to the electrical engineer. It is regarded as a matter of course that all mechanical means for accomplishing the result are to be discarded if possible, and the difficulties which the mechanical engineer has failed to overcome in the purely mechanical problem of varying the ratio between speed and torque are to be imposed upon the electric motor.

It is reasonable to presume that the solution of a problem which has proved so difficult mechanically may involve electrical difficulties as well. Although electrical apparatus may be provided which will accomplish the desired purpose, yet this may be at the expense of added complication, additional apparatus, or increased cost. It is not proper, therefore, to decide *a priori* that because speed variation *can* be effected by an electric motor that the variable speed motor should *always* be used regardless of conditions, specific requirements and cost.

Electric motors for continuous current may be divided into two types, represented by the series motor in which the speed varies when the load changes, and the shunt motor which in general has a speed which is constant with different loads. The series motor is particularly adapted for railway service, crane service and the like. The shunt or constant speed motor may operate at the same speed at all times, or the speed may be changed at the will of the operator, and the motor will then run at a desired speed independent of the load. The speed of the motor depends upon the number of turns in series in its armature, the strength of its field and the e.m.f. applied to its armature. In practice, speed changes are produced by one of these three methods, or by combinations of them. When the shunt motor is arranged to run at different speeds over a considerable range, it will usually be found that the generating plant and the supply circuits are of special type, or the controlling devices are of complicated form, or the motor is of greater weight and cost than it would be if it operated at one speed only. Therefore, a constant speed direct current shunt motor is to be preferred *per se* to a variable speed motor.

The alternating current induction motor like the shunt motor is inherently adapted for constant speed service. It may be used also for variable speed work with characteristics analogous to those obtained with the rheostatic control of a shunt motor with unvaried field. It may also be wound so that either of several numbers of poles may be used, thereby securing either of several definite speeds, which are sensibly constant with varying load. Just as a shunt motor may be operated at different speeds from generators giving different voltages, so the induction motor may be operated at different speeds from generators giving different frequencies. The single speed induction motor is, however, the type usually used.

In selecting the apparatus for a new plant it is proper to consider the problem as a whole, to take a general view before concentrating attention upon specific parts. What proportion of the power is to be supplied at constant speed? What proportion of the variable speed work cannot be served satisfactorily from a constant speed drive with variable pulley ratios or variable gear ratios? What proportion of the work which requires delicate speed adjustment falls within the range of simple and satisfactory mechanical speed changing devices? What advantage in lessened cost of equipment will be secured by group driving, by furnishing a single large motor for delivering the average power required by a number of machines instead of a large number of small motors each for delivering the maximum power of the machine to which it is connected? What advantage will there be under the particular surroundings of the installation in reducing the complication and the amount of auxiliary apparatus and putting in motors of the simplest possible type? Taking the plant as a whole, what are the general advantages of one type of apparatus over another, and does the general balance sheet show that the advantages of individual speed control by means of the motors themselves are of sufficient moment to dictate the scheme and plan for the whole installation? The varying answers which will be given to these questions in different cases will necessitate different solutions to the problem of selecting the best system.

We are fortunate, this evening, in having presented to us several methods of speed control of continuous current motors. These methods are not theoretical and untried; they have the prestige of being methods which are in actual commercial operation, and of having been selected by manufacturing companies as being well adapted for general service. Although speed control can be effected so admirably by the electric motor, it is fitting that we should not go too far and apply the variable speed motor indiscriminately. The various methods of control which we are to consider this evening must be taken as specific ways by which certain ends can be accomplished; and it must be recognized at the same time that there is the larger problem to be determined in connection with each proposed installation; viz., whether on the whole speed variation by the motor itself should be chosen.

A paper read at the 170th Meeting of the American Institute of Electrical Engineers, New York, Nov. 21, 1902.

THE OPERATION OF MACHINE SHOPS BY INDIVIDUAL ELECTRIC MOTORS.

BY R. T. E. LOZIER.

Data concerning the load factor and operation of machine shops, and a description of the advantages derived from the use of individual electric motors. Illustrated.

The individually-applied motor is now accepted as an established feature of every well equipped machine shop. The period of careful investigation, followed by that of cautious probation, is passed, and this type of power application has now been in practical service sufficiently long to provide data that can be studied with profit. These data enable one to make more accurate deductions than were possible in the past, and enable those unfamiliar with the art to undertake its application with greater certainty of desired results.

From the data that have been collected on power transmission in industrial shops, much of which is to be found in the transactions of the various engineering societies and in the magazines, it appears that if a certain maximum horse-power is required by all the tools of a shop, say 100 h.p., it will require at least 100 h.p. additional to transmit this effective power by belts and shafting. This loss of 100 h.p. remains constant whether the effective horse power is reduced or not. This means that 200 h.p. must be generated. Should these same tools be driven by individual motors, instead of 100 h.p. being required for transmission only 43 h.p. is required, even if every tool is running; but it is found that in the average industrial shop every tool is not running at the same time, some being shut down and others operating on lower than maximum speeds, thus requiring less horse-power. It has been determined practically that in the ordinary manufacturing establishment the mean effective power is but 30 per cent. of the aggregate effective power which is required when all the tools are running at maximum load. This percentage is termed the load factor. In the case of belt-drive there is, then, 100 h.p. assumed loss for 100 h.p. effective load; that is, an efficiency of 50 per cent. Applying the load factor as above, it is found that there is but 30 mean h.p. to use and that it requires 100 h.p. to transmit it, thus giving the real efficiency as only 23 per cent. With the individual motor drive the loss varies with the load. Taking the same load factor, and assuming 30 per cent. as representing the loss incurred by the 30 h.p. effective load, there is but 13 h.p. loss against 100 h.p. with the belt drive. Thus, with individual drive, there is generated 43 h.p., of which 30 is effective, giving an efficiency of 70 per cent. against 23 per cent. by the shaft and belt method.

In a paper read by the author before the New York Electrical Society in November, 1901, it was shown that, assuming steam power to cost $36 per horse-power per year (or 3,000 hours), with the shaft and belt system the power would amount to two per cent. of the cost of the establishment's product. With sub-divided motors it would be one per cent., and with individually driven motors it would be something less than 4/10 of one per cent. of the cost of the product; so that, assuming a plant with an output of $1,000,000 a year, the following statement results:

Method of Drive.	Cost of Power.	Yearly Saving.
Belts and shafting....	$17,000.00	
Sub-divided motors ..	8,500.00	$8,500.00
Individual motors. ...	4,000.00	13,000.00

It appears from such information as the author has been able to obtain since that time, that the above figures are correct. These data relate to the average machine shop, and not to establishments run under conditions peculiar to their line of work, and which must be put in a class by themselves, the law of averages being applied to their peculiar conditions.

Assume that in the average machine shop 60 per cent. of the motors installed are to have variable speeds. These variable speed motors will have a rated capacity considerably higher than the average amount of power they will be called upon to supply. Assume that the rated capacity of the other 40 per cent.

represents the exact amount of power that they will consume—and this assumption is justified because their speed is not varied. Of the sum of the total rated capacity of the variable speed motors and that of the constant speed motors, 35 per cent. fairly represents the mean power that all of these motors will be required to furnish, if they are all running at the same time. This mean power, of course, varies with that percentage which the variable speed motors bear to the total installation. If the load factor of 30 per cent. be now applied—which provides for the shut down of tools and reduction in the power due to slow speed—it is found that the average power that must be provided by the generating plant is but 10.5 per cent., of the aggregate *rated capacity* of the individual motors installed. While it is true that 60 per cent. of the motors have a much larger rated capacity than is actually required, still this very small amount of power required is an evidence of the remarkable efficiency of the individual drive system. It cannot be assumed that this 10.5 per cent. is the capacity of the generating plant required, because provision must be made for maximum conditions, and inasmuch as that percentage represents but a mean condition. However, the system is so efficient that ample margins of say 100 or 200 per cent. can be applied, which may also provide for "stand by" purposes. And yet the purchaser who applies this individual motor system comes well within that power plant which he would otherwise have to supply to meet the mean conditions of a belted plant, without providing any "spares" for the latter. The author feels that if it were not for the empirical data presented time would be wasted in stating an already well accepted fact; *i. e.*, that the individual motor drive is highly efficient, and many times more so than the old system of belt transmission, or its modification of belted motors in groups. It is not claimed that the latter itself has not a sphere of usefulness and that a large one, the foregoing being merely a comparison of the relative economy of these different systems.

It would not be possible to use the individual motor, if means were not available for successfully varying its speed. To control the speed of a motor it is necessary to apply to the armature terminals a voltage corresponding to the speed desired. This can be accomplished in several ways:

The Rheostatic Method.—In this case the current is generated at any ordinary source of supply at a fixed voltage. Before reaching the motor, it is passed through a resistance which is adjusted to consume just so much of the voltage as will reduce the speed of the motor to the point desired. This method has three limitations, viz.: (*a*), that if the load put upon the motor varies, the proportion of the voltage consumed in the rheostat is altered, and this changes the speed of the motor, which may not be desirable; (*b*), the system is inefficient, because that percentage of the voltage which is consumed by the rheostat represents a dead loss; and (*c*), the dimensions of the rheostat necessary to dissipate the energy may reach an inconvenient size.

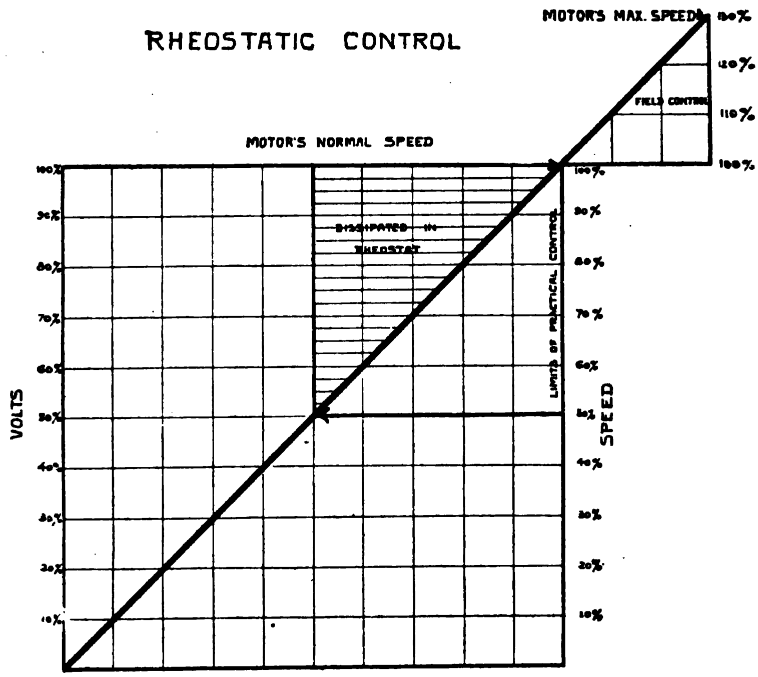


Fig. 1.

Within its limitations, however, the rheostat system of control can be made very useful. Fig. 1 is a diagrammatic representation of this system. It will be seen that the motor cannot be reduced from its normal speed more than 50 per cent., because below that point the fluctuations in speed, due to variations in torque, are too great.

Multi-Voltage Method.—This method consists essentially in supplying the motor with as many different voltages as are necessary to cover the desired range of speed. In its simplest form this method consists of generators, each adjusted for different potentials This, however, is not necessary, because it has been found that where several motors are involved they will balance up against each other in such a way as to divide amongst themselves the full voltage, so as to give the respective desired speeds It is, therefore, only necessary to supply the main generating plant with a small balancer to take up any differences that there may be. By dividing the voltage at three points, there are six possible combinations which successfully cover the full range of speed as far as general requirements

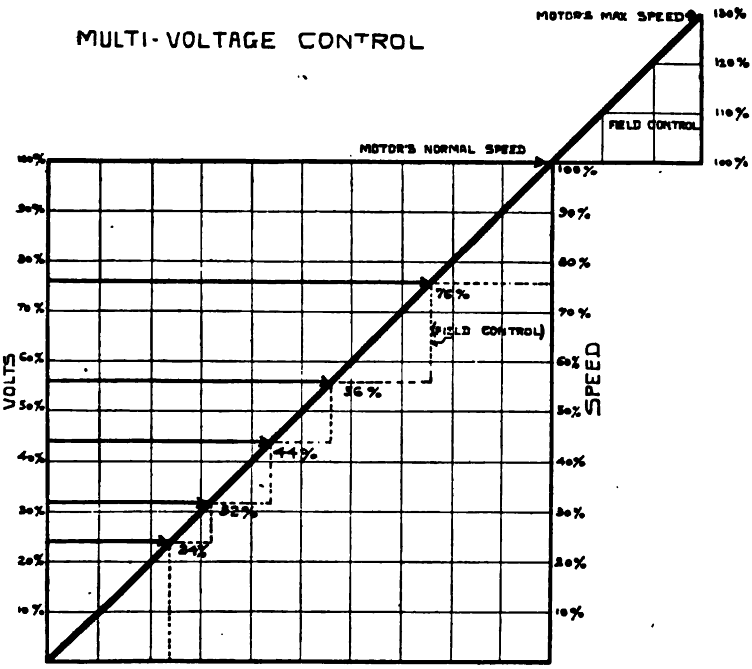


Fig. 2.

are concerned. The advantages of this system are: (*a*) that any one of the lower steps can be maintained constantly and quite independent of variations in the torque or load upon the motor—this is absolutely essential to successful tool operation; (*b*), that the system is highly efficient; (*c*), that appliances to control it are of very small dimensions and convenient to operate (see Figs. 2 and 3).

Special Methods.—In this class are to be found various methods which have been devised to meet the special requirements of

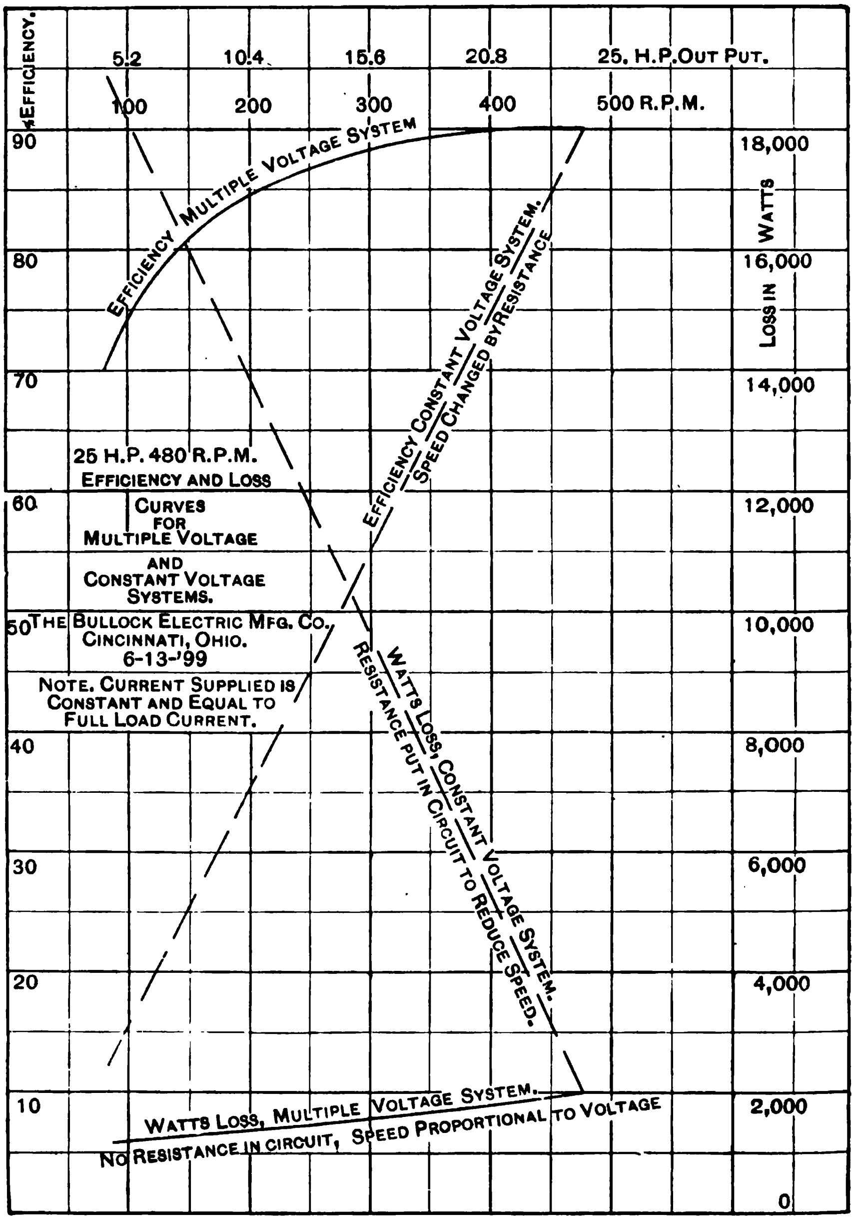

% Efficiency.
5.2
10.4
15.6
20.8
25. H.P. Out Put.
100
200
300
400
500 R.P.M.
90
80
70
60
50
40
30
20
10
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Loss in Watts
Efficiency Multiple Voltage System
Efficiency Constant Voltage System.
Speed Changed by Resistance
25 H.P. 480 R.P.M.
Efficiency and Loss
Curves
for
Multiple Voltage
and
Constant Voltage
Systems.
The Bullock Electric Mfg. Co.
Cincinnati, Ohio.
6-13-'99
Note. Current Supplied is
Constant and Equal to
Full Load Current.
Watts Loss, Constant Voltage System.
Resistance put in Circuit to Reduce Speed.
Watts Loss, Multiple Voltage System.
No Resistance in circuit, Speed Proportional to Voltage

Fig. 3.

some one power application. Among these is the teaser system. Fig. 4 represents a system designed to take care of unusual conditions, such as are to be found in the operation of large printing presses. In such cases the motors can also be operated at a very low rate of speed. The method consists essentially in employing a small motor, which takes current from the main source of supply at the full voltage. This motor drives a small generator wound with large current capacity, and this current it supplies to the main working motor, but at low voltage, because the speed is very slow. It is because of the latter fact, and further because it is in service for so small a space of time, that the apparatus can be made small.

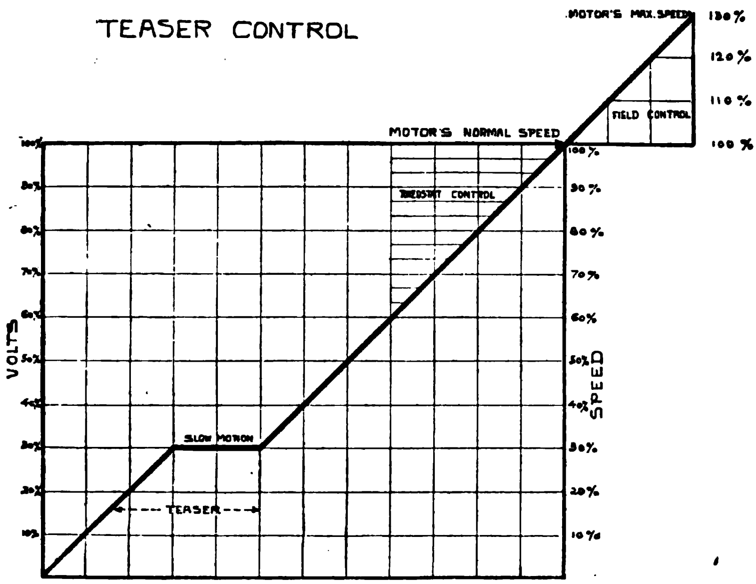


Fig4. .

Field Control.—The foregoing methods vary the voltages applied to the terminals of the motor armature. There is a method of changing the speed by varying the field strength of the motor and in that way changing the counter electromotive force at a given speed e.m.f. This has two limitations: (*a*), the first one met with in practice; viz., that as the field of the motor is weakened it goes farther and farther off from its electric balance, and its distress is soon evidenced by sparking at the commutator, due to reaction of the armature upon the weakened field; (*b*), the torque will fail, if the field is weakened beyond a given point. In a motor designed to come fairly well up to the limitations of its normal rating, the speed should not be increased more than 30 per cent. If, however, the motor is large for its work, *i. e.*, under-rated, according to commercial standards, then of course its speed can be increased until the limiting conditions of speed control, as established by its rating, are again reached. Or if the motor is operating at a lower potential impressed upon its armature than that of its normal rating, its speed may be increased over a larger range by weakening its field. But, generally speaking, it is well to understand that field control, while most useful within its limitations, cannot be successfully carried beyond such limitations and that such limitations represent an increase of not more than 30 per cent. of the normal speed of the motor. It must always be remembered, that field control increases the normal speed of the motor and does not decrease it.

In combination with the multi-voltage system—which is available for producing certain speeds that remain constant, even with varying torque, throughout the entire range—the rheostatic control can be used for reducing any one of the fixed speeds to the next fixed speed. Field control can also be used for increasing any one of the fixed speeds to its next graduation. By these means, speed increments can be obtained as finely divided as one pleases, that will carry the speed of the motor from zero to maximum, with high efficiencies and practical constancy at any one point, in spite of varying torque. The multi-voltage is depended upon to form the frame work of the speed control, while the rheostatic and field control supplies the detailed elaboration, where such may be necessary. The multi-voltage is carried throughout the entire plant, usually by two conductors in addition to the two main circuits, while the rheostatic and field control is applied locally as circumstances may require.

Thos. A. Edison marked an important epoch, when, about seven years ago, in his great ore milling undertaking, he put into operation a principle that had long been accepted by him;—that machinery and equipments are cheaper than labor and general expense and that it is better to use up the machinery at a high rate, if by so doing the output is materially increased.

About four years ago the matter of determining exactly the speed limitations of iron working machinery was taken up by a few enterprising engineers, and these limits have since been kept in view with the greatest amount of success. Where formerly the old thumb rule governed, the slide rule is used. While labor was bitterly opposed to the principle of the employer inducing his operators by additional incentive, to work up to the highest efficiency—which incentive was withdrawn when that point was reached, and their wages perhaps, still further reduced, should they fall behind—it has been led to recognize the benefits to be obtained by securing to the operator his mean wage, and allowing him to share in the benefit gained by his working up to his normal capacity. These methods at present come within two general classifications. I will mention them here, because they are pertinent to the general subject of variable speed control. The first is the premium system, in which the law of averages is applied to past work and the result is taken as a standard for determining what can be done in the future. This determined amount is generally cut down in order to provide for the increased efficiency at which the man is supposed to work. Now, if a man is able to improve upon that time, he is given a pro rata share of the gain. This system is based upon empirical data. The other system is more recent and is known as the bonus plan. It is as follows: First, the limit of speed and depth of the cutting tool are determined, then the area to be traversed by that tool determines the minimum space of time in which the tool can traverse it at its maximum cutting speed and depth. In making this calculation, it is assumed that the operator has always available the speed that represents the maximum limitations of the tool. Stability of the machine tool itself, and the capacity of the power transmitted to do the work, must be carefully considered. The operator is given explicit directions as to the shape of the cutting tool, the feeds, speeds and general method to be applied in doing the work and the exact time involved in such method is also given him. These instruction cards are not only theoretically correct, but state conditions that can easily be obtained in practice. If the operator succeeds in meeting these conditions, he not only receives his regular pay, but is also presented with a fixed bonus. With such a method of operation as has just been described, the practical operator immediately recognizes the essential points.

1st.—He must have a cutting tool that will stand up to the work.

2d.—He must have a motive power having a range of speed from which he can always select, and quickly, the speed that will produce the result expected. This motive power must be able to stand up to its work.

3d.—The machine tool must have sufficient strength to stand the strains that may be put upon it.

The limit of high speed operation is not to be found in cutting tools, or in the ability of motors to successfully do the work and to vary their speed, or in the motor's first cost, but is to be found in the stability of the machine tool itself, which is generally designed to stand the lower strains and the smaller powers required by the old cutting rates. I have prepared a table which I believe fairly well represents what was possible in the way of cutting speeds, four years ago, and what can be readily obtained in practice to-day, provided the machine tool can stand the strain.

CUTTING RATE.

(Revolving.)

Material.	By old Methods.	New Methods*	Cut.	Feed.
Cast iron.........	20 ft.	60–80 ft.	$\frac{3}{8}''$	$\frac{1}{8}''$
Forged steel, unannealed....	12 ft.	40–60 ft.	$\frac{3}{8}''$	$\frac{1}{8}''$
Steel casting.....	10 ft.	40–70 ft.	$\frac{3}{8}''$	$\frac{1}{8}''$

*Using Novo, Taylor White or Firth Sterling Tool Steel.

It is interesting to point out in connection with this table, that at these high cutting rates, a speed range must be provided to allow for the variation in the material itself and therein the variable speed motor, with its large range of easily selected speeds, serves a most important function.

The Bickford Drill & Tool Company give some interesting information as to progress in increased cutting speeds for drills. While two years ago the speed ranged from 9 to 188 revolutions and the feed ranged from .005″ to .007″, they are now enabled to drill a $\frac{3}{8}''$ (.375″) hole at a feed of 1/16″ (.06″) per revolution.

Upon the conclusion of the paper Mr. Lozier said:

Your President in his opening remarks said that the mechanical engineer had put upon the electrical engineer the responsibility of applying the system of varying the speed of motors. He pointed out that while the problem appeared to be a mechanical one, it was really an electrical one. This is true. What I particularly wish to point out in this paper is the close relation that the individual motor with its variable speed drive, bears to what is now known as the new shop method.

When I refer to it as "method," I probably ought to say "methods," for there are a number of means for increasing shop production. These methods were first evolved, probably not more than four years ago. Perhaps Edison was one of the first to enunciate the principle that it is better to waste the tool if you can save your labor. He put this theory into practical operation in his large cement works; and I know that for years he has always worked to the end of increasing his product as being the most practical means of increasing his profit.

Experiments were made beginning some four years ago at one of our largest steel works, and thousands of dollars were expended in experimenting, not only with cutting steels, but also with variable speeds. It was found that the general machine shop practice was far, far behind its possibilities. Under the old methods, the man who had served his apprenticeship was turned over to the blue print and stock and by the rule of thumb he got the best out of the stock that he could. Modern tools, instead of applying the thumb rule, apply the rule best adapted to the work, and increase the output from 100 to 200 per cent., and in some cases to 300 per cent. This is an enormous increase. It means that a shop which has been in the habit of working day time and night time, can increase its output by working only day time, and shutting off its night force. It means that if America applies these new shop methods and the old countries do not, the old countries will be left behind; they cannot hold the pace we will set for them. I was told two weeks ago by the superintendent of one of the largest shops in this country that by variable speed motors they increased their output over 40 per cent, and so I say that the variable speed motor bears an intimate relation to the new shop methods.

I think the mechanical engineers have not been disappointed in placing upon the electrical engineers the responsibility of introducing the new methods of tool operation.

There are one or two specific points I should like to bring up. What is involved in a multi-voltage circuit? The multi-voltage circuit involves a given source of supply—isolated plant or central station—having two wires. It then involves a balancer. The balancer is not as is generally supposed, a large device, having a capacity sufficient to carry all the motors at the lowest speed, any more than a life insurance company is organized and premiums adjusted on the basis of all the policy holders dying the same day. The larger the number of tools driven, the smaller the balancer may be; and we have taken it as a rule that the armature of a multi-voltage balancer need not be larger than sufficient to operate the largest single motor on the circuit at its lowest speed. This rule is borne out in practice in a number of cases.

If I may have the screen for a moment, I will show you what corresponds to the multi-voltage balancer. This picture is a shop operated by individual motors, in which you notice the clear head room, and the other is a shop in England driven by belts. I think we are all so familiar with the advantages of individual driving that the pictures perhaps are not necessary. The next picture illustrates a multi-voltage balancer. There would be one commutator here, another there, and the third commutator would be at the other end. The next picture will show the connections of the circuit. In this particular case we have voltages of 60, 80 and 110, giving a total of 250 across the circuit. The interesting point in distributing the load on these circuits, is that if the motor is on 60 volts, it does not require more power than is passing through the balancer circuits. It acts as a shunt. As the power on the motor is increased, however, less and less current passes through the balancer and more passes through the motor.

A paper read at the 170th Meeting of the American Institute of Electrical Engineers, New York. Nov. 21, 1902.

THREE-WIRE SYSTEM FOR VARIABLE SPEED MOTOR WORK.

BY N. W. STORER.

A description of the operation of variable speed D.C. motors on the three-wire system. Illustrated.

At the present time, when the possibilities of the electric motor are being realized and it is everywhere taking its place in factories, machine shops, steel mills and in practically every kind of industrial enterprise, the type of motor to be used and the best method of applying its power are much discussed topics in engineering circles. In deciding the type of motor to be used it is generally recognized that the alternating current induction motor has its own particular field; the D. C. and A. C. motors have a common field, and the D. C. motor in turn has its own special field. In deciding the method of applying the power, the choice lies between a separate motor for each machine and group driving of machines from counter-shafts driven by constant speed motors. If individual motors are selected, when variable speed is desired, there is the further choice between the constant speed motor with mechanical speed changing devices and a variable speed motor direct connected to the machine. In this latter class of work is found the special field for the D. C. motor.

Omitting cranes, street railways, hoists, and other classes of service where the series motor with rehostatic control is used, we find that variable speed motor work may be divided into three classes:

(1.)—Machines requiring a torque increasing with the speed. Blowers and fans belong in this class. The power required for the machine increases very rapidly as the speed increases and great care should be exercised in selecting motors for such service. However, as the variation required is usually small, the requirements can be met with standard motors on a single voltage system. Motors should preferably be compound wound and the speed should be varied by means of a resistance in the shunt field.

(2.)—Machines requiring a constant torque. In this class pumps and air compressors are the most conspicuous examples. The speed variation required for such service is usually small and it is generally best and most economical to supply compound motors and to vary the speed by means of the shunt field rheostat, as in the case of the fans and blowers. A series winding is especially beneficial for this class of work in preventing the heavy fluctuations of current that would take place with a constant speed motor in passing through the different parts of the cycle. A compound motor may be used for this work because a constant speed at any point on the controller is not necessary.

(3.)—Machines requiring approximately the same maximum output at any speed, or a torque varying inversely as the speed. This class includes most of the machine tool work where automatically constant speed regulation on any notch of the controller is especially desirable. It is, therefore, necessary to use a shunt motor having good inherent regulation.

It is the last named class of service that has caused the most discussion. Several companies have entered this field with different systems of variable speed motor control. Some of these companies are able to place their motors on the standard and well known systems of power distribution, while others seek to introduce special systems. The writer has been interested in the development of the three-wire system for this class of work, and it is the purpose of this paper to describe its operation and advantages.

The Generator:—The standard Edison three-wire system for general power distribution is so well known that it is unnecessary to describe it. The power station equipment, consisting of two 125 volt generators connected in series with the neutral wire brought out between them, is also well known and the single voltage generator with a motor-generator set of sufficient capacity to carry the unbalanced current, is used in many places. But the type of generator which is rapidly attaining prominence is the so-called three-wire generator, consisting of a standard D. C. generator designed for the maximum required e.m.f. having collector rings connected to the armature winding like a two-phase rotary converter. The leads from these rings are connected to auto-transformers or balancing coils, the middle points of which are connected to the neutral wire. With no external devices whatever, the neutral wire is thus maintained at a voltage midway between the outside wires of the system (see Fig. 1). These generators may be operated in multiple with any standard three-wire system, whether it consists of two machines operated in series, a single voltage generator with a balancing set, or a

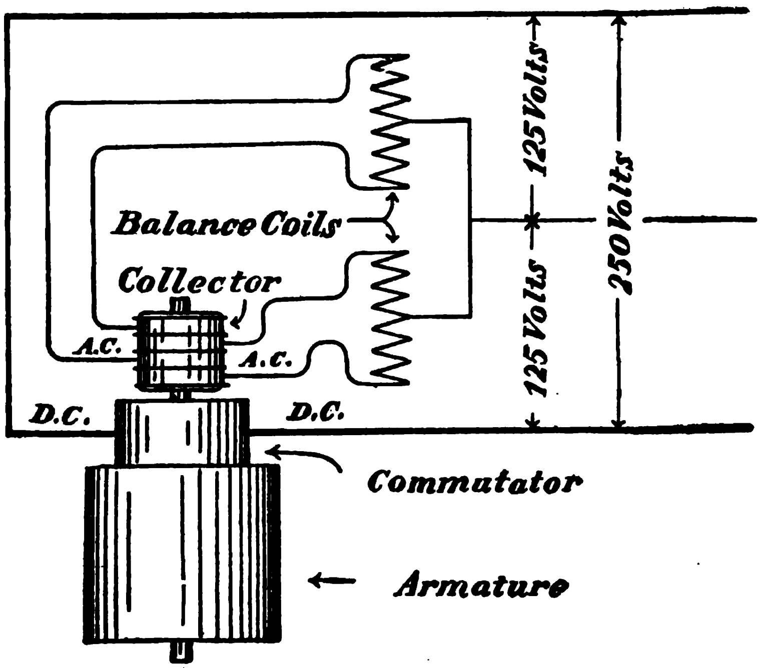


FIG 1.

double commutator generator. Any standard single voltage system may be changed into a three-wire system by adding collector rings to the generator and using balancing coils to supply the neutral wire.

The Motor:—The standard type of motor is used on this system. If only a small variation in speed is desired, as about 2:1 or less, only one voltage is used and the speed variation is secured entirely by changing the shunt field current. If wider variations are required, it is preferable to use the two voltages of the three-wire system. It is necessary simply to make a 220 volt motor connected so that it may be operated on either 110 or 220 volts. The minimum speed is secured on the 110 or low voltage circuit with full field strength. Any other speed less than double the minimum will be secured on the same circuit by decreasing the field current. All higher speeds are obtained on the 220 volt or high voltage circuit in the same manner. Operated in this way the motor is started on the 110 volt circuit, having in series with the armature a resistance, which is cut out for the first running notch. The speed is increased in successive steps by inserting resistances in the field circuit until the maximum 110 volt speed is reached. Then the controller changes the motor to the 220 volt circuit with a resistance in its armature circuit, and at the same time gives the motor a stronger field. The resistance in the armature circuit is used only in passing to the higher voltage, and is immediately cut out for the first runnnig notch. For higher speeds, resistances are again inserted in the field circuit, as before, until the maximum desired speed is reached.

In this manner a variation in speed of 1:6 is easily obtained. Greater variations may be obtained if desired, but are not to be recommended except in special cases, as the size and cost of the motor will be so great that larger variations than 1:6 are hardly to be recommended on any sytem. The size of motor is determined by the output at the lowest speed, so that unless the maximum speed is excessive, the motor size will be very large for the output required if variations even of 1:6 are required

Operation.

Commutation:—The operation of motors on this system is most satisfactory. The fact that the speed is increased so much by weakening the field might lead some to think that the commutation would suffer, but such need not be the case. An example will demonstrate the truth of this statement. A certain machine requires a 5 h.p. motor to operate it with a speed variation of 1:4, say from 375 to 1500 r.p.m. On the three-wire system this motor will be a standard 10 h.p., 220 volt motor operating normally at a speed of 750 r.p.m. Run with full field strength on the 110 volt circuit, it will develop 5 h.p. at about 375 r.p.m. Operating on this circuit, which has only half its normal voltage, the motor will easily stand an increase of speed 60 per cent. to 75 per cent., bringing the speed up to 600 or 650 r.p.m. When it is changed to the 220 volt circuit, it will have its normal capacity for 10 h.p. at 750 r.p.m.; but only half load is required and it will commutate this as easily at a speed of 1500 as it would 10 h.p. at 750, because both field strength and armature current will be divided by two. From this it may be seen that when the motor is running at full armature current, the voltage is only one-half the normal voltage. When the motor is operating at full voltage, the armature current is only one-half the normal current. If speed variations of 1:6 are required, they can be secured by a very slight increase in the normal field strength of the motor.

Regulation:—The performance of the motor in speed regulation on the separate controller points is very good. As the lowest voltage used is 110 volts, the proportion of voltage lost in resistance of motor, brushes, armature, controller and wiring will be very much less than it would be if a minimum voltage of 60 were used, consequently the speed regulation will be much better. On an extremely slow speed motor the resistances of the different parts of the circuit play a very important part in the speed regulation. Where a very low voltage is used the speed variation from no load to full load may be as much as 20 per cent. or 25 per cent.

Controller:—The smoothness of operation in changing from one speed to the next is very noticeable. The field strength changes very gradually no matter how suddenly the field resistance is changed. Consequently, there can be no sudden change in speed. In this respect it is better than a system which changes the speed by changing the armature voltage without a resistance in the circuit. At the only point where the armature voltage is changed on the three-wire system, a resistance is inserted in the armature circuit, which effectually prevents a sudden jump in speed.

Efficiency.

Motors:—The efficiency of the motors, as well as of the entire system, is high. Operating on the low voltage, the motor is at all times running under full load conditions with the efficiency increasing as the speed increases, because the field current and core loss are decreased at the higher speeds. When operating at 220 volts at the minimum speed, the efficiency corresponds to the half load efficiency of the standard motor. As the speed is increased, the copper loss in the armature remains constant and the field loss and core loss decrease so that unless the increased friction over-balances them, the efficiency will increase up to the maximum speed. This is in marked contrast to a motor operated on a system supplying a different armature voltage for each speed. To fill the requirements of the above case on the multi-voltage system, a motor of the same weight but normally rated at 20 h.p., 220 volts and 1500 r.p.m. will be required. It will operate at a voltage of about 60 at minimum speed and will there require the normal full load current of the motor to develop 5 h.p. This would be double the current of the motor operated at 110 volts at the same speed; and while the copper loss in the armature and field and the core loss would be about the same as in the other motor, the loss in brushes would be doubled and the loss in controller and wiring very much greater. An increase in the speed will increase the core loss very rapidly, the field will remain constant and the copper loss in the armature will decrease. The efficiency of this motor may be explained by the statement that at the only time the motor is operating under its full load armature current, it is running at 60 volts and the efficiency is necessarily low. At the maximum speed where the normal voltage of the motor is reached, it operates at only one-quarter load and consequently with a low efficiency. At no point on the curve does its efficiency equal that of the motor on the three-wire system.

Transmission:—The efficiency of transmission on the three-wire system is high. Practically all of the current is transmitted at the maximum voltage, as the motors are equally distributed between the two sides of the system for their low speeds. The chances for unbalancing are thus very much less than on a multi-voltage system that requires all of the motors to have corresponding speed notches on the same circuit.

Generating Plant:—The efficiency of the generating plant is also a maximum. The three-wire generator itself has the same efficiency as the standard D. C. generator of the same capacity. The losses in the balancing coils with 15 per cent. unbalanced load will not exceed one-quarter of 1 per cent. of the capacity of the generator. This gives the most efficient type of three-wire generating apparatus. Comparing it with the complicated generating outfit required for a multi-voltage system, shows at once its superiority, both in efficiency and in the amount of attention required in operation.

Economy:—The three-wire system is very economical in the wiring. As practically all of the current is transmitted at the higher voltage, the neutral wire may be very small. In this respect also, it is superior to the multi-voltage system. The latter really has two neutral wires, but as the unbalancing is likely to be much greater, they must necessarily be larger than the neutral of the three-wire system, and all the wires would be larger if the same percentage of line loss were maintained. Branch lines to the motor, forming a considerable part of the total wiring system, must be much heavier than on the three-wire system as there are more wires, heavier currents to be carried and greater losses.

Controller:—The controller of the three-wire system is very simple. It is of the standard drum type, designed mechanically like a street car controller. It has the field and armature resistances in the base, making the whole controller very simple and compact.

The advantages of the system described in the foregoing may thus be summed up as follows:

(1.)—Simplicity, not only in the generating plant, but in the transmission lines, motors and controller.

(2.)—Efficiency in generating plant, transmission line and motor.

(3.)—Economy in first cost of generating plant and transmission lines.

(4.)—Constant speed regulation from no load to full load.

(5.)—Smoothness of operation in changing from one speed to another.

These advantages are all easily apparent for work where the motor output is the same at all speeds. In such work the weights of the motors will be practically the same as those on the multi-voltage system. But it is recognized that in work where a constant torque over a wide range of speed is required the multi-voltage system has certain advantages. The motor required will be smaller, depending on the range of speed to be covered However, for the small amount of such work that is to be done it is better to sacrifice a little in the size of a few motors than to introduce the complicated generating plant and the expensive transmission lines necessary for the multi-voltage system. Motors running on the three-wire system will meet all such requirements. It is only a question of making them large enough.

In cases where it is impracticable to have two voltages, and a wide range of speed is necessary, a double commutator motor may be used with excellent results. This motor may be built with both ends of the armature wound for the same voltage, in which case they will be connected first in series, then in parallel, giving speed changes corresponding to the speed variations on the three-wire system.

A paper read at the 170th Meeting of the American Institute of Electrical Engineers, New York, November 21, 1902.

THE STORAGE BATTERY AS A FACTOR IN SPEED CONTROL.

BY H. B. COHO.

A description of the use of storage batteries in connection with the operation of printing presses and with the multiple voltage system.

In presenting this paper to the INSTITUTE, nothing very new or novel in the idea of varying the voltage across a battery, in order to secure speed variation is claimed. There seem to be some differences of opinion as to the rights of different persons to the multiple voltage system of control, and this opportunity is taken to call attention to the part which the storage battery may play in this important work. The many short comings of the storage battery are appreciated, but recent experience has taught that while the watts per pound of material have not been so materially increased in recent years, the life of high grade storage cells has been increased to such an extent that the old ideas as to cost of maintenance will have to be modified, and the charges of 10 per cent and 15 per cent of first cost per annum for renewals must be cut in half.

All are no doubt quite familiar with the various ways in which batteries may be utilized, and it is the purpose in this paper to dwell particularly on a method of using a storage battery as an auxiliary or independent source of supply in connection with the operation of printing presses.

With printing press work, the operations of making up and threading in paper require a positive fixed speed of from 12 to 20 r.p.m. on the main shaft of the press. The methods of obtaining this speed from electric motors, which are common, are to employ either fixed resistances, armatures in multiple and series, or separate sources of supply, such as motor-generators. The motor in the last case is a shunt machine, wound for the line voltage, while the generator is a shunt machine with field separately excited from the line and supplied with a constant voltage. The armature is wound to give a fixed voltage from 12 to 40 volts, depending upon the special requirements.

It is in connection with this last system that the method mentioned in this paper is particularly applicable. Fig. 1 shows the connections to the storage battery and to the motor through the controller. The following data have been obtained in connection

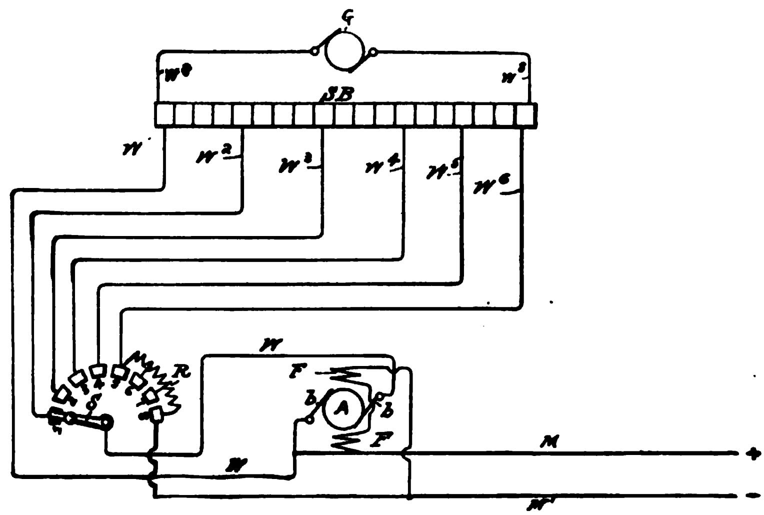


Fig. 1.

with the utilization of this system for the operation of quadruple Hoe printing presses of moderate size. These presses operate at 12 r.p.m. in making up and threading in, and require for this purpose a current of 150 amperes at 40 volts. The threading in and making up process per press lasts at a maximum not more than ten minutes. This process has to be repeated not more than fifteen times in twenty-four hours. From these data it is apparent that a 200-ampere-hour battery on an hour rating will more than fulfil the requirements.

A battery of accumulators to give 40 volts and 200 amperes for one hour will cost not more than $400, which is not a prohibitive figure, especially when considered in connection with the following additional advantages:

(*a*).—One battery will do for a number of presses, for the reason that all of the presses in any establishment are not simultaneously in operation.

(*b*).—The battery can be on charge at a very low rate at all times when current is flowing on the mains, thus insuring the best possible results from the battery at a minimum cost for current.

(*c*).—The battery having no moving parts, such as bearings and commutators to get out of order, will doubtless appeal to the press operators.

(*d*).—The e.m.f. of a battery is constant, while that of any other independent source of supply is variable, depending upon the line voltage. Many a press operator has lost his fingers because of sudden variations of voltage supplied to the motor.

The operation of elevator motors by means of a storage battery placed directly across the line, and in connection with a multiple series controller, offers an excellent means of varying speed. The battery can be figured on a two-hour rate in the severest service, so that the first cost is not excessive, while the saving from repairs to resistance plates and contact pieces is a matter of no small importance in comparing the economic advantages of two systems.

The use of a battery for the multiple voltage operation of machine tools, presents another phase of the subject. The high first cost of batteries militates against their adoption. In a shop requiring about 100 k.w. average motor load, the battery capacity will have to be calculated on a three-hour rating. The first cost will be about 30 per cent. more than that of equivalent multiple voltage generators as now employed. That the battery is 30 per cent. more expensive in first cost does not, however, exclude it from competitive consideration, because the increased efficiency of the cells over that of multiple voltage generators when operating at varying loads.

As a substitute for storage batteries one can often use so-called counter electromotive force cells. These may be constructed with unformed lead electrodes in an ordinary battery electrolyte. The necessary electrode surface is not determined by the ampere-hour capacity of the plates, but by the internal resistance requirements for economic operation. The cost of construction of these cells is much less than that of equivalent batteries. The cutting down of supply voltage by counter electromotive force is the natural method dictated by economic consideration, while to cut it down by resistance is unnatural.

Referring to the above paragraph, it is probable that careful examination will prove that the c. e. m. f. method of multiple voltage control, taken in connection with the weakening of the field of motor to give the last 25 per cent. speed variation, will result in the most economical system to operate and the lowest first cost for installation.

A paper read at the 170th Meeting of the American Institute of Electrical Engineers New York, Nov. 21, 1902.

ELECTRICALLY OPERATED COAL HOIST, HAVING VARIABLE SPEED CONTROL.

BY P. O. KEILHOLTZ.

A description and data concerning the operation of a coal hoist. Illustrated.

The use of electric machinery for coal hoisting has many advantages over steam machinery when the hoist is considerable. It has also the advantage of less cost of operation and maintenance. Its initial cost, however, is greater.

There are two distinct operations in coal hoisting: raising the loaded shovel and lowering it empty. All that is required for raising is a smooth acceleration for closing and raising the shovel, and full power application as long as possible in order to decrease the time of hoisting. Full power application can be continued longer with an electric hoist than with steam, owing to the less inertia of the former. A smooth acceleration is required because the cables are without stretch and for very high hoists would introduce objectionable strains in the structure or damage to the gearing. It is in lowering the empty shovel that the electric hoist has marked advantages. With steam hoist the lowering is accomplished by braking, and with high hoists, large shovels and rapid lowering the large amount of heat generated by the brakes is difficult to get rid of. As brakes depend upon friction, which is a function of two things—the surface conditions and the pressure between the rubbing surfaces—the amount of friction is uncertain, and braking, therefore, is objectionable because violent surgings are introduced in the boom structure and tower. With the electric hoist, owing to the perfect reversibility of the electric motor, the motor is used as a generator having a separately excited field and driven by the weight of the descending bucket. In its armature circuit is a rheostat to dissipate the heat generated. It is at once apparent that this heat dissipation can be better accomplished with a rheostat than with a brake band.

The Ward-Leonard system of control is used and the apparatus

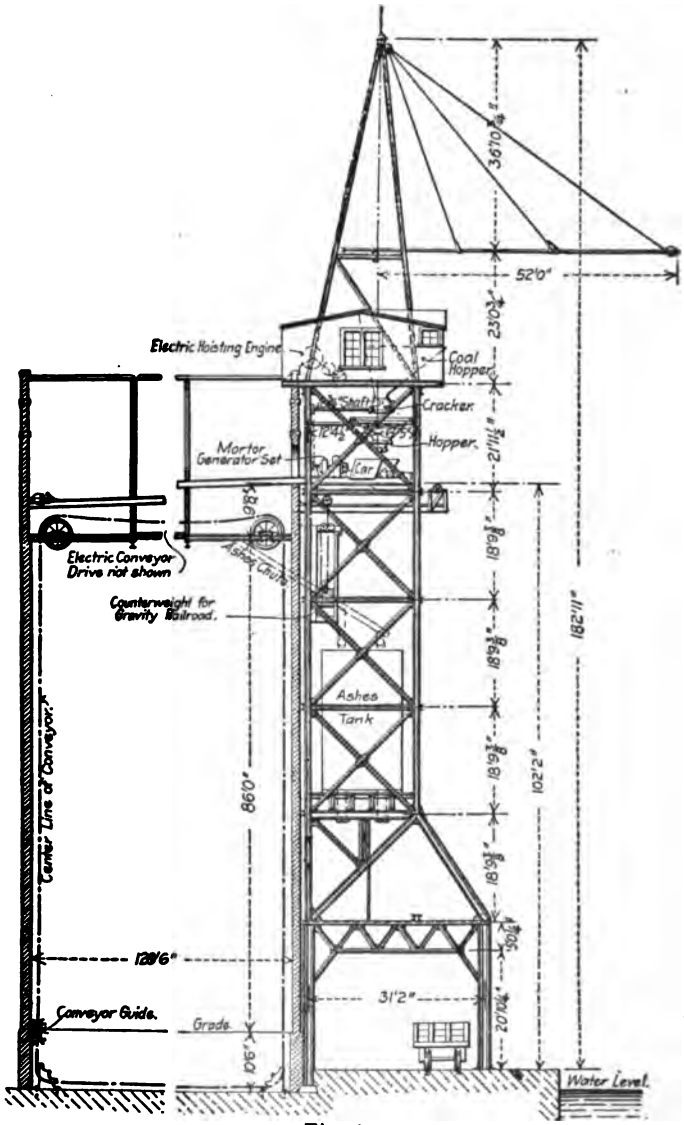


Fig. 1.

consists of a motor generator set and a hoist motor which receives its power from the motor generator set, the motor of which is supplied with 550 volt direct current. The field of the generator is separately excited and its strength is controlled by the operator by means of a foot operated rheostat. The field of the hoist motor is excited by the 550 volt, direct current. By means of a double throw, three-blade switch the foot rheostat is cut out of the generator field circuit and cut into the field circuit of the hoist motor; and the armature leads of the hoist motor cut from the armature circuit of the generator to the rheostat.

Appended will be found sketches of coal hoisting tower, wiring diagram, distance-time curve and a velocity curve, together with data of test and other particulars.

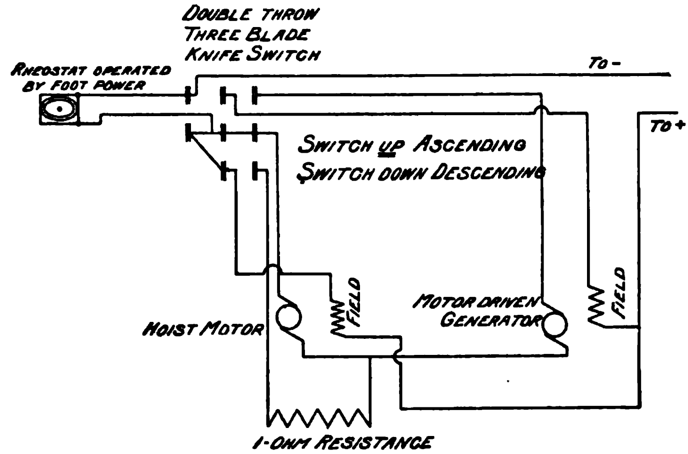


Fig. 2.

Weight of coal hoisted, average of 7 shovelfuls..............lbs. 2,330
" " shovel empty .... " 2,907
Total weight, lifted exclusive of weight of ropes ...... " 5,237
Average lift ....feet, 126
Readings of main motor.
Volts..540
Average current in amperes to close shovel 57
Maximum " " " " " " 73
Average " " " " raise loaded shovel........189
Maximum " " " " " " " 243
Field current, not included, in above, 2.8 amperes.

From the velocity curve (ascending) it will be seen that it took 11 seconds to close the shovel, and from the distance-time curve 26 seconds to close the shovel and raise it to the dumping hopper. Therefore, 15 seconds is the time taken to raise the loaded shovel; and as the lift is 126 feet, the average velocity is 8.4 feet per second.

The efficiency is, $$\frac{\dfrac{8.4 \times 5237}{550}}{\dfrac{189 \times 540}{746}} = 58\tfrac{1}{2}\%$$

Performance test:

Coal lifted, tons, 101.86.
Time, minutes, 87.33.
Rate, 70 tons per hour.

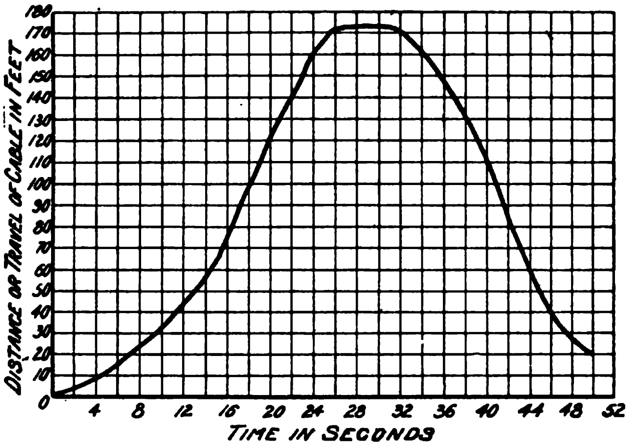


FIG. 3.

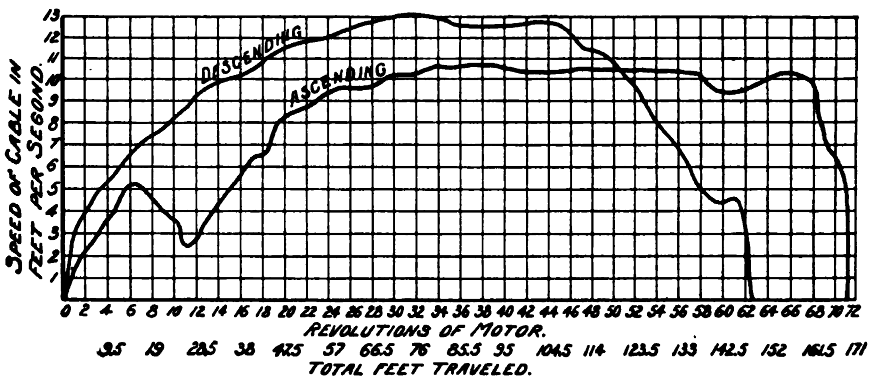


FIG. 4.

PARTICULARS OF ELECTRICAL APPARATUS.

Main Motor:

M.P., 6—150, h.p., 450.
Volts, 550.

Generator:

M.P., 6—85, k.w., 450.
Volts, 250.

Hoist Motor:

M.P., 6—100, h.p., 200.
Volts, 250.

A paper read at the 170th Meeting of the American Institute of Electrical Engineers New York, November 21, 1902.

A SERIES-PARALLEL SYSTEM OF SPEED CONTROL.

BY GEO. W. FOWLER.

A description of the parts of a system including a double commutator motor, switchboard, controller, automatic switches and emergency switches. Illustrated.

The system of control of stationary direct current motors which I shall endeavor to describe to you has been quite extensively and successfully used for driving various kinds of machinery, especially large printing presses.

The component parts of the system are a double commutator type motor, a switchboard, controller, a pair of automatic solenoid switches, and a set of emergency switches. These are shown in Figs. 1, 2, 3, 4, 5 and 6. The motor is shown in Fig. 7.

The motor is of the ordinary slow speed, compound wound type, with the exception that it has two separate windings and commutators on the one armature body, operating in one magnetic field. The field windings are so arranged that the series turns can be cut out after starting, thus obtaining the advantages derived by using a compound wound motor at starting, exerting a powerful starting torque with a minimum amount of current; and the constant speed features of the shunt motor, by cutting out the series, after the motor has reached a certain fixed speed.

The armature windings are, of course, thoroughly insulated from each other, and have no connection excepting that obtained through the operation of the controller.

By an inspection of the controller, Fig. 2, it will be seen that it consists of numerous contacts and contact rings mounted upon a slate, the sub-structure carrying the controller arm, which moves over the contacts. For convenience, some external means is generally used to operate the controller, such as the lever shown in Fig. 3, which is frequently used in connection with printing-press work. It is through the movement of this one controlling lever, that all the combinations of windings and connections, with the resultant variations in speed, are obtained.

Upon closely examining the controller in Fig. 2, you will notice that the contacts appear to be divided in two separate divisions. To the left the contacts are sub-divided into many small ones. To the right there are but few larger ones. Those to the left are

FIG. 1

in use only when the armature windings are in series, while those to the right are in use only when the windings are in parallel. The two divisions have no connection with each other whatever. For use in graduating the speed, there are two banks of resistance used; one bank in circuit with the armature windings when they are in series and which is connected to the smaller contacts to the left, and another bank in circuit when the armatures are in parallel, and which is connected to the larger contacts, to the right. The contact rings on the controller are in circuit with the shunt field of the motor, and the small round contacts for the purpose of interposing resistance therein for the highest speeds.

With any variable speed control system wherein a combination of windings or machines are used to obtain the speed variations, it generally becomes necessary at some point in the operation to open the circuit, preparatory to making some rapid change in the combination, in order that the speed changes shall be gradual. When performing this operation it has been, and now is, the custom to use magnetic blow-out coils to prevent excessive flashing of the controller contacts. In the series-

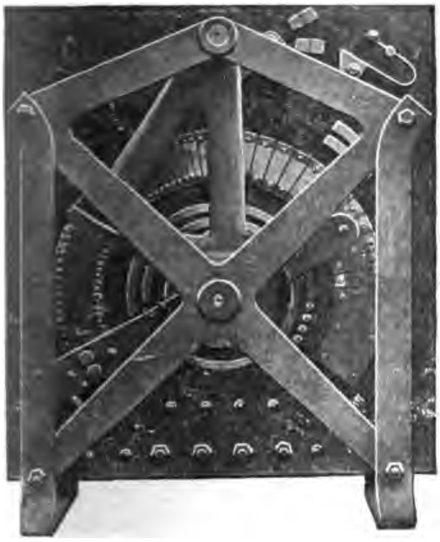


FIG. 2.

FIG. 3.

parallel system it is necessary to open the circuit when changing from series to parallel, for it is quite obvious that the windings cannot be in series and parallel at the same instant.

In this system of series-parallel control no blow-out coils of any kind are used and the change from series to parallel or vice versa, is obtained by the use of an "Automatic Solenoid Switch." A very good idea of the construction of the switch can be obtained by an inspection of Figs. 4 and 5. Two solenoids enclosed in a cast iron case, the object of which is to form a good path for the lines of force, are mounted upon one side of a slate. Through the centre of these solenoids is a plunger slotted in the centre through which passes a small pin, thereby making a flexible connection between it and the shaft carrying the switch arm on the opposite side of the slate. When energized at the proper time, first one and then the other solenoid operates, throwing

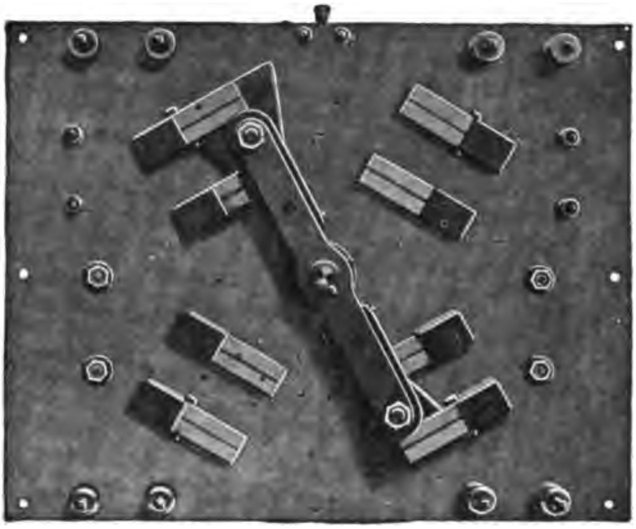


Fig. 4.

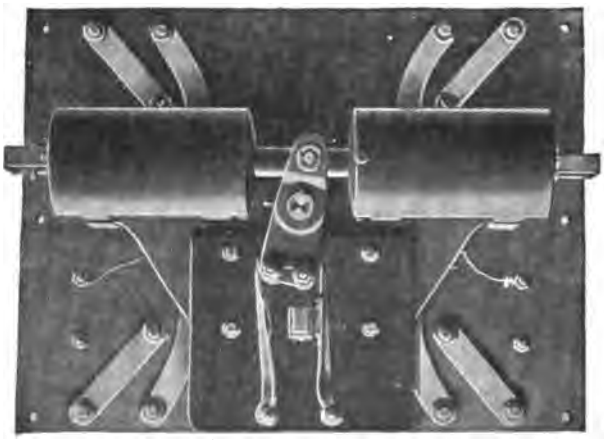


Fig. 5.

the switch arm to the right or left, as the case may be. The connections of the switch jaws shown on the front of slate are such that when connection through them is completed by the switch arm, the armature windings on the motor are first in series, and when the arm goes to the other side the windings are in parallel. Therefore, during the time when the switch is operating from series to parallel, the circuit is opened; the action being instantaneous, there is no noticeable change in the speed, neither is there the slightest flashing at the contacts of either controller or switches.

Two of these automatic switches are used with each equipment, one to perform the operation as outlined above, the other to " stop and start " the motor—that is, to open and close the circuit. There is no open point on the controller except between the series and parallel side, and when the lever is thrown to the position which is normally " off," the solenoid switch used for this purpose opens the circuit. Likewise, when the lever is moved " on," the switch closes the circuit. This absolutely

FIG 6

prevents the slightest flashing at the controller contacts, when stopping the motor. By the use of the second mentioned switch, it is also possible to stop the motor from any one of several points, which is required in newspaper printing.

To accomplish this the emergency switch, Fig. 6, is used. This switch is so connected with the controller (see Fig. 9) that when the plunger is depressed, connection is made through the solenoid which throws the switch " off." In Figs. 12 and 13 is shown an improved type of solenoid switch, wherein one coil is used for each switch.

A reference to Fig. 8 will give a fair idea of the controlling device complete. Here the solenoid switches are mounted at the top, the controller and lever at the bottom. The circuit breaker shown to the left is of the " no voltage " and overload type.

In Fig. 9 is represented a diagram of the wiring and connection of a complete series-parallel equipment. A careful inspection will disclose the following conditions when the equipment is in operation.

With the controller lever " off," the two solenoid switches are in a position corresponding to " off," on the one and " series " on the other. The lever being moved to contact 2 (on controller) one solenoid switch throws "on," the other still remaining in a

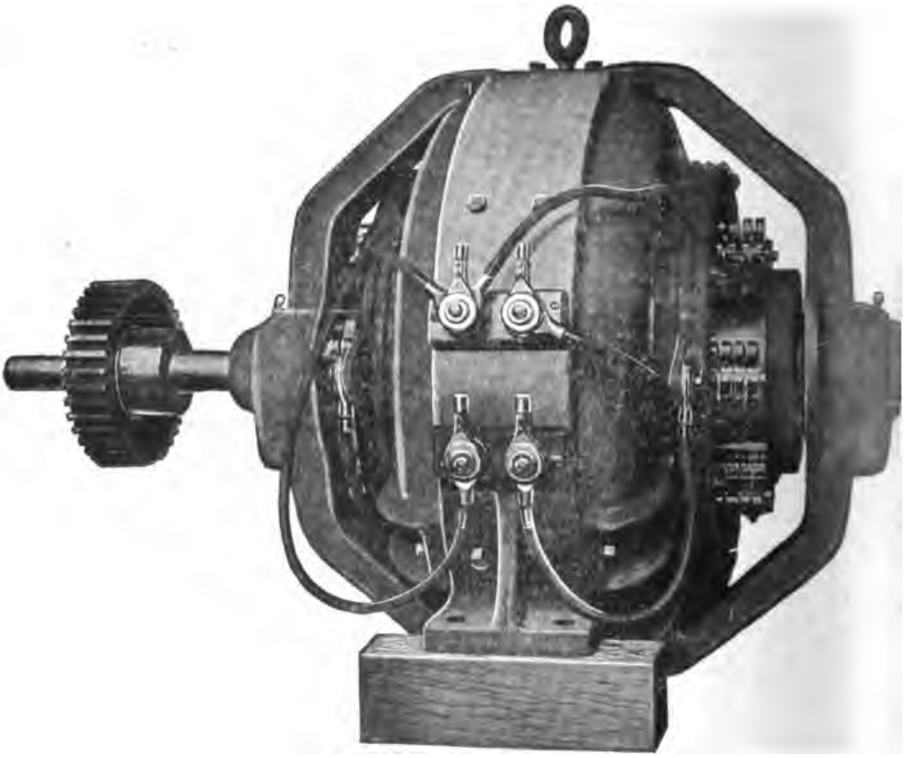


FIG. 7.

series position. The current then flows through the two armature windings, in series, in series with the series field and in series with the resistance connected between controller contacts 1 to 40. This gives the slowest speed obtainable, which, when used for newspaper printing, is 5 per cent of the maximum. The next successive moves of the controller lever, simply cut out resistance in the armature circuit, until contact 38 is reached, when it is all out. At this point the series field on motor is gradually cut

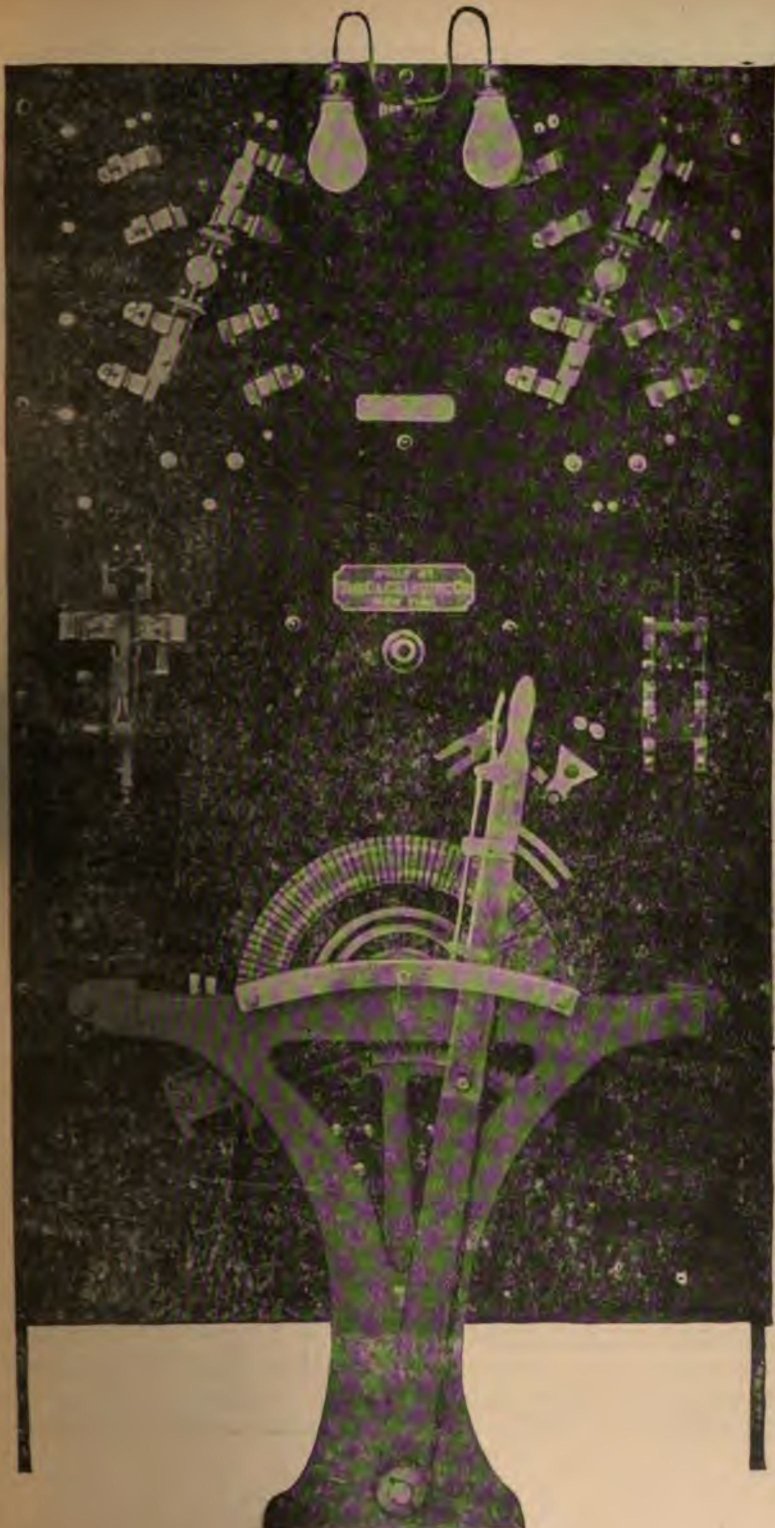


FIG. 8.

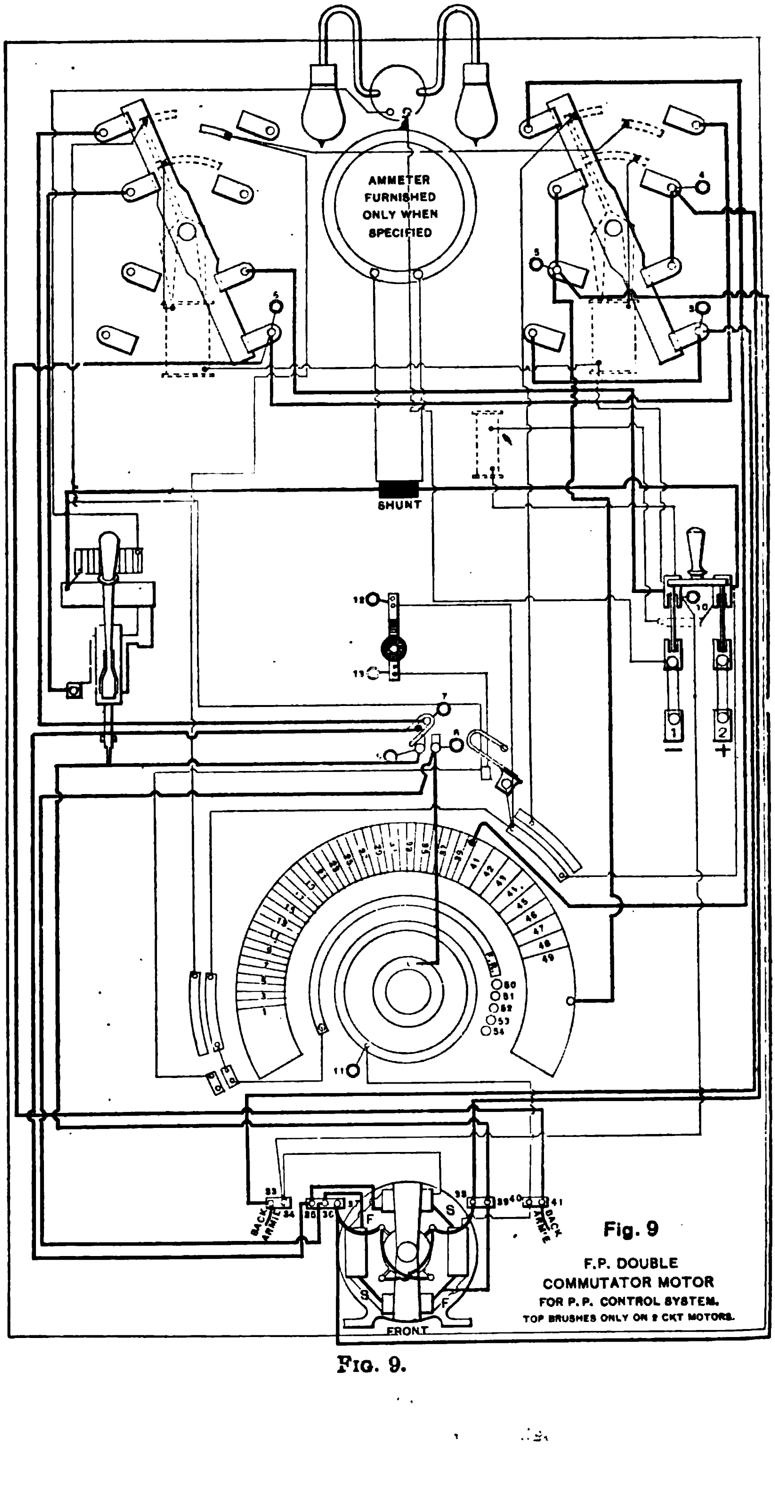

AMMETER
FURNISHED
ONLY WHEN
SPECIFIED
SHUNT
BACK ARM'E
BACK ARM'E
FRONT
Fig. 9
F.P. DOUBLE
COMMUTATOR MOTOR
FOR P. P. CONTROL SYSTEM.
TOP BRUSHES ONLY ON 2 CKT MOTORS.

FIG. 9.

out. As will be noticed the series field is connected to terminals 7, 8 and 9 on the controller and permanently attached to terminal 7 is a small quadrant switch operating between two switch jaws, on 8 and 9. As the controller lever moves under 7, 8 and 9, the switch at 7 is engaged by the controller and enters switch jaw on 8. This short circuits one-half the series field coils on motor. Continuing the movement of controller, the switch enters switch jaw at 9, thus connecting 7, 8 and 9 and entirely cutting out the series field. Therefore, the motor is now running as a shunt machine. with the armature windings in series.

Now, as the controller lever is moved to cover contact 41 and 42, the solenoid switch previously mentioned is brought into connection and changes the armature winding from series to parallel. At the same time enough resistance is inserted in the circuit to keep the speed and current normal. (See curves, Fig. 10.) As the lever is moved over 43 and 44, etc., resistance is gradually cut out until 49 is reached, when the motor is running without resistance in the armature circuit and the windings are in parallel. There are still five more speeds, which are obtained by inserting resistance in the shunt field. At the last of these the speed of the motor is at its maximum. To stop, the emergency switch connected as shown on Fig. 9 may be operated, which throws the solenoid switch " off," thereby opening the circuit, and stopping the motor.

Before the above operation can again be repeated, the lever must be brought back to the starting point, when over contact 2, one switch is thrown back to " series " (that is so that it connects the armature windings in series) and the other switch " on." Then to continue as before would simply be to move lever from 2 and so on, or if to stop it altogether, move to contact 1, where the solenoid switch throws " off."

The diagram of connections shows a slightly different type of solenoid switch from that illustrated; one in which a single solenoid accomplishes the same result. This is shown thus, as it is much easier to trace out the path of current, in illustrating the operation of the system.

The relative advantages of the series-parallel system over the rheostat control with one commutator is readily apparent by an inspection of Fig. 10, in which the curve shows the comparison between the two systems, when operating a Hoe Quadruple Press. It will be seen that the current required to exert the maximum torque when starting the press from rest is somewhat

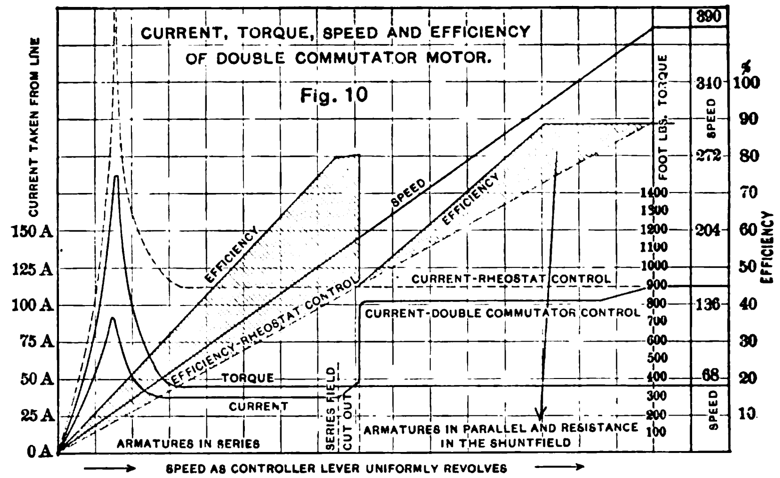

CURRENT, TORQUE, SPEED AND EFFICIENCY
OF DOUBLE COMMUTATOR MOTOR.
Fig. 10
CURRENT TAKEN FROM LINE
150 A
125 A
100 A
75 A
50 A
25 A
0 A
EFFICIENCY
SPEED
EFFICIENCY
EFFICIENCY-RHEOSTAT CONTROL
TORQUE
CURRENT
CURRENT-RHEOSTAT CONTROL
CURRENT-DOUBLE COMMUTATOR CONTROL
ARMATURES IN SERIES
SERIES FIELD CUT OUT
ARMATURES IN PARALLEL AND RESISTANCE IN THE SHUNTFIELD
FOOT LBS. TORQUE
SPEED
EFFICIENCY
SPEED AS CONTROLLER LEVER UNIFORMLY REVOLVES

Fig 10.

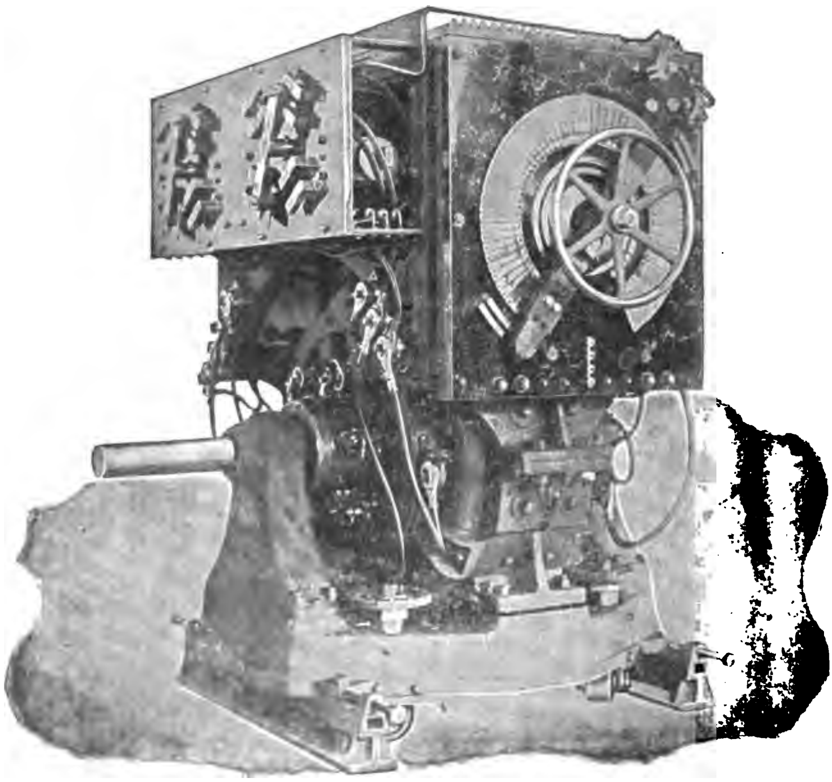


Fig 11

less than the current required for the same operation by a single compound wound motor with rheostat control. Also the efficiency at all speeds is much better.

While the system was originally designed especially for operating Webb presses, it is equally well adapted to any service requiring heavy starting torque, a wide range of speed variation, ease of manipulation and high efficiency.

FIG. 12.

FIG. 13.

A portable motor for use in testing printing presses, is shown in Fig. 11. This gives a very good idea of what can be accomplished in this direction. The entire apparatus is mounted on the motor frame, and is quite easily moved to various departments.

A paper read at the 170th Meeting of the American Institute of Electrical Engineers, New York, Nov 21, 1902.

MULTIPLE UNIT, VOLTAGE SPEED CONTROL FOR TRUNK LINE SERVICE.

BY H. WARD LEONARD.

A description of a single phase, high tension, alternating current system for operating trunk line railways. Conversion takes place on each locomotive and substations are eliminated. Illustrated.

In February, 1894, I read a paper before this INSTITUTE describing a system which I considered applicable to the operation of a trunk line electric railway. The essential features of this system were:

1st. The generation and transmission of a high tension single phase alternating current, the power houses being placed as far apart as the insulation of an alternating current transmission would permit.

2d. The entire elimination of sub-stations.

3d. A transformation of the energy upon the locomotive so as to secure a voltage speed control for the electric motors, thereby obtaining smooth acceleration and efficient control of the locomotive at any desired speed and in either direction.

At that time there were no engineers, so far as I know, who agreed with me that these features were essential for the operation of a trunk line railway by electric motors.

In the recent past, however, many prominent engineers both abroad and in this country have declared themselves in favor of these essential features, and I therefore feel warranted in describing an improvement upon the system I originally proposed, by which I can secure the important and now well understood advantages of a multiple control of any desired number of locomotive units.

Fig. 1 illustrates diagramatically one form of my multiple unit, voltage speed control as applied to two locomotive units for trunk line service.

The current is generated in the form of a single-phase alternating current at as high an e.m.f. as is practicable to-day, say 20,000 volts. A moving contact leads the single phase alternating current upon the locomotive. If desired, static transformers can be placed at suitable points along the line of the railway which will reduce the initial e.m.f. to any desired lower e.m.f. upon the contact conductor.

In many instances it may be desirable to place upon the locomotive a transformer S′ for reducing the tension of the alternating current led to the synchronous motor A^1.

A single phase synchronous motor on the locomotive receives this alternating current and is driven by it continuously at a practically constant speed; the current after passing through the motor, being led to ground through a moving contact. This

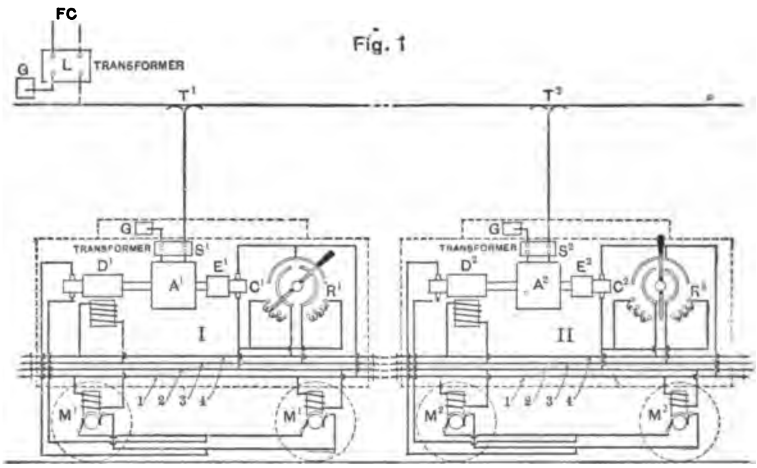


Fig. 1

single phase motor A^1 drives continually a small exciter E^1 and also a large continuous current dynamo D^1 whose field is separately excited by the exciter E^1 and has in its field circuit a reversing field rheostat R^1. The armatures of the propelling motors are connected in multiple directly across the terminals of the armature of the dynamo D^1. The field magnets of the propelling motors M^1 are separately and constantly excited by the exciter E^1.

By manipulating the reversing field rheostat R^1, the current through the armatures of the motors M^1 necessary to obtain the required tractive effort, can be obtained at any desired voltage from the lowest voltage to the full speed voltage, and in either direction.

A perfectly smooth and rapid acceleration can thus be obtained with minimum energy from the source of supply.

The simultaneous multiple control of the several locomotive units is obtained by means of the four small wires 1, 2, 3, 4, which are lead along the train.

In Fig. 1 the operator is supposed to be upon the locomotive I. The exciter E^1, which is producing a constant e.m.f., has its terminals connected to the wires 1 and 2. Across these wires 1 and 2 are connected the field windings of all of the propelling motors on the two locomotives, so that they are all constantly and fully excited.

The wires 3 and 4 are also supplied by a current from the exciter E^1, but the reversing field rheostat R^1 is in the path of this current. The fields of the two dynamos D^1 and D^2 are connected in multiple across these wires 3 and 4 which extend along the train.

It will be evident that by manipulating the reversing field rheostat R the operator can vary, simultaneously and similarly the field exciting currents supplied to D^1 and D^2 and that therefore he can cause the voltage of these two dynamos to vary in exact unison from 0 to the maximum voltage in either sense. Thus, the operator can cause the two locomotives to start, accelerate, run at full speed, retard, and reverse in perfect unison, always dividing the load perfectly under these various conditions.

By placing the controller R^1 in its open position and going to the other locomotives, the operator can similarly control the two locomotives simultaneously by means of the controller R^2.

By the use of this system I expect to be able to secure the following advantageous features:

1st. The haulage over existing roadbeds, grades, bridges, etc., of very much heavier trains than can be hauled by any steam locomotive.

2d. A material reduction in the cost of maintenance of the locomotives as compared with steam locomotives.

3d. A material saving in the maintenance of the road bed because of the absence of hammer blow, shouldering, rocking and skidding.

4th. A material increase in the weight of the train which could be hauled around a certain curve by a locomotive having a certain weight on drivers.

5th A material increase in the load which could be started upon a certain grade by a locomotive having a certain weight on drivers.

6th. A material reduction in the dead load necessarily hauled by a steam locomotive, represented by the part of the steam locomotive and tender not on drivers.

7th. A very large increase in the number of trains of given weight and speed which could be operated from a given power house compared with the series parallel or cascade systems. Or, to state this another way: a very much higher rate of acceleration with the same maximum output from the power house, the same conductors, the same weight per train and the same watt hours per ton mile, than is possible with the series, parallel or cascade systems.

8th. As each locomotive unit can be equipped with any desired number of driving axles and any desired number of locomotives can be operated under multiple control, the amount of power which can be applied to a single train and controlled by a single operator is practically unlimited.

9th. Fifty per cent. of the energy now wasted on friction brakes can be saved in the form of useful electrical energy restored to the system.

10th. The first cost of equipment will be very much less than that of any system, for equivalent service, which involves the use of sub-stations.

11th. The cost of haulage per ton mile will be greatly reduced as compared with steam locomotives, especially because of the large increase in the weight of the train which can be hauled.

12th. Difficulties due to electrolysis would be reduced to a minimum.

A paper read at the 170th Meeting of the American Institute of Electrical Engineers, New York, Nov 21, 1902.

CONTINUOUS CURRENT MOTORS FOR MACHINE TOOLS.

BY F. O. BLACKWELL.

A description of the characteristics of the different classes of metal working tools, of the requirements of motors for operating them, of the conditions limiting the range of speed variation and some of the methods of obtaining it with continuous current motors.

The application of electric motors to machine tools is a subject requiring a great deal of study in order to obtain the best results, each case having to be treated as an individual one. In most shops it might be economical to have the bulk of the machines driven by individual motors, while in others group driving would be better.

Planers, slotters, milling cutters and many other tools need only a slight variation in speed, as the relation between the tool and its work is always the same, variation in speed only being required for different classes of work, that is, for hard or soft metal or for a roughing or a finishing cut. Such work does not require more than a 2 to 1 variation, while, on the other hand, lathes, boring mills and other rotating tools may require an 8 or 10 or even 40 to 1 variation, necessitated by the varying relation between the tool and different diameters of the work. For instance, take a lathe in which is being turned a shaft 6″ in diameter, to obtain a cutting speed of 50 r.p.m., it will require approximately 32 r.p.m. of the main spindle; while if the flange of a 48″ wheel was being turned, it would require only 4 r.p.m. of the spindle to obtain the same cutting speed. It can therefore be seen that such tools of necessity require a large amount of speed variation to obtain the best results.

There are a number of methods in use for attaining this variable speed by means of the electric drive, the more common being rheostatic, field, and multiple voltage control.

Either the rheostatic or the multiple voltage method combined with the field control of the motor makes a very flexible system. For example, a motor having 100 per cent. field control used on the three-wire system will give a speed variation of 4 to 1, or a motor having 35 per cent. field control used on a four-wire system with potentials of 60, 80, 110, 140, 190 and 250 volts, will give a speed variation of approximately 6 to 1, or having potentials of 40, 80, 130, 170, 210 and 250 on 8 to 1 speed variations, the gaps in speed between the various potentials being filled in by field control of the motor.

Having at hand an easy method of control, the question arises,—how far can we efficiently apply this method to advantage? It has been demonstrated many times that it takes practically a constant horse-power to remove a given amount of metal per minute, irrespective of the rotative speed of the tool. Therefore, the main spindle of a lathe taking a ⅜″ cut on a 6″ steel shaft with a feed of ⅛″ and a cutting speed of 50 r.p.m. makes 32 r.p.m. and takes a certain horse-power to drive which we will assume to be 15 h.p., and the motor will be working on its highest potential or 250 volts. Now, if we are using the multi-voltage system with the last-named potentials above, and should put a 48″ wheel in this same lathe and turn up its rim with the same cut, feed and cutting speed, the main spindle would run at about 4 r.p.m., or one-eighth of the previous speed, but still requires 15 h.p. to drive. With this condition the driving motor would have to run on its lowest potential or 40 volts, and would be consuming fully six times the amount of current it did previously. It is therefore seen that a motor to be used on the multi-voltage system will have to be sufficiently large to carry its maximum horse-power at the minimum potential, or in other words, at say 40 volts on a 250 volt system, the motor will have to be six times too large when working on its maximum potential. For this reason I feel that we must keep the lowest potential employed as high as possible in order that the size and cost of the motor may be within reasonable limits. A potential of 40 or 60 volts, requires such large conductors if they are laid out for a small drop that their cost is prohibitive in a plant of any size. If a large drop is used, the motor falls off in speed under load and its speed regulation under changes of load is little better than with the rheostatic control.

With the three-wire system and a 100 per cent. variation in the motor speed by field control, we can obtain a 4 to 1 total variation which, for general machine shop work, is sufficient to cover a single operation on a given tool. The total range, however, on a tool can be increased greatly by having a few gear changes. For example, on a back-geared lathe with a gear ratio of 4 to 1 a total variation of 16 to 1 can be obtained. In the same manner on a double-geared lathe a variation of 64 to 1 might be obtained.

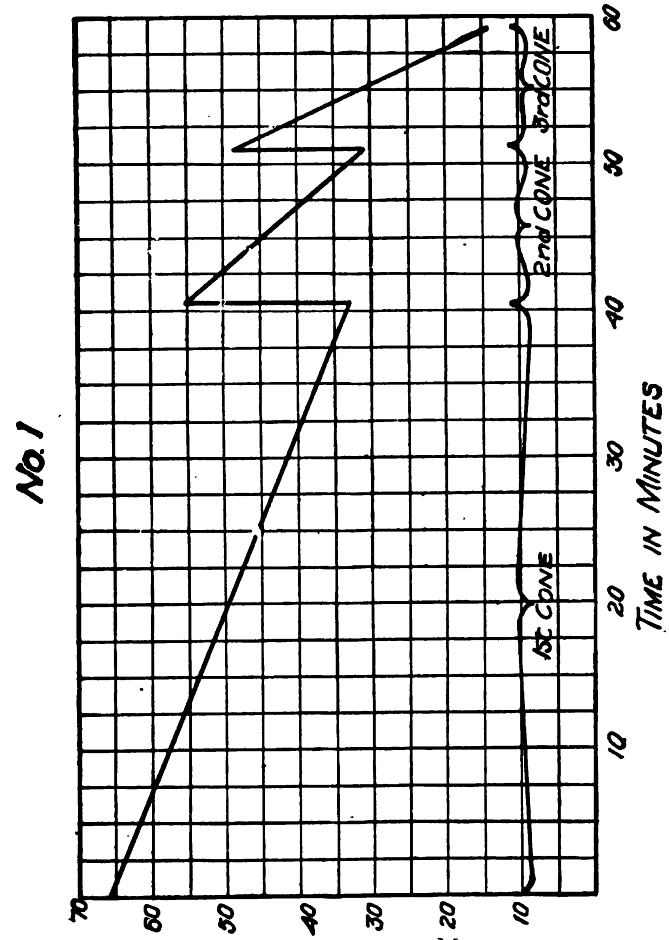
The reduction effected by different sets of back gears on machine tools will be found to vary from 4 to 1 to 6 to 1. All tools can be arranged with 4 to 1 changes between back gears without any difficulty. In many cases a single back gear is sufficient for a tool. By putting a magnetic clutch on this back gear and making the electrical connections in the controller, it is possible to get a 6 to 1 variation electrically and without increasing the cost of the motor more than would be required for a 4 to 1 variation.

Where machines must run at various speeds, the usual practice has been to employ step cone pulleys and changeable gears. The speeds obtained in this way, however, are few in number, and therefore as a wide range of speed is necessary, the different speeds must be far apart. The minimum speed change of lathes, for instance, is usually from 25 per cent. to 50 per cent. If the speed with one combination of gears and pulleys is a little too high, it can be reduced to the next lower speed (25 to 50 per cent. lower), with a loss of output nearly equal to the reduction in speed. If, on the other hand, power is furnished by a variable speed electric motor with a range sufficient to fill in between the mechanical steps, the tool may be driven always at the highest possible speed and maximum production. This is best illustrated by the curves plotted from a test on a 72″ lathe.

Fig. 1 shows the cutting speeds and the time taken to face a 72″ cast iron disc from a maximum diameter of 72″ to a minimum diameter of 6″, using three different steps of the cone pulley, the time for shifting the belt from one cone to the other not being included. The cone pulleys on a mechanically driven tool do not permit the tool to start at the maximum cutting speed, and in this case the mechanic, having no guide but his eyes, did not change the speed on the cone pulley as soon as desirable for greatest production.

Fig. 2 shows a test on a similar lathe but driven by a motor. With the electrically driven tool the cut begins and **ends** at the maximum cutting speed that the work permits.

As will be seen from the curves, a belt driven lathe required **59** minutes to complete the cut, while the motor driven lathe did **the** same work in 31 minutes. The electrically driven tool, there**fore,**



CUTTING SPEED IN FEET PER MINUTE.

did the work in 53 per cent. of the time, or putting it in **another** way the belt-driven tool required 90 per cent. more time to **do** the same work.

With electrical control a man can keep his hand on the **con**troller and his eye on the tool, increasing the speed from time **to** time. Being limited only by the temperature of the tool, it **has** been found that much higher cutting speeds are unconsciously attained with a motor-driven tool than would be thought possible were any fixed rule followed. It is therefore apparent that this increased production in many cases is so great as to fully justify the installation of an electric system, even if there were no other advantages to be secured.

The costs of motors vary with their size and (for a given horse-power) nearly in proportion to the variation in speed which can be obtained from them. The approximate relative sizes of the motors expressed in the horse-power capacity at which they could be rated at the maximum potential are about:

SYSTEM.	SPEED VARIATION.	RATIO OF MAXIMUM H.P.
Two-wire	50–100	100
Three-wire	25–100	200
Four-wire	16–100	400
Four-wire	12–100	600

Beside the cost of the motor there is to be considered with the four-wire system the cost of the supply plant, that is, the generators, motor-generators and conductors.

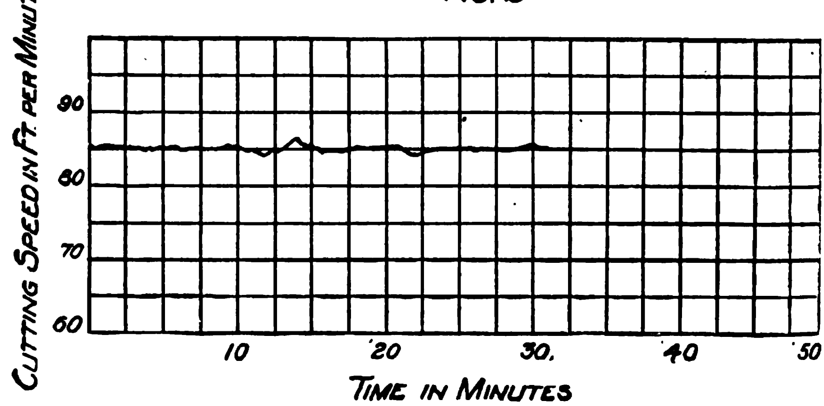
The three-wire system is now generally employed for lighting and requires no special appliances. Nearly all central power stations distribute their current for lighting and power on the three-wire system so that it can generally be obtained and the erection of a special power plant avoided. The three-wire system can be always arranged so that the motors running at one-half potential will be equally divided between the two sides of the system, which will therefore be in balance, and as there is but little or no current flowing in the neutral wire, it can be of nominal size. The three-wire system does not necessarily require two generators or a balancer set, an alternating neutral with collector rings on the generator being extensively employed.

The four-wire system requires a three commutator motor generator set which must have sufficient current capacity at the lowest potential to run all the motors that could ever be in service at one time at their full horse-power at that potential. The motor generator set and the heavy wiring for the low potentials of the four-wire system will much increase the cost, exclusive of motors as compared with a three-wire system. If the motors are made of sufficient capacity to run the rotary tools at reduced speed and the motor generator set and distributions cables are made of proper size to take care of the unbalanced load, the four-wire system will altogether cost several times as much as the three-wire system.

In conclusion, I would say that in my opinion it will generally be found best to use motors with field control, allowing a total speed variation of 2 to 1 with the two-wire system or 4 to 1 with the three-wire system, believing that the four-wire system is too expensive for general application if the plants employing it are properly designed and equipped with large enough electrical apparatus.

For reciprocating tools a two-wire system will meet all requirements, and there are very few cases with rotating tools where it is

No. 2



not better to vary mechanically the speed for greater than 4 to 1 changes in speed.

The most important consideration in the electric driving of machine tools is to make the control of the tool as convenient as possible and arrange the system so as to permit small changes in speed, and consequently be able always to drive the tool at its highest possible speed and greatest output.

After reading the paper Mr. Blackwell said: I have a diagram of an actual test on two lathes, one with the electric motor drive and the other driven by cone pulleys and belts. The diagram on the left shows the cutting speed and time required to face a seventy-two inch cast iron disk, starting from the outside and working towards the centre. The workman started the machine as near the maximum cutting speed as possible, but it was not the maximum speed he could get. In this case he started at 65 feet a minute, and worked down to 30, which he thought was the right point to change, then he changed to the next cone of the pulley. The actual time required to finish that face plate was about 60 minutes. On the electric tool he had a variable field control and as he had the controller in his hand, he could watch his tool all the time; and he tried to run as near as he could to the maximum, which was supposed to be about 100 feet per minute. As a matter of fact, he got rather low. He started on 85 feet per minute, the variations being only 4 or 5 per cent. The result was he kept cutting at 85 feet per minute throughout the run, and finished the entire cutting in 32 minutes, practically half the time he took with the cone pulleys; that is about the experience of nearly every one who has had anything to do with electric driving of machine tools. The use of the electric drive nearly doubles the total output.

Discussion.

President Scott:—We have had a meeting which is particularly interesting, because all except two papers have considered what is practically the same problem, the means of accomplishing the same end. We will have the discussion opened this evening by another gentleman who has given a great deal of attention to this same problem, Mr. Gano S. Dunn.

Mr. Dunn:—The Company with which I am connected is at present engaged in litigation involving a number of the features presented this evening; and very greatly to my regret the attorneys of the company have requested that I do not take part in this discussion. However, as you have been so kind as to call upon me, I think I may with propriety refer to certain matters relating to the general design of electric motors.

Several of the authors describe systems in which a motor is expected to give a constant horse power over a speed range varied from 1 to 2, by means of field weakening. This means that if a motor is fully loaded at a given speed, it will be called upon to take the same current and deliver the same horse power at double the speed, and with a field weakened 50 per cent. My experience is that it will not do this satisfactorily unless it is a special motor. The question is particularly important in connection with the operation of machine tools, on the system described by Mr. Storer, since the motor might be used to drive a lathe, where heavy torques occur in the lower ranges of the speed, when the motor runs with a greatly weakened field on 110 volts. The motor, which he describes as a 5 h.p. motor, running normally at 375 r.p.m., might be called upon for that 5 h.p. at a speed nearly equal to 750 r.p.m., under a field weakened nearly 50 per cent. If the motor is designed to give proper commutation with normal field strength, then in my experience it will not give it with only half of that field strength. A motor designed with an abnormal and excessive field strength is, of course, susceptible of speed increase by a reduction of this excess, but such a motor is special and expensive.

If you submit a standard motor to a similar degree of field weakening, the commutation will be unsatisfactory. Unsatisfactory commutation does not always mean sparking. It means commutation that in the course of time destroys the commutator.

President Scott:—As I intimated in my opening remarks, we are quite fortunate in having the actual apparatus which is presented by different companies for this class of work, represented by representatives of the companies. While we regret that Mr. Dunn has found his limitations, for once at least, in discussing the merits of the direct current motor, still the reason is one which we must, of course, respect; and we must remember that although there are often limitations of this kind introduced, particularly with regard to new subjects, we ought to be glad to hear as much as possible from our members upon important subjects, even though they must stop when the limit comes We can hardly afford to decline to hear anything of a new subject simply because all cannot be told. Under such circumstances we would often have to wait until the subject became stale before we could learn anything about it. We will be glad to hear from Mr. H. E. Heath, of Windsor, Connecticut.

MR. HEATH:—I am obliged to you for calling on me, but I may say I have practically left this branch of the subject after having given it fifteen years' attention. I agree with Mr. Dunn in saying with the ordinary construction of the standard motor, if you propose to get a wide range of speed by variation of field, it will necessitate the use of a much larger motor. But that is not saying that a special construction of motors cannot be used, because I know, and perhaps a number of other gentlemen here know, that a form of motor can be made that will give us practically sparkless commutation over a fairly wide range, and still not be largely in excess, with regard to either cost or weight, of the standard motor. For reasons perhaps similar to those of Mr. Dunn, I do not care to say much more about this. I think that within a year or so he will be at liberty so say a good deal more than he can now.

PRESIDENT SCOTT:—Will Mr. S. T. Dodd of the Stanley Electric Manufacturing Company, favor us with some remarks?

MR. DODD:—It is so late I really do not feel I should take up any time in discussing this subject. I was interested in Mr. Leonard's article on the application of his multiple-unit voltage speed-control to railways systems. I would ask Mr. Leonard what facts he can give us in regard to the weight efficiency of such a locomotive as he describes. It will be impossible ever to apply such a system as he describes to single cars or small units, and the only field for such a locomotive will be for trunk line service. Now, let us consider a large locomotive like the B. & O. tunnel locomotive. The weight is 96 tons. I do not know exactly how much waste room or waste weight there is, but I do not think there is much of either. These locomotives are operated by a motor-generator booster set, which weighs 36 tons, and raises the voltage from 500 to 700. Suppose that these locomotives were equipped on Mr. Leonard's system and that each was furnished with a motor-generator, which instead of being a booster was capable of developing the whole current for the locomotive at full voltage, that is, had a capacity of about 750 k.w. Such a motor-generator would weigh at least 50 or 60 tons, making the total weight of the locomotive about 150 tons. Such a weight is not prohibitive, but it would seem to indicate that an electric locomotive equipped on Mr. Leonard's system would weigh a good deal more than a steam locomotive for doing the same work. On the contrary, we have been anticipating and prophesying that the electric locomotive of the future would increase rather than decrease the weight efficiency of our moving units.

PRESIDENT SCOTT:—A gentleman who has to do with motors at work is Mr. Arthur Williams, of the New York Edison Company. We would like to have Mr. Williams give us his experience in this matter, bearing on the general subject under discussion.

MR. WILLIAMS:—Our experience in applying motors directly to shop tools has been very much of the order described by Mr. Lozier, but I think, Mr. President, he takes almost too low an average for the demand upon the supplying service. If I understand his figures, this average is about 10 per cent. In my experience it is more nearly 25 per cent. to 30 per cent.

There is also to be remembered in using for regulation the neutral wire of the three-wire distributing system, that large power loads are apt to unbalance the system and lessen the quality of the service. That has to be very carefully considered. In New York are certain points where in single units, 120 volt motors are as large as 50 h.p., even larger, but there are few sections of the system that can withstand so much unbalancing.

It seems to me that these strides in the equipment of factories with individual motors are in the right direction, and quite in line with what was predicted of the future at a meeting of the INSTITUTE some three years ago. The first cost of installing individual motors is much greater, but the difference is partly offset by the saving in shafting and belting. As soon as the two methods are compared, one using belts and shafting and the other individual motors, there is no question whatever as to the inferences to be drawn in favor of the individual motors. Work can be turned out at sometimes 100 per cent. greater speed, and even higher percentages of increase, and there is great economy in power. I think it is not improper to say that the average loss of power in machine shops where belting and shafting are used, is 50 per cent. of the total power consumed; by using individual motors a very large part of this loss, not substantially all, can be saved and such savings aggregate a very large sum annually. The cost of power service, using individual motors, with current at 6 or 7 cents a kilowatt hour at the meter, is from $20 to $30 a year per h.p. These figures are based on the capacity of the plant, and are actual in general machine shop work, and in several of the largest printing establishments.

PRESIDENT SCOTT:—We have a gentleman with us this evening, who joined the INSTITUTE in 1888, and he is therefore one of the oldest members, but this is, I believe, the first meeting of the INSTITUTE which he has attended. He is a man who has had a great deal to do with the subject now in hand, as he has been superintendent, and is now manager, of one of the largest machine shops of the country, in which electric drive is employed, and he may have a few words to say in regard to this subject. I refer to Mr. Philip Lange of Pittsburg.

MR. LANGE:—I do not believe that I can add anything to what has been said about controlling variable speed direct current motors. All of the machinery of the establishment with which I am connected is driven by constant speed two-phase motors, and we have been compelled to accomplish with alternating current motors those results which were pointed out as having been accomplished by direct current motors. Most of our tools are grouped, and we are using the individual motor drive only for some large tools, and there we accomplish the variations in speed by some mechanical devices such as variable speed counter shafts, nests of gears, etc. I fully agree with Mr. Blackwell's statement that it is very important to provide means to vary quickly the speed of tools in order to get results such as he described; in one instance, reducing the time required for machining by one-half by the use of a proper speed controlling device. We have accomplished similar results by mechanical speed varying devices, as the alternating current motor is not very well suited for speed adjustment

If any of the gentlemen present wish to ask any questions as to how we accomplish some of the results we have attained by means of alternating current motors, I am ready to answer, but I cannot add anything to what has been said regarding the performance of direct current motors.

MR. CHARLES DAY:—I have been very much interested in the papers of the evening, which have described in such detail the varions systems of obtaining variable speed by means of the direct current motor, but I have not as yet heard a satisfactory answer to the question asked by the President when opening this discussion, a question of utmost importance to al. manufacturers contemplating improvements or extensions to their machine shops—does it pay to put individual motors on machine tools, and if so, does it pay to go to the additional expense of obtaining variable speed?

Mr. Lozier touched on this subject in the latter part of his paper, where he referred to the radical changes that shop management and practice have undergone during the last few years.

Over seven years ago Mr. Horace L. Arnold wrote a splendid article on this subject entitled " Production to the Power Limit,"* stating in the most forcible manner the principles underlying economic production. It seems to me that any one who is contemplating the advisabliity of driving machine tools with individual motors, could not do better than read this short article and then endeavor to follow up this line of thought by making a most thorough study of the requirements of each particular machine.

During the past three years few subjects have received more attention in the technical papers and engineering organizations than the use of the motor as a means of driving machine tools, but so far the discussions have usually dealt with details of motor design and operation, or the advantages derived from electrical driving only, considered in the most general way. It is time that we consider this subject from a broader standpoint,

*See *Engineering Magazine*, August, 1895.

giving the motor the position that it rightly holds, but not losing sight of other factors, the development of which are essential to the efficient operation of the scheme.

If a machine shop is to be run in the same way after the introduction of a costly system of motor driving as before such an expenditure, interest and depreciation will not be made on the investment. On the other hand, the shop superintendent who is thoroughly alive to the possibilities in machine shop work may find in the motor a solution to certain details which make possible the highly efficient results he is aiming for.

Ease of handling and close speed regulation, the principal advantages claimed for the variable speed motor, are terms that can only be used in a relative sense; and the saving effected by bettering these conditions will only justify a certain expenditure, therefore the cost of different methods of arriving at the results should be most carefully considered.

One of the speakers said in the discussion that the problem of machine tool operation had been turned over to the electrical engineer, the mechanical engineer failing to accomplish the desired result.

I feel that it is a great mistake to intimate that a field of as broad a character as the one we are discussing should be entirely in the hands of any one division of engineers, their combined efforts being necessary if the desired result is to be arrived at in the least time. There is no definite amount of data that can be placed in the hands of the electrical engineer to form a basis for his work, but he must personally familiarise himself with every detail of shop equipment, methods and requirements before the need of certain improvements is felt with sufficient force to call forth his best efforts in design and construction. The impressions and convictions that one arrives at after earnest study of present conditions and possibilities in the machine shop lose their force when repeated to another party, and the relative importance of all the details that make up the general scheme is lost entirely.

Such details as the total range in motor speeds and the number of running points required, differ in each of the systems described this evening, and if we wish to decide which one to adopt we must know the character of the metal we are machining, the cuts we can remove and the speed made possible by the tool steel used and the facilities for driving the work. The means provided for determining the cutting speed is another important factor, as is the ability to use the apparatus to its full efficiency under working conditions that determines its real value. I have seen over and over again controllers designed to give a speed regulation of 5 per cent. introduced into machine shops where the operators had no facilities for judging the correct cutting speeds closer than 30 to 40 per cent., the advantages of the much-talked-of close speed regulation being entirely lost.

Mr. Blackwell stated that 4 to 1 was sufficient range in speed of efficiently machining any *given piece of work*, and dwelt at some length on this particular case, showing charts of the savings effected by the use of a variable speed motor. In shops doing a general line of work, it is very seldom that work turns up where the tool cuts from the outside to the center, and this problem is never the deciding factor in the range required. Speed control is obtained in nearly every case by a combination of mechanical and electrical means, the motor range and gear ratios depending upon the machine, and the average variation in diameters and kind of material handled.

When attaching motors to old tools, such as lathes and drill presses we must, as far as possible, adapt our speed range to the present gear ratios, in some cases by introducing additional gears, and in others without change to the machine. We have found that the gear ratios vary from 3 to 1 up to 15 to 1, depending on the size and character of the machine.

We have frequently endeavored by careful figuring to show just what saving would be effected by replacing the belt and step cone by a variable speed multi-voltage system, assuming in each case that the equipment was driven to its full capacity.

Taking into account all the limitations arising from variations in material, and so on, we have found it hard to show by such comparison a saving greatly in excess of the interest and depreciation on the investment. It is, however, the indirect savings that make the motor of such value as a method of operating machine tools. The power limit on most of the standard machines is absurdly low when we consider the high cutting speed that the modern air hardening steels permit of. On large machines, such as boring and turning mills doing general work, it is impossible to have the machinist shift his belt as often as he should, as by so doing he would be physically worn out at the end of each day, or if such a condition can be arrived at it would only last a short time, the workman soon relaxing his efforts until the old conditions exist again. The motor with its great facility of control removes all these difficulties, and but small incentive is necessary to assure the continued efficient operation of the plant.

We must ever bear in mind, while considering machine tool driving, that it is inconsistent to spend all our energy to develop one detail while other equally important factors are ignored. The feed mechanism on a lathe, for example, is too often neglected and so it is with many other details.

I want to call attention before closing my remarks to the erroneous impression usually conveyed when citing as a *characteristic example* the time saved on a given job; such data has no real value unless we know just how long the tool runs under cut, the hours it is working each year, the wages of the operator and many other details that it is impossible to carry in one's head.

At the works of our clients, the Link Belt Engineering Company Nicetown, Pa., we have obtained data extending over four years from which we can figure the pound price of their product.

After taking into account every factor which might in any way affect the result and deducting 10 per cent. which was given the workmen in changing from a 10 to a 9-hour day, we can show a clear saving of 30 per cent. on the entire labor bill. This is due to better methods, tools, and tool steel, and better methods of driving the machines; and the saving is largely in excess of the interest and depreciation on the entire expenditure necessary to effect it.

It seems to me that if shop managers who have installed the motor as a means of driving individual machines, would endeavor to get data of this kind, the advantages which can be derived from such an installation would be made evident and aid greatly in the general adoption of such systems.

PRESIDENT SCOTT:—Mr. Day's remarks seem to me to be an elaboration of the first sentence which I used in introducing the papers on this subject, to the effect that applications of electricity lead to the revolution of old methods as well as to the evolution of new ones. What he says reminds me of the remark which I heard the superintendent of a factory which is at present enlarging its capacity, make within the past week. He said that of the new machines which were being ordered, a very large number were ordered specially, at an excess cost of 50 per cent., simply in order that they may be mechanically strengthened so as to stand the high speeds at which it is expected to operate them.

If there is no one else who wishes to add to the discussion we will close by calling on those who have read papers. I will call upon the gentlemen in the inverse order.

MR. LOZIER:—One point that has been referred to by Mr. Williams is the question of distributing motors over a system operated by three-wires. If you divide the number of motors by 6 you get a smaller quantity than if you divide by 2; in other words, if you are using a three-wire system, with only two voltages, and these voltages cannot be combined to give three voltages, the motors will bunch up on one voltage much more than if you distribute them among the six. We have not found that the balancer is at all disturbed by the motors running at any one speed bunching up on one voltage.

I would like to go on record to say that it is up to the tool builder to give us tools that will be strong enough. I say this in order to help the general cause, because at present we are limited in the output of the tools, because they are not strong enough.

MR. N. W. STORER:—I believe the only question raised in regard to my paper was brought up by Mr. Dunn in reference to the commutation of the motors with a weakened field. He claims that it is impossible for a standard motor, properly designed, to commutate with a field one-half its normal strength. I am entirely unable to agree with Mr. Dunn. Referring to the point I sought to bring out in my paper, I gave as an example a 10 h.p. 220 volt low speed motor. Running at half the voltage and half the output, the current in the armature would be the same as at the normal rating of 10 h.p. It ought to be well understood that a motor running at a lower voltage than its normal will commutate through a greater range of load with a weak field. I believe Mr. Dunn will agree with that. If you consider the Ward Leonard system, which is quite well-known, you will find a generator which commutates from possibly one-fifth or one-sixth of its normal voltage up to its maximum voltage with any load within its range. I have not heard that point questioned tonight. It is possible that that is quite a special generator, but I do not think you will find it so. A low voltage gives greater possibility for the motor, and the standard motor on a low voltage, the motor being properly designed, ought to be able to commutate with an extremely weak field. I have run these motors to the point where the field was only one-half the strength of the armature, and they were perfectly stable. It is well known that in designing and in building motors of different sizes, standard parts may be variously combined for specific purposes, so that it is very simple in some combinations to get better proportions than would be made if one were to design especially for some exact condition. It is so with a 220-volt motor. I do not think there is any difficulty in reaching the condition which I outlined in my paper. Mr. Dunn made the point that this would be a special motor. It may be a specially good motor. It is a standard make of motor, however. Will a motor used on the multi-voltage system be a standard motor. The example which I gave you called for a 20 h.p. motor, rated normally at 220 volts and 1,500 r.p.m., and it met the conditions which I gave for a 5 h.p. variable speed motor. Prominent manufacturers do not make 20 h.p. motors, normally running at 1,500 r.p.m. I do not think there is anything in the market which calls for such a motor, with a range of speed of only 4 to 1. If you have 6 to 1, unless you get 200 revolutions or thereabouts for minimum speed, which makes an enormous motor, you will have a normal speed of the motor of possibly 2,000 or 2,500 revolutions. Such a motor is not a standard motor. That is a point you must consider. You might take a 110 volt motor, and in that case you would have to run it at double its normal voltage, and it would have to be an especially good 110 volt motor.

These are some of the points which must be considered. The three-wire system requires a somewhat different type of motor; it is primarily a good commutating motor, and I believe there are a half dozen different firms in the country which are putting out such a motor. A multi-voltage system requires a special motor, or a motor designed for a speed out of the range of what is ordinarily required. It must be designed with the idea of using it for the multi-voltage system. Mr. Heath, I believe, agrees very nearly with me in that respect. He claimed that while the standard motor ordinarily would not do that, it was usual to make a motor which would do it with practically no increase in cost. That is what should be done.

In regard to Mr. Leonard's paper, Mr. Dodd struck the nail on the head. Such a system, I believe, will increase the weight of the locomotive far beyond what is ordinarily required for the power of the locomotive. I believe if you take a large locomotive, you will have scarcely any excessive weight necessary, if you consider the motors and the necessary parts of that locomotive. This is my experience in figuring on railway work, and I believe if you add to these a motor-generator outfit you will have a locomotive which is 50 per cent. heavier than it should be.

Mr. H. Ward Leonard:—Before touching upon the question of the weight of the locomotive, I would like to make a slight response to the point that the multi-voltage system requires something special in the shape of a motor. I think if there is any system that requires nothing more than the simplest standard form of motor, it is that system. The first time the multi-voltage system was tested was when I presented it to William Sellers & Co., in 1891, and the simple standard shunt motor in use at that time was tested over the entire range of the various motors touched on this evening, with perfectly satisfactory results in every way.

As to the locomotive question, I will not spend any time on the B. & O. locomotive, which, although historically interesting, we all know is absolutely uncommercial as a possibility in the direction of freight haulage on trunk line service. I think it is likely there is not much room on that particular locomotive for a motor-generator, as I know that after the locomotive had been put in service, the company which built it, carefully considered whether they could put a motor-generator on it, and apparently they did not find room for it. As to the question of the effect of the weight of the motor-generator in locomotive practice, I beg to point out that the heaviest locomotives which have been made in recent years, such as the decapod locomotives, have only about 50 per cent of their entire weight on drivers (including tender). When the cylinder capacity was then increased in an endeavor to secure better power results and to secure larger tractive effects, the next difficulty that was met was that they would too readily skid the wheels as the weight on the drivers was not sufficient to take care of the power produced, and various complicated devices have been invented and used in recent years to shift a part of the weight of the locomotive when starting the load, in an endeavor to secure more weight on the drivers at that time. It is, therefore, not only important, but really essential that you get more weight upon the drivers of any locomotive such as I am considering than the weight of the motors alone would give you. Furthermore, admitting for the sake of argument that the point is well taken that the dead weight hauled is increased by the motor-generator, I still wish to point out that the weight of such a motor-generator would not compare with the weight of the propelling motor, nor with the weight of a motor-generator, such as is put in a substation. Such a motor-generator as would be employed on a locomotive would be comparable with generators that are driven by steam turbines, as to size and weight, and if the gentlemen who have spoken on this subject are interested in following the matter further they will find quite detailed figures as to the weight of the motor-generator relative to the total weight of the locomotive in a paper read before the Zurich Electrical Society by Mr. Huber, last spring, describing locomotives of the Oerlikon Company, which are being built on my system, and which will go into commercial use on a government railway in the next few months. Still, however, going back to the matter of the weight, I wish to point out that if the present type of steam locomotive, having 50 per cent. of its weight on drivers, could be so made as to utilize double the horse power it now has, even though only 50 per cent. were on drivers (the remaining 50 per cent. of dead weight being more than equivalent to having to haul the motor-generator), the effect of such a locomotive as that would be enormous in the economies it would accomplish in the haulage of freight at the present day. There is scarcely a railroad in the United States that is not struggling with the problem of hauling its freight and what is wanted is locomotives which will haul twice as many tons as are now hauled; and even though it be a fact that in my system a few more tons are placed on the locomotive—50 or 60 tons or any such figure—when compared to the entire weight of a 3000 ton train, the haulage of this slight additional weight becomes entirely insignificant.

[Communication after Adjournment.]

Mr. Dowie:—In connection with Mr. Leonard's paper regarding speed control of individual motors on locomotives, it may be interesting to compare the well-known Ward Leonard system of controlling direct current motors with some slight modifications of this system. The names given are sufficiently well known not to require any detailed description of the apparatus employed:

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
Ward Leonard	100	148	123	371	271
Boost & Retard	100	74	61½	235½	135½
Teaser, Boost & Retard	100	49	42	192	92
Equalizer, Teaser, Boost & Retard	100	21	18	139	39

Column No. 1 gives capacity of working motor.
" No. 2 gives capacity of generator of motor dynamo, based on 90 per cent. efficiency and 33⅓ per cent. allowance for weakening of field.
" No. 3 gives capacity of motor of motor dynamo, assuming 90 per cent. efficiency.

Column No. 4 gives total capacity of machines required.
" No. 5 gives the excess capacity above that of the working motor.

It will of course be understood that the controlling apparatus becomes more complicated as the systems progress, but suitable controllers could be designed to give a full range of speed from zero to maximum in either direction.

In connection with the remarks made on multiple voltage systems, it is pertinent to call attention to the desirability of confining the range of voltage to as small limits as practicable. Where a wide range in voltage is used an excessively large motor must be employed, the wiring of the whole system must be heavy, especially the wiring of the small branch circuits and of the individual motors,—the use of circuit breakers on the individual motors is impracticable, because the size of balancing transformers becomes excessively large and the cost of installation is excessive.

If we can obtain a suitable direct current motor which will give a range in speed on constant voltage of about 3 to 1—and such a motor is entirely possible—then by the use of suitable changes of gearing we can obtain as wide a range of speed as is usually desirable. We avoid the complication of multiple voltage wiring, of special controllers, and the constant loss of the balancing transformer.

In order to obtain a very wide range of speed it is necessary to use changes of gearing; the question, therefore, to be determined is, how far shall the electrical variation be carried before the mechanical changes are introduced?

In designing shop equipments, not only must the best methods of obtaining variable speed be considered, but also care must be taken to install apparatus large enough to handle the increased output which is sure to follow when a system has been installed which provides easy means of adjusting the speeds of the tool.

Mr. Coho:—As my paper provoked no discussion, I must either take it for granted that the gentlemen agree with me, or that they did not consider the paper worthy of comment.

With reference to Mr. Leonard's remarks, it seems to me that before the greatly increased speeds which we can obtain by means of electric locomotives and various forms of speed control, can be of any material benefit, it will be necessary for us to increase our track capacities enormously.

For the benefit of Mr. Dunn and Mr. Heath, I will say that if they will call at my office I will show them a motor which has a speed variation of 300 per cent. by means of field control, and which does not spark at the commutator.

President Scott:—If no one has anything further to add to the discussion, a motion to adjourn is in order.

[Adjourned.]

COMMUNICATION AFTER ADJOURNMENT BY GEO. A. DAMON.

The selection of the proper method of motor application and of speed control involves so many considerations that it seems to be a difficult matter to evolve what might be termed " standard practice" from the various methods offered. We are therefore fortunate in having the subject presented from different points of view and it is to be hoped that the discussion of these papers in the various INSTITUTE meetings will indicate the " tendency " of engineering practice along these lines.

There can be no doubt that the individual motor is gaining favor as the advantages of its use become more generally understood and as the investors begin to appreciate the dividend earning possibilities of an investment in electrical drive equipment. It is therefore possible for an engineer in planning a new shop to provide for a separate motor on each machine and it would be instructive to determine under what circumstances such a course is justifiable.

If the shop is to have an entirely new equipment of tools, then the use of a separate motor for each machine should be carefully considered. Nearly all the tool builders are re-designing their products so as to accommodate the individual motor and the results indicate that the more flexible connection of power and the wider range of speed control made possible by the motor drive has allowed for a great improvement in the design of the tool itself. With the higher cutting speeds made possible by the individual drive,with the deeper cuts allowed in new steel and other materials, it is not unreasonable to expect the new tool, which has been designed with these improved conditions in view, to have an output capacity at least 50 per cent. greater than a tool for the same class of work but of the former belt-driven type. Under these conditions the individual motor appears to be good practice. But it more often happens that the shop tool equipment is to include a number of tools which have already been used in the old shop and which are poorly adapted to the direct application of individual motors. Take, for instance, a group of lathes driven by belts from speed cones. To put an individual motor on each lathe would require a multiple voltage or double commutator system of speed control, either of which would involve an investment in motors and controllers and wiring at least six times as large as the cost of one line shaft motor to drive the entire group and in addition to this, is the expense of special brackets and mechanical connections between the motors and the tools. Under these circumstances, it is problematical whether or not the extra investment in electrical equipment is to be justified. The " tendency" at present seems to be to arrange the old belt driven tools in groups, allowing a ten to twenty horse-power motor for each group.

If the shop is to run on a "piece work" "premium" or similar system of compensation for its mechanics, then the use of elaborate systems of speed control for individual motors may be justified. If each operator has a constant incentive to keep the output of his machine up to its full rated capacity for a given grade of work—and it is possible to vary this output by changing the speed of the machine by easy steps through a wide range—then the results obtained by the most efficient operation of the tool at all times may make insignificant the question of the extra investment required to install the control system.

On the other hand, there are situations in which an easy method of controlling the speed may be a disadvantage. For a large printing establishment, it was found necessary to design a device to lock the speed controllers so that if the press was run at all it was operated at a given speed, which speed was determined by the foreman for each job. In this way, it was made impossible for the feeder to soldier on his work behind the bosses' back. This incident is intended to emphasize the idea that if full advantage is to be taken of refined methods of electrical control, the operators in charge should also be worked up to their highest efficiency.

The practice at the present seems to be to put all tools requiring 5 h.p. and over on the individual motor basis and group all the smaller tools. There is certainly a tendency toward equipping even smaller machines with separate motors, down perhaps to 3 h.p. and also a corresponding tendency to reduce the size of the shafting motors driving groups, with the idea of having, as far as possible, one standard size for shafting motors all through the plant.

BRANCH DISCUSSIONS.

Discussion at Pittsburg, Dec. 4, 1902.

The meeting was called to order by P. M. Lincoln, who read extracts from the President's introductory remarks at the New York meeting, November 21, 1902.

The papers presented at the New York meeting were then abstracted as follows:

N. W. Storer abstracted his own paper, "The Three Wire System in Variable Speed Motor Work," and F. O. Blackwell's paper, "Motors for Machine Tools."

H. P. Maxim abstracted paper by H. B. Coho, "The Storage Battery as a Factor in Speed Control."

W. A. Dick abstracted paper by Geo. W. Fowler, "A Series-Parallel System of Speed Control."

E. M. Tingley abstracted paper by H. Ward Leonard, "Multiple-Unit Voltage Speed Control for Trunk Line Service."

R. W. Stovel abstracted paper by R. T. Lozier, "The Operation of Machine Shops by Individual Electric Motors."

G. H. Gibson then gave a resumé of the New York discussions upon the above papers.

The discussion as to the advisability of supplying tools with individual variable speed motors was participated in by Messrs. Stovel, Storer, Dusinberre, Dick, Lincoln, Campbell, Winslow Tingley, Stevenson and Barr. In this discussion the fact was brought out that where individual motors have been installed, the testimony is universally in favor of the system. The advantage of the individual motor system over the group system is not so much a question of efficiency as of greater convenience and increase of shop output. Numerous cases were cited of plants that had been equipped with individual motor-driven tools where the output had been very considerably increased and the quality of the work improved.

The discussion of Mr. Leonard's paper was participated in by Messrs. Storer, Tingley and Barr. It was generally admitted that the smoothness of speed control obtained by this system was ideal, and that a single trolley was the most feasible method for conducting current to the car. It was, however, pointed out that a single phase motor is difficult to start and time is required to synchronize. It may be started by means of a storage battery or by a split phase starting motor. A change in line voltage, the jumping of the trolley, etc., is almost sure to throw the motor out of synchronism. The motors on the different cars of a certain section are in synchronism and therefore rigidly connected together. Should one motor get out of step the remaining motors on the section would also get out of step. The single-phase motor is more subject to " pumping " than the polyphase motor and in general it is much more difficult to operate and is more liable to trouble. The apparatus on the locomotive is very expensive, notwithstanding that it may be driven at high speed. On account of the heavy starting current demanded from the generator with low field charge, it is necessary to make the generator with large overload capacity.

A number of claims are made in Mr. Leonard's paper as to the advantages of his system. It was pointed out that the reason for these different claims was not clear from the paper; and exceptions were taken to many of them as follows:

Second Claim: " A material reduction in the cost of maintenance of locomotives as compared with steam locomotives."

It was pointed out that the depreciation of the direct current generator operated at very high speed would be large on account of the fact that it must deliver heavy starting currents at low voltage, which would make good commutating conditions extremely difficult to obtain.

Sixth Claim: " A material reduction in the dead load necessarily hauled by a steam locomotive, represented by the part of the steam locomotive and tender not on drivers."

It was pointed out that the weight of the electrical equipment of the locomotive would be extremely heavy and at least 50 per cent. greater than would be necessary to give the necessary tractive weight on the driving wheels.

Seventh Claim: " * * * a very much higher rate of acceleration with the same maximum output from the power house, the same conductors, the same weight per train and the same watt-hours per ton mile, than is possible with the series-parallel or cascade systems."

Exception was taken to this claim on the ground that even if the claim is true on a trunk line railway, the gain of acceleration is of no material importance.

Ninth Claim: "Fifty per cent. of the energy now wasted on friction brakes can be saved in the form of useful electrical energy restored to the system."

Regarding this claim, it was thought that while it was possible that 50 per cent. of the energy expended in braking might be returned to the system under certain favorable conditions, it would ordinarily be very much less than 50 per cent., and for trunk line service the amount of power saved by this feature would be negligible.

Tenth Claim: "The first cost of equipment will be very much less than that of any system for equivalent service which involves the use of sub-stations."

The first cost of the equipment will depend upon the number of locomotives employed. If the number is large, the first cost will probably exceed that of a system involving sub-stations, as the cost of the locomotive equipment will be very high and the cost of motors will be higher than the cost of series motors for the same service.

In the discussion of Mr. Coho's paper, Mr. Maxim was asked for information regarding the operation of a series of storage cells when the load is drawn from only a portion of the cells in the series. Mr. Maxim stated that the cells from which the load is taken would be discharged more than the remaining cells, but that this difference was ordinarily not serious and when the batteries were again charged, the cells from which the load had not been taken would be slightly overcharged.

[COMMUNICATED AFTER ADJOURNMENT BY MR. H. WARD LEONARD, IN REPLY TO PAPERS AND DISCUSSION, NEW YORK, NOVEMBER 21; PITTSBURG, DECEMBER 4, 1902].

After the meeting at New York City, Mr. Dowie presented a table giving the capacity of the rotary converter in comparison with the capacity of the propelling motors.

For the simplest form of my system, as described in my paper of November 21st, Mr. Dowie places the capacity of the generator at 148 when the motor capacity is 100. He states that this is "based on 90 per cent. efficiency and 33⅓ per cent. allowance for weakening of field."

If by "capacity," Mr. Dowie means kilowatt capacity, his figure of 148 is incorrect. I point out that the kilowatts supplied by the generator are practically identical with the kilowatts received by the motor in any of the modifications of my system, since there is no loss of energy in rheostats in the armature circuit.

If by "capacity" Mr. Dowie intends to mean the weight of the apparatus, which seems to be the only other possible interpretation, I wish to point out that the rotary converter would, of course, in practice be operated at much higher speeds than the propelling motors, and that consequently the weight per kilowatt would be very much lower for each half of the rotary converter than in the case of the propelling motors, so that Mr. Dowie's figures of 148 for the "capacity" of the generator to supply a "capacity" of 100 in the motors is quite incorrect under any possible interpretation of the word "capacity."

Mr. Dowie's table shows that by the use of my "boost and retard" system, described before the INSTITUTE November 18, 1896, and more fully described in my patent No. 572,903 of December 8, 1896, the capacity of the converting apparatus can in certain instances be reduced to one-half of that necessitated by the simplest form of the system, and that in other forms of the system the capacity of the converting apparatus can be still further greatly reduced, but at the expense of simplicity. All of the figures presented by Mr. Dowie in his table can be still further reduced, if they are intended to refer to weights, by reason of the higher speeds referred to above, and by other modifications of the system, not mentioned by him.

The printed record of the Pittsburg meeting of December 4, 1902, shows that exception was taken by certain speakers to several of the claims I made for my system, because the reason for these claims was not clear from the paper itself. I made the paper as brief as possible, expecting that in case the claims I made were not admitted, that the discussion would enable me to explain fully my basis for making the claims.

The first point questioned was my claim that the system would effect a material reduction in the cost of maintenance of the locomotives as compared with steam locomotives.

The steam locomotive has a steam boiler the depreciation of which is quite high; and the multitude of reciprocating parts and the necessity of perfect alignment and adjustment upon a rigid wheel-base cause a depreciation which is extremely high, as compared with an electric motor, particularly when the electric motor is one in which the field current is never opened, and the armature circuit is never opened.

So far as the propelling motors are concerned, all of the depreciation met with in the series type of motors now in use, due to the sudden breaking of the main current passing through the armature and field, is entirely avoided.

This sudden opening of the circuit of the present type of series-wound motor is probably the principal cause of depreciation in the present railway motors, and it seems a marvel that the depreciation is not even more, in view of the terrific abuse to which all insulations are subjected to by this sudden rupturing of the current passing through the armature and field in series. It will be evident that the larger the series motor the worse this difficulty becomes. In my system the conditions are the most favorable possible to keep the depreciation of a railway motor to a minimum. As to the depreciation upon the rotary converter, the conditions are even more favorable; for it is entirely on springs relative to the roadbed, is in a clean, dry location and under continual observation.

The tests of this Heilman locomotive and the numerous applications of my system which have been in use for many years upon elevators, printing presses, traveling cranes, etc., show conclusively that the depreciation suggested, due to sparking at the generator brushes, is no more than that met with at the commutator of an ordinary incandescent lighting generator. Those desiring to verify this can readily do so by inspecting the elevator plants in the Singer building, the Fahys building, the Sampson building, the Gillender building or the New York Athletic Club, all in New York City.

Mr. Keilholtz, in his paper at the same meeting, in describing a coal hoist operated by a 100 h.p. motor, with my system, stated that the cost of operation and maintenance was less than that of a steam hoist. I therefore think that there can be no reasonable doubt that the depreciation of a locomotive on my system will be materially less than that of a steam locomotive.

The next point criticized was my claim that I could effect "a material reduction of the dead load necessarily hauled by a steam locomotive, represented by the part of the locomotive and tender not on drivers." It was said in criticism of this claim that the weight of the electrical equipment would be extremely great, and at least 50 per cent. larger than that required to give the necessary tractive effort on the driving wheels.

In answer to this, I refer to my statements above, from which, I think, it will be apparent that the weight of the locomotive will not be increased 50 per cent. by the added weight of the rotary converter. But for the sake of argument, I will suppose that the rotary converter does add 50 per cent. to the weight of the locomotive; how do we then compare with a steam locomotive of equal tractive effect? Under this admission, one-third of my locomotive is an unnecessary weight, but every pound of it is on drivers and is therefore available to produce tractive effort; whereas in the standard heavy freight locomotive of to-day the weight of the tender and the part of the locomotive not on drivers is far in excess of one-third of the total weight of the locomotive and tender, and this weight, not on drivers, is of no use under any circumstances.

It does not seem to be appreciated by those making this criticism that the chief problem in the railway freight service to-day is, how to secure largely increased tractive effort in a locomotive, as the economies in freight haulage are almost directly proportionate to the tractive effort of the locomotive.

In the steam locomotive it is difficult to increase materially the number of drivers, because of the necessarily rigid wheel-base of the locomotive, which cannot be lengthened beyond a certain point on account of the difficulties in getting around curves.

The weight carried upon each driver has in recent years also been forced up to its limit upon existing roadbeds. What is needed is more drivers upon a flexible wheel-base, while keeping the weight per driver as at present, and this can be readily obtained with my system, as the parallel rods are then entirely unnecessary, although they probably would be necessary in the case of any form of series motor. In explanation of this, I point out that with a separately excited motor field, the motors could not skid and race up to full speed when starting a train, even upon a slippery piece of track; whereas with any form of series motor, the maximum joint tractive effort could only be obtained by the use of the very objectionable parallel rods, which all railway engineers would like to avoid.

My claim was questioned that the first cost of equipment for my system would be very much less than that of any system for equivalent service which involves the use of substations. This seems to me almost self-evident when one considers the tremendous reduction in the cost of copper for the transmission, and the fact that the capacity of the rotaries in the substations must be several times that represented by the average demand, in order to take care of the much heavier starting current needed, and also to provide against breakdowns or an unusual congestion of trains. With my system, the rotary converter on each locomotive has a capacity adapted to the motors and need not have any such excessive margin.

On the other hand, each substation also involves real estate and buildings. Even under the very favorable conditions for substations in London, on account of the density of the traffic, the cost of the substation system as brought out by the arbitration proceedings in the recent Yerkes case, and based upon the figures given by the advocates of the substation system, was about $30 per kilowatt, for the rotary substations and $34 per kilowatt for conductors (*Engineering*, November 8, 1901).

With my system, the cost per kilowatt for the converters would be much less than $30 per kilowatt, and the cost of conductors would probably not exceed $10 per kilowatt. If a similar comparison were made upon the basis of trunk line freight service, instead of the heart of London, the cost of my system would not be materially affected per kilowatt, whereas the cost of the substation system would be enormously increased and in fact would become so large as to make any serious consideration of it almost absurd.

I do not admit that the series motor is cheaper per kilowatt than the separately excited motor of my system. On the contrary, I think that the separately excited motor when made in the same quantities, would be cheaper; because of the less amount of insulation needed, and the reduction of heat in the field windings, and other points of advantage leading to cheaper design and reduction of weight.

Bronxville, N. Y., Jan. 8, 1903.

Discussion at Chicago, Dec. 2, 1902.

Mr. R. H. Pierce:—In the past we have had a good deal of trouble in receiving the papers and getting them to the local members early enough to be read over before the evening of the meeting, so that the subjects have not been discussed as fully as they should have been. This year there has been a change in the policy of the Institute, as shown in the address of President Scott. The policy of the Institute now is to have a large number of papers on interesting subjects, to have the papers in hand as early as possible, and to have local organizations in each of the large cities. The idea is that the local members shall conduct their own local meetings as may seem best to them, and have meetings at regular intervals. It is also the policy of the Institute at present to have these meetings attended by anyone interested in the papers to be discussed, whether members or not, and to have anyone who is interested enough to come to the meeting, take part in the discussion should he so desire.

We have practically decided among ourselves that in order that we may be sure of having these papers, it will be well to hold our meetings about ten days or two weeks after the New York meeting, and in this way be prepared for the discussion.

The paper on an "Electrically Operated Coal Hoist, having Variable Speed Control," by Mr. P. O. Keilholtz, was then read by Mr. Peter Junkersfeld, of the Chicago Edison Company, who added:

"The particular electrically operated coal hoist, described by

Mr. Keilholtz, if it is not the one at the new power station of the Manhattan Railway Co., in New York City, is at least very similar. A satisfactory coal hoist is of course a particularly important part of such a station and a slight difference in first cost would by no means be the determining factor.

In this tall tower, something like 186 feet high, carrying clamshell buckets handling 70 tons per hour, quick handling and smooth acceleration are of vital importance. As I remember the Manhattan station, this is the only drive requiring 550 volts, and it appeared to me somewhat peculiar as to just why they selected 550 volts instead of 250, which is the voltage used on some of their other auxiliaries.

On the whole, I think Mr. Keilholtz shows very nicely one very good application of that system of control."

Other papers presented at the New York meeting, November 21st, were read as follows:

"A Series-Parallel System of Speed Control," by Mr. Geo. W. Fowler, was read by Mr. H. R. King, of the Western Electric Company.

"The Operation of Machine Shops by Individual Electric Motors," by Mr. R. T. E. Lozier, was read by Mr. Geo. B. Foster, of the Bullock Electric Manufacturing Company.

"Three Wire System for Variable Speed Motor Work," by Mr. N. W. Storer, was read by Mr. J. J. Gibson, of the Westinghouse Electric and Manufacturing Company.

"The Storage Battery as a Factor in Speed Control," by Mr. H. B. Coho, was read by Mr. O. E. Osthoff, of the Electric Storage Battery Company.

Mr. Osthoff added:

"I do not believe the arrangement shown in Fig. 1, (see page 136) is at all practicable.

As a substitute for this method might be suggested the employment of about 23 cells in a group; and four groups, say, 92 cells in all, which could be connected in multiple series. On the first notch all the cells would be in multiple; on the second notch there would be two groups in series and two in multiple, and on the third notch they would all be in series; on the last notch the cells could be cut off and the motor thrown across the supply mains. While the motor was taking current from the supply mains, the battery could be charged at a slow rate separately. In this way all the cells would be discharged equally.

Another advantage in favor of this scheme is the fact that when the greatest current is required, all the cells are in multiple, so that the battery is in the best position to give the high current. As far as the point B is concerned with this plan, the battery cannot be on charge at all times when current is flowing on the mains, but I do not believe it would make very much difference in the cost of this current. In the plan suggested here, the battery would get a continual supply of current, but by the other scheme the current would only be put into the battery when the controller is on the last notch. This method of control is exemplified daily in the use of the automobile, as far as grouping the cells in multiple-series is concerned.

In the last paragraph on the third page he speaks of a substitute for storage batteries in the way of counter-electromotive-force cells, and ends by saying " the cutting down of supply voltage by counter-electromotive-force is the natural method dictated by economic consideration, while to cut it down by resistance is unnatural." It is not quite clear to me what he means by one being the natural method and the other the unnatural, because the amount of energy wasted is exactly the same in the two cases, so the only advantage which the electromotive-force cells would have would be the fact that the voltage you would subtract from the mains would be the same, regardless of the amount of current flowing.

MR. PIERCE:—The system proposed by Mr. Leonard is one which gives any variation of speed control that is desired, simply by turning the handle of a field rheostat. Mr. Leonard first proposed it as a system for operating street cars. The main applications of this system have been made in connection with large stationary motors. This system has proved particularly advantageous where it is desirable to operate very large motors, and run them at speeds varying from nothing to full load, as in mining work, for operating large pumps and hoists; also for electric cranes.

At the time when the alternating current first came into use for transmission in connection with railway work, Mr. Leonard suggested the additional improvement on his system of using an alternating current motor to drive his direct current generator. With this arrangement, it is possible to transmit, with an alternating current, a very high voltage and at the same time, to use low voltage direct current motors for doing the actual traction work. In the paper read this evening, Mr. Leonard shows the additional advantage of this arrangement as a " multiple unit system." It will, of course, be apparent that if you can vary the voltage upon one armature, you can vary it on any number of armatures at the same time, and therefore give them all the same speed. I believe Mr. Leonard's paper is worthy of great consideration, as it calls attention to the lines along which we may look for development in electric railroading.

The very men who have done the most in developing the present polyphase systems, have expressed the belief that we shall eventually come to some single-phase system. The single-phase system is the simplest of all systems, and there is a tendency in electricity, as in every art, towards simplicity in apparatus and elimination of everything that is complicated.

At first glance, Mr. Leonard's devices may seem complicated, but his system is certainly able to do away with what we are now using, which is extremely complicated and not very efficient—that is, the use of rotary-transformer substations, which call for enormous investments in copper and machinery, and large losses in power, besides cost of attendance. It was stated by Mr. Leonard in the New York discussion, that his system was to be put into use abroad in the near future. While I am not prepared to discuss the relative efficiency and cost of his system, as compared with those now in use, it seems apparent to me that it reduces the cost of both the generating and transmission plants to a minimum, and that it will materially increase the distance over which it is commercially practical to operate long-distance railroads. The apparatus on the car will certainly pull heavier loads, and at the same time give a quick acceleration and absolute control over the motion of the train.

PROF. D. C. JACKSON:—I did not know that a meeting was to be held here to-night, nor the subject to be discussed, until this afternoon, so that I have little to say. The presentation of these papers shows how far the commercial application of variable speed motors has taken possession of the minds of the electrical manufacturers, and how far it is soon to take possession of the minds of the users of electrical machinery and machine tools. This is something that a few have foreseen as a coming necessity for perhaps six or eight years. As a witness of this, I will say that I read papers before the Western Society of Engineers and the American Society of Mechanical Engineers a number of years ago. I have never read a paper on variable speed motors before the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS, as this has appeared to me to be rather a matter for discussion before and amongst the users of machine tools and electric motors, than by the manufacturers of the motors.

The reason, I think, that variable speed electric motors have not been more fully adopted by the users of machine tools and other machinery, is the delay on the part of the electrical people in the development of motors with reasonably satisfactory speed control, which could be put on the market at a price at which the ordinary user could afford to purchase them. This delay has been partially due to the fact that the electrical people have been so busy that they have not been willing to undertake any special equipments, which involve so many difficulties.

MR. B. J. ARNOLD:—There were two or three points not brought out in Mr. Lozier's paper.

The author lays considerable stress upon the increased efficiency in operation of the multi-voltage system, all of which is undoubtedly true, but that is simply an increased efficiency in the consumption of power. He failed to mention the fact that that system or any other system which requires a large number of individual motors, or a larger size of motors than would ordinarily be used for constant speed, must necessarily cost considerably more, and the interest on the increased investment more than offsets the saving in power. I did not notice that that point was touched upon in the paper. I do not make that as an argument against Mr. Lozier's particular system, but against individual-motor systems in general, namely: that if you put a large number of individual motors into a plant, the cost per horse-power of work done runs up so high, due to the interest on the increased investment, that it more than offsets the power economy.

If my understanding is correct, that paper, as well as the others, advocates individual motors on tools, as against the grouping of a number of small tools on a piece of shafting, driven by a motor. The grouping of motors not only increases the investment greatly, as just stated, but also loses the advantage in electrical efficiency, which is gained by putting a few tools on a short piece of shafting, due to the fact that the average load of several machines is less than their maximum load. In my own experience, in every case where we have had to deal with railroad shops, when it came to buying the motors, we have finally figured on the principle of grouping the machines for all small tools.

MR. PIERCE:—In this paper I notice Mr. Lozier compares the efficiency of the individual motors with that of the grouping and claims that it is very much more efficient to use the individual motors.

MR. ARNOLD:—He disregards the fact that the first cost is so much more when a large number of individual motors is used.

MR. PIERCE:—I do not see how he can be correct, unless he figures that they are all operated with a steady load. Your experience has been, has it not, that, taking the motors as they are ordinarily run, the efficiency of the system of individual motors would be less than with the grouping.

MR. ARNOLD:—Yes, as a general principle, because these larger sizes of individual motors are running very much at underload; and then the point I tried to make, was the fact that the first cost of these individual motors and the interest on that cost, is very much greater. The theory is a very beautiful one, and we all at first start out to put it into practice, but we generally land the other way. It is a case of the other man paying the bill. We would land sooner if we paid it. I do not want my remarks to be understood as referring to any particular system; simply the general principle of machine-shop work which has guided me in purchasing for machine-shop work, electric apparatus for railway work.

MR. GEORGE B. FOSTER:—I am very glad Mr. Arnold brought out the point of the first cost in connection with the saving effect. The saving in the full, as Mr. Arnold states, may not warrant the additional first cost, but while this point should not be overlooked, it is not the great advantage to be offered for the system. Machine tools equipped with individual motors show an increased output over the mechanically driven tools of form 25 to 100 per cent. This fact alone would warrant the installation of individual motors on such tools.

The result of a test on a disk 30 or 40 inches in diameter appeared in one of the trade papers recently. This disk was first turned in a belt-driven lathe, with cone pulleys for speed changes. The time required to do the work was 60 minutes. A duplicate disk was turned by the same type of tool, except that it was driven by a variable speed motor, and the time required to do the work was 32 minutes, showing an increase in the output of a tool of this character and this class of work, of almost 100 per cent.

MR. ARNOLD:—I will admit there is a good deal in that, but whether it offsets the other or not, I am not prepared to say. I presume it does.

MR. FOSTER:—There is a large concern in the West which recently equipped new shops with machine tools driven by variable speed motors. Some of these tools in the new shop are identical with some of the tools in the old shop, except that they are electrically driven, and the work they handle is of exactly the same nature. One of the engineers reported to me that these tools were showing an average increased output over the old shop of considerably more than 25 per cent.

MR. ARNOLD:—That answer is perfectly satisfactory to me, and I have no doubt it figured out more than the increased fixed charges on the motors. It is a question of machine shop economy; a question of how much work you get out of the tool. One point I failed to make is that I would not use this tool-grouping plan for large tools. I would put individual motors on large tools always. It is only for small tools that we should group the motors on a short piece of shafting. I would put individual motors on the larger tools, such as heavy mills, planers, large lathes, etc., and all such tools as are moved around the shop to the work.

MR. ERNEST GONZENBACH:—I have just been through the experience of the equipment of individual motors for the repair shop of an interurban railway, and it may be of interest to some of the gentlemen here for me to quote figures from memory.

On obtaining prices for individual motors, I found that the cost of the motors for driving tools, worth $6.500, would amount to nearly $4,000, and that the total horse-power capacity of the motors would have to be about 35 h.p. if individual motors were used, while by grouping the tools (two groups were finally decided upon), we were able to drive the whole outfit with two 5-h.p. motors. Of course this is not such a case as Mr. Foster refers to, but simply a case of a repair shop where a few tools would be in use at one time, and the point which Mr. Foster makes in regard to manufacturing has practically no bearing on this case.

I would like also to refer to the question of substation maintenance. I think anyone who has been connected with polyphase railways has been against that practice. It has been my fortune to be connected successively with three railways operating polyphase substations, and in every case I found that the most serious difficulty was putting into the hands of comparatively inexperienced men the complicated equipment which is necessary in the rotary substation. It seems to be impossible to get men capable of running substations at ordinary wages. The man in charge of a substation has really more responsibility than the man at the power-house, as he has to rely entirely on his own wit in emergencies.

Another argument against substations is that in order to run a train service in any way similar to steam railroads, one has to be very careful to arrange the schedule so as not to have an undue proportion of trains or cars between any two substations, otherwise your unit in substations will require to be very large. For instance, with the Aurora, Elgin and Chicago Railway, there is a total capacity of 2,500 kw. in rotary converters, required to be operated from a generator of 1,500 kw. capacity, simply for the reason that it is possible that there are times when trains are more numerous on one part of the road than on another. With an express service in addition to local service, it becomes readily possible that trains might call for operating a total rotary capacity two or three times the generator capacity. With the avoidance of substations, or with an alternating current system, it becomes easier to put more of that load on the power station and divide the load among a larger number of static transformer stations. I think that is a point not usually brought out in discussions of this sort.

MR. V. R. LANSINGH:—I should like to ask Mr. Arnold if he can tell me the relative cost of repairs and maintenance on the group and individual-motor systems.

MR. ARNOLD:—I would not care to answer that question without I could give you an intelligent answer. I only know about the side of it which comes to me when we are endeavoring to decide a question as to whether the saving will warrant the increased investment. I have no figures which would be of any value. The cost of maintenance, however, in shops that I am somewhat familiar with, has not been excessive.

PROF. JACKSON:—In regard to the question of grouping which my friend Mr. Arnold and others have raised, this is largely a matter of engineering common sense. If one has to deal with large engine or locomotive shops, where are found enormous machine tools, each of which requires considerable power, there is no question but that individual motors with variable speed attachments give the best result, and the individual motors undoubtedly (as shown by experience in various shops) have increased the volume of output from 20 per cent. upwards. I know of one shop where the increased output was 40 per cent., brought about by the proper employment of electric motors. On the other hand, in a small shop intended for a variety of job work, and where different classes of tools are used, all being more or less of small size (the individual units of the plant being idle a considerable portion of the time), grouping is undoubtedly the right thing to use. It may be taken for granted that a great manufacturing establishment that has a reasonably uniform product—that is, a product of one kind (especially in the iron manufacturing line)—should ordinarily be greatly improved by electric drives with a great many individual motors applied to the individual tools and a large proportion of the motors of variable speed types. This statement is founded partially on a theorctical basis, but the theoretical basis has been completely borne out by the experience I am familiar with.

MR. PIERCE:—It seems to me that regardless of the question of economy in the use of variable speed motors, there is no doubt about their advantages. In most cases, the saving in power is a comparatively small matter. The cost of the fuel in an ordinary manufacturing establishment commonly amounts to only 3 to 5 per cent. of the cost of the product. Should the output be increased 20 per cent. or a great deal less than 20 per cent., the advantage would amount to more than the total saving in fuel.

The question before us this evening is the various *methods* of obtaining this variable speed control, and we would like to have as much discussion on that as possible. I will call upon Mr. Cutler, who, I believe, has had a very variable experience in that line.

MR. CUTLER:—I think I can speak on this subject from an unbiased standpoint; possibly more so than the people who have written these papers, for the resaon that about the first thing I noticed was that each and every one of them advocated the system promulgated by his own company, and we, of course, must expect to see the good points set out prominently, and the other points absolutely neglected.

I will take up the papers as they were presented, and endeavor to point out the other side of the question, which I presume is entirely in order from the standpoint of this association and what the discussion is intended for.

The first paper, I believe, advocated the Ward-Leonard system for the use of controlling apparatus for hoisting coal. Now, there are two difficulties in using this system for that purpose:

In the first place, it is very slow to act. The first thing desired is to get as much coal out of that vessel in a certain time as possible. It is not possible to alter the field strength of a generator in a few seconds of time. I think that is perfectly understood by motor manufacturers, and it is not necessary for me to point out the reason.

The second reason is that the system compels the use of a plain shunt-wound motor, which will not pick up the load as quickly as a plain series-wound motor. That question does not need any discussion.

It appears to me that the best system for operating large coal hoists is one similar to several that my company have in operation in which we use a plain series-wound motor with ordinary armature resistance, controlled by magnets, which eliminate al-sparking. These magnets are energized by means of an independent lever, retarded by a dash-pot, thereby obtaining, with proper adjustment, the maximum speed acceleration that it is possible to get out of a motor. We have several very large plants in operation on this principle.

The next paper was by Mr. Lozier, in which he advocates the multi-voltage system. Discussion has already taken place between Mr. Arnold and Mr. Foster, in which the fact was brought out that there was a great saving in the output, but this does not by any means prove that that increased output is due to the use of the multi-voltage system. There are plenty of other systems which can be used. On this subject I might say that it is absolutely necessary for me in my business, when any particular application of the motor is brought up, to have some system which I can freely recommend as appearing to me to be the best suited.

My idea of operating machine tools is to let the motor alone as far as possible and to learn our lessons from the automobile manufacturer, and use sliding gears, etc. This will give a motor which is not too large for the work and can be put in at the minimum cost and will give exactly the requirements which are necessary for the machine to do its work. There are several disadvantages with respect to the multi-voltage control, but the time is so limited I will not discuss them now.

Mr. Storer's paper relates more particularly to a method of obtaining a three-wire system from a single generator, and advocates variable speed by using the extreme limit of shunt field regulation. He has apparently gone to the extreme in that matter.

The next paper was by Mr. Geo. W. Fowler, advocating the use of what is known as the "C. & C. Series-Parallel" system. There are several methods of operating printing presses which have not been brought out at all. I am a firm believer in the double motor drive system, for the reason that this system gives the actual speeds required in practical work at good economy. There is no necessity in practical work of providing for an unlimited number of steps, from minimum to maximum speed.

The storage battery system of operating printing presses, I would look at with a good deal of mistrust, especially if we have to use storage batteries in multiple-series connection.

I think the whole question of motor control sifts right down to the "survival of the fittest," and selection of the proper system. As a rule, the consumer is overwhelmed with a number of salesmen, all talking their particular system, and he does not know what to use. There is simply one remedy—let him consult the engineer and we will all be benefited thereby, as well as the consumer.

While there is a good deal of room for improvement in motor control, I feel perfectly confident in stating that there are reliable systems for almost every practical application that comes up, that the consulting engineer is able or should be able to recommend to his customer, independent of any particular hobby which any particular manufacturer may have to recommend for his own private commercial reasons.

MR. PIERCE:—I would like to ask Mr. Cutler his veiws on the amount of speed regulation practical for shunt control. The Westinghouse representative says they can get 2 to 1 variation in speed, and the paper read by Mr. Foster states that 30 per cent. is all that is practical.

MR. CUTLER:—I stated that I did not advocate personally any material change, for the reason that it does not correspond with the requirement of the tool. That is, in the machine tool the torque must increase as the speed decreases, which you cannot get commercially out of a motor without using an abnormally large one, and I do not advocate any change in the speed of the motor greater than possibly the 20 per cent. variation, or 15 per cent. in the shunt field.

MR. FOSTER:—Would not the installation and operation of special gears be rather cumbersome?

MR. CUTLER:—No, it is practically practical to do that.

MR. FOSTER:—In my experience I found it was more expensive to adapt a special set of gears to a tool for acquiring a wide range of speed, than putting in larger motors, and after they were adapted, they could not be operated with the same facility as the motor with the controller.

MR. CUTLER:—I maintain that I do not think it is possible to supply a large motor as cheaply as you can use sliding gears.

MR. F. J. PEARSON:—As I understand this discussion, it was intended to cover more particularly the relative merits of the various systems of speed control outlined in the several papers presented this evening.

In this connection, I desired to ask if we can hear something in regard to the comparative first cost, as well as cost of operation of the multi-voltage system of control as compared with the variable field method, interest, depreciation and losses considered. Take a case requiring a certain horse power, with a 50 per cent. speed variation, would we be justified in using the multi-voltage system at a higher first cost and consequent higher interest charge, as well as depreciation, as against the employment of a larger motor frame with a single standard voltage and a 50 per cent. speed variation, by the variable field method.

I understand that the cost of the multi-voltage system is about 60 per cent. higher than the variable field control method for the same horse power, and with a ratio of speed control of two to one.

MR. FOSTER:—The case you cite is not an average case. Take the average machine shop with a 2 to 1 ratio, and it will not cover the average range of work to be handled. For the particular case you cite, I would not advoçate a multiple voltage system with a range of six voltages for only 50 per cent. variation in speed. Instead of the case which you cite, suppose you had a truncated cone to be turned, the smaller diameter 2 inches, the larger 30 inches. With the speed range of 2 to 1, this piece of work could not be handled with any degree of success. If, however, you had a 7½ to 1 range with a back gear, giving an actual variation of 15 to 1, with 52 different steps, you can readily see what a saving of time could be effected in doing this particular piece of work.

MR. PEARSON:—In using the expression 2 to 1, I was in error. I should have stated, a total speed variation of 50 per cent.

MR. FOSTER:—The three-wire system described by the representative of the Westinghouse company, is a modified multiple voltage system, having two steps. The number of wires installed and combination of voltages can be carried indefinitely, but as I stated before, if only 50 per cent. variation in speed were required, I do not think that a representative of the Bullock company would advocate a multiple voltage system having six different voltages.

MR. PEARSON:—The point I was trying to bring out was the relative cost of the two methods of control; that is, whether or not the saving in the multiple system would offset the interest on the investment on that eventually. If I understand it correctly, you would use on 5 h.p. outfit maximum, say 10 h.p. multi-voltage.

MR. FOSTER:—For 50 per cent. variation?

MR. PEARSON:—Yes.

MR. FOSTER:—Yes, we might.

MR. PEARSON:—My idea is that you would use a 20 h.p. motor for the same outfit on the variable speed control, same range of regulation.

MR. FOSTER:—The size of the motors for the three-wire system and the multiple voltage system for the same range in speed, would be the same. In the multiple voltage system, however, this range is carried to a total ratio of 7½ to 1, which would, of course, require a larger motor than the three-wire system, having only a range of 4 to 1.

MR. OSTHOFF:—The discussion would naturally be of those papers presented as to the choice of systems described. Personally, I am inclined to believe that variable speed can be obtained mechanically in most instances, but there do exist cases where an engineer might advocate a variable speed to be obtained in the motor. We offer our system as being the most competent to obtain that end. We claim that the efficiency in the motor is practically as good, the wiring less complicated and a less amount of copper needed, and that the losses outside the motor are less than in the multiple system.

MR. H. R. KING:—In the solution of variable speed problems, it appears that no one system of control can be used to the best advantage in all cases. A variation of speed from full load speed in steps of 10 per cent. to 10 per cent. of the full load speed, the load varying with the speed, is an entirely different proposition from one, the requirements of which are a constant load with a speed variation of only 25 per cent.

We have a means of speed variation of from 15 to 25 per cent. in standard commercial motors, by means of shunt field regulation, the amount of variation depending on the normal sparkless limit for which the motor is designed. This method of control takes care of a great many propositions where the speed variation is small, while the load on the motor is practically constant. It also has the advantage of using standard motors. Varying the speed by means of varying the field strength, may be carried still farther by using an accumulative compound-wound motor, the series winding being divided, and each section under the control of the operator. We can take this same combination of shunt and series control and place the armature across the varying voltage as is done in several of the systems described to-night. If this armature voltage control is not carried too far, standard motors may be used, providing we do not resort to the sectional series.

In addition to the above arrangements, which give the highest efficiency of operation, we car resort to the armature resistance control—a very inefficient method and one which should not be used except in extreme cases.

I regret very much that no paper has been read on the various mechanical control systems which are now on the market and which are destined to play quite an important part in future speed control problems. They are efficient and generally free from the complications of the electric control.

[Adjourned.]

A paper read at the 2d Meeting of the Cincinnati Branch American Institute of Electrical Engineers, February 9, 1903.

METHODS OF SPEED-CONTROL.

BY WILLIAM COOPER.

A consideration of the speed-control of shunt-wound direct current motors. Applications of this type of motor to the operation of machine-shop tools.

I have been requested to read a paper at this meeting on the subject of " Methods of Speed Control." As the field covered by this innocent little title in electrical business is so great and includes such a variety of apparatus in its ramifications, I was impressed with the impossibility of thoroughly covering the whole ground within the limits of such a paper, and have, therefore, concluded to confine my attention to very narrow limits, to the consideration of the speed-control of the shunt-wound direct current motor. Further than this, I will confine myself to the individual application of this particular type of motor to the operation of machine-shop tools.

I realize that I may encroach upon the territory covered by a number of papers read at a recent meeting of the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS, but I trust I may be able to throw some additional light on the subject. In the discussion that followed the papers read at this meeting of the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS, there appeared to be some misunderstanding.

There seems to have been a difference of opinion, which was largely, I think, to be accounted for by different comprehensions of the point in question, namely; the constant h.p. rating of the motor, as spoken of. I hope that I may be able to make myself plain on this point, so that there will be no misunderstanding of the fact.

Conditions to be Fulfilled.

The prime condition to be fulfilled in operating machine-shop tools is to keep the cutting-speed at the maximum at all times. This maximum speed is limited, of course, by the quality of the cutting tool, the kind of material being cut, and whether or not any extraneous means are employed to keep the tool from heating.

Nearly all ordinary machine-shop work may be classified under two heads; machining of cylindrical surfaces and of plain surfaces.

In considering the first class of operations, the piece being operated upon is usually rotated, and as a very small proportion of this work has but one diameter on each piece, there must, of necessity, be provided some way of changing the speed of rotation in order to keep the cutting-speed at the maximum. This condition is arrived at in ordinary machine shop practice on this class of work by using certain arrangements of change gears, and by belts on so-called cone-pulleys. While it is entirely possible to get a change in this manner of 10 per cent. per step, the complication resulting from the mass of gears and multiplication of steps on the cone-pulleys would not be permissible, to say nothing of the time lost in making the changes. As the result of years of practice, this system has developed into an arrangement where the changes are approximately 50 per cent. apart; that is to say, that each increment of increase would be 50 per cent., often being as much as 100 per cent. It is obvious that such an arrangement must be very wasteful of time where the diameter of the piece to be machined is slightly less than the nearest combination which would give the maximum cutting speed. The machine, therefore, must be run at slightly more than one-half or two-thirds of the maximum permissible cutting-speed, consuming, consequently, nearly 50 to 100 per cent. more time for a given operation than would otherwise be required.

Mr. F. O. Blackwell, in a paper read before the American Institute of Electrical Engineers, said, "The reduction effected by different sets of back-gears on machine-tools will be found to vary from 4 to 1 to 6 to 1. All tools can be arranged with 4 to 1 changes between back-gears without any difficulty. In many cases a single back-gear is sufficient for a tool. By putting a magnetic-clutch on this back-gear and making the electrical connections in the controller, it is possible to get a 6 to 1 variation electrically and without increasing the cost of the motor more than would be required for a 4 to 1 variation."

Mr. Chas. Day, in the discussion which followed the reading of

Mr. Blackwell's paper, said, " When attaching motors to old tools, such as lathes and drill presses, we must, as far as possible, adapt our speed range to the present gear ratios, in some cases by introducing additional gears, and in others without change to the machine. We have found that the gear ratios vary from 3 to 1 up to 15 to 1, depending on the size and character of the machine."

From the above we see that there is some difference in opinion as regards the range of the back-gears of ordinary machine-tools. As a matter of fact, the back-gear ratio of ordinary machine-tools varies from 3 to 1 up to 15 to 1, as stated by Mr. Day. There is also another fact which has not been touched upon and that is that the range of speeds given by the cones on a great many machine tools are not consistent with the ratio of the back gearing. That is to say, it is frequently found that the difference between the lowest speed with the back-gears out and the highest speed with the back-gears in is very much greater than the difference between two cone-speeds. Some machines have as much as 3 to 1 variation in speeds between these two conditions. The writer has in mind a case of a comparatively small sized boring-mill, made by a prominent manufacturer, in which the back-gear ratio was 12½ to 1. In this particular case the difference between the lowest speed with the back-gears out and the highest speed with the back-gears in was a great deal more than the difference in the cone-speeds. However, in this case, if we were to allow that the best possible arrangement had been made, the average difference between speeds throughout the entire range of the machine would be about 1.9 to 1, the machine being equipped with a four-step cone.

Subdivision of Speed Range.

It is obvious from above considerations that some arrangement must be introduced that will subdivide the speed changes to a greater extent. Many mechanical devices have been brought out for this purpose and some of them have come into quite extensive use; more particularly those where the gradation from one condition of speed to the next (as regulated by gears or driving belts) could be subdivided into any number of parts. While these devices fill the requirements of being able always to obtain the maximum cutting speed, the complication and cumbersomeness of the device is not desirable and has prevented its coming into general use.

A letter from Mr. E. H. Symington was read before the Central Railway Club, at their meeting at Buffalo, November 14th.

Mr. Symington, in speaking of electric-drive in general, very strongly recommended alternating current. In speaking of variable speed motors, he said: "With the advent of the perfected speed-changing devices, there is less necessity for having speed flexibility in the motor itself. However, where there are a quantity of traveling cranes and other variable speed apparatus, it is well to consider the advisability of a small direct current generating set for this purpose only."

Methods of Subdividing Speed Range.

We are still waiting for the advent of the perfected mechanical speed-changing device. However, we must admit that we can not, practically, get a speed variation from an electric motor that will cover the entire working range of the average machine-shop tool. There are some tools in which this can be done, for instance, planers, slotters and machines of this character where the cutting speed of the tool is in constant relation to the work, regardless of its dimensions, and speed variation is only required for differences in material.

However, in that great class of tools in which the piece being operated upon is of circular form and the rotative speed varies directly with the diameter, a very wide range of rotating speeds is required. In this class of machinery it is practically impossible to cover the entire range by varying the speed of the driving motor.

Speed-control is obtained in nearly every case by a combination of mechanical and electrical means, the motor range and gear ratios depending upon the machine and the average variation in diameters and kind of material handled.

Mr. Blackwell made the further statement in his paper that "With the three-wire system and a 100 per cent. variation in the motor-speed by field-control, we can obtain a 4 to 1 total variation which, for general machine-shop work, is sufficient to cover a single operation on a given tool."

Any system of variable speeds to be applicable and to cover the ordinary working conditions must be able to cover all possible speeds within the range of the tool and not be confined to a single operation, as would be necessary to come within Mr. Blackwell's limits.

Since it is impracticable to get the entire range of speeds on the class of machinery mentioned directly from the motor, a compromise must be effected. We have in any given case a certain total range to cover in any given machine. Let us take for example a 48-inch engine-lathe. Practice has shown that even with the best tool-steels at present obtainable, it is desirable and almost necessary to have a cutting speed as slow as 16 feet per minute. This, of course, determines one limit of the speed range, and is absolutely fixed, while the other limit of maximum speed at which the machine is to operate is not fixed, and is determined for each particular case by the probable minimum diameter to be machined. If two inches be assumed as the smallest diameter and a maximum cutting speed of 100 feet per minute, at this diameter the maximum revolutions will,therefore, be approximately 150 times the minimum. This, therefore, is the total range of speeds to be covered by the driving mechanism.

The question that next present itself, and the one that cannot be determined by any hard and fast rule, is what portion of this range will be covered by the variations of the speed of the motor, if a motor be used, or what other equivalent system will give equally good results. The case cited in regard to the boring-mill is almost exactly the same as the one under consideration. As stated, the builder solved the problem by using cone-pulleys and one set of gears. It must be admitted, however, that this solution was very crude. On the other hand, the question is: How many different speeds should be provided within this range and how will they be obtained. As stated, it is impracticable and well-nigh impossible to cover this range entirely by varying the speed of the driving motor.

The next step, consequently, is to use one set of back-gears. This will call for back-gears to be approximately 12½ to 1 ratio; therefore, the limit of speed variation on the motor will be 12½ to 1. The next combination available is to use two sets of back-gears, which shall have equal ratios and which shall gear into each other. In this case the variation of the motor speed will be as the cube-root of the total variation, or approximately as 5.5 to 1.

This same line of reasoning may be followed, duplicating the gearing indefinitely, until the variations in speed are entirely taken care of in the gearing. This brings us to the future perfected mechanical speed changing device, which has not yet made its advent.

Advantages of Subdividing Speed Range.

The question is often asked: "What advantages are to be derived from driving machine-shop tools independently by electric motors." The answer to this is, that the principal advantage is in the ability to obtain any number of different speeds on the tool, thereby being able to work up to the maximum output at all times.

Mr. L. R. Pomeroy, in a paper read before the Central Railway Club, in Buffalo, November 14th last, quoted a celebrated authority, without naming the authority, as follows: " Where we have to decide whether we shall install one large motor or a number of small ones, I would give preference to the small motors down to a limit of 5 h.p. for light machines and 10 h.p. for heavy machines; this for cases in which the problem is one of distribution only. Where the introduction of motors would have any effect on the product, I would dismiss entirely the question of power and decide solely with regard to the convenience of operation afforded, and would not hesitate to put in the very smallest motors, mounted upon any kind of machinery, notwithstanding their greater cost and lower efficiency, if they increase even to but a slight degree the product of the labor of the shop. Gains in this direction cause other gains to sink into insignificance."

Mr. Blackwell voiced the same sentiment, as follows: " The most important consideration in the electric driving of machine-tools is to make the control of the tool as convenient as possible and arrange the system so as to permit small changes in speed, and consequently be able always to drive the tool at its highest possible speed and greatest output."

Another question that usually follows is: " But the tools in this shop are not designed to stand the higher speeds that the modern tool-steels will permit, therefore, it is not possible to work them up to the maximum." A reply to this is, that if the machine will not stand the strains brought about the by high-cutting speed of the modern tool-steel, they still have their maximum; and there is just as good reason for working these tools to a maximum as any other tool to its maximum, although the maximum of these tools may be determined by a different factor.

We might state, however, that there is no reason why a machine-tool that is adapted to do a certain work, should not do this work at two or three times the speed. The reason for this seems obvious in the fact that the strains on a machine are due entirely to the torque required to make a given cut. With this given cut, the speed may be increased three or four times without producing any greater strains on the machine itself, because the torque remains constant. However, the h.p. will increase directly in proportion as the increase in speed; and right here we have a factor that limits the ordinary belted machine-tool—the belts will not pull the load. For instance, suppose that we have a given machine running with a belt on the largest step of the cone-pulley on the machine, and taking a certain cut; assume the cutting speed be 20 feet a minute. If it is desired to increase this cutting speed to, say, 80 feet per minute, it is found necessary to put the belt on the smallest step on the cone. We at once encounter the difficulty that the belt will not begin to pull the cut. This is also true of the various mechanical speed-changing devices that have been introduced. Thus it will be seen that machine-tools that were designed on the lines of the cutting speed of 20 feet per minute are not adapted at all to cutting speeds of 80 feet per minute. However, they are not limited by the strength of the tool, *but by the pulling power*. Under these conditions, it is only necessary to increase the pulling power of this machine to make it do four times the actual work that it formerly did. Here again is where the electric motor gets another big advantage.

Thus it is seen there are two good reasons (and there are many more) for equipping machine-shop tools with electric-drive, namely: first, the ability at all times to run the tool at its maximum cutting speed; secondly, ability to supply the necessary pulling power. Among the other numerous advantages in equipping machine-shop tools with electric drive might be mentioned the ability of placing machine in any position at will, making them as it were, portable machines; absence of belts from the shop, with their accompanying obstruction to light and accumulation of dirt.

Selection of Motors.

In equipping machine-shop tools with electric-drive, there are many points to be considered in the selection of suitable motors. The first consideration which directly affects the cost of installation, is the highest permissible speed at which the motor can be operated.

After determining this point, the next point is its lowest speed. Then we have the range through which the motor is to operate, and after determining this range, the next question is the determination of the method of obtaining this range of speed, if it is desired to get different speeds by varying the speed of the motor. When using the so-called variable-speed motor, there are two methods available which practice has shown to be good;

one by varying the field strength, the voltage on the armature remaining constant; the other by varying the voltage on the armature, the field strength remaining constant. The method which first presents itself is, varying the field strength of the motor. This is a very simple and effective way, but it is accompanied by the disadvantage of requiring a larger motor than the other method. For instance, if a speed range of 2 to 1 is required, and the motor is run from a source of constant potential, the motor would require to be twice as large as a motor giving the same range by varying the voltage on its armature. In other words, a motor that will give 1 h.p. at 2,000 r.p.m. maximum with a weakened field, and would also be capable of running 1,000 r.p.m. on a full field, would give 2 h.p. at 1,000 r.p.m. This motor would, of course, if designed to run at full field strength at 2,000 r.p.m., give 4 h.p.

In the second method—that of varying the voltage on the armature, the field remaining constant—the size of motor required for a given range can be compared as follows: Assume as above that a speed range of 2 to 1 is required and the speed will be varied by changing the voltage on the armature. One h.p. being required at all speeds as above and 1,000 r.p.m. being the minimum and 2,000 r.p.m. being the maximum, a motor that would give 1 h.p. at 1,000 r.p.m. on full field would give 2 h.p. at 2,000 r.p.m. with the same field strength, but with double the voltage on the armature. Thus it is seen that in one method the motor has minimum h.p. at its maximum speed while in the other, the motor has minimum h.p. at minimum speed.

Mr. L. R. Pomeroy in his paper before the Central Railway Club, spoke of interposing armature resistance in circuit with an electric motor for various speeds. He said in that connection: " While it is obviously not advisable to presume in using the full range of such speed variation continuously, yet in conjunction with step-cones and back-gears, any intermediate speed between the cones or gears can be exactly met by the introduction of very slight amount of resistance or electrical regulation, and under such conditions such variation is feasible and practicable. This represents the cheapest form of utilizing motor speed-variation from a standpoint of first cost. Next in point of cost is the use of a special type of motor, giving 100 per cent. field regulation. By this type of motor the varying requirements of almost any tool can be met at a slightly increased cost over constant-speed or standard motors. This, in the writer's judgment, is a rational method of meeting the case, as the range of speed is liberal, and its cost moderate. A motor of ordinary design will not permit of any considerable field weakening without deleterious sparking at the commutator, but with a special motor having small armature reaction, a variation in speed of 2 to 1 can readily be obtained; and when delivering a constant horse-power, the current will be approximately the same at all speeds, because the potential across the armature terminals is always the same. As the field current of a motor is only a small fraction of the total current, the efficiency of this method of control is practically the same at minimum and maximum speeds and allows the use of a much smaller controller and renders it possible to get a greater number of running speeds than can be economically arranged for with any other control."

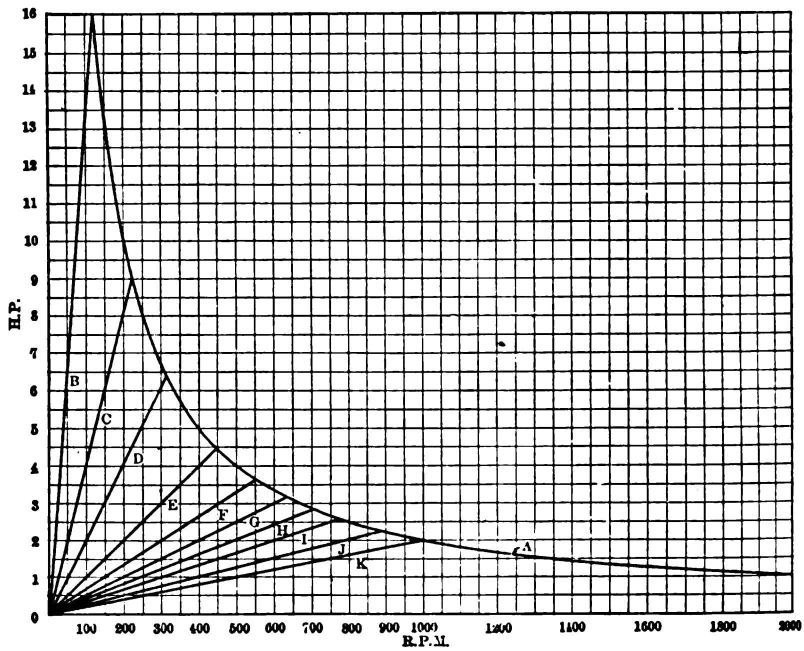
He says that a motor with 100 per cent. field regulation, giving a speed range of 2 to 1, costs but little more than a standard constant-speed motor to do the same work. As a matter of fact, this motor is four times as large as a constant-speed motor to do the same work at the maximum speed. Furthermore, this motor with 100 per cent. field regulation, if supplied with different voltages across its armature terminals, can be made to give another 100 per cent. speed variation by voltage regulation, thereby yielding a total speed variation of 4 to 1. Mr. Pomeroy says the speed variation of 2 to 1 is liberal, but if the same motor can be made to give, without additional cost, speed variation of 4 to 1, there would seem to be no reason why it should not be done and it would be more than liberal. This same conclusion was arrived at by Mr. Blackwell in his paper. He said:

" In conclusion, I would say that in my opinion it will generally be found best to use motors with field-control, allowing a total speed variation of 2 to 1 with the two-wire system, or 4 to 1 with the three-wire system, believing that the four-wire system is too expensive for general application if the plants employing it are properly designed and equipped with large enough electrical apparatus."

It is seen from the foregoing that there is a great desire to obtain as wide a range of speed variation in the motor as possible. What one person may consider sufficient in this respect, would be considered entirely insufficient by another. The speed range through which a motor is to be operated for any given case is governed by a number of different considerations. The additional cost of the motor for increased range of speed variation will be offset by a saving in additional gearing and the ease of manipulation. The consideration of the last point is all important. The time spent in juggling the gearing of any given machine will accumulate during the entire life of the machine, and means a constant expense which may, under some circumstances, be much greater than the interest on an investment by which it would be eliminated in considering the difference in size and cost of motors to perform different functions.

Determination of Minimum Size Motor.

If it is desired to have a motor that will give a speed variation



No. 1. Horse Power Curve Multiple Voltage and Field Regulation.

of 4 to 1 by shunt-field resistance, instead of 2 to 1 as in the former case, the motor would be four times as large (instead of twice as large as in that case) as a variable voltage motor to do the same work. Thus, it is seen that the limitation of shunt-field control is soon reached. However, a combination of shunt-field control and multi-voltage circuits gives an arrangement by which a comparatively wide range of speeds can be obtained without the motors being of excessive size. This may be readily understood by referring to curve sheet attached. Fig. 1. Curve

" A " represents change in h.p. of any motor when running on a weakened field. This might be called a diminution of h.p. curve. For instance, on the curve we see that a motor that will give 5 h.p. at 400 r.p.m. gives 1 h.p. at 2,000. From this curve we can determine the minimum size motor that will be required for any given case, using either shunt-field regulation entirely, or combining shunt field-regulation and multi-voltage, or multi-voltage entirely.

It might be stated that the very large class of machines which operate on cylindrical work, barring a slight change in friction load through the different speeds of the machine, the cutting speed remaining constant, the h.p. remains constant. Suppose for instance that a given machine tool requires 1 h.p. to operate it under all varying conditions of service, and it is required to have a speed range of 4 to 1, we can get this in three ways: one by using entire field regulation, which will require a motor 4 h.p. at 500 r.p.m. with normal field strength, Fig. 1, or a motor can be used, if two voltages, one of which is double the other voltage, are available, this motor will be required to be 2 h.p. at 1,000 r.p.m., at normal field strength, or one-fourth as large as the motor giving this range by field control entirely, or this motor can be run at 2,000 r.p.m. by increasing the voltage. The h.p. of this motor, due to reduction in speed, by reduction in voltage, will decrease along line " K," Fig. 1, so that at 500 r.p.m. it will give 1 h.p. and also give 1 h.p. at 2,000 r.p.m. by weakening its field, following line " A," Fig. 1. It is seen from the curve that with two voltages, one of which is double the other, in combination with weakening the field, that the range of speed of 4 to 1 is the maximum that can be obtained from a motor which will be worked to its full capacity at both the minimum and maximum speeds.

If any greater range than this is required under these conditions, a larger motor must be used. For instance, suppose that a speed range of 5 to 1 is required, and the variation obtainable by changing voltage is only 2 to 1. Assume as before that the maximum speed is 2,000 r.p.m., the minimum speed will be 400 r.p.m. Now as 400 and 800 will be the speed variation by change in voltages, these voltages being in the ratio of 2 to 1 (say 110 to 220 volts), a motor will be required that will develop 2½ h.p. at 800 r.p.m. on full field, or in other words, where the curve " A " crosses the ordinate of 800 r.p.m., Fig. 1. The h.p. of this motor will decrease as all other motors, directly in proportion to its speed by reduction in voltage, will therefore be 1¼ h.p. at 400 r.p.m., follow line " E," Fig. 1, being, in this case, slightly in excess of the power required at the slowest speed. The motor, however, in this case would be equivalent of a 3.1 h.p. at 1,000 r.p.m., as found by continuing line " E " to 1,000 r.p.m., or more than 50 per cent. larger than a motor to do the same work with a speed range of 4 to 1.

Mr. N. W. Storer in a paper read before the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS, in New York, November 21st last, in defense of the system as outlined above, said:

" The operation of motors on this system is most satisfactory. The fact that the speed is increased so much by weakening the field might lead some to think that the commutation would suffer, but such need not be the case. An example will demonstrate the truth of this statement. A certain machine requires a 5 h.p. motor to operate it with a speed variation of 1 to 4, say from 375 to 1500 r.p.m. On the three-wire system this motor will be a standard 10 h.p. 220 volt motor, operating normally at a speed of 750 r.p.m. Run with full field strength on the 110 volt circuit, which has only half its normal voltage, the motor will easily stand an increase of speed of 60 per cent. to 75 per cent., bringing the speed up to 600 or 650 r.p.m. When it is changed to the 220 volt circuit, it will have its normal capacity for 10 h.p. at 750 r.p.m.; but only half load is required and it will commutate this as easily at a speed of 1500 as it would 10 h.p. at 750, because both field strength and armature current will be divided by two. From this it may be seen that when the motor is running at full armature current, the voltage is only one-half the normal voltage. When the motor is operating at full voltage, the armature current is only one-half the normal current. If speed variations of 1 to 6 are required, they can be secured by a very slight increase in the normal field strength of the motor."

The last sentence of this quotation from Mr. Storer's paper, would lead one to believe that there was but a slight difference between a motor that would give a speed range of 6 to 1 and a motor that would give a speed range of 4 to 1. As a matter of fact, the motor that would give a speed variation of 6 to 1 on the three-wire system, as outlined by Mr. Storer, would be 2¼ times as large as the motor to give 4 to 1 on the same three-wire system. This is very easily deduced from the curve shown. However, if a different ratio of voltages were available to operate the motor upon, a motor that would give a 6 to 1 variation would be only

50 per cent. larger than a motor to give a range of 4 to 1.

Assume that a speed range of 10 to 1 is required, with, as before, 1 h.p. at all speeds, the motor which would fulfill the conditions of being worked to its full capacity at the minimum and the maximum speeds would be the motor whose h.p. would be represented by the line " G," Fig. 1. This motor would have as maximum rating 3.2 h.p. at 640 r.p.m., or a range of speeds by voltages of 3.2 to 1, so that the range of voltages must bear this ratio. A motor that will give this speed variation by shunt field regulation entirely would be 10 h.p. at 200 r.p.m. This motor would give 32 h.p. at 640 r.p.m., if designed to run with full field strength at this speed, or would be ten times as large as a motor giving the same range, operating on a combined system of multi-voltage circuits and shunt field regulation. Thus it would seem that shunt field regulation is prohibitive for any such speed range as 10 to 1.

In explanation of the curve, it might be said that the lettered lines representing the change of h.p. due to change in speed, are not strictly according to change in voltage, but change in revolutions per minute, but they vary so little from this that no great error will be introduced in using these lines to represent the range of voltages as well. The curve " A " representing the decrease in h.p. due to change in speed by shunt field regulation is strictly correct.

In further explanation of the use of the curve attached, in any given instance if the speed range has been determined, as well as the maximum and minimum speeds, the full field voltage or normal rating of the motor can be ascertained from the curve as follows: Locate on the curve " A " the point corresponding to the maximum speed which it is desired to operate. Trace to the left from this point on the scale of ordinates and read the h.p.

This h.p. may not be the actual h.p. in any given case, but it can be assumed as proportional to the actual h.p. required.

Again trace from the minimum speed, which is desired to operate, vertically until the horizontal line which represents the same h.p. that was determined from the curve " A " is reached. Through this point draw a straight line from the origin " O," intersecting the curve " A." From the point of intersection trace downward to the base line and the full voltage full field speed of the motor will be found.

Now, to get the minimum speed we must use some other method than field control, because the field is already up to its maximum strength, and we therefore introduce a lower voltage. The ratio that this lower voltage bears to the normal voltage is the same as that which the lower speed bears to the normal speed. By this combination of multi-voltages and field control we are able to get the minimum size motor for the given work.

To illustrate, let us assume that it is desired to operate the motors at a minimum speed of 350 r.p.m., a maximum of 2,100 r.p.m., as has been suggested for some installations.

We have a rating of approximately 1 h.p. from the curve " A." Tracing vertically from 350 r.p.m. to the line which correspond to 1 h.p., and drawing a straight line from the origin " O," through this point until it intersects with the curve " A," we find that the full voltage full field speed of the motor should be 825 r.p.m., I Fig. 1.

The ratio between 350 and 825 is $2\frac{3}{10}$ approximately. This would, therefore, be the ratio of the voltages (maximum and minimum) to be used. If the maximum voltage is 250 volts, the minimum voltage would be 110. The motor would run at 350 at full field on 110, and run at 825 on full field at 250; and 2,100 on weakened field at 250 volts.

However, assume that it is desired to get this same speed range, the ratio of voltages being 2 to 1 instead of $2\frac{3}{10}$ to 1, as in the previous case. As the minimum speed will be given by the lowest voltage, the highest voltage will of course give twice that speed, or 700 r.p.m. From the curve " A " it is at once seen that the smallest motor that can be used to give 1 h.p. at 2,100 r.p.m. will give $2\frac{8}{10}$ h.p. at 700 r.p.m. This is a point which is found by tracing vertically from base line at 700 r.p.m. to the curve " A," Following the line " H," Fig. 1, towards the origin, until we come to the point that corresponds with 350 r.p.m., we see that this motor will give 1.4 h.p. at 350 r.p.m., or is in excess of the power required at this speed.

In comparing the size of the motors required to do given work, one at full voltage full field speed of 700 r.p.m., the other at full voltage full field speed of 825 r.p.m., one would give 3.3 h.p. at 825 r.p.m., as against 2.4 h.p. at 825 r.p.m. of the motor having the wider range of voltage.

It has developed that the multi-voltage system, consisting of four wires and three different voltages, having a total range of voltages of about 4 to 1, while fulfilling the conditions for which it was designed, is not being worked to its utmost capacity as regards speed range; the reason for this being mechanical limitations. That is to say, that where a range of 7½ to 1 is now obtained, one would be able as far as the motor is concerned electrically to get a range of 16 to 1. The reason for this is that the motor is not speeded up above its full field full voltage speed to as great an extent as it might be, and still develop the same power that it develops at its minimum speed.

As seen by the curve referred to, the available range of speed for constant h.p. on any given motor is as the square of the ratio of the voltages on which it is operated. That is to say, if a speed range of 9 to 1 is desired, the voltages need have a ratio of only 3 to 1. From this it is at once observed that it is unnecessary to use a range of voltages of 4 to 1 for a speed range of 7½ to 1.

In referring to constant h.p. it is not to be understood that this h.p. is the maximum h.p. of the motor. It is the maximum h.p. however that the motor will yield at its minimum and maximum speeds. At all intermediate speeds it will have an excess power.

All of the limitations in regard to speed range for any given range of voltages, is based on using a motor of the smallest possible size to develop at its minimum and maximum speeds the power called for. This applies only to motors delivering practically a constant h.p. at all speeds.

Motors for Slotters, Planers, etc.

Great care should be exercised in selecting motors for different machines to determine whether the h.p. required is practically constant, or varies with the speed. In most machines of a reciprocating nature, slotters, shapers, planers, etc., the power required varies with the speed, as the power is consumed in the machine in reversal and not in the actual work being done. In cases of this kind the motors should be specified to run on full field, full voltage at the maximum speed required, getting speed variation by the use of the multi-voltage circuits and shunt field resistance for intermediate speeds. That is, no resistance is to be used in the shunt field of the motor, when the motor is operating on full voltage.

Some trouble has been encountered in getting speed variation on the class of machinery in which the h.p. varies with the speed by using shunt field resistance. This will be entirely overcome by the arrangement proposed.

In some installations, the speed range as well as the number of different speeds is very much less than has been gotten with the four-wire system of multi-voltage. Where a range of 7½ to 1, with 26 different speeds has been obtained by the four-wire multi-voltage system, the range has been 5 to 1, with six and eight speeds on other systems. It is evident that such a reduction in speed range and in the number of speeds must naturally reduce the cost of an equipment, at the same time very materially reducing its efficiency.

In the case of a speed range of 4 to 1, considering a maximum speed of 1450 or 1500 r.p.m., as in the previous case, the minimum speed instead of being 200 would be 360 to 375 r.p.m., and as the minimum speed determines the size of the motor for a given h.p., the motor should be just that much smaller.

Mr. Blackwell, in his paper, said: "It is therefore seen that a motor to be used on the multi-voltage system will have to be sufficiently large to carry its maximum h.p. at the minimum potential; or, in other words, at say 40 volts on a 250-volt system, the motor will have to be six times too large when working at its maximum potential."

This is, of course, strictly true, and applies equally as well to speed regulation obtained by shunt field resistance, only in a very much magnified degree. While a motor will be six times too large when operating at six times its speed, the speed being increased by an increase in voltage in order to get the same range by shunt field regulation, the motor would require to be 36 times the size it would be if only operating at the one maximum speed. This in itself is sufficient proof of superiority of the system of getting variable speeds by variable voltages over the system of shunt field regulation exclusively.

From this, it follows that a motor whose speed is to be varied by change in voltage, field excitation remaining constant, will be directly proportional in size to the change in speed, while a motor whose speed is to be varied by change of field excitation, will be in size as the square of the change in speed.

Rules for Determining Size of Motors.

In conclusion, the writer would indicate a few rules to be used in determining relative sizes of motors for constant h.p. application.

First.—The total range of speed, using both variable voltage and field regulation, will be as the square of the range of voltages.

Second.—Change of h.p. will be directly proportional to change of voltage on armature, field being constant.

Third.—Change of h.p. by change of field strength will be inversely proportional to change in speed, voltage on armature remaining constant.

Fourth.—The relative size of motor as referred to the maximum speed will be directly proportional to its speed variation when using variable voltages.

Fifth.—The relative size of motor as referred to the maximum speed will be as the square of the speed variation when using field regulation.

A paper read at the 171st Meeting of the American Institute of Electrical Engineers New York, December 19th, 1902.

BRAKING AND TRACTION BRAKES.

INTRODUCTION BY PRESIDENT SCOTT.

In considering the engineering problems connected with the operation of cars or trains, our minds naturally turn to the positive features. The motive power and the means provided for controlling it while starting or running cars or trains are the matters which at first attract attention. The negative problems, however, are of importance and become of greater moment as weights and speeds increase.

I well remember as a boy the difficulties encountered by passenger trains in stopping at stations. The brakemen were called to the platforms by the engine whistle, but frequently the trains were considerably past the station platforms before they stopped. It was then necessary to back to the station. I remember also learning from a friendly engineer that the engineers of his road insisted that their pay should be increased for the added duties which were to be placed upon them when they would be called upon to do the work of the brakemen through the agency of the air brake.

Difficult braking problems are now being encountered in electric traction. Weights have increased tenfold and speeds on our streets have increased three or fourfold, thereby increasing the stored energy in the car one hundred times, and the old hand brake of the horse car is inadequate. Interurban railways with their still heavier cars and far greater speeds make the problem of braking quite similar to that in steam railway service.

In electric service on elevated and underground city railways, where stops are frequent and high schedule speeds are essential, certain new elements have entered into the braking problem.

Ordinarily, brakes are for the purpose of facilitating traffic and preventing accident. The new feature of commercial value which has come into the problem is that of quick retardation. The run from one station to the next consists in acceleration, running at a sensibly constant maximum speed, and retardation. To increase schedule speed, it is important to lessen the time of retardation as well as that of acceleration. This is a new demand. It presents a new point of view in braking problems which have not previously been of importance in regular service.

This is illustrated by the marked difference which may be made in the schedule speed under average conditions such as prevail on the elevated railways of Greater New York, by changing from a low rate of braking to quick retardation. A change in the rate of retardation from one mile per hour per second to three miles per hour per second, all other conditions remaining exactly the same, increases the schedule speed about 10 per cent. This effects a saving in time to the passengers of 10 per cent., and it reduces the number of trains required for carrying a given number of passengers by 10 per cent.; or what is more important, the same cars may carry 10 per cent. more passengers.

We may divide the brakes in ordinary use into two classes; hand brakes and power brakes. The latter may be again subdivided into air brakes and electric brakes. When the air brake is used on electric cars, electricity is an acceptable auxiliary through the agency of the motor-driven pump.

Electric brakes are of several general types. The motor itself may act as a brake in either of several ways. The motor may be reversed. This is a severe measure which is seldom applied except in an emergency. The motor may be used as a dynamo for absorbing the energy or motion of the car. The power delivered by the motor (or dynamo) may be employed usefully by being returned to the line, in charging a storage battery on the car, or by heating rheostats which are used for heating the car, or on the other hand, it may be wasted in rheostats under the car.

Again, the current from the motor may be used for operating some form of magnetic brake. In this case the car is retarded both by the energy taken by the motor acting as a dynamo and also by the friction produced in the magnetic brake. The brake in this case may consist of two discs one stationary and the other mounted on the car axle, or it may be a track brake in which there is friction between moving shoes and the track rail.

Magnetic brakes may be operated independently of the motors by current obtained from the line or from a storage battery.

These methods indicate various ways in which electricity may be used for braking and make obvious the extreme flexibility of electricity in its application to problems of this kind. The application of the braking effect in proper amount at the proper time and with a reliable method of control, places very exacting requirements upon the designer of braking appliances.

The importance of the braking problem makes it a fitting and appropriate subject for consideration by this INSTITUTE. We may congratulate ourselves upon having to-night two papers, one of which presents the results of tests upon an important city railway, while the other sets forth the general problem of braking in a comprehensive manner and presents the subject in a way which will be of great value to those who have to deal with the design and equipment of braking apparatus and to those who are called upon to determine the requirements and to select the apparatus for particular installations.

A paper read at the 171st meeting of the American Institute of Electrical Engineers, New York, December 19, 1902.

SOME BRAKE-TESTS AND DEDUCTIONS THEREFROM.

BY J. D. KEILEY.

A description of a method of making brake-tests, and of a recording apparatus used in this method; also results from tests on a number of varieties of brakes and an empirical equation showing the operation of these brakes under different conditions, the coefficients entering into the equations being derived from the tests. Illustrated.

On account of the widely varying conditions of electric railway operation, and of the fact that the design of equipment and track has been in a period of evolution from horse-car practice to a condition approximating heavy railroad practice, many branches of the art, especially the subject of braking, have not been developed in the same proportion to their possibilities as has the subject of train-braking with locomotive traction. It is apparent that the conditions of electric traction and the service requirements and constructions which have made desirable, and even necessary, great advances in the methods of braking, have also to some extent rendered these advances possible, and have given to investigators of the subject, as well as users of train- and car-brakes, a new interest and a broader field of activity.

On the braking of elevated and light interurban cars or trains, the aspect of the problem has, of course, been changed from the con ditions of locomotive traction—slow acceleration to comparatively low maximum speeds, and the braking of light cars with maximum passenger load equal to 60 or 70 per cent. of weight of cars—to the conditions of electric traction with distributed motors. In the latter case the motors are carried on the passenger trucks, with armatures geared directly to axles; here we find rapid acceleration to high maximum speeds, and the braking of cars with maximum passenger loads equal to but 45 or 50 per cent. of the weight of cars. The rapid acceleration and high maximum speeds with very efficient braking make possible high schedule speeds under conditions of frequent stops. A concur-rent condition, in many instances of the first importance, is the relation between effective braking and liability to accident. Notwithstanding these changes in mechanical limitations and operating requirements, many small electric railroad companies, and even many very large systems, have apparently been satisfied with old apparatus and have continued to use the single floating lever (or sway bar) inherited from horse-car practice. Another class of users have, at great expense, equipped their cars with novel and complicated apparatus, to be used in developing greater force for the application of brake-shoes to wheels than could be produced with similar dispatch by human muscular effort when applied to brake-wheels or crank-handles. A third

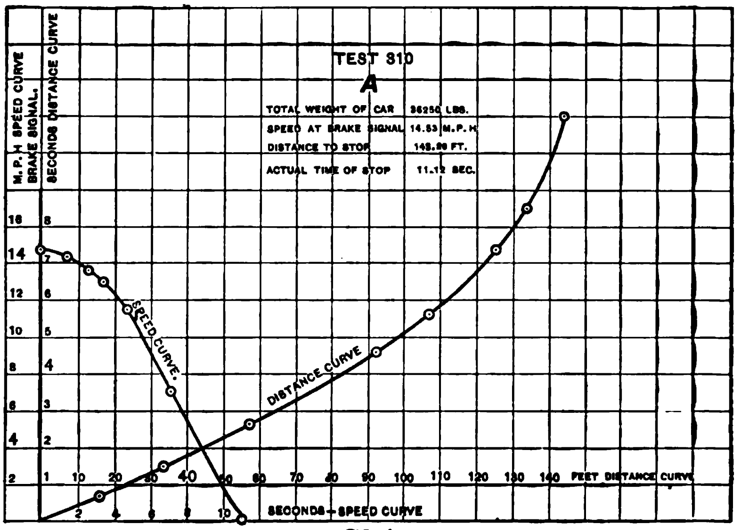


FIG. 1

class of users and a large class of investigators have endeavored to effect the retardation of cars by other means than friction between wheel and rail set up by the pressure of brake-shoes upon wheels.

A class of braking which is of the first importance on account of the very large number of cars in service, and the magnitude of the accident liability affected by them each year, is the emergency braking of cars of from 15 to 25 tons weight (including passenger load), from speeds which are under 30 miles per hour. This class of brake-service is clearly differentiated from what is commonly known as "high-speed" braking, and requires for its accomplishment a different sort of apparatus. Consider, for instance, the case of a double-truck electric car used in city, suburban or interurban runs, or for all three classes of service collectively. This is a very ordinary case, and perhaps the most exacting requirements on the braking apparatus of such a car are those met with in the city or suburban runs, where cars are operated over public highways and unprotected crossings at comparatively high speeds. Under these conditions, emergency stops must often be made and a braking apparatus is required of sufficient capacity to stop a car that is moving at a rate varying from 15 to 30 miles per hour, and in the shortest possible distance after the motorman receives notice of the necessity of checking the speed.

Such cars are frequently equipped with either merely a hand-brake and a single floating lever (giving anywhere from 25 per

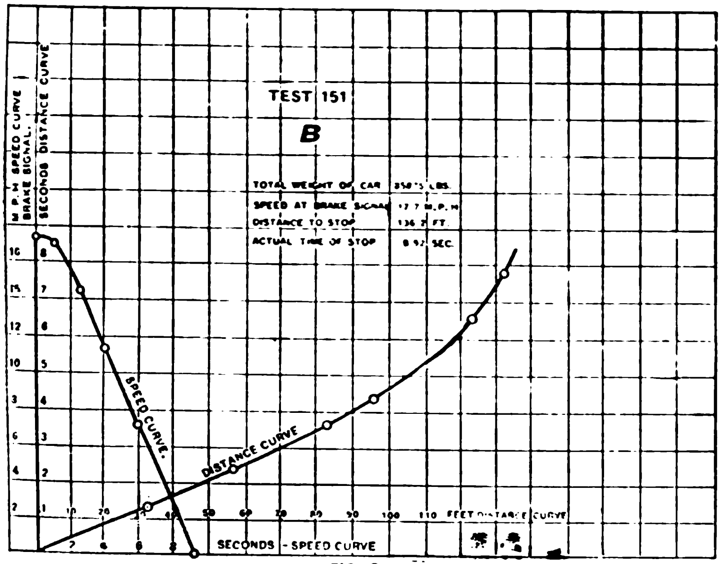


FIG. 2

cent. to 40 per cent. excess brake-pressure on the rear brake); with a hand-brake and some system of equalizing levers; with air, or other power-brake and equalizing levers; or with some power-brake in which, in addition to the friction introduced by a rail-shoe depending for its friction upon a portion of the weight of the car, there is an entirely separate frictional force set up by electromagnetic action between the rail-shoe and the rail. None of this apparatus, except, perhaps, the last mentioned, exhibits any marked advance over the braking of cars used in locomotive traction in city or suburban service.

No attempt will be made in this paper to give a comprehensive summary of the principles and theory of braking, distribution of

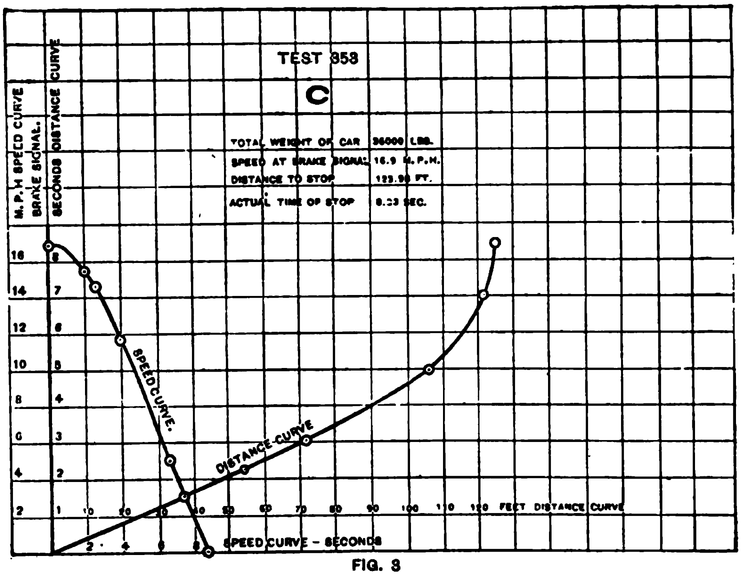

TEST 358
C
TOTAL WEIGHT OF CAR 36000 LBS.
SPEED AT BRAKE SIGNAL 16.9 M.P.H.
DISTANCE TO STOP
ACTUAL TIME OF STOP
M.P.H SPEED CURVE
BRAKE SIGNAL.
SECONDS DISTANCE CURVE
SPEED CURVE.
DISTANCE-CURVE
FEET DISTANCE CURVE
SPEED CURVE – SECONDS

FIG. 3

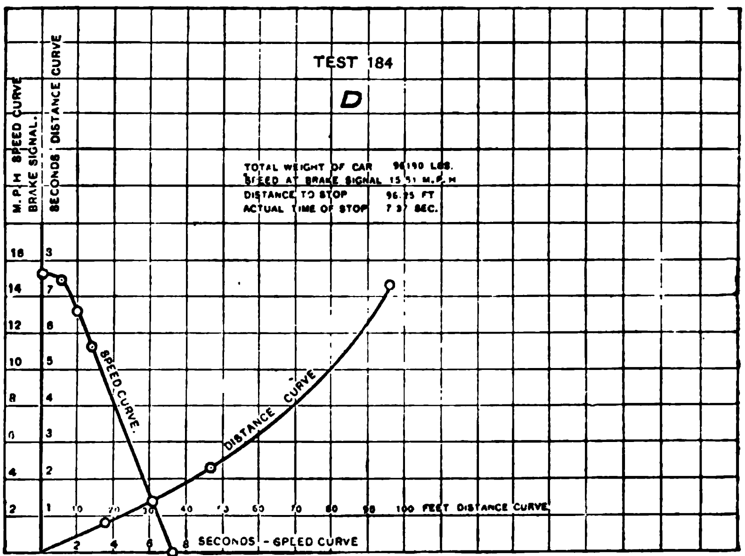

TEST 184
D
TOTAL WEIGHT OF CAR
SPEED AT BRAKE SIGNAL
DISTANCE TO STOP
ACTUAL TIME OF STOP
M.P.H SPEED CURVE
BRAKE SIGNAL.
SECONDS DISTANCE CURVE
SPEED CURVE.
DISTANCE CURVE
FEET DISTANCE CURVE
SECONDS - SPEED CURVE

FIG. 4

pressure between trucks or wheels or the design and construction of foundation rigging, or truck rigging. It will contain a brief statement of certain methods which have been used in the determining for an electric traction company the relative merits of several types of power-brakes.

In desiginng new or investigating existing brake-apparatus, the identity and relative importance of the several consecutive events which occur in the stopping of a car under ordinary conditions should be fully considered. It was thought desirable in the brake tests described below to plot accurately a curve-sheet, such as is shown in Fig. 8, where the distances in which a car can be brought to a stop from different speeds at brake-signal, are shown

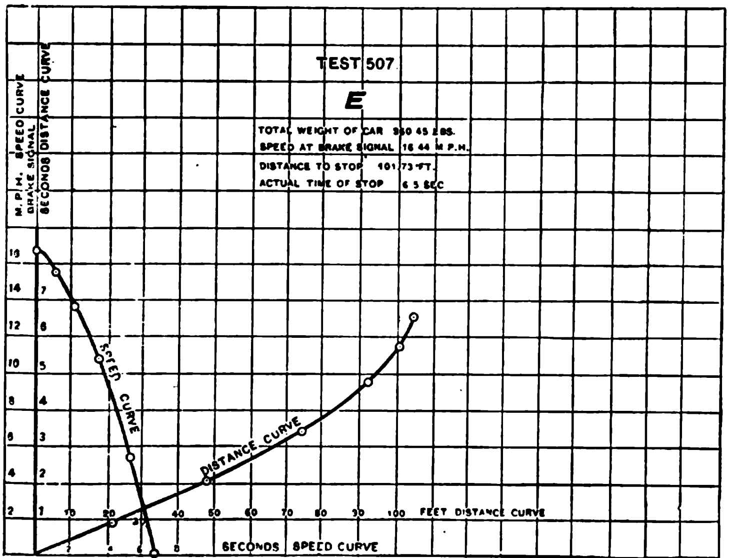


FIG. 5

graphically for the brakes under consideration, as this is the first question usually asked concerning the performance of a brake. A curve-sheet was worked up for each braking test, and specimens of these sheets for individual stops are shown in Figs. 1 to 6. A considerable number of individual sheets were worked up for each type of brake tested, and from these sheets were determined coefficients or equations of curves of comparison, as shown on chart, Fig. 8.

Figs. 1 to 6 are specimen speed—time and distance—time curves for emergency stops with six different types of brakes. Fig. 7 is a diagram showing the method of obtaining accurate measurements of the distance required for stops. Fig. 8 is a comparison chart showing stops from speeds of 12 to 18 m.p.h., with 6 different brakes. In Fig. 9 the recording apparatus used in these tests is illustrated, the means shown for producing a simultaneous record of current and voltage not being required for use in these brake-tests.

The following method was adopted to secure the requisite data for plotting these curves:

In all tests the same type of car was used, mounted on similar trucks, and all cars were put in as nearly the same condition as possible and loaded to the same gross weight by an amount equivalent to a heavy passenger load. The cars were run in the same direction over the same section of track on a uniform grade, wind

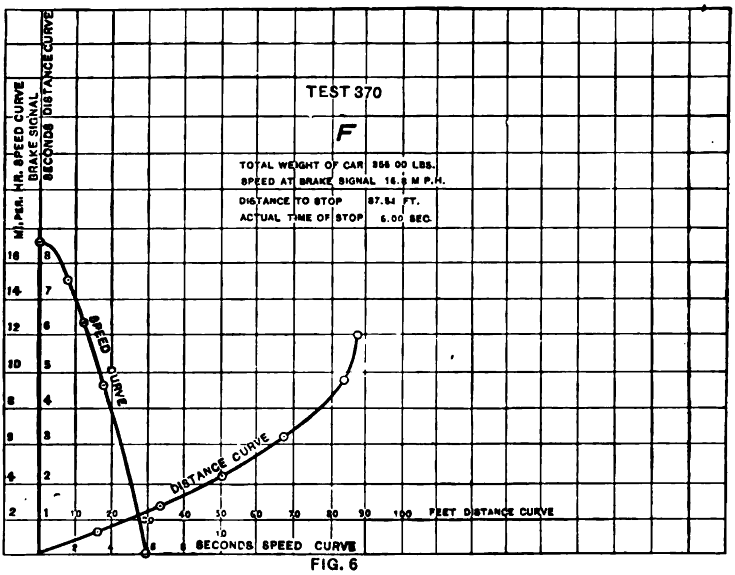


FIG. 6

and humidity conditions being as nearly uniform as possible, and great care was taken to determine with accuracy in each case the speed of the car at brake-signal and the actual distance traversed between brake-signal and the stopping of the car. An axle of the car was fitted with a drum carrying a contact plate which momentarily closed a battery circuit once in each revolution; this circuit energized an electromagnet operating one of two recording pencils, under which a strip of paper was drawn at uniform speed by a very accurately adjusted spring-motor. The operating magnet of the other pencil of the two above mentioned was energized by a circuit which was closed every half second by a contact maker actuated by a carefully adjusted clock-movement. It will be readily seen that with this apparatus a record-sheet could be obtained that would contain a clear record of wheel-revolutions; from this the number of revolutions during any interval or the duration of any particular wheel-revolution could be determined with great accuracy; the method of using this apparatus to obtain the data desired was as follows:

DIAGRAM SHOWING METHOD OF DETERMINING DISTANCE FROM BRAKE-SIGNAL TO STOP.

When the arrow mark on wheel is in contact with rail, the revolution-counter circuit is closed by contact on axle. Each run started with this mark in contact. At stop the point of contact between wheel and rail was marked on rail, and the car rolled on until the arrow mark on wheel again came in contact with rail, giving the final fractional part of a revolution to be used in getting the total length of run by wheel-revolutions, which was subtracted from the length of run by tape measurement to get the distance skidded.

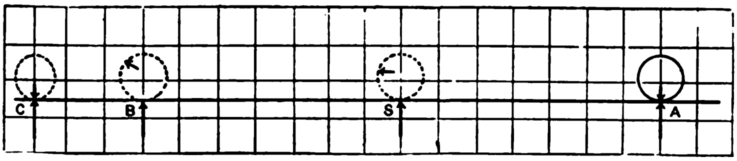


FIG. 7

A—Position of wheel at start.
B—Position of wheel at stop.
C—Position to which wheel was rolled to get last fractional part of a revolution.
S—Point at which brake-signal was given, determined by record of revolution-counter.
A B—Tape measurement; total distance run.
A S—Computed from Revolution-Recorder.
A B—A S = Distance to stop = S B.

The car was placed near the starting point and moved backward or forward until the contact on the axle drum was closed, then the point of contact between the wheel and rail was chalk-marked both on wheel and rail. Then the record-paper was put in motion, the car started and brought up to speed very gradually to avoid the possibility of slipping of the wheels. When the desired speed was attained, an electric bell was rung as a signal for a emergency stop. The circuit of this bell traversed the operating magnet of the chronograph pencil, and by drawing this pencil farther than it was ordinarily drawn by the clock circuit, produced a clearly defined record of the exact time at which the signal-bell was rung. When the car was brought to a full stop, the bell was rung again in order to make a record of the time elapsed between brake-signal and stop. The position of the point of contact of the front wheel was then carefully marked on the track and the car moved slowly along until the first chalk mark made on the wheel was brought again in contact with the rail, and the rail was marked at this point. A tape measurement was then made between the first and second marks, giving accurately the total length of run; and between the second and third marks, to determine the distance traversed in the final fractional part of a wheel-revolution. The distance from start to brake-signal determined by the wheel-revolution record on the chronograph-chart was calculated; this distance deducted from the total length of run (a tape measurement), gave an accurate measure

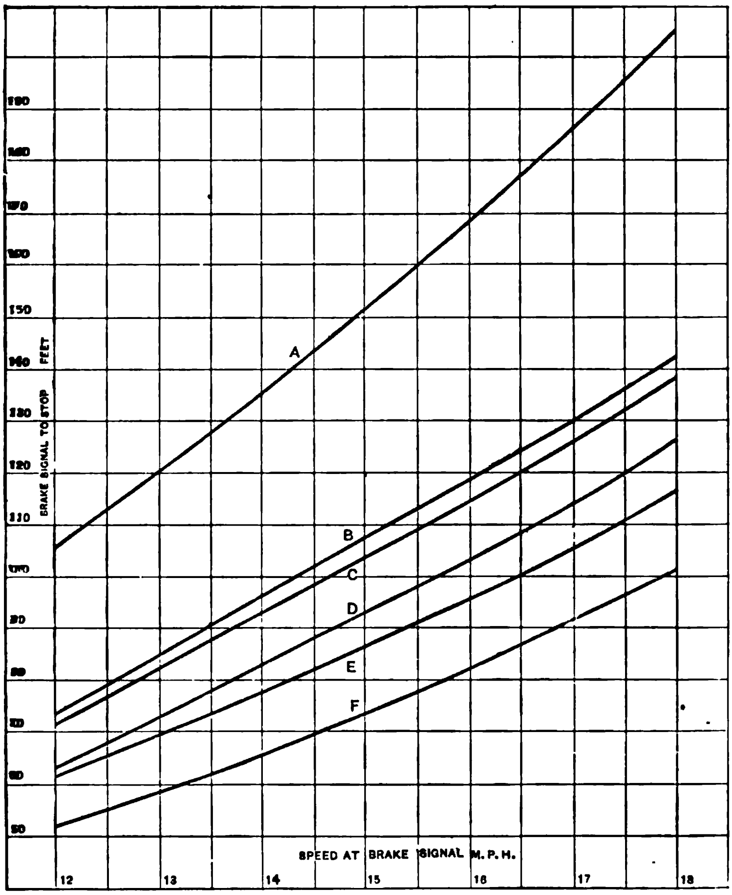


FIG. 8

of the distance from brake-signal to stop. Furthermore, where there was a difference between the total distance run by tape measurement and the total distance indicated by the wheel-revolution chart, such difference only occurred in case of skidding, then the difference was the measure of the distance skidded.

It should be noted that by the use of the methods outlined, the measurement of the two quantities whose accurate determination is essential to an accurate brake-test—namely, the speed at brake-signal and the distance to stop—are obtained with a high degree of accuracy and with apparatus which can be attached to any car in a few minutes. This apparatus is complete in itself, no stops, signals or other special appliances being required on the track or roadbed.

The time elapsing between brake-signal and stop, may for the present purpose of tests of emergency stops be divided into three parts:

1. Duration of time between brake-signal and beginning of movement of brake-handle or lever by motorman; that is, the personal equation of motorman.

2. Duration of time between beginning of movement of brake-handle or lever and setting of the brake-shoes.

3. Duration of time between the setting of the brake-shoes and stopping of the car.

The first interval of time above depends on the motorman, the second on the brake-mechanism, and the third on the amount of the frictional resistance which can be developed between the car and the rails, for a stop from a given speed. The first and second intervals of time are practically constant for a given motorman and brake-apparatus and independent of speed; the third interval will vary with the speed at brake-signal.

After being brought up to speed and allowed to run without power, the speed of cars on the test-track was found to fall off at the rate of about 0.16 miles per hour per second. Hence, for a given brake and motorman the distance run by car from time of brake-signal to time of full application of brake-shoe would be:

$$\left(S - \frac{0.16\,T}{2}\right)1.467\,T = d \text{ (distance in feet)}$$

where $S =$ speed at brake-signal in miles per hour,

$T =$ time from brake-signal to application of brake-shoes.

At the end of time T the car would have run a distance d and would have a speed of $(S - 0.16\,T)$ miles per hour, and from this point to the point of stop, the distance d' would be:

$$\frac{(S - 0.16\,T)\,1.467}{2} \times \frac{S - 0.16\,T}{R} = d'$$

or

$$(S - 0.16\,T)^2 \frac{1.467}{2\,R} = d'$$

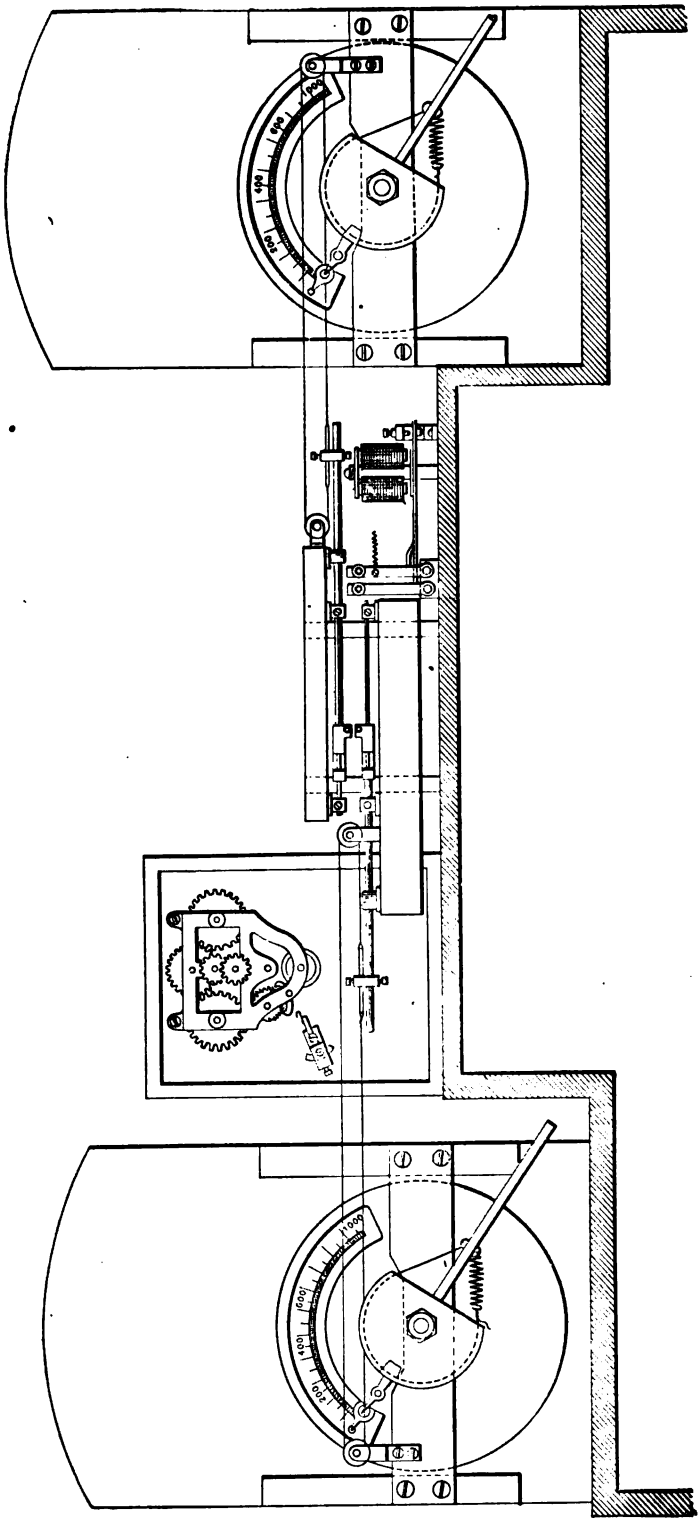


Fig. 9.

where R = rate of braking in miles per hour per second from setting of brake-shoes to stop.

The total distance being the sum of $d + d^1$, we may write

$$\left(S - \frac{0.16\ T}{2}\right) 1.467\ T + (S - 0.16\ T)^2 \frac{1.467}{2\ R} = D$$

where D = total distance from brake-signal to stop. Collating the coefficients of S and S^2, we get the following equation, showing the relation between D and S:

$$D = L\,S^2 + M\,S + N$$

$$\text{where } L = \frac{0.733}{R}$$

$$M = \left(1.467 - \frac{0.235}{R}\right)T$$

$$N = \left(\frac{0.0188}{R} - 0.117\right)T^2$$

L, M and N being practically constant for each equipment.

From test stops, with each brake, curves were plotted showing speed on a time-base from the brake signal to time of stop. From these curves may be obtained values for T and R, and from these the values of the coefficients of S^2 and S in the above equation may be computed. From this equation with D and S as variables, we may compute the values of D (distance) corresponding to several values of S (speed), and plot a curve showing for different speeds the distances run from brake-signal to stop for each of the equipments tested.

To get the time elapsed from brake-signal to stop from different speeds at brake-signal we have the following relations:

T = 1st and 2d parts of time above referred to.

$$\frac{S - 0.16\ T}{R} = \text{3d part}$$

Hence, the total time from brake-signal to stop from a given speed at brake-signal will be:

$$t = T + \frac{S - 0.16\ T}{R}$$

where t = time in seconds from brake-signal to stop.
T = time from brake-signal to setting of shoe.
S = speed at brake-signal.
R = rate of braking in miles per hour per second from setting of shoes to stop.

The coefficients of this equation for any equipment may be obtained as noted above from the speed-curves, and, these coefficients once determined, the values of t for several values of S may be computed; and from these values a curve may be plotted showing for different speeds at brake-signal the time from brake-signal to stop for each of the equipments tested. Distance- and time-curves have been plotted in this way for brakes A, B, C, D, E and F.

These charts show the relative efficiencies of the various brakes

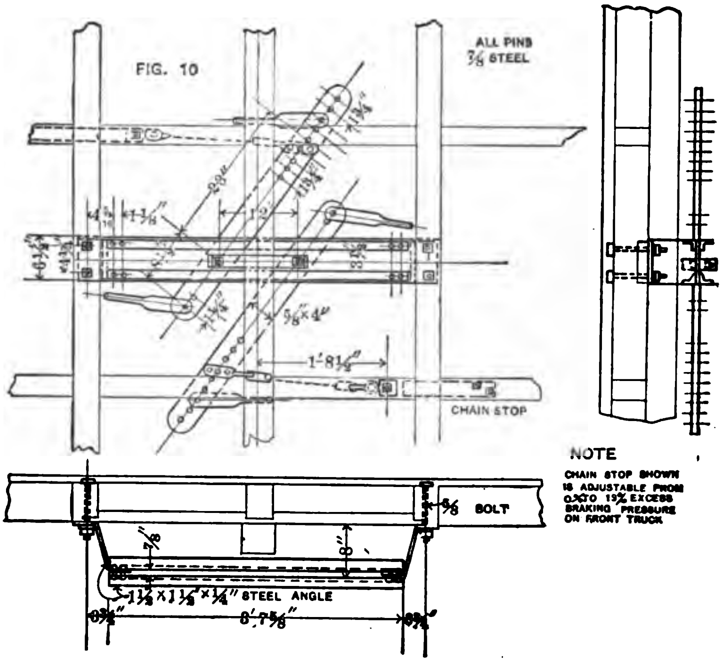


Fig. 10.

for emergency stops; for instance, at 15¾ miles per hour speed at brake-signal, the distance from brake-signal to stop are:

For Brake	A, hand-brake,	164 ft.
" "	B, power "	115 "
" "	C, " "	112 "
" "	D, " "	100 "
" "	E, power-brake B, with differential levers,	93 "
" "	F, power-brake,	80 "

These curves show plainly the relative efficiencies of the several brakes in making emergency stops.

To reduce the liability to accident and to effect economy in the use of motive power, it is desirable to secure as high a rate of braking as is consistent with the comfort of passengers; and if we assign a total cost per equipment per year to each type of brake considered, then the most desirable brake will be that for which this total is a minimum. The total cost per equipment per year should include the following items:

Cost of maintenance, labor and material.

Cost of power for operating brakes.

Interest on investment.

Cost of accidents per equipment per year.

The cost of maintenance and for power must be estimated from the best data at hand. As to the cost of accidents, a figure was readily obtained for hand-brakes. A figure was also obtained for brake D, for which the record of a number of equipments was accessible. From these amounts, chargeable to hand-brakes and brake D, the amounts which should be applied to the other brakes were estimated by a graphical method, taking into consideration the distances in which stops may be made with the respective brakes. Under the item of cost of power in the original comparison a charge was made against the hand-brake, which represents the amount of power necessary for operation with hand-brakes in excess of what would be required with a power-brake, due to the lower rate of braking with hand-brakes; as the same schedule speed can be maintained at a smaller expenditure of energy by using a more effective brake, the time of running with power being reduced and cars allowed to coast a greater distance.

Below is given an approximate comparison table for several power-brakes:

APPROXIMATE COMPARISON TABLE.

	A	B	C	D	E	F
Maintenance of power-brakes and extraordinary repairs, chargeable to brakes......		58.80	10.95	36.25		29.20
Power...............		29.20			25.00	
Interest.............		15.00	5.00	6.50	17.50	11.50
Accidents...........		58.00	53.00	37.00	30.00	15.00
		161.00	68.95	79.75	72.50	55.70

The totals above, which are, of course, only of approximate accuracy, show that under certain conditions a very considerable

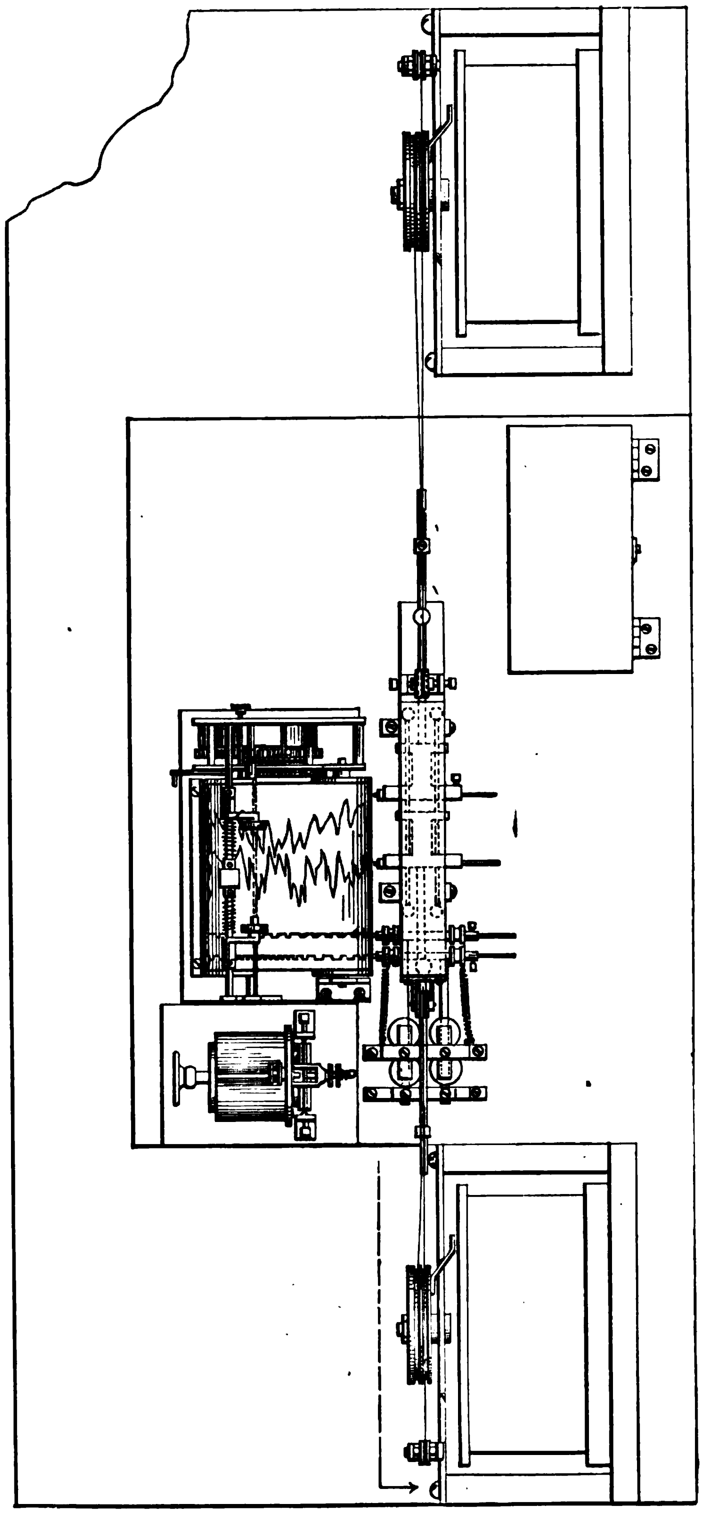


Fig. 11.

amount per annum may be saved by the judicious selection of brakes.

One practical result of the tests above described was the application by the writer of differential levers to hand-brakes; one form of construction of this type of foundation rigging being shown at Fig. 10. The levers as shown may be varied from 0 per cent. to 19 per cent. excess pressure on the front truck and may be adjusted to suit different types of car-bodies. Another result was the application of differential levers to one type of power-brake, the braking characteristic curves *B* and *E*, Fig. 8, showing that the distance required to stop a car with power-brake *B* has been reduced by approximately 18 per cent. by the use of non-equalizing levers, applying to the front truck a braking pressure exceeding that applied to the rear truck in a certain predetermined ratio.

A paper read at the 171st Meeting of the American Institute of Electrical Engineers, New York Dec. 19, 1902.

RAILROAD-CAR BRAKING.

BY R. A. PARKE.

A sketch of the practical development of brakes in railroad services: an analysis of the results of investigation of brake-shoe friction; a definition of the requirements and limitations of brake efficiency in practice; a consideration of the loss of braking efficiency through disturbance of the normal rail-pressures by brake retardation and a description of the means of compensating for it. The peculiar characteristics of the magnetic brake are also briefly described. Illustrated.

The braking problem is as old as railroading and, in the early conception of it, the problem appeared a simple one. Practical railroad ng had no sooner accomplished the motion of trains than the necessity for stopping them appeared, and it was early perceived that the " adhesion," as it was usually called, or the frictional resistance to sliding of the wheels upon the rails, through which the wheels continue to rotate in spite of considerable resistance, is the most available retarding force. The application of a brake to the wheel to excite the retarding influence of the rail friction has naturally suggested itself, and when, in addition, the simple mechanism was provided for manually applying the brake to the wheel with sufficient force, in an emergency, to cause the wheel to slide upon the rail, the braking problem appeared to have been satisfactorily solved. Under the operating conditions of railroading then existing, the application by hand of brakes to a portion of the wheels of a train was ordinarily sufficient for all practical purposes, and when, in an emergency, the brake resistance so acquired was sufficient to overcome the rail friction and cause the wheels to slide upon the rails, it was quite generally conceded that the most that could be expected had been accomplished and a disaster not averted by such means was accepted as one of the unfortunate but unavoidable contingencies of railroading. This early method of controlling the speed of trains has since been modified only by the substitution of mechanical for physical power in the application of the brakes, which has been extended to all the wheels, and by so restricting the pressure of the brake shoes that the wheels shall *not* be caused to slide upon the rails; but the diversified and intricate character of the influences now recognized as constituent elements in the efficiency of the power-brake, have involved the subject in much complication.

The advantage of the use of power, under the control of the engineer, for promptly applying brakes upon all the wheels of a train, early became recognized, and the special advantages of compressed air for the transmission of the power throughout trains of considerable length, established the air-brake in a pre-eminent position. At first, the compressed air was stored in a reservoir upon the locomotive and, by means of a line of iron pipe, extending throughout the length of the train, with flexible hose and couplings between vehicles and an operating valve upon the locomotive, it was conducted to the brake-cylinder upon each car, by which the brakes were applied to the wheels, through the intervention of suitable rods and levers. The time required to convey the necessary volume of compressed air from the storage reservoir upon the locomotive to all the brake-cylinders of even a comparatively short train, and the total disability resulting from rupture at any point of the air-conduit, caused this form of air-brake to be supplanted by the automatic air-brake, in which an auxiliary storage reservoir, of sufficient capacity to operate a single brake-cylinder, was added upon each car. Through the operation of a triple-valve device, which connects the train-pipe or air-conduit, the auxiliary reservoir and the brake-cylinder upon each car, admission of compressed air into the train-pipe causes each auxiliary reservoir to become charged to operate the brakes, and discharge of air from the train-pipe, from any cause, causes communication with the auxiliary reservoir to be transferred from the train-pipe to the brake-cylinder, whereby a corresponding quantity of compressed air is discharged from the auxiliary reservoir into the brake-cylinder. By defining the reduction of pressure of air in the train-pipe, the pressure of the brake-shoe upon the wheels may be graduated to any desired degree within the limit established by the ultimate equalization of air-pressure in the auxiliary reservoir and the brake-cylinder, and accidental rupture of the train-pipe instantly operates to stop the train and to prevent further progress without effective repair. In any case, restoration of the air-pressure in the train-pipe actuates the triple valve to re-establish access to the auxiliary reservoir, whereby it is recharged with air-pressure, and to transfer communication with the brake-cylinder from the auxiliary reservoir to the atmosphere, through which the brakes are released.

When the automatic air-brake became employed upon freight-trains, it was discovered that, in making a quick stop by venting the train-pipe at the locomotive, the interval of time required to cause an operative reduction of the air-pressure in the train-pipe at the rear end of the train was so considerable that effective application of the brakes upon the rear cars was delayed until sufficient retardation of the forward portion of the train had become effected to cause collision with the rear cars that damaged and often disabled the cars and did violence to the lading. To remove this obstacle, the automatic air-brake became superseded by the quick-action automatic air-brake, in which, when a quick stop is desired, each triple-valve opens a vent in the train-pipe, in addition to the vent upon the locomotive. By this means, an operative reduction of the air-pressure progresses throughout the train-pipe, of the longest trains, with nearly the velocity of sound, and damage from the serial character of the application of brakes by compressed air becomes practically eliminated. Incidentally, also, in the local venting of the train pipe air at each succeeding triple-valve, the utilization of this source of power, formerly wasted at the engineer's operating valve, was accomplished by conducting the vented air into the adjacent empty brake-cylinder, before it receives the ordinary supply provided by the auxiliary reservoir. Thereby, the ultimate air-pressure in the brake-cylinder is augmented about 20 per cent., and the character of the application of the brakes in disaster-threatening emergencies is further distinguished from that in ordinary service, where neither the violence nor the power of the emergency application is desirable or even tolerable.

While the character of the development of the compressed air brake has thus been chiefly dictated by conditions rendered conspicuous by increased length of trains, and would hardly have been suggested under the conditions to which electric railroad operation appears best adapted, the high operative efficiency and other advantages thereby acquired are participated in by short as well as long trains, and are therefore of interest in dealing with the question of braking in electric service. Where even only two cars are operated together as a train, the automatic feature of the air-brake is still essential, in precisely the same way, if not in the same degree, as in longer trains, and, except where cars are always operated singly, the same is true of the increased efficiency secured through the quick-action feature of the automatic brake.

The first systematic or comprehensive investigation of the effect of brakes upon the wheels of moving vehicles was that of an elaborate series of experiments, conducted upon the London, Brighton and South Coast Railway, in 1878, with apparatus constructed and operated by George Westinghouse, under the supervision of Capt. Douglas Galton, representing the Institution of Mechanical Engineers, and which are now commonly known as the " Westinghouse-Galton " brake-tests. The ingenuity and perfection of the apparatus, and the scientific and unbiased character of the experiments, establish this investigation upon a high scientific plane and give its results an authoritative standing which has never been impaired or supplanted by subsequent investigations. Had the range of these experiments been extended but a little farther, the entire subject would have been elucidated. In fact, while later experiments have demonstrated the importance of additional information, that information has not yet been definitely supplied, and the Westinghouse-Galton investigation still stands as the only reliable source of definite knowledge concerning the important characteristics of brake-shoe friction.

More recent investigations have been conducted upon a machine devised for experimenting upon the friction of brake-shoes, but their purpose has been to determine the relative commercial values of brake-shoes of different materials, rather than to supplement the information furnished by the Westinghouse-Galton tests. While such investigations have doubtless been useful in indicating the relative advantage of different materials for brake-shoes, and have perhaps satisfactorily determined, within limits, the degree of efficiency which may properly be required of brake-shoes, they have added to previous knowledge of brake-shoe friction only in suggesting certain general characteristics, without furnishing adequate data to extend our knowledge of the action of brakes in stopping a train.

The Westinghouse-Galton experiments were conducted in a moving four-wheeled car, provided with the necessary recording apparatus, the wheels being steel-tired and the brake-shoes of cast iron, and the results of the experiments may be summarized as follows: The coefficient of brake-shoe friction decreases with increased speeds and, at constant speed, it decreases with the increase of the time that the surfaces are in contact. The coefficient of friction does not appear to increase with increased pressure per square inch. When the wheels roll without sliding upon the rails, the rail-friction (or adhesion) is unaffected by the speed, but declines greatly with sliding of the wheels, when it varies inversely with the speed, corresponding with the brake-shoe friciton, but is much inferior thereto. The rail-friction is very materially affected by the condition of the rail, being greatest when the rail is perfectly dry or very wet (as when washed by a hard rain) and least when the rail is quite moist; but, by the use of sand upon the rails, the effect of moisture is practically eliminated.

The actual variation of the brake-shoe friction with increased speeds is very regular, beginning with the friction of rest (static friction) and declining, very rapidly at first, but with continually decreasing rapidity, up to the highest speeds of the experiments. The undoubted fact that the friction cannot vanish for any finite speed, considered in conjunction with the peculiar character of the decline, suggested to the writer that the results of the experiments might be properly represented by a portion of an equilateral hyperbola, and upon applying the theory of probability to the mean results, the coefficient of friction is found to be represented by the equation

$$f=\frac{.326}{1+.03532\,V}$$

in which V represents the speed in miles per hour. The following table shows both the computed coefficients of friction from this formula and the means of the observations, up to a speed of 100 miles an hour.

Speed V.	Coefficient of friction, f.		Speed V.	Coefficient of friction, f.	
	Computed.	Observed.		Computed.	Observed.
0	.326	.330	45	.126	.127
5	.277	.273	50	.118	.116
10	.241	.242	55	.111	.111
15	.218	.223	60	.105	.074
20	.191	.192	65	.099	
25	.173	.166	70	.094	
30	.158	.164	80	.085	
35	.146	.142	90	.078	
40	.135	.140	100	.072	

It is worthy of note that the mean observed result for a speed of 60 miles per hour differs materially from the result of a law that applies with remarkable fidelity to the observed results at other speeds. This is perhaps attributable to two causes: first, while each of the other results (except for the lowest three speeds) is the mean of from 54 to 90 experiments, that for 60 miles represents but twelve experiments—much the smallest number at any speed—of which, the maximum observed result was .123 and the minimum was .058. The other probable cause is that, it having been discovered that the coefficient of friction is less at high speeds, the pressure was much increased at the very high speeds to compensate, and it is now known that the coefficient of friction is an inverse function of the pressure. The mean result at 60 miles an hour does not, therefore, appear to be fairly comparable with those at other speeds, and it has been rejected in determining the constants in the above formula.

In the tabulated results of these experiments, Capt. Galton gives the maximum and minimum, as well as the mean value of the coefficient of friction observed for each speed. It is observable that the maximum values very well follow a similar law to that above given for the means, while the minimum values are too irregular to suggest more than a general inclination to decline as the speed is increased. As the maximum values correspond more nearly with the results of more recent experiments, the writer has also formulated them. The most probable law is represented by the equation

$$f=\frac{.382}{1+.02933\,V}$$

and the calculated and observed values are given in the following table:

Speed V.	Coefficient of friction, f.		Speed V.	Coefficient of friction, f	
	Calculated.	Observed.		Calculated.	Observed.
0	.382		45	.165	.179
5	.333	.340	50	.155	.153
10	.295	.281	55	.146	.136
15	.265	.280	60	.138	.123
20	.241	.240	65	.131	
25	.220	.205	70	.125	
30	.203	.196	80	.114	
35	.188	.197	90	.106	
40	.176	.194	100	.097	

The decrease of the coefficient of brake-shoe friction from continued contact apparently follows the same character of law as does that from increase of speed; that is, the fall is rapid at first, but the rate of fall quickly begins to decline. It was assumed by Capt. Galton that the decline of the friction is as the increase of the time of contact, but a careful analysis of the results shows that it is a function of the product of the speed and the time, or of the distance through which the shoe rubs upon the wheel. It is very unfortunate that the observed effect of continued rubbing does not extend over sufficient time to permit reliable formulation. The more recent experiments appear to show that, at the same speed, the friction becomes constant after a time, but it is probable that the coefficient of friction continues to yield to the influence of continued rubbing throughout stops from the highest speeds yet attained in practice. In formulating the incomplete data of Capt. Galton, therefore, the purpose is merely to present as comprehensive a view as possible of the complexity of the subject, and the results must not be accepted as trustworthy for practical use. Accepting the conclusion drawn from later experiments, that the coefficient of friction remains stationary after some definite period of continued rubbing at constant speeds, the question is still open as to whether the stationary point is the same for all speeds or is simply a function of the initial coefficient of friction, corresponding to the speed and brake-shoe pressure. While there is no definite information upon this point, beyond the limited observation of the Westinghouse-Galton experiments, that, so far as it goes, points to the latter view, and all our information suggests the probability that the ultimate level is different for each different initial coefficient of friction. The corresponding equilateral hyperbola is therefore represented by an equation of the form

$$f_1 = \frac{1 + h\,s}{1 + c\,s} f$$

where f is, as hitherto, the initial coefficient of friction, corresponding to the speed and pressure, s is the distance, in feet, through which the surface of the wheel has travelled in frictional contact with the brake-shoe, and h and c are constants. Applying the theory of the least squares to the observations of Capt. Galton (except those at a speed of 60 miles an hour, which are rejected for reasons already given), the values found for h and c cause the above expression to become

$$f_1 = \frac{1 + .000472\,s}{1 + .002390\,s} f$$

Thus the coefficient of friction, f, for a given speed, as indicated in the tables already submitted, becomes reduced, after the brakes have been applied through a distance of 50 feet, to .914 *f*; after 100 feet, to .845 *f*; after 200 feet, to .740 *f*; after 300 feet, to .665 *f*; after 500 feet, to .563 *f*; after 1000 feet to .434 *f*; after 2000 feet, to .336 *f*; and the ultimate level, which is not yet reached after two miles, is 472/2390 *f*, or about .2 *f*. The later experiments upon the efficiency of brake-shoes included some temperature tests, the results of which indicate that, under the conditions of those experiments, the stationary level is reached after from 2000 to 3000 feet, and there is good reason to believe that it is much higher than .2 *f*. Of the observations employed in determining the constants in the above expression, none was for a greater distance than 814 feet and the larger number were for short distances, which thus gave undue weight to the rapidly falling feature of the curve. In the absence of more extended observation, no practically useful mathematical application of this characteristic of brake-shoe friction can be realized. As it exerts a very important and effective influence upon the friction and the rate of retardation during every stop, the impossibility at present of determining the rate of retardation under varying conditions is obvious. Grade, for instance, not only affects the rate of retardation by directly modifying the effective retarding force, but also, in varying the distance in which a given reduction of speed occurs, it again indirectly affects the rate of retardation. It thus happens that experimental determinations of the rate of retardation are more misleading than useful under any other conditions than exactly those of the experiments. Experimental stops of the same train, made one right after another, from the same speed, at the same place, on the same track, differ very materially from obscure causes of this character, while the conditions apparently differ so little that they are looked upon as "practically" the same. The errors, accidents and other sins that occasionally result from the prevailing custom, in this practical, money-getting age, of founding conclusions upon premises that are "good enough for practical purposes," have no better illustration perhaps than in the matter of train stops, in which the enjoyment of confidence in one's conclusions generally varies inversely with accuracy of understanding of the subject.

In order to observe the effect of varied pressure in the Westinghouse-Galton experiments, a set of brake-shoes was made with projections cast upon their face, so that only about one-third the whole surface of the shoe came into contact with the wheels.

What actual pressure was then applied to the wheel is not recorded. From statements of Rennie, concerning the results of experiments upon the relation of pressure to static friction, it was expected that the coefficient of brake-shoe friction would be considerably increased by the increased pressure per square inch resulting from this modification of the brake shoes; but Capt. Galton says of these experiments simply that he is not prepared to say that any greater coefficient of friction was obtained, and that but a very small number of experiments were made with these special brake-shoes because the projections were entirely worn off in twelve applications, In view of the division of the rubbing surface into a considerable number of small surfaces with edges more or less sharp, it is doubtful if any reliable conclusions could have been drawn from pressure experiments in which the variation of the pressure per square inch is secured by such means. More recent experiments have shown very conclusively that, other conditions being the same, the coefficient of friction declines as the pressure increases and, while insufficient data has yet been presented to determine the character of the decline, there are substantial reasons for believing that it follows the same character of law as do the declines from increased speed and extended rubbing contact.

This view of the dependence of the coefficient of friction upon pressure, throws some light upon the considerable range of observed values recorded, at the various speeds, in the experiments to determine the influence of speed upon the coefficient of friction. In some cases, the brake-shoe pressure employed was more than three times the weight upon the rails, while at other times the pressure was but about one half that weight, so that the pressure varied from about 40 to about 250 pounds per square inch of brake-shoe surface. It is most significant, also, that in the cases cited in Capt. Galton's reports to illustrate special conditions, high pressures are accompanied by coefficients of friction that are about the minimum observed for the corresponding speeds, while the lowest pressures are accompanied by the maximum coefficients. As it is to be assumed, of course, that the coefficients of friction given in the tables for different speeds are those observed at the beginning of application only, it appears most probable that the quite uniformly large range of values for the different speeds is principally due to variation of pressure. Under such conditions, therefore, it can only be assumed that the table of mean coefficients of friction for different speeds is representative also of the mean brake-shoe pressure during the experiments, which is probably about 90 pounds per square inch, though it cannot be definitely determined from the data given in Capt. Galton's reports, while the table of maximum coefficients appears to represent a pressure of from 40 to 50 pounds per square inch, or a total pressure of about 2,000 pounds upon the standard brake-shoe in this country.

The coefficient of rail-friction was found to vary for dry rails from .19 to .35, and averaged about .25. Upon wet or greasy rails, without sand, it fell to as low as .15 in one experiment, but averaged .18. With sand upon wet rails, it never fell below .20 and rose in some cases as high as to .40, so that, with the use of sand, the rail-friction of a wet rail is at least equal to that of a dry rail without stand. When the brake-shoe friction overcame the rail-friction, and caused the wheels to slide upon the rails, the coefficient of rail-friction immediately began to decline and then varied inversely as the speed, in much the same way as brake-shoe friction, but is much inferior thereto. This may be readily explained by the greatly reduced area of contact and consequent high pressure per square inch between wheels and rails. It may also, of course, be due in some measure to inferior frictional qualities of the steel wheel upon steel rails, as compared with cast-iron brake-shoes upon steel wheels.

The maximum retardation which may be utilized in stopping railroad vehicles by the customary means of brakes is therefore that which is realized by so applying brake-shoes to the wheels that the resulting brake-shoe friction shall be uniform, and just insufficient to overcome the constant, static rail-friction. If sand be suitably provided whenever the condition of the rail requires it, the coefficient of rail-friction always available (unless perhaps in the case of railroads running in streets) is at least .20 and may doubtless be safely regarded, in at least all cases where emergency calls for the highest efficiency, as .25 of the pressure of the wheel upon the rail. A brake system of ideal efficiency in the time of necessity is thus one in which the brake-shoes are so applied to the wheels that a retarding rail friction equal to one-fourth the weight of the train is instantly realized and continuously maintained throughout the stop. In such a case, the retardation (ignoring the resistances of rolling friction and the atmosphere) is one-fourth the acceleration of gravity, or 8.04 feet per second. which amounts to reducing the speed at the rate of almost 5½ miles an hour per second. Stops would be made in a distance represented by .1338 V^2, where V is the initial speed in miles per hour, or in 482 feet at 60 miles an hour, 214 feet at 40 miles an hour and only 53½ feet at 20 miles an hour. The obstacles to the realization of a brake of such efficiency are apparent at once when the variable nature of the coefficient of brake-shoe friction is understood, and the difficulties which attend variation of the pressure of the brake-shoe upon the wheel to compensate for the fluctuation of the coefficient of friction through the simultaneous operation of such complex influences, appear insuperable. But the problem is not entirely hopeless and it is useful to consider what has been and what may yet be done to increase the efficiency of braking.

In the outset, while at first glance the coefficient of static rail-friction, which measures the maximum retardation, appears to be inflexibly established, such is not altogether the case. The inferiority of the coefficient of friction between the wheel and the rail to that of the brake shoe upon the wheel must be attributed chiefly to the very great difference in the areas of the surfaces in contact and the consequent difference in the pressure per unit area. The convenient doctrine of Morin, that the friction is independent of the area of the surfaces in contact, has been the cause of much misapprehension and of many errors of construction. Mr. P. H. Dudley has clearly demonstrated that broad-headed rails yield a materially greater tractive power to locomotives than narrow-headed ones, and it may be confidently assumed that any means of increasing the surface of contact between wheels and rails adds to the resistance which measures the maximum efficiency of the brakes. The theoretical *line* of contact between a wheel and a rail broadens out practically into a somewhat pear-shaped surface, which differs in form and extent with different materials and pressures. The head of the rail is locally depressed and the circular periphery of the wheel becomes flattened, resulting in a surface of contact, the extent of which depends upon the elasticity of the materials, the diameter of the wheel and the forms of the rail-head and wheel-tread. It is evident that a greater contact area occurs with a large than with a small diameter of wheel, and it is equally clear that greater elasticity of the material of either wheel or rail conduces to the same result. Steel is generally more elastic than chilled cast iron, and recent observation indicates a higher coefficient of rail friction with steel-tired wheels than with chilled iron. It is true that, while such a result should be expected because of a larger area of contact, it may also be that the frictional qualities of the materials in contact constitute a factor of some importance. It has generally been understood that the dynamic friction of cast-iron brake-shoes upon chilled cast-iron wheels, exceeds that of the same shoes upon steel-tired wheels. While this conclusion does not appear to have been actually established, yet, even if it be correct, it does not follow that the static friction of steel-tired wheels upon *steel rails* may not be greater than that of chilled cast-iron wheels. But, whatever the fact may be in this respect, it is reasonable to expect that the most effective *surface of rail-contact* occurs with large, steel-tired, straight-tread wheels upon broad rails, and, so far as our information yet extends, observation confirms this view sufficiently to warrant the statement that it is a matter of considerable importance.

The utilization of the retarding force available as rail-friction, by means of brakes, involves the application of a brake-shoe pressure which shall (*a*) diminish as declining speed causes the coefficient of friction to increase, which shall (*b*) increase as increased distance of frictional contact causes the coefficient of friction to decline, and which shall (*c*), when diminishing or increasing for such purposes, further diminish or increase as reduction or increase of pressure itself causes the coefficient of friction correspondingly to increase or decline. The combined effect of declining speed and increasing distance is far from being uniform in stops from different initial speeds. The friction apparently declines from continued rubbing in about the same proportion, through a given distance—the first 100 feet of the application, for illustration—whether the initial speed is high or low; but the elevation of the coefficient of friction by declining speed during such first 100 feet of application, is much less proportionally when the initial speed is high than when it is low. The two opposing influences are thus not uniformly effective. In stops from low speeds, the coefficient of friction increases, slowly at first and rapidly at the close, but continuously from beginning to end. At high speeds, the elevating influence is proportionately less effective at first, so that, for a time, the friction remains about stationary, or even declines at first before becoming stationary; but it always subsequently rises with an increasing rapidity that becomes so great as to be almost abrupt at its termination. It is therefore a characteristic of all stops that the coefficient of friction is comparatively low during the early portion and much higher toward the close; and, while manipulation of the pressure to compensate for the compound fluctuation of the coefficient of friction appears hopelessly complicated, a partial realization of the efficiency of such an ideal brake system may be accomplished by employing a comparatively high brake-shoe pressure during the early part of the stop and subsequently so reducing it that the high coefficient of friction near the end of the stop shall not cause the wheels to slide upon the rails. The provision of means by which this partial utilization of the advantage of compensating the pressure is practically realized constitutes the latest and highest progress thus far made in the practical development of the air-brake.

In accomplishing the purpose of applying an increased brake-shoe pressure during the early part of the stop, the quick-action automatic brake has been modified by the addition of an automatic pressure-reducing valve to each brake-cylinder, by the use of which a high air-pressure is utilized in the brake-cylinder in emergency applications of the brakes, and is gradually reduced to the level of that which, in earlier forms of the air-brake, is maintained continuously throughout the stop without sliding wheels at the close. That material progress in braking is marked by this step will be easily appreciated when it is understood that, with the use of this apparatus, called the " high-speed " brake, stops from the higher speeds are about 30 per cent. shorter than those attained by the quick-action brake. By the more prompt application of a greater brake-shoe pressure than immunity from injurious wheel sliding permitted in ordinary applications of the brakes, the " emergency stop " became clearly distinguished by the quick-action air-brake, and, in passenger train service, it was shortened to about 80 per cent. of the shortest stop of the older automatic air-brake. By the application of a greater brake-shoe pressure during the early period of stops, for utilizing a larger proportion of the retarding force realized at lower speeds, the high-speed brake shortens emergency stops from high speeds, to about 70 per cent. of those of the quick-action brake, or 56 per cent of those of the old automatic brake. The increased brake-shoe pressure is secured by the use of a high air-pressure, which, through the operation of the automatic reducing valve, is available only in emergency applications of the brakes, the moderate pressures of the old automatic brake being still preserved in ordinary operation to prevent possible injury of wheels. But the higher storage-pressure of the auxiliary-reservoir air is equivalent to a correspondingly increased volume of air stored at the pressure of ordinary service, and thus the high-speed brake also provides for repeated brake-applications without recharging the auxiliary reservoirs—an incidental advantage greatly increasing the security of trains under conditions of daily occurrence.

It is opportune to digress at this point to consider an application of the high-speed brake which concerns conditions to which electric railroad operation is peculiarly adapted. Hitherto, the ordinary stops of railroad trains have generally consisted of a preliminary reduction of speed at a long distance from the stopping point, to bring the train under full control, and then of a gradual reduction of the remaining speed, continuously or in stages, to suit the conditions or the operator's views, until the train comes to a standstill at the stopping point. The stops of express trains have been infrequent, and the speed of way trains has been moderate, so that, in both cases, the time occupied in the stop has not called for careful consideration. But with the rapid growth of suburban traffic in all large cities, particularly since the introduction of electric railroads, the changed operating conditions of suburban trains give great importance to the time consumed in the frequent stops. Both in steam and electric railroad traffic of this kind, large expenditures of thought and money have been made to secure high acceleration in starting trains, while almost nothing has been done to secure the equally important high retardation in stopping. Every start is accompanied by a stop, and if economy of time is important in one, it is equally important in the other. The neglect which efficiency of stopping has suffered is doubtless due to the fact that, while acceleration in starting has generally been limited to that which may be acquired from the rail-friction of a few wheels, the retardation resulting from brakes upon practically all the wheels is so effective in comparison that its inferiority to what it *might* be is overlooked. Moreover, the character of the train-stop of ordinary service has been so firmly established and avoidance of the use of the full power—the emergency application—of the brake has been insisted upon for such good reasons, that departure from the customary " service " application of the brakes does not readily suggest itself. But the conditions now under consideration are quite different. At low speeds, the violence of the emergency application is apt to result in discomfort to passengers, and the brake-shoe pressure is too near the wheel-sliding limit to be desirable. But at the high speeds attained between stations in efficient suburban service, the initial coefficient of brake-shoe friction is so low that no perceptible shock or disagreeable effect accompanies an emergency application of even the high-speed brake; and the coefficient of friction near the end of the stop is so much lower, through the effect of continued rubbing through so much longer distance than in a stop from the lower speeds, that the danger of wheel sliding is not troublesome.

There is also another important time-saving feature of the emergency application for service stops in train service of this character. In making an ordinary service application, the personal equation of the operator is an important element. The proper point at which to apply the brake, the force of initial application and each subsequent increase or reduction of the braking force (to prevent over-running or stopping short of the station) are matters of personal judgment in which men differ materially; the consequence of which is that, to be safe, the brakes are usually applied too early and time is lost in drifting into the station at low speed. In an emergency application, the personal element is largely eliminated, as the full application is practically instantaneous and, where definite speed may always be depended upon, the point at which the brakes should be applied may be designated by a signal post. Thus, full speed might be obtained over much the larger part of the distance traversed during an ordinary service stop, followed by a quick stop of the high-speed brake, and fully half the time occupied by the service stop would be saved.

Thus far, consideration of means for approaching the theoretically possible retarding force has been confined to those for overcoming the obstacles due to the complicated variation of the coefficient of brake-shoe friction. This is a subject which, while of manifest interest and importance to those who operate railroads, chiefly concerns those who supply the motor mechanism for applying the pressure of the brake shoes upon the wheels. The distribution of pressure upon the rails, through the wheels, which defines the maximum rail friction itself, and the construction of running gear and brake-beam supports to permit the utilization of the rail-friction for retardation, constitute a branch of the subject which ought seriously to concern those who construct the running gear and apply the motive power, but which is almost invariably subordinated to every other consideration and is usually overlooked entirely. It is a strange fact that, although the brake occupies the uppermost position of importance among railroad safety appliances, the actual work of stopping trains when disaster impends, depending entirely upon it—and almost as much depending upon it as upon the motive power apparatus for high efficiency in local and suburban train operation—every effort is apparently concentrated upon attaining the maximum acceleration in starting trains and the almost equally important matter of high retardation in stopping is so far neglected that efficient foundation brake-gear is not only usually not provided but often prohibited, and especially where electricity is the motive power. It is obvious that the force with which the brake-shoes should be applied to a pair of wheels depends primarily upon the pressure of those wheels upon the rails. In car construction, the weight is usually, but not always, equally distributed upon the various wheels. In electric car construction, it frequently occurs that the motors are so applied that greater weight is supported by one pair of wheels than by another. In any case where the wheel pressure materially differs, proper regard for brake-efficiency demands that the brake-shoe pressure shall correspondingly differ. But, entirely independent of the normal distribution of weight upon the various wheels of a vehicle, retardation itself, caused by the application of brakes to the wheels, involves a redistribution of the weight which, where the retardation corresponds to the maximum brake application, inevitably results in a very serious loss of braking efficiency, unless means be provided for varying the brake-shoe pressure to correspond with the changed wheel-pressures. Whatever the source of the retarding force, its operative effect in retarding the motion of the car is the same as that of an infinite number of small retarding forces, each engaged in retarding the motion of an elementary portion of the mass of the car, and therefore, in order that a single retarding force, or a combination of retarding forces, shall so operate, without either changing the direction of the car's motion, or producing rotation of the structure as a whole, or calling into operation other forces to prevent such deviation or rotation, the force or the resultant of the combination of forces must be so applied that it shall pass through the centre of inertia of the mass, in a direction opposite to that of the motion of the car. In utilizing the rail-friction for the retarding force, while it has the proper direction, it is applied at the lowest points of the mass of the car and must therefore either cause rotation of the entire structure or the interposition of other forces which combine with the retarding force to preserve the simple motion of translation. The car may be considered as a single mass or as being composed of three separate masses, according as it is provided with one rigid or two swiveling trucks. Rotation of the car by the eccentric retarding force does not occur in either case; but, in the first, it is because the reacting pressure of the rails upon the forward pair of wheels exceeds that upon the rear pair of wheels in such measure that the contrary rotative moment, thereby introduced, just balances that of the eccentric retarding force, also applied by the rails to the wheels. In the case of the car with two trucks, the retarding force is applied at the lower extremity of the two trucks, being equally divided between them (if constructed alike); that portion of the retarding force necessary to retard the mass of the trucks is absorbed in so doing, and the remainder is applied by the trucks to the car body at substantially its lowest extremity. In consequence, the center of inertia of the car body being above the points of application of the retarding force, rotation through the eccentrically applied retarding force is prevented only by the resisting rotative moment of a greater supporting pressure from the forward than from the rear truck. Each truck is subject to the combined rotative moment of the eccentric retarding force at its lower extremity, and the eccentric reacting force from the car body at its upper extremity, and rotation is prevented only by the contrary rotative moment of a greater supporting pressure by the rails upon the forward than upon the rear pair of wheels. Thus the very act of applying the brakes to the wheels produces a new and very different system of wheel pressures upon the rails, and it is the wheel pressures under these conditions which determine the available retarding force. As the total pressure of all the wheels upon the rails cannot vary, it is obvious that the existence of a greater rail pressure for the forward than for the rear pair of wheels of the truck implies the virtual transfer of a portion of the normal pressure from one pair of wheels to the other. The brake-shoe pressure upon the rear pair of wheels must be insufficient to cause the wheels to slide upon the rails, and must therefore be cut down in proportion to the transfer of weight from the rear to the forward pair of wheels. But as the forward pair of wheels will become the rear pair when the car moves in the opposite direction, the brake-shoe pressure upon that pair of wheels must also be limited in the same way. Thus, the braking pressure upon each pair of wheels must be restricted to correspond with the minimum pressure of the wheels upon the rails, and when it is understood that this minimum rail-pressure, which occurs in the maximum application of the brakes, is less than 85 per cent. of the normal, or, in other words, that the effective wheel-pressure, available for braking, of an ordinary eight-wheeled passenger car is but 85 per cent. of the weight of the entire car, the importance of the provision of means to compensate for such a serious loss of retarding efficiency becomes clearly manifest, and a solution of the problem, devised by the writer, is therefore submitted.

The first step in determining the rail-pressure is to find the reactions between the car-body and trucks, after which, investigation is confined to truck-conditions alone. The only means of the application of force to the car-body are the trucks and the draw-bars. In any case where, in a train of vehicles, the ratio of the retarding force of the brakes to the weight is greater for some vehicles than for others, the forces transmitted through the draw-bars require consideration; but in electric service, where cars are either operated singly or in trains that permit equally effective brake-retardation upon the several vehicles, no one produces a retarding effect upon another, so that draw-bar forces are eliminated and the problem is more simple than in the case of steam-railroad trains, where draw-bar forces accompany brake-application, because all vehicles are not uniformly braked. It is true that, in a train of electrically operated cars, defective apparatus upon one or more of the cars might result in the application of the brakes upon only a portion of the cars, whereby retarding forces would be transmitted through the draw-bars to the unbraked cars, but consideration can hardly be extended to such uncertain accidental conditions.

Fig. 1 represents the body of a car, from which the trucks have been removed and replaced by arrows representing the supporting and retarding forces which they apply to the car. The trucks being alike and subject to the same retarding rail-friction, each truck contributes the same horizontal force (H) to retard the mass of the car-body, and the forward truck applies a vertical supporting pressure P_1, while the rear truck similarly applies the supporting pressure P_2. The weight (W_1) of the car body is represented by an arrow acting downward through the center of inertia of the car, midway between the truck supports and at distance k above them. The distance between the truck supports is represented by l. These are all the real forces acting upon the car-body (in the absence of draw-bar forces), as the resistance of the atmosphere is so insignificant in comparison with the rail-friction that it may be neglected.

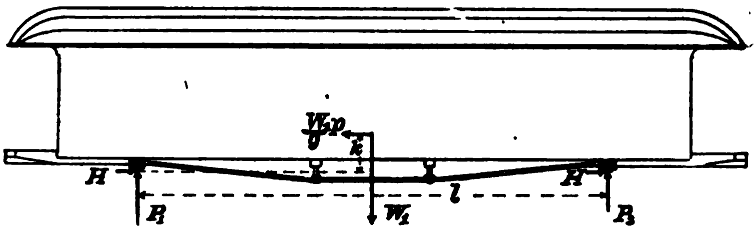


FIG. 1.

The rail-friction causes all parts of the car-structure to be retarded at a certain rate (p) and the horizontal forces (H) from the trucks are absorbed in overcoming the resistances of inertia of all the various elements of mass of the car-body, which latter thus constitute a system of imaginary forces that may be represented in the aggregate by an equivalent horizontal force, which is the product of the mass of the car-body (W/g, where g represents the acceleration of gravity) and the common retardation (p), acting at the center of gravity in a direction opposite to that of the retarding forces H. The operation of the real forces must thus be equal and opposite to that of the imaginary forces, and the following conditions are therefore evident:

$$P_1 + P_2 - W_1 = 0, \text{ or } P_1 = W_1 - P_2$$

$$2H = \frac{W_1 p}{g}, \text{ or } H = \frac{W_1 p}{2g}$$

$$W_1 \frac{l}{2} - P_2 l = \frac{W_1 p}{g} k, \text{ or } P_2 = \frac{W_1}{2} - \frac{W_1 p k}{g \; l}$$

Also, combining the first and last of these equations,

$$P_1 = \frac{W_1}{2} + \frac{W_1 p}{g} \frac{k}{l}$$

By comparison of these values of P_1 and P_2, it is evident that, of the weight $W_1/2$, normally supported by each truck, the weight $p\,k\,W_1/g\,l$ has, through the application of the brakes, been removed from the rear truck and transferred to the forward truck. The center of gravity of car-bodies, especially in electric-car construction, where apparatus of considerable weight is carried below the floor, is generally low, so that the fraction k/l is usually not great, and in some cases its consideration may be neglected in what follows. It is clear, however, that, inasmuch as the rail-pressure upon the rear truck is that which limits the brake-shoe pressure upon either, we are concerned only with the conditions relating to the rear truck, and any conclusions reached regarding the application of brakes to that truck, are also applicable to the forward truck.

Fig. 2 represents the rear truck, to which is applied the vertical car-body pressure P_2, midway between the wheels, and the horizontal reaction H from the car-body, opposing the retarding force applied by the truck to the car body, at a height h above the rails. The rails have been removed and in their place the rail-pressures R_1 and R_2 and the corresponding rail-frictions T_1 and T_2 are indicated by arrows, as applied, respectively, to the forward and rear *pairs* of wheels. It may be noted, in passing, that, although each wheel has a separate rail-pressure and rail-friction, the pair

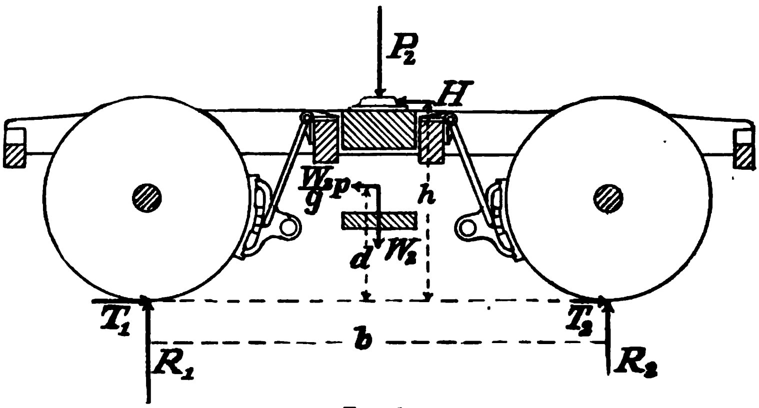


FIG. 2.

of wheels mounted upon the same axle are rigidily secured together, so that, if one turns or slides, the other must accompany it, and the simpler method of treating the pair as a single element, operating under the sum of their rail-pressures and brake-shoe frictions, is subject to no objection of any kind. The weight (W_2) of the truck is represented by an arrow, acting vertically downward through the center of inertia, at a point midway between the wheels and at a height d above the top of the rails. These constitute all the real forces acting upon the truck from without. (Although other forces, due to the brake-shoes and apparatus, act coordinately, they are altogether internal forces and therefore have no influence upon the relation of the truck to external masses.)

Each elementary portion of the mass of the truck is retarded and, through the resistance of its inertia, absorbs a portion of the retarding force, such resistances constituting a system of imaginary forces equivalent to the horizontal force $W_2\,p/g$, acting at the center of gravity, in a direction opposite to that of the retarding forces T_1 and T_2. From the equality of the real and imaginary forces, the following relations are evident:

$$R_1+R_2-W_2-P_2=0,\ \text{or}\ R_1=W_2+P_2-R_2$$

$$T_1+T_2-H=\frac{W_2\,p}{g},\ \text{or}\ T_1+T_2=H+\frac{W_2\,p}{g}$$

$$W_2\frac{b}{2}+P_2\frac{b}{2}-R_2\,b-H\,h=\frac{W_2\,p}{g}d,\ \text{or}$$

$$R_2=\frac{W_2}{2}+\frac{P_2}{2}-H\,\frac{h}{b}-\frac{W_2\,p}{g}\,\frac{d}{b}$$

Also, combining the first and last of these equations,

$$R_1=\frac{W_2}{2}+\frac{P_2}{2}+H\frac{h}{b}+\frac{W_2p}{g}\,\frac{d}{b}$$

Giving H and P_2 the values already found, the last three of these equations become, respectively,

$$T_1+T_2=\frac{W_1+2\,W_2}{2}\,\frac{p}{g}$$

$$R_2=\frac{W_1+2\,W_2}{4}-\frac{W_1p}{2\,g}\left(\frac{h}{b}+\frac{k}{l}\right)-\frac{W_2\,p}{g}\,\frac{d}{b}$$

$$R_1=\frac{W_1+2\,W_2}{4}+\frac{W_1\,p}{2\,g}\left(\frac{h}{b}-\frac{k}{l}\right)+\frac{W_2\,p}{g}\,\frac{d}{b}$$

Here again, comparison of these values of R_1 and R_2 shows that, beside reducing the rail-pressure upon each pair of wheels of the rear truck, to the extent of $p\,k\,W_1/2\,g\,l$, the effect of applying the brakes has also been to transfer from the rear to the forward pair of wheels the weight

$$\tfrac{1}{2}\,\frac{p}{g}\,\frac{h}{b}\,W_1+\frac{p}{g}\,\frac{d}{b}\,W_2;$$

and, as the front pair becomes the rear pair of wheels upon reversing the direction of motion of the car, the available wheel-pressure for braking purposes has been reduced from

$$\frac{W_1+2\,W_2}{4}$$

for each pair of wheels, to

$$\frac{W_1+2\,W_2}{4}-\left\{\frac{W_1}{2}\frac{p}{g}\left(\frac{h}{b}+\frac{k}{l}\right)+W_2\frac{p}{g}\frac{d}{b}\right\}$$

From the first of the last three equations,

$$p=2\,\frac{T_1+T_2}{W_1+2\,W_2}g$$

For simplicity and greater convenience, $W_1+2\,W_2$, the weight of the entire car, may be designated by W and thus

$$p=2\,\frac{T_1+T_2}{W}g$$

Applying this value of p in the expressions for R_1 and R_2,

$$R_2=\frac{W}{4}-\left\{W_1\left(\frac{h}{b}+\frac{k}{l}\right)+2\,W_2\frac{d}{b}\right\}\frac{T_1+T_2}{W}$$

$$R_1=\frac{W}{4}+\left\{W_1\left(\frac{h}{b}-\frac{k}{l}\right)+2\,W_2\frac{d}{b}\right\}\frac{T_1+T_2}{W}$$

It is to be observed that these expressions for the rail-pressures of the rear and forward part of wheels of the rear truck are true for any rail-frictions, T_1 and T_2, that may be available. If f_1 denotes the coefficient of static rail-friction, the maximum values of T_1 and T_2 are f_1, R_1 and f_1, R_2, respectively. If then for R_1 and R_2, their corresponding values T_1/f_1 and T_2/f_1, respectively, be substituted, the above equations may be solved for T_1 and T_2, and their values found for the condition of maximum efficiency. They are

$$T_1=\frac{f_1\,W}{4}\,\frac{W\,b+2\,f_1\,(W_1\,h+2\,W_2\,d)}{\left(W+2\,f_1\,W_1\frac{k}{l}\right)b} \qquad (1)$$

$$T_2=\frac{f_1\,W}{4}\,\frac{W\,b-2\,f_1\,(W_1\,h+2\,W_2\,d)}{\left(W+2\,f_1\,W_1\frac{k}{l}\right)b} \qquad (2)$$

In order to understand now what results from this transfer of weight in practice, where it is customary to apply to each wheel the greatest brake-shoe pressure that will slide none of them, let $T_1 = T_2 = f_1 R_2$ be substituted in the value of R_2; then, upon solving the equation,

$$T_1 = T_2 = \frac{f_1 W}{4} \frac{W b}{W b + 2 f_1 \left[W_1 \left(h + \frac{k}{l} b \right) + 2 W_2 d \right]}$$

The average conditions for the passenger cars of steam-railroad service are fairly represented by the values $b = 84''$, $h = 34''$, $k = 32''$, $l = 480''$, $d = 21''$, $W_1 = \frac{2}{3} W$ and $W_2 = 1/6\ W$. Assuming that, in safe average practice, $f_1 = .25$, it is thus found that, instead of a maximum rail-friction of $f_1\ W/4$, for each pair of wheels, as ordinarily supposed, the maximum is but $.834\ f_1 W/4$.

This serious loss of available retarding force induced the writer some time since to investigate the conditions for the purpose of finding, if possible, a means of automatically proportioning the brake-shoe pressure upon the forward and rear wheels of the truck, so that they should more nearly correspond to the rail-frictions of equations 1 and 2. Using the above values of b, h, k, l, d, W_1 and W_2, in those equations, $T_1 = 1.151\ f_1\ W/4$ and $T_2 = .806\ f_1 W/4$, so that $T_1 + T_2 = .978\ f_1\ W/2$ might be realized, while only $.834\ f_1 W/2$ is ordinarily attained in practice. Any means of making the possible rail-friction of the forward pair of wheels fully available would thus increase the braking efficiency more than 17 per cent.

The investigation disclosed the fact that a structural feature of truck brake-gear that had been found to complicate the application of brake-shoe pressure to the wheels, might be so employed that it would serve almost entirely to recover this lost efficiency in braking. It is, in brief, the angularity of the hanger-link, by which, if the brake-shoes be applied upon the inner face of the wheel—that nearest the center of the truck—and the hanger-link supporting the brake-shoe be inclined at a proper angle with the tangent to the wheel at the center of the bearing surface of the brake-shoe, the brake-shoe pressure is proportioned to the wheel pressure. This matter merits very careful consideration.

More as a matter of convenience than for any other apparent reason, it has generally been customary, in passenger-car construction, to suspend the brake-shoes from the end-timbers of the truck at the outer face of the wheels. It is true that the brake-shoes are thus more accessible for renewals, but the arrangement is inconvenient in other respects, requiring the disconnection and often the removal of the brake-beams to remove the wheels. The application of the brake-shoes at the outer face of the wheels results in an upward thrust of the brake-hangers, proportional to the brake-shoe friction, upon the end-timber at the rear end of the truck, and a corresponding downward drag upon that at the forward end. It has already been shown that the retardation of the car by the rail-friction produces a rotative effect upon the truck, which is greatly augmented by this direct action of the brake-shoe friction through the hanger-links, and the result is that a considerable rotation or tilting of the truck frame acutally occurs, compressing the forward equalizing-bar springs and relaxing those at the rear. The reaction or recoil of these springs is the cause of the frequently observed violent backward surge or shock, so disagreeable to passengers and sometimes throwing unguarded standing persons to the floor, at the instant of stopping. If, however, the brake-shoes were suspended at the inner face of the wheels, the upward thrust of the hanger-links would act upon the forward portion of the truck-frame, and the downward thrust upon the rear portion, so that the effect would be to counteract and neutralize, instead of aggravate, the disagreeable influence of the rail-friction.

Another and still more serious objection to this method of suspending the brake-shoes is the evil effect of the angular inclination of the hanger-links, which is not only desirable to insure clearance of the shoes from the wheels when the brakes are released, but is usually unavoidable for constructive reasons. This feature will be better understood upon further consideration of the effect of inclining the brake-beam hanger-links.

Fig. 3 represents the outlines of the usual form of passenger-car truck, in which are indicated by arrows the forces applied to each brake-beam. These forces are not all in the same lateral plane, the actuating brake-force P from the brake-cylinder being applied at the center of the brake-beam, while one-half of each of the other three forces is applied to the brake-shoe at each end of the beam; but it is simpler and without objection to treat them as represented. The forces Q_1 and Q_2 are the reacting pressures of the forward and rear pairs of wheels, respectively, upon the brake-shoes; the forces F_1 and F_2 are the corresponding frictional forces resulting from the pressures Q_1 and Q_2; and the forces V_1 and V_2 are the reactions upon the brake-shoes from the hanger-links. The center of the brake-shoes should be about three and one-half inches below the center of the wheels, and the angle between the radial direction of the pressures Q_1 and Q_2 and the horizontal, is

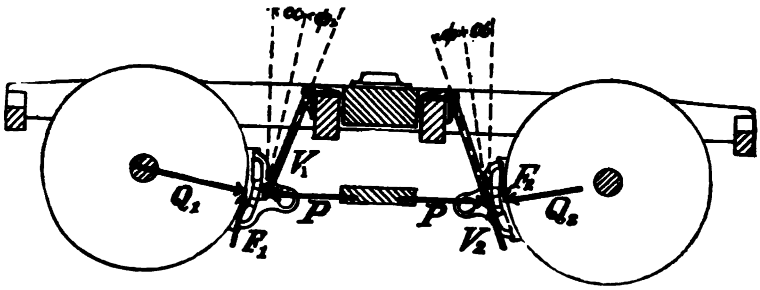


FIG. 3.

designated by α. The mean frictional forces F_1 and F_2 conseqeuntly incline at the same angle with the vertical. The inclination of the hanger-links to the tangential direction of the frictional forces F_1 and F_2 is designated by ϕ. The forces being resolved into rectangular components, with reference to the direction of the hanger links of each pair of wheels, the following relations are evident:

$$Q_1 \cos\phi - F_1 \sin\phi - P\cos(\alpha+\phi) = 0$$
$$Q_2 \cos\phi + F_2 \sin\phi - P\cos(\alpha+\phi) = 0$$

If the coefficient of brake-shoe friction be designated by f_2, then, whatever be its value, $F_1 = f_2 Q_1$ and $F_2 = f_2 Q_2$. Replacing Q_1 and Q_2 by their values in terms of F_1 and F_2, these equations may be combined and solved for ϕ and P, with the results that

$$\tan\phi = \frac{1}{f_2}\frac{F_1 - F_2}{F_1 + F_2} \qquad (3)$$

$$P = \frac{(F_2+F_1)\cos\phi - f_2(F_1 - F_2)\sin\phi}{2 f_2 \cos(\alpha+\phi)} \qquad (4)$$

In retarding the motion of the vehicle, the friction of the brake-shoes must resist rotation of the wheels to the same extent that the rail friction urges continued rotation; but, in addition, it must also destroy the rotative energy of the wheels. That is, the stored energy due to the rotary motion of the wheels, which is entirely independent of the energy due to the motion of translation (and which would still consume considerable work if the simple motion of translation of the entire vehicle, wheels and all, could be overcome by means not affecting the rotation of the wheels), absorbs a part of the work done by the brake-shoes and only what then remains of that work operates to excite rail-resistance to wheel sliding. The peripheral velocity of the wheels being the same as the velocity of translation, if r_1 represent the radius of the wheel, a retardation p of the vehicle is accompanied by an angular retardation p/r_1 of the wheel's rotation. If, also, w represent the weight of each wheel and r_2 the radius of gyration, then, when the rail-friction causes the retardation of the motion of the car the corresponding retardation of the rotary motion of the wheels requires at the surface of each wheel a retarding force equal to $w\,r_2^2\,p/g\,r_1^2$. By careful computation, the square of the radius of gyration of car wheels is found to be almost exactly six-tenths of the square of the wheel-radius. Therefore, the brake-shoe friction being required to supply both retarding forces, the relation between the wheel-forces of the two pair of wheels is obviously

$$F_1 = \frac{1.2\,w}{g}\,p + T_1$$

$$F_2 = \frac{1.2\,w}{g}\,p + T_2$$

If now the maximum rail-friction which may exist with the unequal distribution of weight upon the different pairs of wheels, as found in equations 1 and 2, is to be realized, it is necessary that the brake-shoe frictions F_1 and F_2 shall correspond with those rail-frictions. Giving T_1 and T_2 the values of equations 1 and 2, respectively, and giving p the value found for it, these brake-shoe frictions become

$$F_1 = \frac{f_1\,W}{4}\;\frac{(W+4.8\,w)\,b + 2\,f_1\,(W_1\,h + 2\,W_2\,d)}{\left(W + 2\,f_1\,W_1\,\frac{k}{l}\right)b}$$

$$F_2 = \frac{f_1\,W}{4}\;\frac{(W+4.8\,w)\,b - 2\,f_1\,(W_1\,h + 2\,W_2\,d)}{\left(W + 2\,f_1\,W_1\,\frac{k}{l}\right)b}$$

Applying these values in equation 3, it becomes

$$\tan \varphi = 2\frac{f_1}{f_2}\,\frac{W_1 h + 2\,W_2 d}{(W + 4.8\,w)\,b} \tag{5}$$

The expression for the braking force applied to the brake-beam may be given a more convenient form for practical work by giving $F_1 - F_2$ the value $f_2\,(F + F_2)\tan\varphi$, desired from equation 3, and, finally,

$$P = \frac{f_1}{f_2}\,\frac{W}{4}\,\frac{W + 4.8\,w}{W + 2\,f_1\,W_1\,\frac{k}{l}}\;\frac{(1 - f_2^2\tan^2\varphi)\cos\varphi}{\cos(a + \varphi)} \tag{6}$$

Thus, by hanging the brake-beams between the wheels, instead of outside, and inclining the hanger-links at a proper angle, the increased pressure and consequently the increased friction of the brake-shoes upon the forward pair of wheels and the diminished pressure and friction of the brake-shoes upon the rear wheels, due to the effect of the friction itself in causing the shoes to press more or less forcibly upon the wheels through the angularity of the hanger-links, are made to correspond with and compensate for the transferred weight from the rear to the forward wheels. In the same manner that running in the opposite direction causes a reversal of the conditions for the transfer of weight, so, too, the rotation of the wheels in the opposite direction causes a reversal of the effect of the inclined hanger-links, and the increased brake-shoe pressure is always applied to the wheels carrying the increased weight.

It will now be more clearly understood why inclination of the hanger-links of outside-hung brake-beams has an evil effect upon the efficiency of the brakes. As the link must necessarily be so inclined, if inclined at all, that the upward movement of the wheel surface upon the brake-shoe increases the brake-shoe pressure, the pressure is *increased* upon the *rear* pair and *reduced* upon the *forward* pair of wheels when the brakes are outside-hung. Thus, the high brake-shoe pressure is always applied to the wheel carrying the reduced weight and the reduced brake-shoe pressure to the wheels carrying the increased weight. The braking force P upon the brake-beam must therefore be so reduced that the rear pair of wheels shall not be caused to slide, and the combined friction of the brake-shoes upon the two pair of wheels is thereby reduced accordingly. The loss of more than 15 per cent. in braking efficiency, which has been shown to result from the use of a uniform brake-shoe pressure instead of pressures proportioned to the rail-pressures, occurs when the hanger-links are not inclined; but it will now be understood that, with outside-hung brakes having the ordinary inclination of hanger-links, the loss is considerably greater, the retardation probably averaging at least 20 per cent. below that attainable by the expedient of inside-hung brakes with properly inclined hangers.

In practice, the application of this method of inclined hanger-links is not without some difficulty. The chief trouble is that no constant angle of the links can be maintained, as the wearing away of the brake-shoes, together with wearing and turning down of the tires of steel-tired wheels, causes constant and considerable variation. Thus, if the angle of inclination and the braking pressure be calculated for the conditions existing when the brake-shoes and wheels are new, the increased angle when the shoes become much worn and the tires have been well turned off, would probably cause the forward wheels to slide upon the rails. On the other hand, if the calculations be made for turned wheels and worn shoes, the rear wheels would probably slide when the wheels and brake-shoes are new. It is therefore necessary to compromise between the extremes, in reference to the angle of inclination of the hanger-links, by inclining the hanger-links at the angle determined from equation 5, when the brake-shoes and wheels are each *half-worn*, and the brake-beam force must then be so established that neither pair of wheels shall be caused to slide in the extreme positions of the hanger-links. The brake-beam force determined by equation 6 would be too great for the forward pair of wheels when the brake-shoes and wheels are fully worn, and also too great for the rear pair of wheels when the brake-shoes and wheels are new. The maximum safe brake-beam force for the forward pair of wheels may be determined from the rail-pressures and the values of the angles α and φ when the brake-shoes and wheels are fully worn, and that for the rear pair from the corresponding conditions when the brake-shoes and wheels are new, and the least of the two is the greatest brake-beam force that can be continuously employed. It is found that the angular variation from the position of the hanger-link when the brake-shoes and wheels are half worn is a little less when the brake-shoes and wheels are new than when they are fully worn, and the brake-beam force to be employed in practice must be determined by the conditions existing when the brake-shoes and wheels are fully worn. It is obvious that the variation of the angularity of the hanger-links, through the allowance necessary for wear (2¾ inches for steel-tired and 1¾ inches for chilled cast-iron wheels), is an inverse function of the length of the hanger-link itself, which should therefore be as long as practicable. With the use of that form of brake-shoe holder or head in which the hanger-link pin is located behind the center of the brake-shoe (illustrated in Figs. 2 and 3, above), the maximum length of hanger is secured. The form of brake-head in which the pin is considerably above the center, shortens the hanger materially, and its use should be avoided.

Whether the maximum rail-frictions are developed by corresponding brake-shoe frictions or not, it is to be observed that the relation between the frictions F_1 and F_2 expressed in equation 3 is one that always exists, being dependent simply upon the angle of inclination of the hanger-links and the coefficient of brake-shoe friction and independent of everything else. Therefore, even though the angle of inclination varies with wear, and the construction of the truck may be such that the full inclination of the hanger, necessary to the greatest efficiency, cannot be employed, a portion of the added efficiency of the system may still be realized by inclining the hanger-links as much as may be consistent with proper length and the limitations of the truck construction, and by employing a corresponding brake-beam force. As the inclination of the hanger-links is insufficient to compensate fully for the reduced rail pressure upon the rear pair of wheels when the brake-shoes and wheels are half worn, the brake-beam force must in this case be determined with reference to that pair of wheels when the brake-shoes and wheels are new.

The problem thus resolves itself into so laying out the truck brake-gear that the center of the half-worn brake-shoe shall be at the proper distance (3½ inches) below the center of the half-worn wheel, and that the hanger-link (as long as possible) shall stand at as great an angle to the wheel-tangent as possible (not exceeding the angle of full compensation, where it has the value found from equation 5 *when the brake-shoes and wheels are each half worn*, and then calculating the brake-beam force P for the angles φ_1 and a_1 that exist *when the brake shoes and wheels are fully worn*, if the angle of full compensation has been employed, or for the angles φ_2 and a_2, that exist *when the brake-shoes and wheels are new*, if an angle less than that of full compensation has been employed. To facilitate the application of the principle of inclined hanger-links, the various angles of inclination for half-worn brake-shoes and wheels, and the corresponding braking forces have been determined for different conditions, as to truck wheel-base and diameter of wheel, and are tabulated below.

It will be observed in equation 5 that the angle of inclination of the hanger-links varies inversely with the wheel-base of the truck, which is fortunate, since long wheel base is desirable also in all other respects (ease of riding, minimum wear and tear of wheel-flanges and truck-frames, etc.), except in cases where curves are so sharp that long wheel base interferes with curving. The full compensating inclination of long hangers may be employed, or any size of wheel, where trucks have a wheel-base of 8 feet; and, for wheels of 33 and 36 inches diameter, it may also generally be employed where the wheel-base is 7½ feet. With passenger-car trucks of ordinary construction, partial compensation may be obtained, for wheels of larger diameter than 36 inches, where the wheel-base is 7½ feet; and, for 33 and 36 inch wheels, it may also be obtained where the wheel-base is but 7 feet. Shorter wheel-base than 7 feet, while requiring a large angle of inclination of hanger-links, provide insufficient room for an inclination of any value, unless the hanger-links are so short that the variation of the angle impairs its utility, or the trucks are low, so that the height h is also reduced as the wheel-base b is reduced.

The method of applying the principle, in cases where the full compensating angle of inclination can be used, depends primarily upon the relations expressed in equation 3. As the braking force must be so established that the forward pair of wheels shall not slide when the wheels and brake-shoes are fully worn, the friction of the brake-shoes upon that pair of wheels must correspond with the rail-pressure at that time, and the friction of the brake-shoe upon the rear pair of wheels will necessarily be

$$F_2 = \frac{1 - f_2 \tan \varphi_1}{1 + f_2 \tan \varphi_1} F_1$$

as found from equation 3, in which φ_1 is the value of the angle of inclination the hanger-link to the wheel tangent when the brake-shoes and wheels are fully worn. It has been shown that

$$F = T_1 + \frac{2.4\,w}{W}(T_1 + T_2)$$

and that

$$F_2 = T_2 + \frac{2.4\,w}{W}(T_1+T_2)$$

and, by combining these two equations,

$$T_1+T_2 = \frac{W}{W+4.8\,w}(F_1+F_2)$$

and

$$T_1 = \frac{(W+2.4\,w)\,F_1 - 2.4\,w\,F_2}{W+4.8\,w}$$

The rail-pressure for the forward pair of wheels was found to be

$$R_1 = \frac{W}{4} + \left\{ \frac{W_1}{W}\left(\frac{h}{b} - \frac{k}{l}\right) + \frac{2\,W_2}{W}\frac{d}{b} \right\}(T_1+T_2)$$

If the full rail-friction of this pair of wheels be utilized, $R_1 = T_1/f_1$ and the above values of T_1 and T_1+T_2 being substituted in this equation for the rail-pressure, it may be solved, with the aid of the above value of F_2 in terms of F_1 and $\tan\varphi_1$, to yield values of F_1 and F_2, which depend simply upon the available rail-pressure of the forward pair of wheels when the brake shoes and wheels are fully worn. These values of F_1 and F_2 being then applied in equation 4 and representing the value of the angle a when the wheels and brake-shoes are fully worn by a_1 the necessary braking force to be applied at each brake-beam becomes

$$c_1 = \frac{f_1}{f_2}\,\frac{(W+4.8\,w)\,(1-f_2^2\tan^2\varphi_1)\cos\varphi_1}{\left\{ W + 2f_1W_1\frac{k}{l} - 2f_1\,\frac{W_1h+2\,W_2d}{b} + f_2\,(W+4.8w)\tan\varphi_1 \right\}\cos(a_1+\varphi_1)}\,\frac{W}{4}$$

In practice, the application of this brake-beam force by the air-pressure in the brake-cylinder is through the medium of a series of levers and connecting rods, pinned together and forming the "brake-gear." A portion of the air-pressure upon the piston of the brake-cylinder is absorbed by the frictional rigidity of the brake-gear; and, as the leverage of the brake-gear is always calculated from the piston-pressure, it is necessary to make proper allowance for the frictional loss in the brake-gear. The only available results of investigation of such loss indicates that, in the ordinary form of passenger-car brake-gear, the brake-beam force is about 80 per cent. of that calculated from the piston-pressure.

As the total braking force of the car is the sum of the forces upon the four brake-beams, if the calculated braking force of the car be represented by B, it therefore becomes $B = 4\,P_f.80$.

Examination of the practice in passenger-car construction of ordinary American steam railroads indicates quite general uniformity in respect to most of the various features which determine the angle of inclination of the brake hanger-link and the braking force. In general, for practical purposes, the average of the conditions existing is sufficiently accurate and may be taken as follows: The coefficient of rail-friction may be regarded as $f_1 = .25$, particularly as the limiting conditions are those of emergency applications. The coefficient of brake-shoe friction most apt to slide wheels is that of low speeds, near the end of the stop, and experience indicates a safe value to be $f_2 = \frac{1}{3}$. Little error will, in any ordinary case, result from making $W_1 = \frac{2}{3}\,W$ and $W_2 = 1/6\,W$. Generally, $h = 34$ inches, and $k/l = 1/15$. The height of the center of gravity of the truck varies with the diameter of the wheels; for 33-inch wheels, $d = 20$ inches; for 36-inch wheels, $d = 20.5$; for 38-inch wheels, $d = 21$; for 40-inch wheels, $d = 21.25$; and for 42-inch wheels, $d = 21.5$; the weights of wheels differ both with the diameter and the construction; a fair average appears to make $4.8\,w = .071\,W$ for 33-inch steel-tired wheels, $.080\,W$ for 36-inch, $.089\,W$ for 38-inch, $.094\,W$ for 40-inch, and $.098\,W$ for 42-inch. With these values (except those depending upon the diameter of the wheels), the maximum braking force, as ordinarily calculated, which may be used without injurious wheel-sliding, becomes

$$B = \frac{15\left(1+\frac{4.8w}{W}\right)\left(1-\frac{1}{9}\tan^2\varphi_1\right)\cos\varphi_1}{16\left\{\frac{46}{45}\,\frac{68+d}{6\,b}+\frac{1}{3}\left(1+\frac{4.8w}{W}\right)\tan\,\varphi_1\right\}\cos\,(a_1+\varphi_1)}\,W$$

In cases where an angle of inclination of less than that required full compensation must be given the hanger-links when the brake-shoes and wheels are half worn, the same mode of procedure is followed to determine the braking force, except that the angles a_2 and φ_2, existing when the brake-shoes and wheels are new, are employed instead of a_1 and φ_1, and F_1 is found in terms of F_2 and φ_2 from equation 3, instead of F_2 in terms of F_1 and φ_1. Thus T_2 and T_1+T_2 are found in terms of F_1 and substituted in the expression for the rail-friction upon the *rear* pair of wheels, which yields values of F_1 and F_2 in terms of simply the rail-pressure upon that pair of wheels and the angle φ_2. These values of F_1 and F_2, being substituted in equation 4, furnish the brake-beam force

$$P_2 = \frac{f_1}{f_2} \frac{(W+4.8w)(1 - f_1 f_2 \tan^2 \varphi_2) \cos \varphi_2}{\left\{ W + 2f_1 W_1 \frac{k}{l} + 2f_1 \frac{W_1 h + 2W_2 d}{b} - f_2(W+4.8w) \tan \varphi_2 \right\} \cos(\alpha_2 + \varphi_2)} \frac{W}{4}$$

From this brake-beam force, in terms of the rail-pressure of the rear pair of wheels and the angles α_2 and φ_2, existing when the brake-shoes and wheels are new, the corresponding braking force, as customarily calculated from the pressure upon the brake-cylinder piston, is found. When the approximate average values of the various fixed symbols are applied, it becomes

$$B_2 = \frac{15\left(1+\frac{4.8w}{W}\right)\left(1-\frac{1}{9}\tan^2\varphi_2\right)\cos\varphi_2}{16\left\{\frac{46}{45}+\frac{68+d}{6b}-\frac{1}{3}\left(1+\frac{4.8w}{W}\right)\tan\varphi_2\right\}\cos(\alpha_2+\varphi_2)} W$$

For convenience in applying this principle to the design of truck brake-gear, the following table has been prepared, showing the angle of compensation which the hanger-link makes with the vertical—that is, $\alpha+\varphi$—instead of the angle φ with the tangent to the wheel, when the brake-shoe and wheel are half worn. The angle is determined by placing the center of the half-worn shoe (assumed to be when the thickness has been reduced ½ inch), 3½ inches below the center of the half-worn wheel, the radius of which is assumed to have been reduced ¾ inch. For convenience, also, the tangent of the angle $\alpha+\varphi$ is given, so that, a convenient definite distance having been laid off from the center of the lower hanger-link pin upon a vertical line through it, a horizontal distance from its upper end, equal to the product of this tangent and the vertical distance so laid off, will determine a point in the hanger-link, and consequently its direction. The upper end will of course be fixed by the position in which the upper pin can be supported by a bracket from the truck-transom, the length, however, being as great as possible. The braking force is also given, as determined from the angles α_1 and φ_1 when the brake-shoe has been reduced 1 inch in thickness and the radius of the wheel has been reduced 1½ inches, or from the angles α_2 and φ_2 when the brake-shoes and wheels are new, according as the angle of inclination of the hanger-links when the brake-shoes and wheels are half worn is that of full compensation or a lesser one. The length of each hanger-link employed in these computations is also given. As already stated, only partially compensating angles of inclination occur for a wheel-base of 84 inches and, with 38, 40 and 42 inch wheels, for a wheel-base of 90 inches. In the other cases, full compensation occurs.

Diam. of wheel.	b = 84 in.				b = 90 in.				b = 96 in.			
	l	$a+\phi$	tan $a+\phi$	B	l	$a+\phi$	tan $a+\phi$	B	l	$a+\phi$	tan $a+\phi$	B
33″	19½	28°–33⅝′	.5444	.956*W*	20	37°–28⅝′	.7668	1.025*W*	20	36°– 6⅝′	.7296	1.028*W*
36″	18¾	24 –29½′	.4555	.929*W*	18¾	36°–16⅙′	.7338	1.016*W*	20	34°–54½′	.6978	1.026*W*
38″					20	29°–10⅙′	.5582	.990*W*	20	34°–10′	.6787	1.024*W*
40″					19½	26°–37′	.5011	.972*W*	20	33°–33⅝	.6655	1.022*W*
42″					19	23°–58½′	.4447	.954*W*	19½	33°– 1⅙′	.6499	1.020*W*

NOTE:—b is thu wheel base of the truck, in inches; B is the braking force, calculated from the bra'ke-cylii der piston pressure, in terms of the weight of the car; and l is the length of the brake-beam hanger link, in inches. The evil effect of shortening the hanger link is illustrated in this table. For a wheel base of 96 inches, the braking force for trucks with 36-inch wheels is less than that for trucks with 33-inch wheels by only .002*W*, where the angle of inclination is that of full compensation and the hanger links are 20 inches long in each case; but, where the wheel base is 90 inches the length of hanger link may, in many cases, be no longer than 18¾ inches for trucks with 36-inch wheels, and the braking force in that case is .009*W* less than that of trucks with 33-inch wheels and 20-inch hanger links. Had 20-inch hanger links been employed, instead of 18¾ inch, for 36-inch wheels, the braking force could probably be increased about .007*W* above that given (1.016*W*).

It would be a serious oversight to dismiss this subject of truck brake-gear construction without mentioning the pernicious break-beam release spring. The custom of hanging brake-beams from the end-timbers of passenger-car trucks has been attended—in the many cases where the inclination of the hanger-links is insufficient to cause the brake-beams to fall away from the wheels by gravity—by the necessary use of springs to insure clearance between brake-shoes and wheels when the brakes are not applied. The loss of brake-shoe pressure from the use of such springs might, of course, be readily compensated by increasing the braking force correspondingly, if such loss could be determined. But these springs vary to such an extent, even when made apparently alike and applied in the same way, that allowance for their influence is well-nigh impossible. Springs, so applied to trucks that they should keep the shoes uniformly away from the wheels, are found to operate so unevenly that, to prevent the brake-shoe at one end of a beam from dragging upon the wheel, that at the other end must be permitted to stand off so far from its wheel that excessive travel of the brake-cylinder piston is necessary to apply the brakes, whereby the air-pressure in the brake-cylinder is reduced and the efficiency of the brakes correspondingly impaired. Even if these springs were so constructed and applied that they exert a uniform influence upon the brake-beams, the inequalities of brake-shoe material cause them to wear unevenly, so that a new shoe at one end of the brake beam is often accompanied by a considerably worn shoe at the other end, and adjustment of clearance that will avoid excessive piston-travel at the brake-cylinder is impossible. The impossibility of adequately measuring and providing braking force for the resistance of these springs, added to the loss of efficiency from excessive piston-travel, or the alternative trouble from dragging brakes, renders the brake-beam release spring one of the most serious evils of modern brake-practice. By the use of inside-hung brake-beams, where sufficient inclination of the hanger-links insures brake-shoe clearance through the action of gravity, both the expense and trouble due to the release-spring is avoided.

To enter into the detail of the air-brake apparatus employed to furnish the braking force, in a paper of this character, would unduly extend it and would also be a work of supererogation. The compressed-air supply generally implies a suitable compressor upon the car, or, if operated in trains, one or more upon each train. Storage of the compressed air in sufficient quantity has, however, been satisfactorily accomplished in some cases and possesses certain advantages. The air is usually stored at a comparatively high pressure (generally 150 pounds) in large reservoirs secured beneath the car, or in any other convenient place. It is delivered through a reducing valve into the " main reservoir " of brake-operation, at the desired pressure, where it is handled in the ordinary manner. In such a system, a single air compressor, of large capacity and high efficiency, compresses the air at a station, where it is stored and charged into the car storage-reservoirs from time to time. The advantages lie in avoiding the cost of installing and maintaining compressors upon all the cars, and in cheapness of operation. The disadvantages consist of the bulkiness of the storage-reservoirs and the time required to stop and charge them, and also the limited distance that may be traversed during the intervals. Where the air is compressed upon the car, the compressor must be accessibly constructed and placed upon the car, and supplied with clean, dry air. It may be operated by steam, by a separate electric motor, or by the car-motor, through suitable connection with the car-axle, as circumstances render it expedient. Its operation should be so controlled by a governor that it shall cease whenever the maximum storage-pressure has been attained in the main reservoir, and shall be renewed when operation of the brakes has reduced the storage-pressure to the inferior limit.

Upon the motorman's operating valve, the satisfactory operation of the brake-system in large measure depends. It must not only present the means of accurately gauging the force of brake-application and of promptly releasing the brakes, but must also define, with precision, the pressure of the air with which the auxiliary reservoirs are charged, to insure the full efficiency of braking without exceeding it to the injury of wheels and detriment of efficiency; while, at the same time, it must provide a superior pressure—that may vary considerably under different conditions—in the main storage reservoir, to insure prompt release of the brakes and restoration of pressure in the auxiliary reservoirs, without any variation of the working pressure in the latter—an exacting combination of conditions. not easy of realization, but of capital importance.

Of the apparatus for the immediate application of the brakes to the wheels, sufficient has already been said, it having been indicated that, in the single case where the unit invariably consists of a single car, simply an air-cylinder, in communication with the motorman's valve, meets all the requirements, while the conditions of every other case justify nothing short of the efficiency of the quick-acting automatic apparatus, and, where characterized by high speeds and frequent stops, the superior efficiency of the high-speed brake is essential to high efficiency of service.

The application of other forms of power than compressed air to brake-service has been practically limited to the vacuum and electricity. The limited pressure and bulky apparatus have restricted the use of the vacuum to comparatively light vehicles and it is fast becoming a mere historical feature of the development of the art of braking. Electricity has been experimentally applied in various forms of apparatus, but has only recently become recognized as a means of promising utility in practical braking. The simplicity of employing the back torque of the car motors of electric railroads for retarding purposes has appeared very attractive to those unacquainted with the objection to dependence upon that means alone. In combination with other means of retardation, so that excessive heating may be avoided, this means of braking cars has been used with some practical success. But the application of electricity to the purpose of braking that appears to overshadow all others is that of the magnetic brake, which embodies such novel applications of old devices, with results so phenomenal, that the use of electricity as the source of braking force in electric railroad service at once occupies an interesting position with a very promising future.

The magnetic brake forms part of a combined braking and car-heating system, in the latter of which, the diverters of the ordinary car-starting apparatus are so also used as resistances for grading the current employed for braking purposes that they serve to heat the car. This part of the system is itself of such interest that, while it is a separate purpose, a brief description is excusable.

It appears to be a well-established fact that the heating effect due to the use of the diverters in starting is not alone sufficient for the practical purpose of heating the car, under the usual varying conditions of service; but when, in addition, the heating effect accompanying braking is also diverted to that purpose, the heat supply is abundant. Two systems of diverters are therefore used, one beneath the car, radiating the heat into the external atmosphere, and the other suitably arranged within the car for heating purposes and called heaters. The two systems may be so combined, according to the temperature and weather that any desired portion of the generated heat, from none of it to all of it, may be employed for heating the car, and any remaining heat is dissipated. The heat supply is, of course, intermittent, but the heaters are so constructed that they readily absorb the intermittently generated heat, and gradually and continuously supply it to the car for uniform heating. In this manner, the cost of the trolley current ordinarily required for heating purposes—an item of no mean proportions—is entirely obviated.

The brake apparatus itself consists of a combination of a track-brake with the ordinary wheel-brake. Track-brakes have long been known and variously proposed for practical use, but no satisfactory application of these devices appears to have been made. The track-brake consists of a system of brake-shoes, arranged beneath the car, directly over the rails, which may be forced down upon the rails to produce the retarding friction. There are several serious obstacles to the attainment of satisfactory efficiency from this method of retardation. In the first place, as the weight of the car must be lifted off from the wheels and transferred to the track-brake shoes, it is obvious that the shoes must be so formed that they will guide the car upon the rails as safely and surely as do the wheels. This appears to be impracticable and, where the track-brake has been employed, only so much of the weight of the car is transferred to the brake-shoes that there still rests upon the wheels sufficient weight to enable them to guide the car securely. Thus only a portion of the weight of the car is available for rail-friction.

Again, it is manifest that the friction of the track-brake-shoes is of the same dynamic character as that of the brake-shoes upon wheels, which varies inversely with the speed and is very much inferior to the static friction of the rotating wheels upon the rails, which is the measure of the available friction of brake-shoes upon the wheels. While it is undoubtedly true that the large area of contact between the rails and track-brake-shoes that may be employed results in a track brake friction which is much superior to that of the sliding wheels (provided the entire weight is transferred to the track-brake-shoes), it is doubtful if the conditions permit the realization of as high a coefficient of friction where brake-shoes rub upon the track as where they are applied with the same force to the wheels, and it is certain that a track-brake of any construction, working upon this principle, is much inferior to an efficient wheel-brake of the "high-speed" type. The combination of a track-brake of this kind with a wheel-brake is merely an added intricacy, as the efficiency of the track brake is entirely at the expense of the wheel brake, in robbing the latter of the rail-friction upon which its effectiveness depends. For these reasons, and for the additional one of constructive complication and cost, no practical application of the track-brake has ever been made, within the knowledge of the writer, except in certain cases of street railroads with exceptionally heavy grades, where an independent track-brake system has been installed for emergency use only, in the event that the wheel-brake system should become disabled.

But the magnetic brake introduces an entirely new element, through which the track-brake not only does not interfere with the efficiency of the wheel-brake but both adds to its normal retardation and provides the operating brake-force. The track-brake-shoe is placed between the two pairs of wheels, and, intsead of being forced upon the rails through an effort from the car, is drawn to the rails by an electromagnet suspended from the car, thereby not merely adding its friction to the unimpaired friction of the wheel-brake but also actually increasing the rail-pressure of the wheels to the extent that the supporting springs for the track-shoes and magnets are in tension through the descent of the track-shoes to the rails. The construction will be better understood by reference to the illustration in Fig. 4.

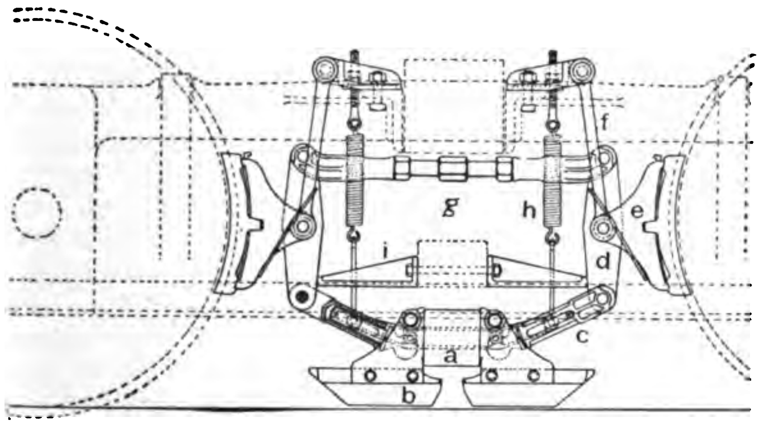


FIG. 4.

In Fig. 4, the magnetic brake apparatus is shown as applied to a four-wheeled, swiveling truck, the parts of which are in dotted lines, more readily to distinguish the brake apparatus. The electromagnet *a*, dividing the track-brake shoe *b* into two parts, is secured by pins to the two push-rods *c*, and suspended at a proper distance above the rails by the adjustable springs *h*. The push-rods are secured by pins to the lower ends of the brake lever *d*, which are connected at their upper ends by the adjustable rod *g* and are pivoted at an intermediate point to the brake-shoe holders *e*, carrying the wheel-brake shoes, and the hanger-links *f*, suspended from the truck-frame. The push-rods *c* are telescopic, as shown in the sectional view of the one at the left, so that a movement of the track-shoe toward the right, relative to the truck-frame, causes the wheel-brake-shoe at the right to be applied to the wheel and the connection *g* to be moved to the left, thereby applying the wheel brake-shoe at the left, the stop *i* preventing the lower end of the brake lever at the left from following the track-brake shoe. A relative movement of the track-brake-shoe to the left is obviously accompanied by application of the wheel-brake-shoes through corresponding movement of the parts in the reverse order.

The brake-controlling device may be incorporated in the running controller or may be a separate device, placed by its side and operatively interlocked with it, so that neither can, through carelessness, be caused to interfere with the operation of the other. In the operation of the apparatus, the current is supplied by the motors, running in multiple as generators—the trolley current being entirely cut off, and is divided between the electromagnets and the diverter combination in such ratio as to cause the track-brake-shoes to be drawn upon the rails with a force proportionate to the braking requirements. The frictional resistance of the rails to the motion of the track-shoes causes the wheel-brakes to be applied with corresponding force. Thus, to the ordinary retardation of the wheel-brakes is added that of the track-brake and also the back torque of the motors, which latter, however, is practically limited to compensation for the rotative energy of the motor and car-wheels. The force of application depends primarily upon the current and upon the electromagnets operating the brake-shoes. The attractive force of the rails upon the magnets is under the control of the motorman up to a limit of about 150 pounds per square inch of brake-shoe surface in contact with the rails. The strength of the magnet is limited by the sectional area of the rail, acting as armature, and where the weight of the car makes a magnet of greater strength desirable, the track-shoe is divided into three parts, instead of two, and wound to form a three-pole magnet, or two combined two-pole electromagnets with one common pole.

The friction of the track-brake-shoe may also be adjusted to some extent through the angular inclination of the push-rods *c*, by which some of the weight of the car may be thrown upon the track-shoes, the levers *d* being correspondingly adjusted to reduce the wheel-brake-shoe pressure in proportion as the weight is transferred to the track-shoe. It will be observed also that the brake-shoes are hung at the inside of the wheels, so that the hanger-links may have an angular inclination to correspond with the transfer of weight from the rear to the forward pair of wheels through the influence of the retarding forces.

The incidental features of the magnetic brake are also of interest and great value. The current declines with the speed during a stop, thereby offsetting the increased coefficient of friction at the lower speeds. In bad weather, when the condition of the rails is liable to be accompanied by wheel-sliding, the braking force operating the wheel-brake is correspondingly reduced, so that the force of application of the wheel-brake is automatically proportioned to the rail-friction which rotates the wheels. But, in addition to this valuable feature, if by chance the wheels should slide upon the rails, the interruption of wheel-rotation is accompanied by the extinguishment of the track-magnet current, through which the pressure of the brake-shoes upon the wheel is instantly relaxed and rotation of the wheels is resumed, without injury or serious loss of time.

In operation, the efficiency of the magnetic brake, under the various conditions of service, is phenomenal and far exceeds that of any other braking system for the retardation of trains, which, combined with the commercial advantage of dispensing with the use of trolley current or any other means for heating cars, seems to assure it a leading position in electric-railroad operation in the future.

DISCUSSION AT NEW YORK.

PRESIDENT SCOTT:—I think we owe a special debt of gratitude to both of the gentlemen who have prepared the papers of the evening. Both are particularly busy men, and they have gone to a great deal of pains and labor. I have been struck, as I am sure many of you have been, by the revelations which come from a scientific and experimental investigation and a mathematical analysis of what is apparently a simple thing. The applying of a brake-shoe to a wheel seems to be so simple that there is nothing of particular scientific interest or intricacy involved; but these papers present beautiful mechanical stories which reveal new things on every page. They show that there are peculiar mechanical features and unsuspected relations in the operation of even the most ordinary simple brake, and that with the more complex and intricate forms of brakes which have been devised these difficulties which at first we did not see are overcome and are advantageously utilized. We have with us this evening several gentlemen who are connected with the general subject of braking in one way or another, and we should have in our discussions some interesting phases of the subject presented. One engineer who is connected with the Manhattan Railway Company of this city is here this evening, Mr. Henry G. Stott.

MR. STOTT:—I can only congratulate the writers of these papers, particularly Mr. Parke, upon the elaborate investigations they have made into the general subject of braking. I want to say, Mr. President, that you have called on the wrong man to-night. I do not know much about the subject of brakes. My end of the system is located in the power house and substations, and I am not very familiar with this problem; for that reason I do not think I could add anything to these papers as they are the work of specialists.

PRESIDENT SCOTT:—It is Mr. Stott's business to make things go, not to make them stop. Mr. C. O. Mailloux has given special attention to high speed work of late, and I think also to the matter of braking, and we would be pleased to hear from him.

MR. MAILLOUX:—Mr. President and Gentlemen: I may say, as a preface, that these papers cannot very well be discussed by any one who has not had ample opportunity to read them carefully and thoroughly. The paper of Mr. Parke, especially, is such an important contribution to railroad engineering literature, that, in order to be able to discuss it intelligently, I feel that I should have at least a week in which to study it, even though I may pretend to have some familiarity with the subject. I regard Mr. Parke as the greatest authority in this country certainly, and in the world perhaps, on the subject or brakes and braking. He has been studying it many years as a specialist, and the paper itself indicates the thoroughness with which he has handled it. His classical contributions to the literature of braking, in the *Railroad Gazette* and other similar publications, bear sufficient testimony to the depth of his study and its far-reaching importance. The present paper of Mr. Parke is a comprehensive resumé, giving a valuable summary of the knowledge and data which are already available, and a highly intelligent statement of problems and puzzles which are still unsolved.

The President well said that we have here an apparently simple phenomenon, which is, in reality, a most complex one; and if you listened carefully to what Mr. Parke said in regard to the very irregular variation of the coefficient of friction, for instance, and if you noted the number of independent variables of which it is a function, then you would begin to realize that braking is indeed a most complicated problem. When an authority who has been studying a subject like this for as many years as Mr. Parke has, is unable to give one a clue as to what might be called a typical brake-curve, then we may indeed realize what a difficult problem we have before us. I have had to deal with the problem of braking-curves as a very important factor in high-speed traction. The problem of the predetermination of the brake-curve becomes interesting in such cases, especially when one is anxious to depict graphically the speed of the train at different instants, so as to predetermine the time and other data regarding the complete service run of the train. In the paper which I presented at the Great Barrington meeting, I referred to the subject of brake-curves somewhat gingerly. I "dodged" it somewhat, and stated very frankly that there was little or nothing about it known. I have sometimes taken from fifty to a hundred brake-curves and plotted them, superposed, in the hope that I might succeed in getting a clue to a typical curve or to an equation, empirical though it might be, which would at least enable me to represent with some degree of approximation, a general typical brake-curve. Mr. Parke, whom I have had the pleasure of knowing for some time, had previously told me of the difficulty, even perhaps the impossibility, of accomplishing this, and I realized very sadly when I came to make the experiment, that he had indeed spoken the truth. Our knowledge of the geometrical nature of the brake-curve is so very deficient that it can scarcely be considered knowledge at all.

The paper of Mr. Keiley, while it is interesting in the comparison which it gives of results obtained with actual brakes, is of perhaps greater interest to me on account of the fact that it represents at least an attempt to obtain practical brake-curves; that is, it shows an interesting mechanism, whereby one may be able to obtain data giving the coördinate points from which brake-curves actually obtained may be plotted. I stated in my paper just referred to, that it is very desirable that we should be able to obtain some sort of an idea of the geometrical character of a general or typical braking-curve I also stated, and it is well known, that these curves are quite erratic; and yet it does seem as if we might be able to arrive at certain general curves which can serve as types for the braking-curves characterizing different classes of service. The paper of Mr. Parke contains valuable material in this direction, especially in the formula for the coefficient of friction as a function of the speed, which appears in the earlier pages of his paper. Mr. Parke succeeded in analyzing the celebrated Galton-Westinghouse experiments, and he worked out this equation some time ago. I notice with pleasure that he has carried his work a little further, making the formula applicable to higher speeds. Important and valuable are his contributions of facts relating to breaking in general and, in particular, showing the manner in which the friction coefficient changes as a function of the speed; so also are the interesting data which he gives concerning certain stops, and the effect of different conditions on the track friction; and there are many others which it would take too long to point out in detail. I would especially mention the highly lucid and interesting manner in which Mr. Parke has called attention to the tilting effect of the momentum of the car body, and the resulting difference in the pressure applied to the track through the front and rear wheels of the truck; and I would also note the ingenious manner in which he proposes to remedy the difficulty by hanging the brake-shoes at a particular angle, all of which is worked out ingeniously and clearly elucidated in his paper. These constitute data of the highest technical and engineering importance, so that the paper contains material which will last for a long time. The paper will be, I have no doubt, just as useful ten years from now as it is to-day. I think that we are to be congratulated upon having had from Mr. Parke what I consider a classical contribution to the subject of electric railroading in general, and to the theory and practice of braking in particular.

PRESIDENT SCOTT:—A gentleman who is now taking up traction problems to some extent, in connection with an engineering and traction company is Mr. O. S. Lyford, Jr., and he may be able to give us some interesting points in connection with the subject under discussion.

MR. LYFORD:—I have listened with great interest to these papers. I am studying this problem at this time with especial reference to heavy electric traction service; but having gone into the matter only very recently, I am not able to throw any light on it at this meeting. As a previous speaker has said, it would be difficult for any of us to add much to the able paper which Mr. Parke has presented.

PRESIDENT SCOTT:—A gentleman who has given attention to heavy railroad work in various particulars, from both the engineering and commercial standpoint, is Mr. Calvert Townley, of New York, and possibly he can contribute something to our discussion.

MR. TOWNLEY:—I echo, in common with the other speakers, the pleasure which has been felt in listening to the papers to-night. I was impressed with the fact, particularly in reading Mr. Parke's paper, that although the subject is abstruse and contains a number of mathematical formulæ, it held the interest of every one in the room from start to finish. The story has been told in a clear and beautiful way and makes interesting reading, apart from the value of its matter.

Tests were conducted in Boston about two years ago by the Boston Elevated Railway Company, to determine a number of braking and other questions with reference to their equipment. A train composed of three similar cars, each equipped with motors, brakes and all the other paraphernalia, was run up to practically its maximum speed, somewhere between thirty-five and forty miles an hour, and then the emergency brakes were set, current being kept on the motors. The object of the test was to determine what the effect would be first on the motors and the car equipment, and second on the speed of the train. It was found that when the train had slowed down to about twenty miles per hour, it continued at a constant speed, showing conclusively that with each car equipped, it is not practicable to stop a train by means of brakes, unless the power be shut off. This fact is easily demonstrable by a braking-calculation, but at the time named it had not been brought out so forcibly and conclusively, and there were a number of people who differed in predicting the result of the tests.

With brake-shoes placed between the wheels, nearly all brake-dust resulting from the grinding off of the shoes and tires, is thrown away from the electrical equipment. Of course, some of it does fall back on the motors, but in general the tendency is to throw the dirt away. Where the motor frames are run open, this arrangement of brake-shoes is of distinct value in keeping the motors cleaner and assisting toward a less rapid deterioration. With brake-shoes placed outside the wheels, the reverse is true, a great part of the dirt being thrown directly over the motors with consequent objectionable results.

PRESIDENT SCOTT:—Mr. W. O. Gotshall, of the New York and Port Chester Railroad Company, desires to ask some questions of Mr. Parke, and we shall be pleased to hear him.

MR. GOTSHALL:—About a year ago I was associated with Mr. Parke in a suit in which we both gave some expert testimony. He gave at that time a statement of some distances within which trains running at sixty miles an hour and less, could be stopped. I believe they asked him whether he knew anything about the relative distances occupied in stopping a train using the electro-magnetic brake and one using the air-brake. If he can answer that question at this time I would like to have him do so. Another question occurs to me, and that is, what are the relative first costs and subsequent maintenance costs of the electromagnetic brake and the high-speed or quick-acting air-brake? I have been trying to find out for some time the relative effect upon the wheels, tracks and equipment of the internal versus the external suspension of brake-shoes, which Mr. Parke describes, and I have not been able to get it.

I was somewhat surprised to learn that Mr. Townley was of the opinion that suspending the brake-shoes inside would protect the motors. I was in Boston some time ago, and understood that they were of the opinion there was more trouble from suspending the brake-shoes inside, than there was from suspending them outside.

A series of interesting tests was shown to me some time ago between a hand-braked car and a power-braked car, under like conditions as to weights, speeds, etc. The power-brake was an air-brake. The tests were made for entirely different purposes than the one they finally served, They showed very conclusively that the energy-consumption in watt-hours per ton-mile, with the power-brake, was about 12 per cent. less than with the hand-brake. I was very dubious about it and thought there might have been an error somewhere. Subsequently another set of tests was made which showed that the first conclusions were about right. The explanation given is that the higher efficiency of the power-brake is due to the fact that the operator of the car does not run with the brakes set up half the time, as is the case with hand-brakes. A man intending to stop the car, after he has used the power-brake for a week or two, becomes accustomed to it and knows what it will do, and therefore he throws off his power first and then applies his brake; whereas he has the hand-brake partly set up all the time. That was new to me, and probably will be to some others of those present.

Mr. Parke:—I regret that I am unable to give definite answers to most of the questions Mr. Gotshall has asked. One of the first questions was in reference to the distance required to stop a car, at a speed of sixty miles an hour, with the magnetic brake. There have been no tests made with the magnetic brake that I am aware of; that is, no systematic definite tests, under known conditions. that would enable one to say how the stops compare with the high-speed brake. It is manifest, on the face of it, that the stops ought to be better, and much better than with any wheel-brake; because while with the high-speed brake even, the brake-shoe pressure is greater during the early portion of the stop, when the coefficient of friction is low, thereby effecting a compensation, and is reduced toward the end of the stop when the coefficient of the brake-shoe friction rises, the same effect may also be acquired with the magnetic brake. It is a mere question of regulation, and in addition there is also all the braking effect of the track-brake. So I can only say as a reply to Mr. Gotshall at this time, that in a general way it is evident that the stops are considerably better, though it has not been definitely shown what they are.

I am sorry I am unable to give prices. They vary a good deal with the character of the construction. One of the difficulties in exploiting the magnetic brake, is the necessity of applying it to a good many different forms of truck-construction; and that, more perhaps than any other thing, has been the cause of its requiring so much time in its development

In regard to the cost of maintenance of the magnetic brake, I doubt very much whether the latter has been in sufficiently long and extensive continued service for the matter to be determined very accurately.

In regard to the effect of inside-hung brake-beams, I can only answer with respect to the experience upon steam railroads. The effect is very much better, so far as the influence upon the cars and upon the passengers in stopping, is concerned. The surging and shock at the moment of stopping, which result from outside-hung brakes, and also the tilting of the truck during the stop, are almost entirely removed. So far as any ill-effect is concerned, I know of none whatever. The stopping-efficiency of the brake is very much increased, and without any accompanying tendency to wheel-sliding. I know of nothing that has been found in the use of inside-hung brakes in steam railway practice that has been objectionable.

MR. GOTSHALL:—In addition to the other questions I have asked, I would like to ascertain what the relative effect on the equipment would be, considering wheels and brake-shoes, between the high-speed automatic air-brake and the old style of air-brake?

MR. PARKE:—Of course, so far as wear and tear is concerned, it is obvious that a greater brake-shoe pressure is accompanied by greater wear both of brake-shoes and wheels. The wheels will wear down more rapidly in having brakes upon them than in running without brakes although it must be remembered, too, that the effect of rail wear upon wheels is very material. I know that in the early days when it was first proposed to apply brake-shoes to the driving wheels of locomotives, one of the objections which was foremost and loudest expressed, was that the tires of wheels were worn rapidly enough already, running upon the rails, without additional wear from brake-shoes; but when brake-shoes of the Ross type were employed, which wear upon the flanges and the outside of the tread and do not wear upon the portion of the tread that is worn by the rail, it was found that tire-dressing by the brake-shoes was cheaper than turning the tires in the shop, and the wear of the brake-shoes compensated upon other portions of the tire for the rail-wear at the center of the tire.

So far as the use of the high-speed brake is concerned, if any additional wear has been observed, it has never come to our knowledge. You understand that in present practice the high pressure occurs only during the early part of emergency-stops. Of course, if it be used in other kinds of service, where the emergency application is employed for ordinary service-stops, it is possible that more wear would result. I believe, that even should greater wear result, the advantage in increasing the efficiency of suburban service would far more than offset it; but so far as we have any information in regard to it, the use of the high-speed brake has been accompanied by no greater wear and tear, not even of the wheels. The brake-shoes probably wear out somewhat more rapidly, but we have heard no complaint even in regard to excessive brake-shoe wear.

MR. GOTSHALL:—Is there any difference per ton-mile or car-mile between the high-speed brake and the other?

MR. PARKE:—Not in the braking apparatus, that I am aware of. Of course, there is an additional piece of mechanism, an automatic reducing valve, which in the long run requires consideration and attention. It is simply that kind of attention which is given the rest of the air-brake apparatus; it is an additional piece of apparatus to clean and maintain, and it requires very little attention—so little attention, in fact, that it sometimes gets none at all until the ill-effect of getting no attention is observed.

MR. MAILLOUX:—I would ask Mr. Parke if the arrangement of the brakes or the ingenious method mentioned in his paper by which he proposes to get the toggle-joint effect on the front brake-shoes, has been in use for any length of time; also whether it can be used with any form of brake. Practically, that would imply the query whether it is a patented invention owned by some manufacturer or whether it is public property.

MR. PARKE:—I will answer the last question first. As I got up the device, I am sorry to say that it could not be patented, so that it is one of those things of which the public may avail itself. I presume that if I could have patented it and made the railroads pay for it, a good many of the railroads that have not done so would have adopted it. It seems to appear to the railroads when they find they can get something good for nothing, that there must be something wrong about it. I believe it is now the standard form of construction, and has been for some years upon the passenger equipment of the Pennsylvania Railroad. They adopted it some years ago and it has been in regular use on their cars, and has been similarly employed by several other roads. with entire satisfaction. The Pennsylvania Railroad found that they were sliding some wheels with the use of inside-hung-brake-beams at one time. The trouble was due to some mistake in the braking power applied, which was too high; when that was corrected, the trouble ceased. So far as I know, no serious objection to the use of the method has yet been found in the practical experience of a number of years. As to its application to different forms of trucks, so far as I know there is no case in which it may not be applied if the brake-beams can be gotten inside the wheels. There are many cases, especially in electrical construction, where it is impossible to place the brake-beams inside the wheels, without some different arrangement of the motors than usually occurs. With the magnetic brake there is no effort to use a brake-beam across the truck. I did not mention that fact in my paper, and perhaps should have done so; but the magnetic brake on each side of each truck, is a unit in itself. Tie rods, at such points as to be out of the way of motors, connect these units and keep the apparatus from swaying; but there is no brake-beam, so that this form of brake is applicable where the motors occupy positions that would not permit the use of an inside-hung brake-beam.

MR. ELIAS E. RIES:—It would appear on the face of it, that by the employment of magnetism, to obtain the pressure, there would be an increase in the friction between the brake-shoe and rail, over that due to the pressure alone, which is given in the paper as being up to a limit of one hundred and fifty pounds to the square inch. I refer to the increased molecular friction between the brake-shoe and the rail due to the magnetization and independent of the pressure, and I would ask Mr. Parke if he has noticed any such effect. If this effect is present, it would seem an important advantage in connection with the electromagnetic brake.

MR. PARKE:—I will say in reply to the gentleman, that the statement regarding the limit of one hundred and fifty pounds to the square inch, refers to the limit of the magnetic attraction of the shoe toward the rail, in other words, that is the force with which the shoe presses upon the rail. No attempt has to my knowledge been made to determine whether a different coefficient of friction exists under such conditions from that which results from mere pressure, without the presence of electricity or magnetism. No systematic experiments have yet been made with this form of brake to determine its exact efficiency, and this question could only be answered with a knowledge of the efficiency of the wheel-brakes by themselves; then the added effect of the magnetic brake could be measured and the coefficient of friction determined therefrom. This has not as yet been done.

MR. RIES:—Have you noticed these effects?

MR. PARKE:—I do not know that there has been any observation whatever of the frictional effect of the magnetic brake. I have not been informed that there has appeared to be any greater friction between the magnetic brake-shoe and the rail than would be accounted for by the ordinary coefficient of friction with the pressure employed.

PRESIDENT SCOTT:—The subject is open for general discussion.

MR. W. N. SMITH:—One of the most interesting parts of Mr. Parke's truly classical paper is his common-sense proof of the fact that the pressure of the forward wheels is greater than that of the rear wheels. An incident that once came under my observation as experimental proof of this, may be of interest. Any member of the INSTITUTE who has at his disposal an electric car equipped with two motors can try it for himself.

Mr. Parke has briefly alluded to the " back torque " method of electric braking, which consists in disconnecting the motors from the line and throwing them in parallel with each other, with armatures reversed. One motor then operates as a generator and tends to drive the other backward, the combination thus acting as a brake. This as an emergency operation has been well known to those operating electric railways ever since it became the practice to use independent reversing switches for two-motor equipments. I have more than once carried a heavily loaded car and trailer down a 4 per cent. grade by this means, when the hand-brake was so bad it could not be worked. After seeing Mr. Elmer A. Sperry's original electric brake, which was brought out in 1894, I experimented a little on a 21-foot double truck street-car with maximum-traction brakes and one G. E. 800 motor on each truck, and I went through this electric-braking operation without applying the hand-brakes. While watching what was going on underneath the car, I noticed that the wheels of the rear truck would vibrate like the balance-wheel of a watch, revolving alternately backward and forward. One motor of course was bound to overpower the other, but it was always the rear wheels that slipped; and with an empty car no reason was then apparent why the rear motor should carry appreciably less weight than the forward one. Mr. Parke's statement as to the increased braking effect on the front wheels, makes it easy to see why it was always the rear motor which lost its grip and vibrated backwards and forwards.

The electric brake in its disk form, that is the fixed magnetic shoe working against a disk keyed to the axle and actuated by current from the motors working as generators, was first developed by Mr. Sperry and has been used some years. It would be a contribution to this discussion if any one present could tell us something about the operation of this form of brake.

Mr. W. J. Hammer:—As a matter of historical interest, I wish to say that any one interested in the magnetic brake may go to the Brooklyn Polytechnic Institute and there see Edison's 1880 locomotive with a passenger car, and underneath the latter a disk-brake on the axle, revolving between the poles of an electro-magnet. That identical outfit of Edison's 1880 Electric Railroad carried over 5,000 people, and attained a speed as high as forty-two miles an hour. Another interesting historical item is that Mr. Henry E. Walter, at one time chief electrician for the Edison General Electric Company at Schenectady, designed a brake which he called a hysteresis-brake with magnetic brake-shoes acting on the track-rail. When Mr. Sperry read his original paper which was referred to, I called attention to this original work of Mr. Walter, as it seemed to me an interesting development in electric brakes. I saw the system tried experimentally by Mr. Walter in London, England, in the early part of 1892.

President Scott:—The discussions which we have at our meetings now have a greater importance than they have had in the past. Our New York meetings are the fore-runners of a number of meetings which will come a little later. Since our last meeting here, meetings have been held in Chicago, Denver, Cincinnati, Pittsburg and other cities, and the attendance at some of these local meetings has been larger than at the New York meeting. One local meeting has had twice as many in attendance as there are here to-night. In addition to these local meetings, which consider the papers that are read before the INSTITUTE, and which also have the benefit of the discussions which take place here, there are other meetings held in colleges and technical schools. I had an interesting conversation this evening with some gentlemen who are present, about our recent work along these lines, and I am sure we would like to hear of this work in the schools and colleges, in addition to hearing further discussion of the subject of the papers. I call upon Prof. W. S. Franklin, of Lehigh University, to address the meeting.

PROF. FRANKLIN:—Mr. President, I have been approaching the point of rising to discuss the papers of this evening, and with your permission I will do so now, inasmuch as my colleague, Prof. Esty, is responsible for the good work which is being done at Lehigh, along the lines of local meetings, to which you refer, and is here to speak for himself on that subject.

My mind has taken an ultra-scientific turn during the discussion, and the assurance I need in making the attempt to unburden myself I received before coming to the meeting by reason of a very satisfactory conversation I had at the dinner table with Mr. Townsend Wolcott. He and I got talking of Maxwell and with a degree of mutual understanding that was a delight.

The matter is simply this—and I do not think it has ever been pointed out before—the real limitation of quantitative mathematics in engineering. We are all familiar with the old problem of the flow of water through a pipe. Nothing in the range of practical hydraulics has been subject to more elaborate experimental study and no formula in hydraulics has been more widely discussed than the formula expressing the relation between the flow of water and the loss of head. I will say flatly that there is no such formula nor any possibility of such a formula.

We deal in physics with two distinct classes of phenomena, to both of which we attempt to apply indiscriminately the notion of quantitative relation or correspondences.

First, are those phenomena, if we may indeed dignify them by the name of phenomena, which are associated with states of equilibrium; and second, are those phenomena or real happenings, which are associated with irreversible processes. As an example of the first class, consider a quiescent gas in a closed vessel. In this case there is an absolutely definite relation between the temperature of the gas, its pressure, its volume, its density and so on; quantitative correspondences do in fact obtain.

As an example of the second class, consider a gas which is streaming through an orifice out of a small chamber into a larger one. In this case the gas has no definite temperature, no definite volume, no definite pressure and no definite density; the changes which it undergoes are strictly infinitely manifold; a complete specification of these changes would involve an infinite multiplicity of details, and these details would not be approximately reproduced if the process were repeated under conditions deviating infinitesimally from those obtaining previously. The fact is that ***infinitesimal variations*** of conditions may produce in general ***finite variations*** in the consequent trend of the dependent phenomena, and this failure of the principle of limits means absolutely the failure of all quantitative correspondences, except such as may be expressed statistically.

As another example of this second class of phenomena consider the flow of water through a pipe. Every one who has observed this phenomenon with his eyes (not through the mediation of an algebraic formula) has no doubt noticed that it is a phenomenon which exhibits in its minute details an utterly irregular succession of fits and starts. Thus, a pressure-gauge connected to a pipe through which water issues from a tank, shows irregular and rapid variations of pressure. The only vigorously logical quantitative study of the flow of water through a pipe, consists of a long series of repeated determinations of discharge under conditions which are as nearly as may be constant, and the result would be *a certain definite **mean** discharge, and a certain **probable** deviation from this **mean***, that is, the results strictly speaking would be expressed statistically. There is not and cannot be a formula for expressing the relation between head and discharge. I wish my remarks to be taken suggestively, for I do not at present know precisely how to state fully what is in my mind, and I may be pardoned if I state a general conclusion, namely, that the present methods of physics do not and cannot serve to reduce the complex real phenomena, even of inanimate nature, to their ultimate elements. The phenomena of meteorology, for example, can never be systematized by present methods of physics; the principle of correspondence, or as it is sometimes called, the principle of cause and effect, in view of what I said a moment ago about finite variations in the phenomena resulting from infinitesimal variations in conditions, fails.

Now, in regard to friction, I believe (in fact, my understanding of the case amounts to much more than a belief), that in this also strict quantitative correspondence fails; there is no such thing as a coefficient of friction, nor any such thing as a functional relation between the force which pushes two sliding surfaces together and the force which is necessary to produce sliding. The whole matter is a statistical one and the scientific method for accomplishing the utmost in the braking of a train would be, first, to study the mean functional relations between ***pressure*** on brake-shoe, *velocity*, *temperature*, *time* and ***retarding force***, and to determine the *probable variation* from this mean; then, second, to devise a brake-mechanism which would cause the pressure on the brake-shoe to vary in such a manner with velocity, temperature and time, as to make it at each moment during the stopping of a train equally improbable that the frictional force might start the wheel skidding; the exact degree of improbability being open to choice and really, if one were to take the pains, determinate.

PRESIDENT SCOTT:—Prof. Franklin has called attention to another method of considering some elements with respect to the subject before us, and just as many different avenues of thought or consideration as we can indicate here in our preliminary discussion, just so much do we open the lines of discussion which may be pursued in the local meetings which are to follow. Prof. Franklin reminded me of a young man who had not had a particularly extensive mathematical training, who attempted to plot graphically the monthly sales of a company. As the accounts varied erratically month by month, during the year, he was not able to get a regular curve. He was much distressed as he thought a curve should be nice and smooth. He was trying to apply a mathematical method to something which did not admit of that sort of analysis, expecting to get a particular kind of result. His method was quite similar to that which Prof. Franklin has pointed out, wherein we sometimes try to apply certain physical laws to cases where they do not quite apply. We should now be pleased to hear from Prof. William Esty, also of Lehigh University.

PROF. ESTY :—President Scott has suggested that perhaps a few words about our local section at Bethlehem might not be amiss. When the proposition to have local sections was inaugurated by our President, I for one felt greatly pleased. I had hitherto supposed that the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS was American in name only, and that it should properly be called the New York Institute of Electrical Engineers. I supposed this simply because I did not happen to live in the neighborhood of New York, and being out on the prairies felt beyond the reach of the INSTITUTE's influence. But now that I have moved nearer New York, approaching it, you might say, as a limit, I realize more than ever the benefit of living nearer the electrical centre of gravity. Hence, for those more distant members of the INSTITUTE, I can forseee the great advantage they will derive from this new policy. I can see, for instance, in the case of our local section, from the interest manifested from the start by the students, it is going to be a big thing for Lehigh; and I am sure by its results it will prove beneficial to the INSTITUTE, perhaps in a small way and I hope in a larger way. We have as a nucleus for our local section the electrical engineering society at the University. The seniors and juniors are active members and the sophomores studying electrical engineering are admitted as associates. We have some thirty-five or forty of the electrical engineering students in the club. We have already held three meetings, and have had a number of interesting papers presented by these students, with discussion afterwards, and you have no idea how stimulating such a reading of papers is with discussions on them, especially when the meetings are held immediately after the regular New York meetings. If things go on as they have started, and I think the enthusiasm will keep on growing, we may be able to send in at the end of the year a substantial addition to the membership list of the INSTITUTE. If you realized how much this new policy was doing for Lehigh and other universities I know of, you would feel disposed to congratulate President Scott on his far-reaching policy in extending the influence and value of our great organization.

MR. C. O. MAILLOUX:—I was very much interested in the remarks of Dr. Franklin, not only in their application to these two papers, but to other things connected with railway work. I wish to state that Mr. Parke himself has done what he could to remove the fallacious opinions which exist about brake-shoe friction and its variability under different conditions. I remember very well that his investigations of the subject, published in serial form in the *Railroad Gazette*, constitute another valuable contribution to the subject of engineering. Dr. Franklin has shown us the physical aspects of the problem, and he has given us reasons why we should not expect constant or uniform results under these conditions. We already knew by experience that we could not expect such results. Dr. Franklin's remarks will find application in connection with another important detail of the problem of electric traction, namely, that of determining air-resistance. As we know, there are few experiments which have been made to determine the increase in train-resistance, at high velocity, due to the resistance of the air, but even the few experiments made seem to indicate a great discrepancy between the results attained. if we measure the train-resistances at different speeds, in given units, such as pounds per ton. It seems to me that the application of Dr. Franklin's remarks is obvious here, because in dealing with air-resistances we have a case where eddies, air-currents, etc., in a fluid substance, air, introduce fluctuations and variations which are exactly analogous to those in the fluid substance water, in the hydraulic example cited by Dr. Franklin. Dr. Franklin's contribution to this discussion points a useful lesson in physics, and it may give us a key to a mystery or puzzle, the solution of which is much needed.

PRESIDENT SCOTT:—Several of the gentlemen this evening have referred in complimentary terms not only to Mr. Parke's paper itself, but to his courtesy in preparing and presenting it; but that credit is not due wholly to Mr. Parke, as I will set forth. It may be remarked that the Committee on Papers enters upon an unknown field when it selects a certain subject, and then endeavors to fill up its programme. In this present case, if I recall rightly, some half a dozen or more papers were projected for exploiting different phases of the braking problem and the methods of solution. The Chairman of the Committee asked me if I would not call upon an engineer of the Westinghouse Air Brake Company for a paper. I sent a note to Mr. H. H. Westinghouse, of that Company, setting forth in a general way what was wanted; but the way in which I put it seemed to be a little too general. A conference with Mr. Westinghouse was arranged, and I called at his office one day when I was in New York. I had armed myself with a copy of our monthly Announcement and one or two volumes of our monthly TRANSACTIONS. After looking them over, his first remark was: " Why, your papers seem to be of a pretty high grade; you want a paper of some weight, and I think the best we can do is to have Mr. Parke prepare a paper, as he can give one having the calibre you need for the INSTITUTE." So it is really due to the judgment of Mr. Westinghouse that Mr. Parke has given the main contribution to our programme this evening; and as Mr. Westinghouse is here, I will ask that he say a word or two.

MR. H. H. WESTINGHOUSE:—Mr. President, I do not think I would have said anything if you had not put the matter in just the way you did. It is quite complimentary for you to say that I recognized the character of papers required by the INSTITUTE and knew of the man who could write a paper for this evening. I am pleased to know that the paper which Mr. Parke has read has been so acceptable. I cannot add much to the discussion of the subject, except perhaps a few words along the lines of Prof. Franklin and Mr. Mailloux. I think it is true that the subject of braking is a sort of indefinite proposition, that the coefficient of friction is rather a flitting bird, and it is hard to locate its tracks definitely. Mixed up with the proposition, also, is the matter of the personal equation of the users of the apparatus. I was thinking of this phase of the question during the time when Mr. Parke was asked as to what had been done, and whether some definite results or data were available in regard to the magnetic brake. An explanation is perhaps due as to why something better in the line of comparative efficiency could not be furnished, and, in explanation, I may say it is on account of a very uncertain element in the question, and that is the man who operates the brake. As a matter of fact, we feel that we have a good apparatus in the magnetic brake, that it contains excellent elements as explained by Mr. Parke, and has an operative efficiency in advance of anything heretofore used; but, as we are manufacturers, the practical aspect of the case is one which always interests us. We have learned that the element of the man who works the brake is so everlastingly combined with the mechanism that there is no use in drawing conclusions until that factor has been tried out. Consequently, when our experiments, tentative as they were, indicated that a generally high efficiency was obtainable, we sought opportunity to put the brake into a wide general practice in Pittsburg, as we felt the necessity of finding out whether the intelligence with which the brake could ordinarily be operated would be such as to produce the effect that the mechanism itself seemed to assure. To determine that point requires considerable time; a few experimental runs, a few satisfactory stops, would prove nothing. We do not contend that the brake is entirely removed from the liability of accident; it is beyond question that there will be accidents due to the failure of the cars to stop in sufficiently short time to prevent collision. Of course, the causes which lead to collisions are many and various; but in every instance where a new brake is employed, when an accident occurs, the explanation always reported is that the *brake failed;* and, therefore, it is necessary that it should be tried long enough and under such widely varying conditions, that those who operate it shall acquire sufficient confidence in it to apply their common sense to causes of trouble and accident, and to determine whether it was the failure of the apparatus or the conditions under which the apparatus was used, which brought about the trouble. Therefore, I may say that the reason why there is no more definite data available now is largely disclosed by the fact that we have not thought it worth while to go after it and get it, until we were assured that the device was in a fair way to receive practical application. I may say, as Mr. Parke has explained, that, so far, everything is moving well, and that we hope at some time in the future something more satisfactory may be presented in the way of data.

PRESIDENT SCOTT:—If there is no further discussion the meeting will adjourn.

Meeting adjourned.

DISCUSSION COMMUNICATED AFTER ADJOURNMENT BY W. S. FRANKLIN.

I beg leave to call the attention of the members of the INSTITUTE to a discussion which will perhaps help to convey my meaning in the statement I made regarding the failure of the principle of limits. If an infinitesimal variation of condition can produce a finite variation in results, it is evident that a finite variation of conditions might produce a stupendous variation in results. In *Science*, Vol. XIV., p. 496, September 27, 1901, I pointed out in detail how this principle may enable us to control meteorological phenomena, and I pointed out also just what kind of knowledge we must obtain in order to realize this possibility. In this discussion I mentioned perhaps too indulgently the smoke-ring cannonading of Burgomeister Stiger, which had attracted considerable attention during 1900 and 1901.

COMMUNICATION AFTER ADJOURNMENT BY R. A. PARKE.

Having had no opportunity to examine Mr. Keiley's paper before it was presented at the December meeting, I was not prepared at that time to call attention to one or two features which appear to me to call for a word of caution. Mr. Mailloux referred to the difficulties he had discovered in making any general use of formulæ for train stops, in his discussion of Mr. Keiley's paper; but it may prove advantageous and useful to point out more specifically the reasons why such formulæ are unreliable beyond the very narrow range of conditions from which they appear to have been derived.

It will be noted, first, that, in deriving the formula, it is stated on page 21 that, after the car was brought up to speed, the speed

" was found to fall off at the rate of about 0.16 miles per hour per second." It is, of course, a well-recognized fact that train resistance or car resistance is a function of the speed, and any formula which contains a constant train resistance can be applicable only to conditions which include the speed to which such resistance applies. Also, the distance run during the nterval that the brakes were applied depends, in the formula, upon the initial speed at the instant of application and a constant retardation R, which is designated at the " rate of braking, in miles per hour per second, from setting of brake-shoes to stop." This quantity R is, in reality, different for every different speed, and, if determined from stops made from a speed of from 15 to 18 miles per hour, the stopping distance given by the formula would be very much too great for a speed of 35 or 40 miles per hour.

The formula for the total distance (on page 23) contains a constant quantity N; that is, one independent of the speed. The use of the constant in such a formula necessarily introduces error in the lengths of stops computed for low initial speeds, which increases as the initial speed becomes lower. It will readily be seen that the formula would require that the car should still run a definite distance if the brakes were applied when the speed is practically zero. Obviously, no formula of general application for stopping distance in terms of the speed can include a term containing the zero power of the speed.

These statements are not intended to imply that arbitrary formulæ of this kind are without practical utility. Such formulæ are very useful and even necessary in reducing the length of stops from known speeds to that of a standard speed, not greatly differing from those from which the test stops were made. Where competitive tests of different brakes are to be made, under definite conditions, for stops from a given speed, the actual stops will generally be made from speeds near, but usually a little more or less than that which it is desired to realize, as it is extremely difficult to attain the exact speed desired at the time that the brakes are applied. It is then necessary, for the purpose of comparison, to reduce the actual stops to the corresponding distance for the required speed, and this may be done very satisfactorily, and with but little error, by the use of such formulæ.

Years ago, I found considerable satisfaction in the discovery of a formula of the same general character as that given in Mr. Keiley's paper—except that it included no constant term. It seemed to correspond very satisfactorily with a considerable number of train stops under known conditions, and it was not until the formula was applied to considerably greater speeds that I became very suspicious of it. I then analyzed the matter very carefully and discovered the difficulty of obtaining a formula applicable to a wide range of conditions. Where train resistance and grade influence are omitted, I found a logarithmic expression for train stops, which may be employed for any initial speed;

Train resistance is so insignificant in comparison with that of the brakes, that suitable provision may be satisfactorily made for it in the constant coefficients of the formulæ; but the effect of grade is quite a different matter, and no general expression, short of an infinite series which does not satisfactorily converge, can be found to apply satisfactorily under the various conditions of regular practice. A complicated and cumbersome approximate expression, involving the cube of the initial speed, was derived; but a sufficient number of stops under sufficiently different known conditions was not available to determine satisfactorily the constant coefficients, and the formula would have been too complicated and tedious in its application for any general use, if the constants could have been determined. Therefore, while the formula in Mr. Keiley's paper may serve well for comparison of the performance of brakes at a given speed and under specific conditions, the absence of any suggestion in the paper that its usefulness does not extend to other conditions and speeds has led me to offer these words of warning to those who may be seeking some simple means of finding the stopping distance of cars or trains from various speeds, as such formulæ are not even approximately reliable under conditions materially different from those under which the constant coefficients were derived.

It appears to me that Mr. Keiley displays considerable courage in attempting to determine the commercial value of different brakes in even a single kind of service. The problem is a most intricate and illusive one, and the reduction to a matter of dollars and cents of the various elementary items entering unto the sum total, to be charged against each brake must, in any case, become a very complicated and difficult matter. For instance, the personal element of the operator of the brake is a most important one, and is so uncertain that the most efficient and economical brake may be caused to take almost any rank from the best to the worst.

Wheel sliding, for instance—which I do not find enumerated under the features of controlling importance in the paper—should condemn a brake possessing practically all the other virtues, but subject to that failing. Hand brakes of high efficiency are especially subject to this evil; because, if adapted to the use of men of moderate strength, wheel sliding is almost certain to result under the manipulation of men of greater strength, unless the greatest care is exercised in operation. In a certain series of competitive tests, a hand brake of especial design attained the most satisfactory results of any of a number tested. In these tests, the brake was operated by a picked man, whose discretion enabled him to make the most satisfactory stops without sliding wheels; but the daily pounding of wheels with worn-flat spots under a large proportion of the cars equipped with it upon the road, clearly indicated that, in the actual service of everyday use, the same brake was a most expensive luxury, in the hands of the average operator.

Also, in reference to the matter of accidents, the rating of a brake may be made or ruined by the character of the men employed, or by the price which a company is willing to pay its employees. Moreover, a brake might be in regular and extensive operation for a number of years without any accident, and so the charge against it in the accident column of Mr. Keiley's method, at the end of that time, would be nil; but the next year an accident might occur (and perhaps under conditions or from causes for which the brake ought to be held in no wise responsible, if the operator did not find it necessary to exculpate himself), of such magnitude that the average annual cost of accidents for all the previous years would thereby become considerable. It might easily occur, during a limited period of observation, that an inferior brake would show a clear accident record, while a superior brake, more simple and sure of operation, would be subject to a heavy charge for one or more accidents, which, if the actual facts and true conditions were all known, could not possibly be attributed to fault or characteristic of the brake or of its operation. It would therefore hardly seem that any figures of this kind could be accepted as really significant of the commercial value of any particular brake, unless made up from statistics from a considerable number of roads, operating under the various different conditions of practice, and extending over a long period of years.

Discussion at Pittsburg, January 5, 1903.

Programme.

Mr. C. F. Scott, Introductory Remarks.

Mr. N. W. Storer abstracted Mr. J. D. Keiley's paper, "Some Brake Tests and Deductions Therefrom."

Mr. R. A. Parke presented his own paper, "Railroad Braking."

Mr. C. Renshaw abstracted the New York Discussion.

Upon motion of Mr. P. H. Thomas, a vote of thanks was unanimously extended to Mr. Parke for his very able and instructive paper.

Mr. Parke took exception to some of the general conclusions drawn by Mr. Keiley in his paper and stated that he had written a letter to the Institute setting forth at some length his views on the subject of this paper.

Mr. F. C. Newell stated that all of our data in regard to braking had been obtained from tests made under steam railroading conditions but that electric traction had introduced many new problems. Mr. Newell said he thought the great majority of accidents which occur in electric traction are due to the inferior grade of operatives employed, and that unless a more intelligent class was obtained the best appliances that could be devised would not be sufficient to prevent many catastrophes.

Mr. Storer stated that the coefficient of friction could be very accurately measured by driving electric cars with brakes applied. Observations of the pressure applied to the brake and the power consumed by the motor would enable accurate calculations to be made.

Mr. Calvin W. Rice called for original papers from members of the Local Section, to be presented before the Section at future meetings.

Mr. Scott called attention to the style of Mr. Parke's paper, saying that it was " a beautiful story; an example of the poetry of common things."

Discussion at Chicago, December 30, 1902.

Local Honorary Secretary R. H. Pierce in the Chair.

The papers discussed were: "Some Brake Tests and Deductions Therefrom," by Mr. J. D. Keiley, and "Railroad Car Braking," by R. A. Parke. The first paper was read by Mr. B. J. Arnold, and the second by Mr. T. P. Gaylord.

At the conclusion of the reading of Mr. Keiley's paper, Mr. Arnold said: I think this is a very interesting paper, but it is more useful as a matter of reference than for discussion, unless one is a little more familiar with the conditions under which the author worked.

At the conclusion of the reading of Mr. Parke's paper, Mr. Gaylord said: Any method of electric braking requires that special attention should be given to the capacity of the motors applied to the car. I know of a number of cases of trouble from motors installed in cars using electric brakes, due to the fact that the motors were furnished on the supposition that they would have their usual relaxation from work during the periods of braking and stopping; but with the use of electric brakes the motors do not derive the same advantages in cooling off. In some instances this will make quite a difference in the size of the equipment to be used.

Mr. J. R. Cravath:—The question of rapid-service stop-braking on interurban equipments has not, apparently, been a very serious one on most of the interurban roads that have heretofore been installed; at the present time the matter is being agitated, and I know of at least one road where the ordinary service stops on the contemplated schedules will call for something that is of the nature of an emergency stop. Then comes the question of getting the same kind of performance out of an ordinary straight air-brake that you get out of a Westinghouse automatic high-speed brake. Of course, most interurban cars are equipped with straight air on account of its simplicity, and the greater ease with which the motorman can handle it. I believe that on the road which I have in mind there was some intention of accomplishing the same results as with the Westinghouse automatic high-speed brakes, by educating the motorman to start in with a very heavy brake application at the higher speeds, decreasing it as the speed fell off. This will require judgment on the part of the motorman regarding the pressure to be used at the first application, and the rapidity with which it should be decreased. However, a motorman with a straight air-brake, such as is used on interurban cars, should always use judgment, for the full storage tank pressure generally carried is sufficient to slide the wheels.

There is another matter closely related to brakes and braking problems which has not been previously referred to to-night. Some of us have recently seen apparatus that is being exploited for increasing the traction between wheel and rail by magnetism.

Some of the tests seem to be very promising. Of course, if it is possible, with a reasonable expenditure of energy, greatly to increase our coefficient of friction between wheel and rail, it has a very important bearing on braking, especially with a slippery rail.

MR. PIERCE:—Have you any data regarding the supposed increase in the coefficient of friction obtained by this means.

MR. CRAVATH:—I believe that the people who are exploiting this device cite tests on a 15-ton motor car at Seattle, on which it was claimed that with an expenditure of 2½ h.p. in electrical energy the tractive effort, before the wheels began to slip, was increased 350 per cent. One peculiar thing about it is that the traction does not fall off in the same ratio after the wheels begin to slip, as it would if the magnetic device were not in operation.

MR. PIERCE:—The wear on the wheels would be correspondingly bad, I suppose.

MR. GAYLORD:—Do you know whether any experiments have been made as to the effect on the bearings?

MR. CRAVATH:—No; I do not know anything about that.

MR. ARNOLD:—If I recall the matter correctly, Mr. Ries, of Baltimore, discussed that thing pretty thoroughly about ten years ago. He got up some kind of device similar to this. In fact, I do not see anything very different in principle between Mr. Ries' scheme and the scheme just referred to. He simply passed a current through the wheel and rail and back through the machine, causing magnetic adhesion between the wheel and rail. That scheme has not revolutionized anything yet, and I think the matter was dropped. This device referred to to-night may be a little different, but the principle seems to be the same.

MR. PIERCE:—I also remember some experiments having been made some time ago. I do not know that they are the same ones as those referred to by Mr. Arnold; but there was a claim made that a current passing into the track of an ordinary system such as is in common use, caused a certain amount of adhesion between the wheels and the rails. The current passing through the wheel would not magnetize it. Did he have a winding, Mr. Arnold?

MR. ARNOLD:—I do not recall the facts very clearly, but I remember he had us somewhat excited; however, it did not amount to anything. I know he passed a current through the wheel and rail. How he brought it back I do not know, but he claimed an increase of friction between the wheel and rail. But I think the amount of energy spent to do this, and the maintenance, will more than offset its advantages.

MR. CLARK:—I do not know whether any of the gentlemen here have seen this device or not. Some models of it have been on exhibition in Chicago in the Rialto Building. It certainly seems very effective. We watched the car climb a grade that it couldn't possibly have climbed unless aided by that device. When you take hold of the car you can hardly hold it back. I do not know whether the device is still on exhibition or not.

Their idea is to put them on locomotives, and when they encounter a steep grade, to apply the magnetic circuit.

Mr. Pierce:—I have not seen this device, but I received a printed invitation to examine it; however, after having examined a full line of similar articles, I thought I would not take time to look at this one, and sent one of my assistants instead. He came back very enthusiastic about it.

Mr. Cravath:—Of course the efficiency of any device of that kind depends a good deal on the length of the magnetic circuit.

Mr. Arnold:—There is no doubt but that it will make the wheel stick to the rail better than if there were no current passing through; the question is, however, how much it will cost you to get the device and how much you will gain by it.

Mr. Clark:—That is a matter of dollars and cents, but when you consider the question of the technical interest, there is no doubt that in turning on the magnetic circuit, you are increasing the traction considerably. That little car could not go up the hill without that device, and with the device it climbed the hill very easily and was able to pull a considerable additional load.

Mr. Eugene B. Clark:—One point of interest that has occurred to me in connection with the magnetic track braking device, mentioned in the latter part of Mr. Parke's paper, and which I was discussing with Mr. Gaylord just before the meeting was called to order, was the question of how much power is supplied by the motors when they are acting as generators. Mr. Gaylord told me it is a very small amount. I might mention an instance that recently came to my attention. The problem of braking the trolley of an ore-handling machine was before us. The trolley weighed about 140,000 pounds and traveled about 1,000 feet a minute across the bridge of a crane about 100 feet in the air. The bridge was about 500 feet long. We took every possible precaution to produce the most effective braking we could devise, we used air brakes and provided the motor brake, consisting of the brake controller, which converts the motors into generators. We also used a hand brake, and besides that, at the ends, a buffer device. We considered that the most effective part of the braking was that done by the motors and that that part which was due to the effect of the disc, or whatever part might be supplied in place of the disc, was of comparatively small importance. Acting upon that supposition, we did not provide anything except straight resistance in the motors; therefore, we simply converted the motors into generators and loaded them to stop the motion of the car. That was very effective—in fact, too effective. It would not take hold until a certain point, and when it did take hold it did so vigorously. One disastrous result which we thought was due to this cause was the breaking of the axles. We designed an axle that appeared to be strong enough, but we had to enlarge it, and then enlarge it again, and even then the axles would break. Now, I would like to know if it is a fact that the same experience has been met with before in braking street cars; do the axles break?

MR. B. J. ARNOLD:—I think the chief objection that has been brought against electric brakes that act upon the clutch principle is the increased size that the motors must have in order to stand up under the work, since they are working all the time, as Mr. Pierce has pointed out and as others here have mentioned. I have never heard of the axles breaking from that cause, although they might have done so, but of course axles break for other reasons. In hilly countries axles are more liable to break than they are in flat countries. It might be that the axles break more on that account than from the magnetic brake.

MR. T. P. GAYLORD:—I am somewhat familiar with the situation in Pittsburg, where conditions with respect to grades are rather severe. As Mr. Arnold has said, the breaking of axles is largely due to mechanical conditions rather than conditions of load on the motor acting as a generator. As to the amount of energy developed in a motor, I understand that in the Newell brake system the energy derived from the motor acting as a generator is just about sufficient to compensate for the energy stored in the revolving elements of the motors and the truck wheels. In other systems I think, perhaps, the amount of energy taken from the motor is considerably more.

MR. CLARK:—It is to be noted in the case I mentioned, that we worked on the assumption that the principal part of the braking was due to the load on the motors. It is not at all unlikely that we were wrong in that assumption. Of course, under such conditions as we were operating, all of the work was done in the motors, and therefore the load on the motors was considerable. There was no braking anywhere else.

MR. PIERCE:—In the use of this system where the current generated in the motors acts on the magnetic brake, how much would that increase the size of the equipment, in ordinary practice?

MR. GAYLORD:—It is difficult to make any general statement; it would vary with every different installation, depending on the frequency of stops.

MR. CLARK:—I can say that we found no difference, as far as we could determine, in the temperature of the motor, whether we were using the motor brakes or not.

MR. PIERCE:—Was the motor acting at a low voltage during the time it was working on the brakes?

MR. CLARK:—Oh, yes. There was probably considerable current, but only for short periods of time. We had an air brake which could be used.

MR PIERCE:—Are you referring to this particular case?

MR. CLARK:—Yes; the particular case of the ore-handling machine. It seems to me that is of interest as a bit of evidence showing that one cannot depend upon the belief that I think is quite prevalent among those who use this method of braking, that the principal part of the braking is in the motor.

MR. PIERCE:—I notice in the paper describing the air brakes, attention was called to the fact that as these brakes were originally installed, the valves acted slowly, so that the brakes were set on the last car considerably later than on the first car; but in the quick-stop, automatic arrangement here described the action is very much quicker.

I notice it said in the paper that the power to be given these valves was transmitted as rapidly as sound. It occurred to me, in reading this paper, that that was not a very great speed at which to transmit this power; that would only be equivalent to about 1,100 feet a second. On a long train, going at a very high rate of speed, the time required to transmit the signal for down-brakes would be from one-half second to one second between the action of the valves on the front car and the last car, and in extreme cases there might be a difference in time which would correspond to a car length in distance. I think it was in 1886 that some tests were made for the application of electricity to operate the air valves, so they were operated simultaneously on all cars. These were tests that the Westinghouse people participated in, and I believe they soon afterwards became owners of the patents. I think that is the last I have heard of the matter. I do not know whether the Westinghouse Company has ever used that device or not. I remember there was a lever by which the electricity was thrown into a device operating the valves, and they all operated simultaneously. The electricity was provided by storage battery. I presume the gentleman who wrote this paper was familiar with what was done at that time, and what has been done since. I should like to know if any one here is familiar with that subject. It seems to me we should get the same result as we do with the multiple-unit system, where we not only accelerate on all the cars, but the acceleration starts at the same instant. If we could start the retardation on all cars at the same time, it would be of great advantage.

MR. ARNOLD:—I was a guest of the Westinghouse Air Brake Company during the time those tests were made. A good many railroad men were invited at that time to witness those experimental air brake tests. It was in 1887. They made some tests between St. Paul and Minneapolis on the Northern Pacific road. and made several runs at various speeds and various applications; then, after making these runs, they showed how rapidly they could stop the train, and how quickly they could pile us up in the ends of the car, if they did not use the quick-acting brake. They finally stopped the train and let us stand along the track beside the train, near the last cars. Then we watched the locomotive, the whistle was pulled the instant they applied the brakes and we could see the steam come out of the locomotive. The brakes on the rear cars would be applied before the sound from the whistle reached us. It showed that the brakes acted more rapidly than sound would travel. I saw that experiment several times.

It is a fact that about that time, or soon after, this electrical brake came out, and it was acquired by the Westinghouse Company, but for some reason they have not developed it. But I understand the fact is, the electrical device which Mr. Pierce spoke of did the work more satisfactorily than the air, but it introduced additional complications that were not really necessary, and because air did the work practically well enough, they have continued to use air.

THE ENGINEER OF THE TWENTIETH CENTURY.

BY CHARLES F. SCOTT.

Response to a toast at the Twenty-fifth Anniversary of the Engineers' Club of Philadelphia, held at Union League, Saturday, December 6, 1902. The invitation to be present at the Anniversary was extended to Mr. Scott as President of the Engineers' Society of Western Pennsylvania and as President of the AMERICAN INSTITUTE OF ELECTRICAL ENGINEEBS.

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GENTLEMEN:—It is significant that the response to this toast is assigned to the representative of the Engineers' Society of Western Pennsylvania. This society represents the engineers of Pittsburg, the city above all others pre-eminent in its industrial and engineering works in the country which is assuming the industrial supremacy of the world. The products of Pittsburg owe their inception to the inventions and designs of the engineer; under his supervision they are manufactured; and in turn they become the materials which other engineers employ in the construction of buildings, railroad and prower plants throughout the whole world. This is the age of steel; Pittsburg furnishes the steel. This is the age of electricity; she produces the largest dynamos. The tonnage of Pittsburg's railways far exceeds that of New York City. The tonnage of the Pittsburg harbor, notwithstanding shallow bottoms and low bridges approximates that of the New York harbor. Industrial Pittsburg! of the engineer! by the engineer! for the engineer!—typical of the present, significant of the future! Do you ask me to portray that future? I ask you to look back fifty years to the time when the first railroad bridge across the Allegheny built against the protest of hack drivers and sympathetic citizens, brought together the track from Ohio and the track to Philadelphia; it brought them together, but it did not join them; for the State legislature had ordained that the gauges of the tracks should be different, in order to prevent domestic cars from wandering too far from home. Compare conditions then with those now. Note what the engineer has done since some of those present reached middle life. Who will venture to predict what we young men may see before we become old? It is with pride that I see how my own city—Smoky City of the Keystone State, the city of engineers and of industry—is growing in influence. A week ago a Philadelphia paper quoted a multi-millionaire thus: "Pittsburg instead of Wall Street must be considered hereafter as the potent factor in the continuation of our national prosperity." When money rates go up in Wall Street and wage rates go up in Pittsburg simultaneously, it is the industrial thermometer which most truly indicates the real prosperity. ENTER ENGINEER: EXIT SPECULATOR.

It is significant also that the reponse to this toast is assigned to the representative of the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS. This organization represents the electrical engineers of America—the country above all others pre-eminent in electrical activity—at a time when its applications are making this the age of electricity. For a retrospect of general engineering we appeal to the memory of men past middle life; but the electrical awakening is within the easy memory of us all.

Electrical work is seldom independent. It does not stand alone, complete in itself. Electricity is usually an instrument, a means to an end. It is not energy derived at first hand from electricity which enables the car to move and the crane to lift a weight. It is power derived from the engine, which happily can be transmitted by electric wires better than by shafts or ropes or belts. It is because electricity is primarily an agent, a means, that its applications have been so diversified, so extensive, and so far-reaching in their effects.

The telegraph, the cable, the telephone have had a profound effect upon political, commercial and social affairs. The applications of electricity bring the evolution of new methods as well as the revolution of old ones. It is a new instrument which has given to the whole world a new method of doing things.

The electrical engineer follows the new gospel, the gospel of service. His mission is helpfulness. Through his aid the mining engineer lights his mine, drives his fans and pumps and drills, and conveys his product. Through his aid the mechanical engineer has modernized the machine shop by the electric crane and by motor-driven tools, which increase output and reduce cost. Through his aid the railway engineer has replaced the horse-car by the people's automobile, which for a few cents will carry anybody from city to suburb more quickly than it was possible by any means at the command of even the millionaire a dozen years ago, and that, too, with the added comforts of warmth and light. Through his aid a new realm is opened to the chemist in the field of electrochemistry. Through his aid the engineer of plant life, the farmer of the west, transforms the desert into a garden by motor-driven pumps and the distant water power. Through his aid the engineer of human life is given a new sight to penetrate the living body and a new stimulus to excite the inactive muscle. Through his aid the luxuries of yesterday have become the necessities of to-day, and the impossible has become the commonplace.

The great discovery of the nineteenth century was *coöperation*, the effectiveness of concentration, the efficiency of largeness. Compare the old days of the hand loom in the home, of the shoemaker at his bench, of the individual oil well and coal mine, of the small railroad and of the small factory—compare these with modern methods, pregnant as they are with unbounded possibilities—possibilities of good and possibilities of evil; of good, because the engineer has provided the means for doing the world's work far more efficiently; of evil, because the social, the industrial, the commercial systems have not kept pace with the advance made by the engineer, but are still tainted with injustice and selfishness.

The tendencies of the nineteenth century projected into the future, reveal in dim outlines at least, the engineer of the twentieth century. He is to deal with large affairs in a large way. He is to be closely related to every department of modern life. He is to become a chief factor in adjusting and operating the intricate mechanism of a new civilization. He is to advance to administrative positions for which his knowledge and his training peculiarly fit him. Note present examples. At the head of the Pennsylvania Railroad, directing its vast affairs in the present and planning to meet the demands of the future, is an engineer surrounded by engineers—President Cassatt. At the head of the interests with which I am connected is a man, successful as organizer and manager and financier, a genius in his foresight, but first of all an engineer, George Westinghouse. Sound judgment, breadth of view, integrity of character, the ability to understand and to control men as well as matter, and to direct human forces as well as physical forces, are essential to the engineer of the future. A recent event which has aided in bringing America to pre-eminence is the victory of our navy. A naval battle is a contest between fighting machines, and these are the products of the engineer. All honor, then, to the engineer, so fittingly represented here to-night by Admiral Melville.

Besides their new relations to others, there will be new relations of engineers among themselves. All that I have said so far emphasizes what we all know, namely, that the several branches of engineering are intimately interdependent and correlated. Take a single instance of large work, the extension of the Pennsylvania Railroad into New York City—the tunnels under the Hudson and East Rivers, the terminal facilities and the electrical equipment—and endeavor to name an important branch of engineering which is not essential to this undertaking. The work of the future demands coöperation, not clanishness—unity, not jealously. Engineers must be specialists, therefore they must work together. The several branches of the profession have their individual interests; they have a larger common interest. As we marvel at what the engineer has done, as we attempt to picture what he may accomplish, do we realize the far-reaching responsibilities which confront us? Shall we rise to meet them? We gave to the world the steam engine, the steam vessel, the railroad, the telegraph and the cable, machinery, industrial processes, the electrical central station—the fundamental requisites which underlie coöperation. Is it not time that we apply to ourselves the great lesson of the last century? What organization stands before the world as representative of the engineering profession? In what way do engineers present themselves to other professions? A noted lawyer recently addressed the annual banquet of a local engineers society containing members of national and international reputation. His remarks were based upon the idea that all engineers were coördinate with a common chainman, and they would have been positively insulting but for his air of blissful ignorance. A few years ago a gentleman of eminence in addressing the American Society of Mechanical Engineers, advised its members not to join in a machinists' strike! Has the engineer been accorded the recognition and the reward which are his due? In what way do engineers coöperate to advance their own profession by mutual helpfulness and by undertaking measures which advance the efficiency and the usefulness of engineering work? There are national engineering organizations of various kinds—the civil engineers, the mining engineers, the mechanical engineers, the electrical engineers, the architects, the naval architects and marine engineers, the engineers in the army and the navy and there are the chemists the electrochemists and others. In general, each knows that other societies exist, and they are mutually respectful, but there is some suspicion here and there that the others are a little too exclusive or that they are a bit jealous. These are the murmurings of littleness, not of largeness.

The several engineering professions, like the constituent States, have their representative bodies, their legislatures, but why should there not be an engineering congress as well? Why not a national representative body, to stand for the profession of engineering as a whole to promote a harmonious coöperation which will strengthen each and elevate all?

An incident of the past year is an auspicious omen. Four great societies have coöperated; they have taken a step which will bring recognition to the deserving individual and credit to the engineering profession. They have founded a medal; and at a recent magnificent dinner they have announced the award of the first John Fritz medal to the venerable man who has just spoken, John Fritz himself. But not less significant than even the medal is the discovery that the societies can work together, and that by doing so they can accomplish worthy ends.

In the vision of the future may we not discern a reflection of the John Fritz medal in the larger life of the twentieth century engineer? Methinks I see in that reflection the outlines of a magnificent building, the Capitol of American Engineering. Into this home, situated in the metropolis of the nation, are gathered the great engineering societies from their scattered lodgings. Here is a great technical library; here are ample assembly halls and comfortable parlors; here are the headquarters of a score of lessor societies restricted in their scope but affiliated in their work. I see all over the country innumerable local sociteies and engineering clubs, no longer isolated but joined together into one great combination. I see them affiliated with the national bodies of the several professions—sometimes as local chapters—altogether constituting one great union. There is individual freedom but general coöperation. Representing all the engineering professions and supported by the great union of the national engineering societies, I see an engineering congress giving to engineers a rank consistent with the importance of their work, and increasing the efficiency of the inter-relations among its members. An eminent body, it is powerful in advancing the common interests of engineers, and it represents the engineering profession in its relation to other professions, to pure science, to education, to legislation, to public improvements and to the general welfare.

Years ago engineers were individuals of trivial consequence compared with men in the learned professions. Now they, too, form a profession of recognized importance. But as yet the national societies of this profession, which has made the nineteenth century an era in the world's history, which has provided the means for the production of unmeasured wealth, and which promises yet greater things for the future, have not even adequate homes of their own. Within the present week the Society of Mechanical Engineers, which has a little house of its own, found it so very little that it was forced to hold its meetings in a large room in a nearby tavern, although there were present men through whose work hundreds of millions have been added to the wealth of this country, and their present efforts are to increase the efficiency of the future. Is this right? Is it just?

But may not the fault lie somewhat with the engineers themselves? Have they fully recognized their own strength and importance? Have they shown a disposition to act together to do large work in a large way? Have they given promise that they would use the enlarged facilities in such a way as to increase the efficiency of engineering work?

The men who are mastering the powers of nature will yet rise in the strength of united effort to meet the increasing responsibilities of the coming years. For it is theirs to build the foundation of the new civilization; it is theirs to establish that material prosperity which is the underlying condition of broader, higher and fuller life.

The end of engineering is usefulness; the characteristic of America is activity; the modern method is coöperation. As engineers of the twentieth century, let us be useful; let us be active; let us coöperate.

American Institute of Electrical Engineers.

CATALOGUE OF MEMBERS.

January 1st, 1904.

HONORARY MEMBERS.

Name and Address.	Date of Membership.
KELVIN, *Lord, D.C.L., LL.D., F.R.S.* 15 Eaton Place, London, S. W., England.	H.M. May 17, 1892
PREECE, *Sir* WILLIAM H., *K.C.B., F.R.S.*, Consulting Electrical Engineer, 13 Queen Anne's Gate, London, S. W., Eng.	H.M. Oct. 21, 1884

Honorary Members, 2.

MEMBERS.

Name and Address.	Date of Election and Transfer.
ABBOTT, ARTHUR V., *C.E.*, Westinghouse, Church, Kerr & Co., 8 Bridge St., New York City.	A Oct. 21, 1890 M Jan. 16, 1895
ACHESON, EDW. G., President, The Carborundum Co., Niagara Falls, N. Y.	A Jan. 3, 1888 M May 1, 1888
ADAMS, ALTON D., Consulting Engineer, Box 1377, Boston; res., 39 Upland Road, Cambridge, Mass.	A Apr. 18, 1893 M Jan. 17, 1894
AHEARN, THOMAS, Ahearn & Soper, Electrical Supplies, Ottawa; Ont.	A July 12, 1887 M Sep. 6, 1887
ALBANESE, G SACCO, Ingenieur Conseil No. 1 Rue Trachel, Nice, France.	A Sep. 20, 1893 M Sep. 27, 1899
ALBRIGHT, H. FLEETWOOD, Electrical Engineer, Western Electric Co., 463 West St., New York City.	A Sept. 27, 1892 M June 20, 1894
ALDRICH, WILLIAM S., Director, Thomas S. Clarkson [Life Member.] Memorial School of Technology, Potsdam, N. Y.	A Mar. 15, 1892 M Apr. 25, 1900
ANDREWS, WILLIAM S., Manager Central Station Sales, General Electric Co., Schenectady, N. Y.	A Mar. 5, 1889 M Apr. 22, 1896
ANSON, FRANKLIN ROBERT, 79 Wall St., New York City.	A Feb. 27, 1895 M Nov. 23, 1898
ANTHONY, WILLIAM A., (*Past-President*) Consulting Electrician, Cooper Union, New York City.	A Dec. 9, 1884 M Jan. 6, 1885
ARMSTRONG, CHAS. G., Consulting Electrical Engineer, Fisher Building, Chicago, Ill., and 1818 Whitehall Bldg., New York City.	A Sept. 27, 1892 M Aug. 31, 1898
ARNOLD, BION J., (*President*) Consulting Electrical Engineer, 1541 Marquette Bldg.; res., 4713 Kimbark Ave., Chicago, Ill.	A Oct. 25, 1892 M Nov. 15, 1893

ATKINSON, WILLARD S., Electrical Engineer and Factory Manager, Zindars & Hunt, 52 Grove St., New York City.	A Oct. 25, 1901 M Jan. 23, 1903
AYER, JAMES I., General Manager American Electric Heating Corporation, Franklin and Sidney Sts., Cambridge, Mass.	A May 19, 1891 M Apr. 19, 1892
BADT, FRANCIS B., Electrical Engineer, F B Badt & Co., 1504 Monadnock Block, Chicago, Ill.	A Apr. 19, 1892 M Mar. 25, 1896
BAILLARD, E. V., Manufacturer of Electrical Instruments, Fox Building, New York City.	A Dec. 3, 1889 M Jan. 16, 1895
BALDWIN, BERT L., Mechanical Engineer, 73 Perin Bldg., Cincinnati, O., and 114 Liberty St., New York City.	A Apr. 22, 1896 M Nov. 18, 1896
BARBOUR, FRED FISKE, Manager, Sales Department, Pacific District, General Electric Co., Claus Spreckels Bldg., San Francisco, Cal.	A May 16, 1893 M Sep. 26, 1900
BARSTOW, WILLIAM S., (*Manager*) Consulting Electrical and Mechanical Engineer, 56 Pine St., New York City.	A Feb. 21, 1894 M Apr. 26, 1899
BARTON, PHILIP PRICE, Assistant Superintendent, The Niagara Falls Power Co., Niagara Falls, N. Y.	A July 12, 1900 M June 28, 1901
BATCHELOR, CHAS., Electrical Engineer, Exchange Court Bldg, 52 Broadway, New York City.	A June 8, 1887 M July 12, 1887
BATES, JAMES H., *M.E.*, Engineering Department, Interurban Street Ry. Co., 621 Broadway, N. Y.	A Sep. 6, 1887 M Oct. 1, 1889
BAYLIS, ROBERT NELSON, The Baylis Co., 140 Washington St., New York City.	A Oct. 1, 1889 M May 17, 1892
BEAMES, CLARE F., Chief Engineer, Compania Mexicana de Gas y Luz Electrica, Ltd., Calle de Santa Clara No. 7, City of Mexico.	A May 21, 1895 M Feb. 28, 1901
BECHTEL, ERNEST J., Electrical Engineer and Superintendent of Lighting, The Toledo Railways and Light Company, Toledo, O.	A Mar. 24, 1897 M July 27, 1900
BEDELL, FREDERICK, Assistant Professor in Physics Cornell University, Ithaca, N. Y.	A Apr. 21, 1891 M May 19, 1896
BEHREND, BERNHARD ARTHUR, Chief Engineer and Chief Designer, Bullock Electric Mfg. Co., Cincinnati, O.	A Jan. 24, 1900 M Sep. 26, 1902
BELL, ALEXANDER GRAHAM (*Past-President*) 1331 Conn. Ave., Washington, D. C., and Baddeck, N. S.	A Apr. 15, 1884 M Oct. 21, 1884
BELL, LOUIS, Ph.D. Consulting Electrical Engineer, 120 Boylston St., Boston, Mass.	A May 20, 1890 M June 18, 1890
BERG, ERNST JULIUS, Engineer, General Electric Co., Schenectady, N. Y.	A Sep. 19, 1894 M July 25, 1902
BERNARD, EDGAR G., Manufacturer, 450 Fulton St., Troy, N. Y.	A Jan. 5, 1886 M July 12, 1887
BETTS, PHILANDER, [*Local Secretary*] Electrical Engineer, Potomac Power Co.; res., The Plaza, Washington, D. C.	A Mar. 25, 1896 M Jan. 25, 1899
BILLBERG, C. O. C., Electrical Engineer, 4726 Kingsessing Ave., Philadelphia, Pa.	A Mar. 21, 1894 M Feb. 27, 1895
BIRDSALL, E. T., *M. E.*, Consulting Engineer, 170 Woodland Ave., NewRochelle, N. Y.	A June 8, 1887 M Nov. 1, 1887
BLACKWELL, FRANCIS O., Consulting Engineer, 49 Wall St., New York City.	A Mar. 28, 1900 M Dec. 18, 1903
BLADES, HARRY H., Electrical Engineer, 419 Cass Ave., Detroit, Mich.	A April 19, 1892 M May 21, 1895

Blake, Francis, Auburndale, Mass.	A Sep. 3, 1889 M Oct. 1, 1889
Blodgett, Geo. W., Consulting Electrician; res., 407 Central St., Auburndale, Mass.	A July 12, 1887 M Sep. 6, 1887
Blood, John Balch, Blood and Hale, Consulting Engineers, 10 Post Office Square, Boston, Mass.	A June 20, 1894 M Dec. 18, 1895
Boggs, Lemuel Stearns, International Railway Co., Buffalo, N. Y.	A Sep. 20, 1893 M May 17, 1898
Boileau, Willard E., Engineer, General Electric Co., Chatta. Light and Power Co.,Chattanooga,Tenn.	A Sep. 19, 1894 M Mar. 25, 1896
Bosch, Adam, Superintendent Fire Alarm Telegraph, Newark, N. J.	A Apr. 15, 1884 M Jan. 6, 1885
Bottomley, Harry, General Supt., Fall River Electric Light Co., Fall River, Mass.	A Apr. 2, 1889 M Jan. 22, 1896
Bourne, Frank, Electrical Engineer, 26 Cortlandt St., New York City.	A Apr. 21, 1891 M Nov. 15, 1892
Boyer, Elmer E., Foreman, Testing Department, Lynn Works, General Electric Co., Lynn, Mass.	A Sep. 25, 1895 M Mar. 25, 1896
Boynton, Edward C., Engineering Department, Christensen Engineering Co., 135 Broadway, New York; res., 128 Third St., Newburgh, N.Y.	A Aug. 6, 1889 M Nov. 24, 1891
Bradley, Chas. S., President, Ampere Electro-Chemical Co., 44 Broad St., New York City.	A May 24, 1887 M Dec. 6, 1887
Brady, Frank W., *M.E.*, Engineering Text Book Writer, International Corr. Schools,Scranton,Pa.	A June 20, 1894 M Mar. 28, 1900
Brenner, William H., Manager, The Zemina Works, Isogo Mura, Yokohama, Japan.	A Sep. 20, 1893 M Mar. 21, 1894
Brinckerhoff, Henry Morton, General Manager, Metropolitan West Side Elevated R. R.; 1001 Royal Insurance Bldg., Chicago, Ill.	A Sep. 23, 1896 M Dec. 16, 1896
Brooks, Morgan, [*Local Secretary*] Professor of Electrical Engineering. University of Illinois, Urbana, Ill.	A May 20, 1890 M June 17, 1890
Brown, J. Stanford, *E.E.*, Consulting Electrical Engineer, Vice-President and Treasurer, New York Realty and Trust Co.; 489 5th Ave., New York City. [Life Member.]	A Sep. 6, 1887 M Nov. 1, 1887
Browne, Sidney Hand, Vice-President and General Manager, The Pittsburg and Allegheny Telephone Co., Pittsburg, Pa.	A Apr. 28, 1897 M Nov. 23, 1898
Brush, Chas. F., Electrical Engineer, 453 The Arcade, Cleveland, O.	A Apr. 15, 1884 M Oct. 21, 1884
Buck, Harold W., Electrical Engineer, Niagara Falls Power Co., Niagara Falls, N. Y.	A Jan. 16, 1895 M Apr. 26, 1901
Burch, Edward P., [*Local Secretary*] Consulting Electrical Engineer, 1210 Guaranty Building, Minneapolis, Minn.	A Jan. 28, 1898 M May 17, 1898
Burgess, Chas. Fredk., Asst. Prof. of Electrical Engineering, University of Wisconsin, Madison Wis.	A Mar. 25, 1896 M Apr. 26, 1901
Burke, James, Electrical Engineer and Inventor, St. Paul Building, 220 Broadway, New York City.	A May 16, 1893 M July 28, 1903
Burleigh, Chas. B., [*Local Secretary,*] Electrical Engineer, General Electric Co., 84 State St., Boston, Mass	A Apr. 21, 1891 M Feb. 16, 1892
Burt, Byron T., Secretary and General Manager, Chatta. Light & Power Co., Chattanooga, Tenn.	A Sep. 25, 1895 M Feb. 28, 1902

BURTON, WILLIAM C., Electrical Engineer, J. G. White & Co., 22a College Hill, London, E. C., Eng.	A Sep. 20, 1893 M Dec. 27, 1899
CAHOON, JAS. BLAKE, Consulting Engineer, 35 Nassau St., New York City.	A June 17, 1890 M May 19, 1891
CALDWELL, FRANCIS CARY, [*Local Secretary*] Professor of Electrical Engineering, Ohio State University, Columbus, O.	A June 20, 1894 M Jan. 24, 1902
CARHART, HENRY S., Prof. of Physics, University of Michigan, Ann Arbor, Mich.	A Sep. 25, 1895 M Apr. 22, 1896
CARICHOFF, E. R., Electrical Engineer, Otis Elevator Co., 17 Battery Place, New York City.	A Mar. 21, 1894 M May 15, 1900
CARTY, JOHN JOSEPH, Chief Engineer, New York Telephone Co., 15 Dey St., New York City.	A Apr 15, 1890 M Nov. 20, 1903
CARUS-WILSON, CHARLES A., Consulting Engineer, 41 Old Queen St., Westminster, London, Eng.	A Apr. 18, 1894 M Apr. 17, 1895
CHAMBERLAIN, J. C., Electrical Engineer, 96 Broadway, res., 1 West 81st St., New York City.	A Dec. 6, 1887 M Jan. 3, 1888
CHANDLER, CHARLES F., Professor of Chemistry, Columbia University, New York City.	A Jan. 20, 1891 M June 7, 1892
CHENEY, W. C., Electrical Engineer, Portland, Or.; residence, Park Place, Or.	A Sep. 22, 1891 M Nov. 21, 1894
CHESNEY, CUMMINGS C., Chief Electrical Engineer, Stanley Electric Mfg Co., Pittsfield, Mass.	A June 20, 1894 M Nov. 22, 1899
CHILDS, ARTHUR EDWARDS, *B. Sc., M.E., E.E.*, Vice-President and Treasurer, The Light, Heat and Power Corporation, 23 Central St., Boston, Mass.	A June 20, 1894 M Apr. 17, 1895
CHUBBUCK, H. EUGENE, Manager, Quincy Horse Railway and Carrying Co., La Salle, Ill.	A Dec. 4, 1888 M Apr. 26, 1899
CHURCHILL, ARTHUR, Manager Purchasing Dept., British Thomson-Houston Co., Rugby, Eng.	A Apr. 15, 1890 M Jan. 17, 1893
CLARK, EUGENE BRADLEY, Electrical Engineer, Illinois Steel Co.; res., 5335 Cornell Ave., Chicago, Ill.	A Mar. 28, 1902 M Nov. 20, 1903
CLARK, ERNEST P., 12 Reid Ave., Brooklyn, N. Y.	A Jan. 8, 1887 M Nov. 1, 1887
CLARK, LEROY, Assistant General Manager, Safety Insulated Wire and Cable Co., 114 Liberty St.; res., 72 W. 52d St., New York City.	A May 15, 1894 M June 19, 1903
CLARKE, CHAS. L., Electrical and Mechanical Engineer, 120 Broadway, New York City.	A Apr. 15, 1884 M Jan. 6, 1885
CLAUSEN, HENRY P., Manager and Designer, American Electric Telephone Co., Chicago, Ill.	A May 19, 1903 M July 28, 1903
COLBY, EDWARD A., Consulting Engineer, Lock Box 113, Newark, N. J.	A Apr. 2, 1889 M May 7, 1889
COLE, WM. HOWARD, Electrical Engineer, Dick Kerr & Co., Ltd., Singapore, Straits Settlement, India.	A Apr. 25, 1900 M Oct. 23, 1903
COLE, WILLIAM WEEDEN, President and Gen. Manager, Elmira Water, Light and R.R. Co., Elmira, N.Y.	A April 25, 1902 M Oct. 23, 1903
COMSTOCK, LOUIS K., Electrical Engineer, George A. Fuller Co., 137 Broadway, New York City.	A Dec. 20, 1893 M Nov. 20, 1895
CONDICT, G. HERBERT, Electrical Engineer, 100 Broadway, New York City.	A July 12, 1887 M Sep. 6, 1887
COOPER, WILLIAM, Consulting Electrical and Mechanical Engineer, 732 Union Trust Bldg. Cincinnati, O	A Feb. 28, 1902 M July 25, 1902
CORNELL, CHARLES L., Treasurer, Niles-Bement-Pond Co., 136 Liberty St., New York City.	A Feb. 7, 1890 M June 27, 1895

CORY, CLARENCE L., Professor of Electrical Engineering, University of California, Berkeley, Cal.	A Apr. 19, 1892 M July 28, 1903
COSTER, MAURICE, Societe Industrielle d'Electricite, 45 Rue de la Arcade Paris, France.	A Sep. 25, 1895 M Mar. 25, 1896
COWLES, ALFRED H., President the Cowles Electric Smelting and Aluminum Co., 361 The Arcade; res., 656 Prospect St., Cleveland, O.	A Mar. 5, 1886 M May 7, 1889
COWLES, JOSEPH W., Electrical Engineer, Edison, Electric Illuminating Co., 3 Head Pl., Boston, Mass.	A Aug. 22, 1902 M July 28, 1903
COX, FRANK POWELL, Electrical Engineer, General Electric Co., Lynn, Mass.	A Oct. 25, 1901 M Apr. 25, 1902
CROCKER, FRANCIS BACON (*Past-President*), Professor [Life Member.] Electrical Engineering, Columbia University; res., 14 W. 45th St., New York City.	A May 24, 1887 M Apr. 2, 1889
CROSS, CHARLES R., Thayer Professor Physics, and Director of the Rogers Laboratory, Mass. Institute of Technology, Boston, Mass.	A Apr. 15, 1884 M Oct. 21, 1884
CUSHING, HARRY COOKE, JR., Consulting Electrical Engineer, 220 Broadway, New York City.	A Sep. 19, 1894 M Nov. 18, 1896
CUTTRISS, CHAS., Electrician, The Commercial Cable Co., 20 Broad St., New York.	A Nov. 1, 1887 M Dec. 6, 1887
DAFT, LEO, Consulting Electrical Engineer, 135 Sylvan St., Rutherford, N. J.	A Dec. 9, 1884 M Jan. 6, 1885
DARLINGTON, FREDERICK, Consulting Electrical En- [Life Member.] gineer, Stanley Electric Mfg. Co., Great Barrington, Mass.	A Nov. 21, 1902 M Apr. 24, 1903
DARLINGTON, FREDERIC W., Consulting Electrical and Mechanical Engineer, 1120 Real Estate Trust Bldg., Philadelphia, Pa.	A Sep. 19, 1894 M Nov. 25, 1895
DAVIDSON, A., Cable Engineer and Electrician, Central and South American Telegraph Co., Lima, Peru.	A May 18, 1897 M Oct. 27, 1897
DAVIS, ALBERT G., Manager, Patent Dept., General Electric Co., Schenectady, N. Y.	A Mar. 23, 1898 M Sep. 26, 1900
DAVIS, CHARLES H., *C.E.*, Consulting Engineer, Broad-Exchange Bldg., New York City, 204 Walnut Pl., Philadelphia, 4 State St., Boston.	A Mar. 18, 1890 M June 17, 1890
DAVIS, HARRY PHILLIPS, Engineer of Detail Dept., Westinghouse E. & M. Co., Pittsburg, Pa.	A Jan. 25, 1901 M Sep. 27, 1901
DAVIS, MINOR M., Traffic Manager and Assistant Electrical Engineer, Postal Telegraph-Cable Co., 253 Broadway, New York City.	A Apr. 6, 1886 M May 16, 1893
DAWSON, PHILIP, Consulting Engineer, Kincaid, Waller & Manville, 29 George St., Westminster, London.	A Sep. 25, 1895 M Feb. 17, 1897
DECKER, EDWARD P., Engineer, with Westinghouse, Church, Kerr & Co., 8 Bridge St., New York.	A Feb. 26, 1896 M Oct. 27, 1897
DELANY, PATRICK BERNARD, Inventor, South Orange, N. J.	A Apr. 19, 1884 M Nov. 24, 1891
DENHAM, JOHN, Electrician, Cape Government, Cape Town, South Africa.	A Jan. 24, 1900 M May 15, 1900
DE WAAL, WM. H., Engineer, c/o Dr. Vermey, Bussum, Holland.	A Apr. 25, 1900 M June 19, 1903
DICKENSON, SAMUEL S., Superintendent, Commercial Cable Co., Hazel-Hill, Guysborough Co., N. S.	A Mar. 6, 1888 M Oct. 1, 1889
DIEHL, PHILIP, Inventor, Singer Sewing Machine Co.: res., 528 Morris Ave., Elizabeth, N. J.	A Apr. 15, 1884 M Dec. 9, 1884

DION, ADOLPHE ALFRED, General Supt., The Ottawa Electric Co., 72 Sparks St., Ottawa, Ont.	A Jan. 7, 1890 M Nov 15, 1893
DOANE, SAMUEL EVERETT, Engineer National Electric [Life Member.] Lamp Co., Mason & Belden Sts., Cleveland, O.	A Aug. 6, 1889 M June 27, 1895
DODGE, OMENZO G., Prof. U. S. Navy, Naval Academy, Annapolis, Md.	A Sep. 20, 1893 M Apr. 17, 1895
DOHERTY, HENRY L., 40 Wall St., New York City.	A Sep. 28, 1898 M July 25, 1902
DOMMERQUE, FRANZ J., Kellogg Switchboard and Supply, cor. Congress and Green Sts., Chicago, Ill.	A Oct. 17, 1894 M Mar. 25, 1896
DONNER, WILLIAM H., Ingleside, 31 Lyndhurst Road, Hampstead, Eng.	A Nov. 18, 1890 M Dec. 16, 1890
DOW, ALEX, Manager, Edison Illuminating Co., 18 Washington Ave.; res., 844 Cass Ave., Detroit.	A Sep. 20, 1893 M Dec. 18, 1895
DOYER, H., Consulting Electrical Engineer, 8 Phœnixstraat Delft, Holland.	A Jan. 7, 1890 M Mar. 18, 1890
DUDLEY, CHARLES B., Chemist, Penn. R. R. Co., Drawer 334, Altoona, Pa.	A Oct. 1, 1889 M Nov. 12, 1889
DUNBAR, F. W., Engineer, Kellogg Switchboard and Supply Co., S. W. cor. Green and Congress Sts.; res., 41 Madison Park, Chicago, Ill.	A Dec. 21, 1892 M May 16, 1893
DUNCAN, DR. LOUIS, (*Past-President*) Electrical Engineering Department, Massachusetts Institute of Technology, Boston, Mass.	A July 12, 1887 M Sep. 6, 1887
DUNLAP, WILL KNOX, Supt. of Construction, Westinghouse Elec. and Mfg. Co., Pittsburg, Pa.	A Sep. 25, 1889 M June 24, 1895
DUNN, GANO SILLICK, *M.S., E.E.*, (*Manager*), Vice-President and Chief Engineer, Crocker-Wheeler Co., Ampere, N. J.	A Apr. 21, 1891 M June 20, 1894
DUSINBERRE, GEORGE BROWN, Assistant to Fourth Vice-President Westinghouse Electric and Mfg. Co., Pittsburg, res., Edgewood Park, Pa.	A Nov. 22, 1901 M July 25, 1902
DYER, R. N., Patent Attorney, 31 Nassau St., New York City.	A July 12, 1887 M Sep. 6, 1887
EASTERBROOK, JOHN F., Electrical Engineer, Westinghouse E. and M. Co., Pittsburg, Pa.	A Nov. 21, 1902 M June 19, 1903
EDGAR, C. L., President Edison Elec. Illuminating Co. of Boston, 70 State St., Boston, Mass.	A Jan. 22, 1896 M May 19, 1896
EDISON, THOMAS A., Mechanician and Inventor, Llewellyn Park, N. J.	A Apr. 15, 1884 M Oct. 21, 1884
EGGER, ERNST, Technical Director, Vereinigte Elektricitäts-Actien Gesellschaft, Simmeringstr. 187, Vienna, X., Austria.	A Feb. 21, 1893 M Mar. 21, 1894
EMMET, W. L. R., Electrical Engineer, General Electric Co., Schenectady, N. Y.	A June 6, 1893 M Jan. 17, 1894
ESTY, WILLIAM, [*Local Secretary*] Assistant Professor of Electrical Engineering, Lehigh University, So. Bethlehem, Pa.	A Mar. 20, 1895 M Apr. 24, 1903
FESSENDEN, REGINALD A., Norfolk, Va.	A Oct. 21, 1890 M Dec. 16, 1890
FIELD, CORNELIUS J., *M.E.*, 29 Broadway, New York City.	A June 8, 1887 M Nov. 1, 1887
FIELD, HENRY GEORGE, Consulting Engineer, Field & Hinchman, 710 Wash. Arcade Building, Detroit, Mich.	A Apr. 22, 1896 M Dec. 16, 1896

(24(

Field, Stephen D., Electrical Engineer, Stockbridge, Mass.	A Apr. 15, 1884 M Oct. 21, 1884
Fish, Walter Clark, Manager Lynn Works, General Electric Co., Lynn, Mass.	A June 26, 1891 M Feb. 26, 1896
Fisher, Henry W., Superintendent, Pittsburg Factory and Electrical Engineer, Standard Underground Cable Co.; res., 5403 Friendship Ave., Pittsburg.	A Jan. 16, 1895 M Apr. 26, 1901
Fitzmaurice, James S., (*Local Honorary Secretary*), Chief Engineer, The Electric Light Branch, 210 George St., Sydney, N. S. W.	A Sep. 20, 1893 M Mar. 21, 1894
Flack, J. Day, *M.E.*, Engineer and Superintendent, A. D. Granger Co., 95 Liberty St., New York.	A Dec. 6, 1887 M May 21, 1895
Fortenbaugh, S. B., Electrical Engineer, Underground Elect. Railways Co. of London, Ltd., 37 Hamilton House, Victoria Embankment, London.	A Apr. 17, 1895 M Dec. 16, 1896
Foster Horatio A., Electrical Engineer, 650 Bullitt Building, Philadelphia, Pa.	A June 8, 1887 M Sep. 6, 1887
Foster, Samuel L., Chief Electrician, United Railroads of S. F.; res. 3687 24th St., San Francisco.	A Feb. 23, 1896 M Nov. 18, 1896
Franklin, W. S., Professor of Physics Lehigh University, Bethlehem, Pa.	A Jan. 22, 1896 M Sep. 26, 1902
Freedman, William H., Professor of Electrical Engineering, University of Vermont, Burlington, Vt.	A Mar. 18, 1890 M Dec. 18, 1895
Freeman, Frank L., Solicitor of Patents, Electrical Expert, 931 F St., Washington, D. C.	A May 7, 1889 M Sep. 3, 1889
Gale, Horace B., Mechanical and Electrical Engineer, Natick, and 247 Atlantic Ave., Boston, Mass.	A Nov. 15, 1892 M May 16, 1893
Ganz, Albert F., Professor of Electrical Engineering, Stevens Institute of Technology, Hoboken, N. J.	A Apr. 26, 1899 M June 19, 1902
Garfield, Alex. Stanley, Engineer, 10 Rue de Londres; res., 67 Avenue de Malakoff, Paris, France.	A Jan. 26, 1898 M June 28, 1901
Garratt, Allan V., Chief Engineer, Lombard Governor Co., 36 Whittier St., Boston, Mass.	A Apr. 2, 1889 M May 7, 1889
Gerry, M. H., Jr., Chief Engineer and General Manager, Missouri River Power Co., Helena, Mont.	A Apr. 18, 1893 M Oct. 21, 1896
Gharky, William David, Engineer & Contractor, 334 North Broad St., Philadelphia, Pa.	A May 21, 1895 M Feb. 26, 1896
Gifford, Clarence E., Electrical Supervisor Lackawanna Steel Co., Buffalo, N. Y.	A May 16, 1893 M Feb. 21, 1894
Gladson, Wm. N., Professor of Electrical Engineering. University of Arkansas, Fayetteville, Ark.	A Dec. 28, 1898 M Jan. 24, 1902
Goddard, Chris. M., Secy. Underwriters' National Electric Assn., 55 Kilby St., Boston, Mass.	A Apr. 22, 1896 M Feb. 28, 1902
Goldsborough, Winder Elwell, *M.E.* (*Manager*), Professor of Electrical Engineering and Director of Electrical Laboratory, Purdue University, Lafayette, Ind.; Chief of Department of Electricity, Universal Exposition, St. Louis, Mo.	A Mar. 21, 1893 M Jan. 25, 1899
Goltz, William, Consulting Electrical Engineer, Goltz Engineering Co., 1504 Monadnock, Chicago, Ill.	A Oct. 27, 1897 M Feb. 23, 1898
Goodman, Wm. Geo. Topp, [*Local Honorary Secretary*,] Electrical Engineer, Noyes Bros., Electrical Engineers, Dunedin, New Zealand.	A Aug. 23, 1899 M May 15, 1900

GOSSLER, PHILIP GREEN, General Superintendent and Electrical Engineer, Montreal Light, Heat and Power Co., New York Life Building, Montreal.	A June 20, 1894 M June 24, 1898
GOTSHALL, WM. C., Consulting Engineer, 76 William St., New York City.	A Jan. 9, 1901 M Jan. 24, 1902
GREENWOOD, WALTER GEORGE, Electrical Engineer and Superintendent, Jalapa Railway and Power Co., Jalapa, V. C., Mexico.	A Jan. 24, 1900 M Oct. 24, 1902
GREGG, TOM HOWARD, Supt. Electrical Construction, U. S. Light House Board, Tompkinsville, N. Y.	A. Mar 22, 1899 M Sep. 26, 1900
GUTMANN, LUDWIG, Consulting Electrical Engineer, 309 Y. M. C. A. Building, Peoria, Ill.	A Sep. 14, 1888 M Mar. 21, 1893
HADAWAY, W. S. JR., Electric Heating Engineer, 228 West Broadway, New York City.	A Nov. 21, 1894 M Oct. 21, 1896
HADLEY, ARTHUR L., Electrical Engineer, Fort Wayne Electric Works, Fort Wayne, Ind.	A Oct. 17, 1894 M Mar. 22, 1901
HADLEY, FREDK. W., Electrical Engineer, c/o Westinghouse, Church, Kerr & Co., 8 Bridge St., New York City. [Life Member.]	A Aug. 5, 1896 M Feb. 28, 1901
HAFER, GEORGE, JR., 8 Live Stock Exchange, East Buffalo, N. Y.	A Nov. 23, 1900 M Apr. 26, 1901
HALL, CLAYTON C., Attorney-at-Law and Consulting Actuary, 10 South St., Baltimore, Md.	A April 15, 1884 M Oct. 21, 1884
HALL, JOHN L., District Manager, Bullock Electric Mfg. Co., 609 North American Bldg. Philadelphia, Pa.	A Sep. 22, 1891 M Dec. 20, 1893
HALL, WALTER ATWOOD, Designing Engineer, General Electric Co., Lynn, Mass.	A Apr. 23. 1903 M Oct. 23, 1903
HAMILTON, GEO. A. (*Treasurer*), Electrician, Western Electric Co., 463 West St., New York City.	A Apr. 15, 1884 M Oct. 21, 1884
HAMMER, EDWIN W., Electrical Engineer, 18 North 22d St., East Orange, N. J.	A Nov. 18, 1896 M June 23, 1897
HAMMER, WILLIAM J., Consulting and Supervising Electrical Engineer, 1406 Havemeyer Bldg., 26 Cortlandt St., New York City. [Life Member.]	A June 8, 1887 M July 12, 1887
HANCHETT, GEO. T., Electrical and Mechanical Engineer, 114 Liberty St., New York City.	A May 19, 1896 M Feb. 15, 1899
HARRINGTON, WALTER E., Electric Railway Engineer, 200 Market St., Camden, N. J.	A Mar. 17, 1891 M May 19, 1899
HARTMAN, HERBERT T., 2d V. P. and Chief Engineer, 1406 Land Title Bldg., Philadelphia, Pa.	A Mar. 21, 1893 M May 19, 1903
HARTWELL, ARTHUR, Sales Manager, Westinghouse Electric and Mfg. Co., Pittsburg, Pa.	A May 15, 1894 M Nov. 20, 1895
HASKINS, CARYL DAVIS, Electrical Engineer, General Electric Co., Schenectady, N. Y.	A Mar. 18, 1890 M June 20, 1894
HASSON, W. F. C., Instructor in Mathematics, U. S. Naval Academy, Annapolis, Md.	A Mar. 18, 1890 M May 15, 1894
HAYES, HAMMOND V., Electrical Engineer, American Telephone & Tel. Co., 125 Milk St., Boston, Mass.	A Nov. 12, 1889 M Mar. 18, 1890
HAYES, HARRY E., Asst. Electrician, American Telegraph and Telephone Co., 125 Milk St., Boston.	A Apr. 18, 1893 M Dec. 20, 1893
HEATH, HARRY E., Chief Engineer, Eddy Electric Mfg. Co., Windsor, Conn.	A Mar. 21, 1893 M Mar. 25, 1896
HEINRICH, RICHARD O., General Manager, European Weston Electrical Instrument Co., 88 Ritterstrasse, Berlin, Germany.	A Oct. 1, 1889 M Oct. 25, 1892

HEITMANN, EDWARD, JR., Electrical Engineer, Stanley Instrument Co., Great Barrington, Mass.	A Oct. 24, 1900 M June 19, 1903
HENSHAW, FREDERICK V., Asst. Engineer, Crocker-Wheeler Co., Ampere, N. J.	A Feb. 5, 1889 M Nov. 20, 1895
HERDMAN, FRANK E., Mechanical and Electrical Engineer, Otis Elevator Co., Chicago, Ill.	A Dec. 18, 1895 M Oct. 21, 1896
HERING, CARL, (*Past-President*) Consulting Electrical [Life Member.] Engineer, Room 615, 929 Chestnut St., res., 901. 69th Ave., Oak Lane, Philadelphia, Pa.	A Jan. 3, 1888 M June 5, 1888
HERRICK, CHARLES H., Superintendent Isolated Lighting and Power Dept., Edison Electric Illuminating Co., 3 Head Pl., Boston, Mass.	A Apr. 21, 1891 M Jan. 17, 1893
HERZOG, F. BENEDICT, *Ph. D.*, President, Herzog Telesme Co., 51 W. 24th St., New York City.	A May 24, 1887 M July 12, 1887
HEWITT, CHARLES, Electrical Engineer, Philadelphia Rapid Transit Co., 428 West Stafford St., Germantown, Philadelphia, Pa.	A Sep. 16, 1890 M May 17, 1892
HEWLETT, ERNEST HOLCOMBE, 64 Victoria St., Westminster, London, Eng.	A Aug. 23, 1899 M Dec, 27, 1899
HIBBARD, ANGUS S., General Manager, Chicago Telephone Co., 203 Washington St., Chicago, Ill.	A Nov. 24, 1891 M Feb. 16, 1892
HIGGINS, EDWARD E., Treasurer McGraw-Marden Co., 32 Waverly Pl., New York City.	A June 8, 1887 M July 12, 1887
HILL, GEORGE, *C.E.*, Consulting Engineer, 100 Broadway, New York City.	A April 19, 1892 M June 28, 1901
HOBART, HENRY M., Consulting Engineer, Oswaldestre House, Norfolk St., Strand, London, Eng.	A Apr. 18, 1894 M Sep. 27, 1899
HOLMES, FRANKLIN S., Electrical Engineer, 26 Cortlandt St., New York City.	A Apr. 21, 1891 M June 20, 1894
HOOPES, MAURICE, Mechanical Engineer, J. G. White & Co., 43 Exchange Place, New York City.	A Nov. 22, 1901 M July 25, 1902
HOSMER, SIDNEY, Electrical Engineer, Edison Electric Illuminating Co., 3 Head Pl., Boston, Mass.	A May 18, 1897 M Jan. 24, 1902
HOUSTON, EDWIN J., *Ph.D.* (*Past-President*) Prof. of [Life Member.] Physics, Franklin Inst., Philadelphia, Pa.	A Apr. 15, 1884 M Oct. 21, 1884
HOWELL, JOHN W., Engineer, Lamp Works, General Electric Co., Harrison, N. J.	A July 12, 1887 M June 5, 1888
HOWELL, WILSON S., Manager, Lamp Testing Bureau, 14 Jay St., New York City.	A Sep. 3, 1889 M Mar. 18, 1890
HOWLAND, LEWIS A., Reid Newfoundland Co., St. Johns, Newfoundland.	A July 26, 1900 M Feb. 28, 1902
HUBLEY, GEORGE WILBUR, Superintendent and Electrical Engineer, Louisville Electric Light Co.; res., 504 West St. Catherine St., Louisville, Ky.	A Sep. 19, 1894 M May 15, 1900
HUMPHREY, HENRY H., Consulting Electrical Engineer, Suite 1305 Chemical Building, St. Louis, Mo.	A Dec. 16, 1896 M April 28, 1897
HUNT, ANDREW MURRAY, Electrical Engineer, 331 Pine St., San Francisco, Cal.	A Feb. 28, 1900 M July 28, 1903
HUNTER, RUDOLPH M., Expert and Counsellor in Patent Causes, 926 Walnut St., Philadelphia, Pa.	A July 13, 1886 M May 17, 1887
HUNTING, FRED S., Sales Manager and Treasurer, Fort Wayne Electric Works, Fort Wayne, Ind.	A Nov. 15, 1892 M May 16, 1893
HUNTINGTON, DAVID L., General Manager and Chief Engineer, The Washington Water Power Co., Spokane, Washington.	A May 20, 1902 M Sep. 26, 1902

HUTCHINSON, CARY TALCOTT, Consulting Electrical Engineer, 56 Pine St., New York City. [Life Member.] — A Feb. 7, 1890; M Dec. 16, 1890

HUTTON, CHARLES WILLIAM, Designing Electrical Engineer, Sacramento, Cal. — A Feb. 15, 1899; M July 28, 1903

HYDE, JEROME W., Asst. Treasurer, The Springfield Steam Power Co., Springfield, Mass. — A June 8, 1887; M Nov. 1, 1887

IHLDER, JOHN D., Electrical Engineer, Otis Elevator Co., Yonkers, N. Y. — A Oct. 2, 1888; M June 19, 1903

IMLAY, LORIN EVERETT, Assistant Superintendent, Niagara Falls Power Co., Niagara Falls, N. Y. — A July 26, 1900; M Nov. 20, 1903

INRIG, ALEC GAVAN, Calydon, Goldworth Road, Woking, Eng. — A Jan. 19, 1892; M May 17, 1892

JACKSON, DUGALD C., Consulting Engineer, Professor of Electrical Engineering, University of Wisconsin, Madison, Wis. — A May 3, 1887; M June 17, 1890

JACKSON, FRANCIS E., Incandescent Filaments Manufacturer, 128 Essex Ave., Orange, N. J. — A Jan. 3, 1888; M June 17, 1890

JACKSON, JOHN PRICE, [*Local Secretary*] Professor of Electrical Engineering, Penn. State College, State College, Pa. — A Sep. 27, 1892; M Jan. 17, 1894

JACKSON, WM. B , Consulting Engineer, Madison, Wis. [Life Member.] — A Aug. 13, 1897; M June 24, 1898

JANNUS, FRANKLAND, Attorney-at-Law, Solicitor of Patents, 141 Broadway, New York City. — A Nov. 12, 1889; M Mar. 18, 1890

JEHL, FRANCIS, I Meszaros-utcza 18, Budapest, Austria-Hungary. — A June 27, 1895; M Jan. 22, 1896

JENKS, WILLIAM J., Secretary, Board of Patent Control, 120 Broadway, New York City — A June 8, 1887; M Nov. 1, 1887

JOHANNESEN, SVEND EMANUEL, Electrical Engineer, Westinghouse E. & Mfg. Co., Pittsburg, Pa. — A Jan. 23, 1903; M Apr. 24, 1903

JONES, BENJAMIN NEEDHAM, Electrician, Marine Eng. and Machine Co., Harrison, N. J. — A Oct. 24, 1902; M June 19, 1903

JONES, FRANCIS WILEY, Electrical Engineer, Postal Telegraph-Cable Co., 253 Broadway, New York City. [Life Member.] — A Apr. 15, 1884; M Oct. 21, 1884

KEITH, NATHANIEL S., Mining and Metallurgical Engineer, High Hill, Va. — A Apr. 15, 1884; M Jan. 17, 1894

KELLY, JOHN F., *Ph.D.*, President and Consulting Engineer, The John F. Kelly Engineering Co., Singer Building, 149 Broadway, New York City. — A May 16, 1899; M July 25, 1902

KELSCH, RAYMOND STERLING, General Superintendent and Engineer, The L. R. H. & L. Co., 160 McCord St., Montreal, P. Q. — A May 20, 1902; M May 19, 1903

KENAN, WM. R., JR., Traders' Paper Co., Lockport, N .Y. — A Jan. 20, 1897; M Apr. 26, 1901

KENNEDY, JEREMIAH J., Consulting Engineer, 52 Broadway, New York City. — A July 26, 1900; M July 25, 1902

KENNELLY, ARTHUR E., (*Past-President*) Department of Engineering Pierce Hall, Harvard University Cambridge, Mass. [Life Member.] — A May 1, 1888; M May 16, 1899

KILGOUR, HAMILTON, Borough Electrical Engineer, 335 High St., Cheltenham, England. — A Apr. 26, 1901; M Jan. 24, 1902

KINSMAN, FRANK E., Electrical Engineer, 91 Liberty St., New York City; res., Plainfield, N. J. — A Sep. 27, 1892; M May 16, 1893

KINTNER, SAMUEL MONTGOMERY, Electrical Engineer, Westinghouse Electric and Mfg. Co., Pittsburg. — A Feb. 28, 1902; M July 28, 1903

KIRKLAND, JOHN W., So. African General Electric Co., Johannesburg, Transvaal.	A Mar. 21, 1894 M Sep. 26, 1900
KNOWLES, EDWARD R., *E.E.*, *C.E.*, Consulting Electrical Engineer, 136 Liberty St., New York City.	A June 8, 1887 M July 12, 1887
KNOX, CHAS. EDWIN, With C. O. Mailloux, Consulting Electrical Engineer, 76 William St., New York.	A May 16, 1899 M Dec. 27, 1899
KNUDSON, A. A., Electrical Engineer, Room 416, 32 Nassau St., New York City.	A Dec. 6, 1887 M Jan. 3, 1888
LAMME, BENJAMIN G., Assistant Chief Engineer, Westinghouse Electric and Mfg. Co., Pittsburg, Pa.	A May 19, 1903 M July 28, 1903
LANGE, PHILIP A., Manager of Works, Westinghouse Electric and Manufacturing Co., Pittsburg, Pa.	A Mar. 6, 1888 M June 5, 1888
LANGTON, JOHN, Engineer, 99 John St., New York [Life Member.] City.	A Mar. 6, 1888 M June 5, 1888
LARDNER, HENRY ACKLEY, J. G. White & Co., 43 Exchange Place, New York City.	A Dec. 19, 1894 M May 16, 1899
LA ROCHE, FRED. A., F. A. La Roche & Co., 664 Hudson St.; res., 28 W. 25th St., New York City.	A Sep. 19, 1894 M Nov. 20, 1895
LAYMAN, W. A., Manager and Treasurer, Wagner Electric Mfg. Co., 2017 Locust St., St. Louis, Mo.	A Nov. 22, 1899 M Nov. 23, 1900
LEE, FRANCIS VALENTINE T., Engineer (Pacific Coast Dept.) Stanley Electric Mfg. Co., 69 New Montgomery St., San Francisco, Cal.	A Mar. 23, 1898 M Dec. 19, 1902
LEMP, HERMANN, JR., Electrician, General Electric Co.; res., 186 Allen Ave., Lynn, Mass.	A Apr. 2, 1889 M Feb. 21, 1893
LEONARD, H. WARD, Electrical Engineer, Prest. Ward [Life Member.] Leonard Electric Co., Bronxville, N. Y.	A July 12, 1887 M Sep. 6, 1887
LESLIE, EDWARD ANDREW, General Manager, Edison Electric Ill. Co., 360 Pearl St., Brooklyn, N. Y.	A Jan. 16, 1895 M Feb. 17, 1897
LEVIS, MINFORD, Consulting Electrical Engineer, 3413 Chestnut St., Philadelphia, Pa.	A Feb. 21, 1893 M June 23, 1897
LEWIS, WARREN B., Consulting Engineer, Room 732 Banigan Bldg., Providence, R. I.	A Jan. 23, 1903 M June 19, 1903
LEYDEN, HARRY RUSSELL, Manager, Hamilton Elec. Lt. and Cataract Power Co., Hamilton, Ont.	A Nov. 23, 1900 M Feb. 28, 1901
LIEB, JOHN WILLIAM, JR. (*Vice-President*), Associate General Mgr., The N. Y. Edison Co., 53 Duane St.; res., 869 West End Ave., New York City.	A Sep. 6, 1887 M Nov. 1, 1887
LIGHTHIPE, JAMES A., District Engineer, General Electric Co., Claus Spreckels Bldg., San Francisco.	A Feb. 21, 1894 M Apr. 17, 1895
LINCOLN, PAUL M., Westinghouse Electric and Mfg. Co., Pittsburg, Pa.	A Sep. 25, 1895 M June 24, 1898
LLOYD, HERBERT, Vice-President and General Manager, The Electric Storage Battery Co., Allegheny Ave. and 19th St., Philadelphia, Pa.	A June 20, 1894 M May 21, 1895
LLOYD, JOHN E., Chief Engineer and General Manager, Cape Town Tramways, Cape Town, S. A.	A Jan. 22, 1896 M Mar. 25, 1896
LLOYD, ROBERT MCA., Electrician, 100 Broadway; res., 5 Gramercy Park, New York City.	A Oct. 21, 1890 M Nov. 15, 1893
LOCKWOOD, THOMAS D., Engineer, Expert and Mana- [Life Member.] ger of Patent Department, American Telephone and Telegraph Co., 119 Milk St., Boston, Mass.	A Apr. 15, 1884 M Oct. 21, 1884
LOOMIS, OSBORN P., Electrical Engineer, Newport News Shipbuilding and Dry Dock Co., 321 49th St., Newport News, Va.	A Sep. 16, 1890 M Dec. 16, 1896

LORRAIN, JAMES GRIEVE, *M.I.E.E.*, *M.I.Mech.E.*, Chartered Patent Agent, Norfolk House, Norfolk St., London, W. C., Eng.	A May 16, 1891 M May 15, 1894
LOVEJOY, J. R., General Manager, Supply Dept., General Electric Co., Schenectady, N. Y.	A Apr. 21, 1891 M Feb. 21, 1894
LOZIER, ROBERT T. E. (*Manager*), General Manager, Sales Department, Bullock Electric Mfg. Co., Cincinnati, Ohio.	A May 20, 1890 M Jan. 24, 1900
LUNDY, AYRES DERBY, Sargent & Lundy, 46–1000 E. Van Buren St., Chicago, Ill.	A Feb. 27, 1903 M July 28, 1903
LYMAN, JAMES, Engineer, Western District, General [Life Member.] Electric Co., Monadnock Bldg., Chicago.	A Sep. 19, 1894 M Jan. 9, 1901
MACCOUN, ANDREW ELLICOTT, Supt. Electrical Dept., The Carnegie Steel Co., Braddock, Pa.	A Nov. 20, 1895 M July 18, 1899
MACFARLANE, ALEXANDER, *D.Sc.*, *LL.D.*, Lecturer on Mathematical Physics. Lehigh University; res., Gowrie Grove, Chatham, Ont.	A Jan. 19, 1892 M May 17, 1892
MAHONY, JAMES J., Engineer General Electric Co., 44 Broad St., New York City.	A May 17, 1898 M July 25, 1902
MAILLOUX, C. O. (*Vice-President*), Consulting Electrical [Life Member.] Engineer, 76 William St.; res., 8 W. 71st St., New York City.	A Apr. 15, 1884 M Oct. 21, 1884
MANSFIELD, ARTHUR N., 125 Milk St., Boston, Mass.	A Dec. 20, 1893 M June 20, 1894
MARKS, LOUIS B., *M.M.E.*, Electrical Engineer, 687 Broadway; res., 1 East 94th St., New York City.	A May 20, 1890 M Jan. 16, 1895
MARKS, WILLIAM DENNIS, *Ph.B.*, *C.E.*, President, City Heat and Light Co., Fostoria, O.	A Feb. 7, 1888 M May 1, 1888
MARSHALL, J. T., Asst. Engineer, Lamp Works; General Electric Co., Harrison; res., Metuchen, N. J.	A Oct. 1, 1889 M Nov. 12, 1889
MARTIN, JULIUS, Master Electrician, Navy Yard, Brooklyn; res., 445 W. 21st St., New York City.	A Oct. 21, 1890 M Nov. 20, 1895
MARVIN, HARRY N., President American Mutoscope and Biograph Co., 11 E. 14th St., New York.	A Apr. 19, 1892 M Jan. 17, 1893
MAVER, WILLIAM, JR., Electrical Expert and Consulting Electrical Engr., 120 Liberty St., New York City; res., 182 Arlington Ave., Jersey City, N. J.	A July 12, 1887 M Apr. 21, 1891
MAYER, GEORGE M., Mechanical and Electrical Engineer, 1131 Monadnock Bldg., Chicago, Ill.	A Dec. 16, 1890 M June 20, 1894
MAYNARD, GEO. C., Electrical Engineer, Smithsonian Institution, Washington, D. C.	A Apr. 15, 1884 M Dec. 9, 1888
McCAY, H. KENT, Prest., McCay Engineering Co., 107 E. German St., Baltimore, Md.	A Sep. 16, 1890 M May 19, 1891
McCROSKY, JAMES W., J. G. White & Co., Ltd., 22a College Hill, Cannon St., E. C., London, Eng.	A Dec. 20, 1893 M Dec. 16, 1896
McCROSSAN, J. A., Electrician, 1049 Harwood St., Vancouver, B. C	A Oct. 18, 1893 M Dec. 18, 1895
MEREDITH, WYNN, Electrical Engineer, Benjamin, Hunt & Meredith, 331 Pine St., San Francisco.	A Jan. 17, 1893 M Nov. 20, 1903
MERSHON, RALPH D., (*Vice-President*), Consulting Engineer, 29 Broadway, New York City.	A Mar. 20, 1895 M Jan. 22, 1896
MILLIS, JOHN, Major of Engineers, U. S. A., Seattle, Wash.	A July 7, 1884 M Mar. 3, 1885

MITCHELL, JAMES, Constructing Engineer and Agent, [Life Member.] General Electric Co., Caixa do Correio No. 954, Rio de Janeiro, Brazil.	A Sep. 25, 1895 M Mar. 25, 1896
MIX, EDGAR W., Electrical Engineer, 12 Boulevard des Invalides, Paris, France.	A Sep. 3, 1889 M Mar. 20, 1895
MOLÉ, HARVEY EDWARD, British Westinghouse Co., Westinghouse Building, Norfolk St., Strand, London, W. C., Eng.	A Nov 30, 1897 M Sep. 27, 1901
MOLERA, E. J., Civil and Electrical Engineer, 606 Clay St., San Francisco, Cal.	A Jan. 16, 1892 M June 7, 1892
MOORE, D. MCFARLAN, Inventor, Moore Electrical Co., 52 Lawrence St., Newark, N. J.	A Dec. 20, 1893 M June 20, 1894
MOORE, WM. E., General Superintendent and Electrician, Pittsburg, McKeesport & Connellsville Ry. Co., Connellsville, Pa.	A Jan. 22, 1896 M Sep. 27, 1899
MORROW, JOHN THOMAS. Green Consolidated Copper Co., Cananea, Sonora, Mex.	A Dec. 21, 1892 M Apr. 18, 1894
DE MURALT, CARL L., Electrical Engineer, 25 Pine St., New York City; res., Zurich, Switzerland.	A May 15, 1900 M Nov. 22, 1901
MURPHY, JOHN, Superintendent Power Houses, The Ottawa Electric Co., Ottawa, Ont.	A May 15, 1900 M Apr. 26, 1901
MURRAY, THOS. E., Second V. P. and General Manager, Edison Co., 55 Duane St., New York City.	A May 21, 1901 M Sep. 26, 1902
MUSCHENHEIM, FREDK. A., Electrical Engineer, Western Electric Co., 463 West St., New York City.	A Apr. 27, 1898 M Sep. 27, 1901
NEILER, SAMUEL G., Member of the Firm of Pierce, Richardson & Neiler, Consulting and Designing Engineers, 1405 Manhattan Bld., Chicago, Ill.	A Apr. 18, 1894 M Dec. 18, 1895
NICHOLS, EDWARD L., Professor of Physics, Cornell University; res., 5 South Ave., Ithaca, N. Y.	A Oct. 4, 1887 M Dec 6, 1887
NICHOLSON, WALTER W., General Supt. Central N. Y. Telephone and Telegraph Co., Telephone Building, Utica, N. Y.	A May 15, 1894 M May 18, 1897
NOLL, AUGUSTUS, Contracting Electrical Engineer, 8 East 17th St., New York City.	A Sep. 27, 1892 M Apr. 18, 1893
NUNN, PAUL N., Chief Engineer, Telluride Power Co., Telluride, Colo.	A Apr. 17, 1895 M Feb. 26, 1896
O'DEA, MICHAEL TORPEY, 71 No. State St., Chicago, Ill.	A June 8, 1887 M Mar. 25, 1896
OSTERBERG, MAX, *E.E.*, *A.M.*, Consulting Engineer and Electrical Expert, 11 Broadway, New York City.	A Jan. 17, 1894 M Jan. 23, 1903
OUDIN, MAURICE A., Electrical Engineer, General Electric Co., Schenectady, N. Y.	A June 20, 1894 M Nov. 20, 1895
OWENS, ROBERT BOWIE, (*Local Honorary Secretary*) McDonald Professor of Electrical Engineering, McGill University, Montreal, P. Q.	A June 17, 1890 M Dec. 15, 1897
PACKARD, GRENVILLE FREDERICK, Chief Engineer, Stow Mfg. Co., Binghamton, N. Y.	A Sep. 26, 1902 M July 28, 1903
PAINE, F. B. H., Westinghouse Electric and Mfg. Co., 120 Broadway, New York City; res., Englewood, N. J.	A Dec. 16, 1890 M Nov. 25, 1891
PAINE, SIDNEY B., General Electric Co., 84 State St., Boston, Mass.	A June 8, 1887 M Nov. 1, 1887
PARKER, LEE HAMILTON, Fort Wayne Electric Works, Fort Wayne, Ind.	A Aug. 5, 1895 M Dec. 16, 1896

PARKS, C. WELLMAN, Civil Engineer, U. S. N., Navy Yard, Boston, Mass.	A July 12, 1887 M May 1, 1888
PARSHALL, HORACE FIELD (*Local Honorary Secretary*), Consulting Engineer, Salisbury House, London, Wall, E. C., London, Eng.	A Sep. 7, 1888 M Mar. 18, 1890
PATTISON, FRANK A., Firm of Pattison Bros. Consulting and Constructing Electrical Engineers, Fuller Building, New York City.	A Sep. 22, 1891 M Dec. 16, 1891
PEARSON, F. S., Engineer, 29 Broadway, New York City.	A Oct. 25, 1892 M Feb. 21, 1893
PEARSON, WALTER AMBROSE, Electrical Engineer, Interurban Street Railway, Co. 621 Broadway, New York City.	A Apr. 23, 1903 M Nov. 20, 1903
PECK, JOHN SEDGWICK, Electrical Designer, The Westinghouse E. & M. Co., Pittsburg, Pa.	A Apr. 26, 1899 M May 15, 1900
PEDERSEN, FREDERICK MALLING, *M.S.*, *E.E.*, Tutor in Mathematics, College of the City of New York, 17 Lexington Ave., New York City.	A Sep. 20, 1893 M June 24, 1898
PEROT, L. KNOWLES, President of Phœnix Gas and Electric Co., 915 Arcade Building, Philadelphia.	A Mar. 15, 1892 M Dec. 18, 1895
PERRINE, FREDERIC A. C., *D.Sc.*, President Stanley Electric Mfg. Co., Pittsfield, Mass.	A Sep. 16, 1890 M Dec. 16, 1890
PERRY, JOHN, Royal College of Science, South Kensington, 34 Palace Gardens Terrace, London, W. England.	A Mar. 22, 1901 M June 28, 1901
PICKERNELL, F. A., Engineer, Amer. Telephone and Telegraph Co., 125 Milk St., Boston, Mass.	A Feb. 7, 1890 M Mar. 18, 1890
PIERCE, RICHARD H., 140 State St., Room 900, Boston; res., 16 Revere St., Jamaica Plain, Mass.	A Apr. 18, 1893 M Dec. 20, 1893
PIKE, CLAYTON W., *B.S.*, Electrical Engineer, Keller, Pike & Co., 112 N. 12th St., Philadelphia, Pa.	A Dec. 16, 1891 M Oct. 25, 1892
PINKERTON, ANDREW, Electrical Engineer, American Sheet Steel Co., Vandergrift, Pa.	A Sep. 25, 1895 M June 28, 1901
POOLE, CECIL P., Editor *American Electrician*, 114 Liberty St., New York City.	A Jan. 3, 1888 M July 23, 1902
POOLE, CHARLES OSCAR, With Hendric & Boltoff, 1621 17th St., Denver, Colo.	A Jan. 24, 1900 M May 19, 1903
PORTER, JOSEPH F., *C.E.*, President and Managing Engineer, Alton Railway, Gas and Electric Co. Alton, Ill.	A Sep. 6, 1887 M Nov. 1, 1887
POTTER, HENRY NOEL, 510 West 23d St., New York City; res., Rochelle Park, New Rochelle, N. Y.	A Sep. 19, 1894 M Dec. 19, 1902
POTTER, WM. BANCROFT, Engineer Railway Dept., General Electric Co., Schenectady, N. Y.	A Jan. 22, 1896 M Mar. 25, 1896
PRATT, ROBERT J., Electrician, Honolulu Iron Works, Honolulu, H. I.	A July 12, 1887 M Sep. 6, 1887
PUFFER, WM. L., Assistant Professor of Electrical Engineering, Mass. Institute of Tech., Boston, Mass.	A Dec. 20, 1893 M Apr. 17, 1895
RAE, FRANK B., Electrical and Mechanical Engineer, Exchange Court, 52 Broadway, New York City.	A Apr. 15, 1884 M Oct. 25, 1892
REBER, HENRY LINTON, General Manager, Sec'y and Chief Engineer, Kinloch Telephone Co., Century Building, St. Louis, Mo.	A May 19, 1903 M Dec. 18, 1903
REBER, SAMUEL (*Manager*), Major, U. S. A., War Department, Washington, D. C.	A Sep. 20, 1893 M Jan. 22, 1896

RECKENZAUN, FREDERICK, Electrical Engineer, 77 Chambers St., New York City. — A Mar. 6, 1888 M June 5, 1888

REDMAN, GEO. A., General Supt., Electric Dept., Brush Elec. Light Co., and Rochester Gas and Elec. Co., 82 Andrews St., Rochester, N. Y. — A Feb. 27, 1895 M May 17, 1898

REID, THORBURN, Consulting Electrical Engineer, 35 Nassau St., New York City. — A Oct. 21, 1890 M June 24, 1898

REIST, HENRY G., Designing Engineer, General Electric Co., Schenectady, N. Y. — A June 17, 1890 M Dec. 19, 1894

RENO, C. STOWE, Electrical Engineer, Triumph Electric Co., 610 Baymiller St., Cincinnati, Ohio. — A Nov. 23, 1898 M July 18, 1899

RICE, CALVIN WINSOR, *S.B.* (*Vice-President*), Consulting Engineer, General Electric Co., 44 Broad St.; res., 348 Central Park West, New York City. — A Jan. 20, 1897 M Apr. 28, 1897

RICE, E. WILBUR, JR., Technical Director, The General Electric Co., Schenectady, N. Y. — A Dec. 6, 1887 M Jan. 3, 1888

RICHARDSON, ROBERT E., Vice-President of Pierce, Richardson & Neiler, 1409 Manhattan Building, Chicago; General Manager, K. C. Electric Light Co., Kansas City, Mo. — A Sep. 19, 1894 M May 18, 1897

RIDLEY, A. E. BROOKE, Electrical Engineer and Contractor, 18 Fell St., San Francisco, Cal. — A Nov. 21, 1894 M Nov. 23, 1898

RIES, ELIAS E., Electrical Engineer and Inventor, 116 Nassau St.; res., 4 W. 115th St., New York City. — A July 12, 1887 M Sep. 6, 1887

RIKER, ANDREW L., Electrical Engineer, Locomobile [Life Member.] Co., of America, Bridgeport, Conn. — A Nov. 1, 1887 M Dec. 18, 1895

ROBB, RUSSELL, With Stone & Webster, 84 State St., Boston, Mass. — A Oct. 18, 1893 M May 21, 1895

ROBB, WM. LISPENARD, Professor of Physics and Electrical Engineering, Rensselaer Polytechnic Institute, Troy, N. Y. — A Dec. 16, 1891 M Mar. 15, 1892

ROBERTS, E. P., E. P. Roberts & Co., Consulting Engineers, Electric Building, Cleveland, Ohio. — A Jan. 6, 1885 M Feb. 3, 1885

ROBERTSON, ROBERT, Partner, John Strain, M. Inst. C. E., 154 West George St., Glasgow, Scotland. — A Jan. 23, 1903 M Apr. 24, 1903

RODGERS, HOWARD S., Vice-President, The Merchants National Bank, Cincinnati, Ohio. — A Sep. 27, 1892 M May 16, 1893

ROHRER, ALBERT L., Electrical Supt., Schenectady Works, General Electric Co., Schenectady, N.Y. — A Nov. 1, 1887 M May 1, 1888

ROLLER, FRANK W., *M.E.*, Electrical Engineer, Machado & Roller, Electrical Machinery, 203 Broadway, New York City. — A May 21, 1895 M Sep. 27, 1901

ROLLER, JOHN E., Commander U. S. N., Navy Department, Norfolk, Va. — A Sep. 19, 1894 M May 19, 1896

ROSA, EDWARD B., Physicist, National Bureau of Standards, Washington, D. C. — A Feb. 17, 1897 M May 18, 1897

ROSS, NORMAN N., Engineer, Stanley Electric Mfg. Co., 203 Equitable Building, Boston, Mass. — A Sep. 20, 1893 M Nov. 21, 1894

ROSS, ROBERT A., Mechanical and Electrical Consulting Engineer 78 St. Francis Xavier St., Montreal. — A Sep. 27, 1892 M Apr. 18, 1893

ROUQUETTE, WILLIAM F. B., Proprietor, Rouquette & [Life Member.] Co., 47 Dey St., New York City. — A Mar. 21, 1894 M Dec. 19, 1894

ROWE, GEORGE HERBERT, Professor of Electrical Engineering, Stanford University, Cal. — A Jan. 23, 1903 M July 28, 1903

RUSHMORE, DAVID B., Asst. Electrician, Stanley Elec. and Mfg. Co., Pittsfield, Mass.	A Sep. 25, 1895 M Jan. 24, 1902
RYAN, HARRIS J., Professor of Electrical Engineering, Cornell University, Ithaca, N. Y.	A Oct. 4, 1887 M Apr. 17, 1895
SACHS, JOSEPH, Electrical Engineer, The Johns-Pratt Company; res., 4 Cone St., Hartford, Conn.	A Mar. 15, 1892 M Dec. 15, 1897
SALOMONS, *Sir* DAVID LIONEL, *Bart.*, *M.A.*, Engineer [Life Member.] 49 Grosvenor St., London.	A Feb. 7, 1888 M May 1, 1888
SAMPSON, F. D., Manager, Charlotte Electric Light and Power Co., Charlotte, N. C.	A Aug. 5, 1896 M Oct. 27, 1897
SANDS, H. S., Consulting and Constructing Electrical Engineer, 1153 Market St., Wheeling, W. Va.	A Feb. 21, 1893 M Nov. 21, 1894
* SARGENT, WILLIAM D., Vice-Prest. and General Manager, N. Y. & N. J. Tel. Co., 81 Willoughby St.; res., 820 Union St., Brooklyn, N. Y.	A Apr. 15, 1884 M Feb. 21, 1894
SCHEFFLER, FREDK. A., General Manager, Marine Engine & Machine Co., Harrison, Glen Ridge, N. J.	A May 16, 1893 M Jan. 26, 1896
SCHMID, ALBERT, Directen Genéral de la Société Industrielle d'Electricité procédés Westinghouse, 45 Rue de l'Arcade, Paris, France.	A Oct. 21, 1890 M Apr. 17, 1895
SCHOEN, A. M., Electrician, South Eastern Tariff Association, 433 Equitable Building, Atlanta, Ga.	A Sep. 20, 1893 M Dec. 16, 1896
SCHWEDTMANN, FERDINAND, General Supt., Wagner Electric Mfg. Co., 2017 Locust St., St. Louis, Mo.	A Nov. 22, 1899 M Nov. 23, 1900
SCOTT, CHARLES F. (*Past-President*), Chief Electrician, Westinghouse Electric and Mfg. Co.; Pittsburg, res., Edgewood Park, Pa.	A Apr. 19, 1892 M Jan. 17, 1893
SCOTT, JAMES B., Consulting Engineer, 808 Maryland Trust Bldg., Baltimore, Md.	A Aug. 5, 1896 M May 17, 1898
SETHMAN, GEORGE HENRY, Mechanical and Electrical Engineer, Skinner & Sethman, Denver, Colo.	A Nov. 23, 1900 M June 28, 1901
SEVER, GEORGE FRANCIS, (*Manager*) Adj. Prof. of Electrical Engineering, Columbia Univ., N. Y. City.	A Jan. 17, 1894 M May 19, 1896
SHAW, EDWIN C., Mechanical Engineer, The B. F. Goodrich Co.; res., 104 Park St., Akron, O.	A May 17, 1892 M Feb. 27, 1895
SHEA, DANIEL W., Professor of Physics, Catholic University of America, Washington, D. C.	A Dec. 20, 1893 M June 20, 1894
SHELDON, SAMUEL, *A.M.*, *Ph.D.* (*Manager*), Professor [Life Member.] of Physics and Electrical Engineering, Polytechnic Institute, Brooklyn, N. Y.	A Dec. 16, 1890 M Oct. 27, 1891
SHEPARDSON, GEORGE D., Professor of Electrical Engineering, University of Minnesota, Minneapolis.	A Apr. 21, 1891 M Jan. 22, 1896
SINCLAIR, H. A., Electrical Engineer, Tucker Electric Co., 35 South William St., New York City.	A June 17, 1890 M Feb. 26, 1896
SKINNER, CHARLES EDWARD, Electrical Engineer, Westinghouse Electric & Mfg. Co., Pittsburg, Pa.	A Apr. 26, 1889 M July 28, 1903
SLICHTER, WALTER I., Electrical Engineer, General Electric Co.; res., 16 Gillespie St., Schenectady, N. Y.	A Apr. 25, 1900 M Oct. 23, 1903
SMITH, FRANK E., Consulting and Supervising Electrical Engineer, 183 Jessie St., San Francisco, Cal.	A Sep. 19, 1894 M July 18, 1899
SMITH, FRANK STUART, 2d Vice-President, Sawyer-Man Electric Co., 510 W. 23d St., New York City.	A Sep. 27, 1892 M Apr. 18, 1893
SMITH, HAROLD BABBITT, Professor of Electrical Engineering, Worcester Polytechnic Institute; res., 20 Trowbridge Road, Worcester, Mass.	A Nov. 24, 1891 M Apr. 25, 1900

Smith, Jesse M., Consulting Electrical and Mechanical Engineer, Expert in Patent Cases, 220 Broadway, New York City.	A Apr. 15, 1884 M June 26, 1891
Smith, T. Carpenter, Member of Firm of M. R. Muckle Jr., & Co., 512 Stephen Girard Bldg., res.; The "Newport," Philadelphia, Pa.	A Oct. 27, 1891 M Dec. 16, 1891
Sparks, Charles Pratt, Chief Engineer, The County of London Electric Lighting Co., London, E. C., Eng.	A Mar. 22, 1891 M June 28, 1901
Sperry, Elmer A., Electrical Engineer, 855 Case Ave., Cleveland, Ohio.	A Apr. 15, 1884 M Feb. 21, 1893
Sprague, Frank J. (*Past-President*), Consulting Engineer, Sprague Electric Co., 20 Broad St.; res., The Turrets, Riverside Drive, New York City.	A May 24, 1887 M Feb. 17, 1897
Springer, Frank W., Assistant Professor Electrical Engineering, University of Minn., Minneapolis.	A Nov. 23, 1900 M Apr. 26, 1901
Stanley, William, Electrical Engineer and Inventor, Great Barrington, Mass.	A Dec. 6, 1887 M Oct. 26, 1898
Stanton, Leroy W., Superintendent of Equipment, The Federal Telephone Co., 901 Electric Building, Cleveland, Ohio.	A Aug. 22, 1902 M Jan. 23, 1903
Stark, Edgar Everett, Electrical Engineer, Waiporé Falls Electric Co., Dunedin, N. Z.	A Jan. 23, 1903 M Dec. 18, 1903
Stearns, Charles K., *E.E.*, Mechanical and Electrical Engineer, 93 Federal St., Boston, Mass.	A Aug. 6, 1889 M May 16, 1893
Stearns, Joel W., President, Mountain Electric Co., Denver, Colo.	A June 20, 1894 M Nov. 20, 1895
Stebbins, Theodore, C. S. & L. Ry., Columbus, Ohio.	A July 9, 1889 M June 17, 1891
Steinmetz, Charles P. (*Past-President*), Electrician, General Electric Co., Schenectady, N. Y.	A Mar. 18, 1890 M Apr. 21, 1891
Stephens, George, Societe des Establissements Postel-Vinay, 219 Rue de Vangirard, Paris, France.	A June 20, 1894 M Dec. 18, 1895
Stevens, J. Franklin, President Keystone Electrical Instrument Co., 9th St. and Montgomery Ave.; Philadelphia, Pa	A Sep. 19, 1894 M Feb. 28, 1901
Stewart, Robert Stuart, British Westinghouse Electric and Mfg. Co., Trafford Park, Manchester, Eng.	A Dec. 20, 1896 M May 15, 1900
Stillwell, Lewis B., Consulting Electrical Engineer, Electrical Director, Rapid Transit Subway Construction Co., Park Row Bldg., New York City.	A Apr. 19, 1892 M Nov. 15, 1892
Storer, Norman Wilson, Electrical Engineer, Westinghouse Electric & Mfg. Co., Pittsburg, Pa.	A Dec. 18, 1895 M July 28, 1903
Storrs, H. A., Electrical Engineer, Reclamation Soc., U. S. Geological Survey, Chamber of Commerce Building, Denver, Colo.	A Mar. 21, 1893 M Jan. 24, 1900
Stott, Henry G., Supt. Motive Power, Manhattan Railway Co., New York City.	A Sep. 25, 1895 M Apr. 22, 1896
Strong, Frederick G., Box 959, Hartford, Conn.	A Oct. 27, 1891 M July 18, 1899
Sunny, Bernard Edward, Western Manager, General Electric Co., Monadnock Building, Chicago, Ill.	A Feb. 27, 1903 M Nov. 20, 1903
Swenson, Bernard Victor, Assistant Professor of Electrical Engineering, University of Wisconsin 404 W. Mifflin St., Madison, Wis.	A Feb. 27, 1895 M Mar. 27, 1903

SWINBURNE, JAMES, Consulting Electrical Engineer, 82 Victoria St., London, Eng.	A Jan 23, 1903 M Mar. 27, 1903
SWINTON, ALAN ARCHIBALD CAMPBELL, Consulting Electrical Engineer, 66 Victoria St., London.	A Mar. 22, 1901 M June 28, 1901
TERRY, CHARLES A. (*Manager*), Lawyer, Westinghouse Electric and Mfg. Co., 120 Broadway, New York.	A Apr. 5, 1887 M May 17, 1887
THEBERATH, THEODORE E., California Gas & Electric Corporation, Rialto Building, San Francisco.	A Mar. 23, 1898 M June 24, 1898
THOMAS, BENJAMIN F., Professor of Physics, Ohio State University, Columbus. O.	A June 7, 1892 M Nov. 15, 1892
THOMPSON, EDWARD P., Solicitor of Patents and Expert, 156 Fifth Ave., New York City.	A Apr. 15, 1884 M Dec. 3, 1889
THOMSON, ELIHU (*Past-President*) Electrician, General Electric, and Thomson Electric Welding Companies, Lynn; res., Swampscott, Mass.	A Apr. 15, 1884 M Apr. 21, 1891
THRESHER, ALFRED A., Electrical Engineer and Proprietor, Thresher Electric Co., Dayton, O.	A Apr. 22, 1896 M June 24, 1898
THURNAUER, ERNST, Manager, Thomson-Houston International Elec. Co., 27 Rue de Londres, Paris, France	A Oct. 14, 1887 M Dec. 6, 1887
TISCHENDORFER, F., Civil-Ingenieur, Elektrotechnisches Bureau, Ottostrasse 11, Berlin, N. W., Ger.	A Apr. 19, 1892 M Nov. 21, 1894
TRAFFORD, EDWARD W., Consulting ElectricalEngineer, 27 Chamber of Commerce, Richmond, Va.	A Feb. 21, 1894 M Dec. 19, 1894
UEBELACKER, CHAS. F., With Ford ,Bacon & Davis, Hackensack, N. J.	A Feb. 7, 1890 M Nov. 15, 1893
UHLENHAUT, FRITZ, JR., Chief Engineer, Pittsburg Railway Co., Pittsburg, Pa.	A May 7, 1889 M Dec. 19, 1894
UPTON, FRANCIS R., *M.S.*, Edison Laboratory; res., 20 High St., Orange, N. J.	A May 17, 1887 M Mar. 15, 1892
VANSIZE, WILLIAM B., Solicitor of Patents, Expert in [Life Member.] Patent Cases, 253 Broadway, New York City.	A Apr. 15, 1884 M Oct. 21, 1884
VAN TRUMP, C. REGINALD, Engineer and Manager, Wilmington City Electric Co., Wilmington, Del.	A Feb. 5, 1886 M Feb. 21, 1894
VARLEY, RICHARD, JR., President, Varley Duplex Magnet Co., Phillipsdale, Providence, R. I.	A Apr. 25, 1900 M Feb. 28, 1901
VON RECKLINGHAUSEN, MAX, with George Westinghouse, 510 West 23d St., New York City.	A Jan. 24, 1902 M Apr. 24, 1903
WADDELL, MONTGOMERY, Consulting Engineer, 135 Broadway, New York City.	A Feb. 7, 1888 M May 1, 1888
WAGNER, HERBERT, A., Consulting Engineer, 415 Locust St., St. Louis, Mo., and *Times* Building, New York City.	A Sept. 28, 1898 M July 28, 1903
WAIT, HENRY H., Assistant Electrical Engineer, Western Electric Co., Chicgao, Ill.	A Sep. 20, 1893 M June 20, 1894
WALDO, LEONARD, Electrical Engineer, 49 Wall St., New York; res., 640 West 8th St., Plainfield,N.J.	A June 5, 1888 M Dec. 4, 1888
WALKER, SYDNEY F., Consulting Electrical Engineer, 12 Leimster Square, London W., Eng.	A June 2, 1885 M May 17, 1887
WALL, LOUIS JAMES BENARD, Full Partner, Splatt, Wall & Co., Perth, Western Australia.	A July 26, 1900 M Nov. 23, 1900
WARNER, ERNEST P., Electrical Engineer, Western Electric Co.; res., 402 Belden Ave., Chicago Ill	A Sep. 20, 1893 M June 20, 1894

WATERMAN, F. N., Mechanical and Electrical Engineer, 150 Nassau St., New York City. — A Feb. 21, 1893; M June 20, 1894

WEAVER, W. D., Editor, *Electrical World and Engineer*, 114 Liberty St., N. Y. City; res. Englewood, N. J. — A May 17, 1887; M May 17, 1887

WEBB, HERBERT LAWS, c\o Sir William Preece, 8 Queen Anne's Gate, London, S. W., Eng. — A Oct. 21, 1890; M Dec. 16, 1890

WEBB, HOWARD SCOTT, Professor of Electrical Engineering, University of Maine, Orono, Maine. — A Oct. 24, 1900; M June 19, 1903

WEBBER, CHARLES EDMOND, Major General, *C.B.* (ret.) *R.F.*, Past-President and Member of Council, Institution of Electrical Engineers, 17 Egerton Gardens, London, S. W., Eng. — A Jan. 9, 1901; M Jan. 24, 1902

WEEKS, EDWIN R., Consulting Engineer, Weeks, Kendall & Newkirk, 606 New Nelson Building, res., 3408 Harrison St., Kansas City, Mo. — A Sep. 6, 1887; M Nov. 1, 1887

WELLER, HARRY W., Electrical Engineer, Room 1, New York Life Building, Montreal, P. Q. — A Oct. 21, 1890; M Nov. 24, 1891

WESTON, EDWARD (*Past-President*), President, Weston Electrical Instrument Co., Waverley Park, N. J. — A Apr. 15, 1884; M Oct. 21, 1884

WETZLER, JOSEPH, President, The Electrical Engineer Institute of Correspondence Instruction, 240 W. 23d St.; res., 257 W. 104th St., New York City. — A Apr. 15, 1884; M Dec. 9, 1884

WHARTON, CHAS. J., Palace Chambers, Westminster, London, Eng. — A Jan. 3, 1888; M May 1, 1888

WHEELER, SCHUYLER, SKAATS *Sc. D.* (*Vice-President*), [Life Member.] President, Crocker-Wheeler Co., Ampere, N. J., — A June 2, 1885; M Sep. 1, 1885

WHITE, JAMES GILBERT, J. G. White & Co., Electrical Engineers and Contractors, 43 Exchange Place, New York City. — A Apr. 2, 1889; M May 15, 1900

WHITE, WILL F., Electrical Engineer and Vice-President, The North American Co., 30 Broad St., N. Y. City. — A Feb. 7, 1890; M July 27, 1898

WHITE-FRASER, GEO., *Mem. Can. Soc., C.E.*; Dominion Land Surveyor, Dawson, Y. T. — A Sep. 22, 1891; M Dec. 18, 1895

WIENER, ALFRED E., Chief Instructor, The Electrical Engineer Institute, 240 W. 23d St., New York. — A May 16, 1893; M May 15, 1894

WIGHTMAN, MERLE J., Electrical Engineer, 302 Broadway, New York City. — A Mar. 5, 1889; M May 19, 1903

WILCOX, NORMAN T., Manager, The Lowell Electric Light Corporation, Lowell, Mass. — A May 21, 1895; M Jan. 22, 1896

WILLIS, EDWARD J., President, Richmond Electric Co., 211 E. Franklin St., Richmond, Va. — A Nov. 30, 1897; M Feb. 28, 1900

WILLYOUNG, ELMER G., Willyoung & Gibson Co., 40 West 13th St., New York City. — A Nov. 24, 1891; M Dec. 20, 1893

WILSON, CHARLES H., General Supt., American Telephone & Tel. Co., 15 Dey St., New York City. — A Nov. 24, 1891; M Feb. 16, 1892

WILSON, FREMONT, Consulting Engineer, 31 Pine St., New York City. — A Mar. 6, 1888; M June 5, 1888

WILSON, HOWARD S., Superintendent, Puebla Electric Light Co., Puebla, Mexico. — A Aug. 23, 1899; M Feb. 28, 1902

WINCHESTER, A. E., City Electrical Engineer and General Supt., City of South Norwalk Electric Works; also Consulting Engineer for Municipalities; res., 4 Gerard Pl., South Norwalk, Conn. — A June 8, 1887; M Nov. 1, 1887

WINSLOW, GEORGE HERBERT, National Tube Co., Frick Building, Pittsburg, Pa.	A Apr. 17, 1895 M Feb. 26, 1896
WOLCOTT, TOWNSEND (*Manager*), Electrician, 39 Whitehall St., New York City.	A Mar. 6, 1888 M Dec. 16, 1890
WOLVERTON, B. C., Engineer, N. Y. & Pa. Telephone and Telegraph Co., Elmira, N. Y.	A Mar. 18, 1890 M Feb. 21, 1895
WOODWARD, WM. CARPENTER, Electrical Engineer, Narragansett Electric Lighting Co., Union Trust Co. Building, Providence, R. I.	A Nov 18, 1896 M Apr. 25, 1902
WORDINGHAM, CHAS. H., Electrical Engineer-in-Chief to the British Navy, London, England.	A July 27, 1898 M Oct. 26, 1898
WOTTON, JAMES A., Manager Wotton Electric and Mfg. Co., 12 St. Charles Ave., Atlanta, Ga.	A Oct. 27, 1897 M Feb. 28, 1901
WRIGHT, PETER, President, Virginia Electric Company, Norfolk, Va.	A May 16, 1889 M Jan. 16, 1895
WURTS, ALEXANDER JAY, Manager Nernst Lamp Co., Pittsburg, Pa.	A Apr. 19, 1892 M Nov. 15, 1892
YOUNG, C. GRIFFITH, Engineer Construction, J. G. White & Co., 29 Broadway, New York.	A Jan. 3, 1889 M Apr. 21, 1891
YOUNG, WALTER DOUGLAS, Electrical Engineer, B. & O. R. R., Roland Park, Baltimore, Md.	A Apr. 26, 1899 M Jan. 24, 1900

(10)

Total, 459.

ASSOCIATES.

Name and Address.	Date of Election.
Aall, Nicola, Assistant Switchboard Engineer, General Incandescent Arc Light Co., 572 First Ave., New York City.	April 23, 1903
Abbott, Charles L., Erecting Engineer, Westinghouse E. & M. Co., 716 Board of Trade Building, Boston, Mass.	June 19, 1903
Abbott, Henry, President, Calculagraph Co., 9 Maiden Lane, New York City; res., 32 So. Clinton St., East Orange, N. J.	Apr. 28, 1897
Abbott, William L., Chief Operating Engineer, Chicago Edison Co., 139 Adams St.; res., 3213 Beacon St., Chicago, Ill.	Oct. 25, 1901.
Abell, Harry Clinton, Engineer, Montgomery Light and Water Power Co., 101 Bibb St., Montgomery, Ala.	May 19, 1903
Abella, Juan, Consulting Engineer, Buenos Aires and Belgrano Tramways Co.; res., 691 Calle Bolivar, Buenos Aires, A. R.	Aug. 5, 1896
Abendroth, William Philip, Student, Columbia University; res., 539 West 152d St., New York City.	May 19, 1904
Ablett, Charles Anthony, Student Testing Department, General Electric Co., Schenectady, N. Y.	Apr. 23, 1903
Abry, Bertrand Buhre, Electrical Engineer, Westinghouse E. & M. Co.; res., 524 Rebecca St., Sta. D., Pittsburg, Pa.	Jan. 23, 1903
Ackermann, Alexander Henry, Electrical Engineer, New York Edison Co.; 117 West 39th, St., New York City.	May 19, 1903
Acker, Charles Ernest, Vice-President and Manager Acker Process Co., Niagara Falls, N. Y.	Jan. 23, 1903
Adams, Comfort A., Jr., Assistant Professor of Electrical Engineering, Harvard University, 13 Farrar St., Cambridge, Mass.	Jan. 17, 1894
Adams, Ernest Kempton, *E. E. A. M.*, Electrical Engineer, 8 East 52d St.; res., 455 Madison Ave., New York City.	July 27, 1898
Adams, Frank Pierce, Electrician, Stockton Gas & Electric Co.; res. 329 E. Channel St., Stockton, Cal.	Feb. 15, 1899
Adams, George Francis, District Engineer, Westinghouse E. & M. Co. Room 1007, New England Bldg., Cleveland, O.	Jan. 23, 1903
Adams, Herbert Harter, Tester, General Electric Co.; res., 703 Union St., Schenectady, N. Y.	Feb. 27, 1903
Adams, Julius LeRoy, Chief Engineer, Hartford, Manchester & Rockville Tramway Co., Manchester, Conn.	Feb. 15, 1899
Adams, Roy Harmon, Assistant Electrical Engineer, Signal Corps, U. S. Army; res., 116 West 8th St., Bayonne, N. J.	Oct. 23, 1903
Adams, Seth C., Salesman and Engineer, Westinghouse Electric & Mfg. Co., New York City; res., New Rochelle, N. Y.	Apr. 23, 1903
Adams, Willis Longfellow, General Manager, Adams Construction Co.; res., 726 Buffalo Ave., Niagara Falls, N. Y	Jan 24, 1902
Adamson, Daniel Joseph Adamson & Co, Hyde, Eng.	Feb. 26, 1896
Addicks, Lawrence, Assistant to Superintendent, Raritan Copper Works, Perth Amboy, N. J.	July 25, 1902
Adler, Alphonse A., F. J. & A. A. Adler, Electrical Contractors, 123 Liberty St.; res., 237 Eldridge St., New York City.	July 12, 1900
Agnew, Cornelius R., 16 William St.; res., 23 West 39th St., New York City.	Mar. 21, 1894

AGNEW, JOHN PATTERSON, Assistant Foreman Westinghouse E. & M. Co., Pittsburg; res., 755 Franklin ave., Wilkinsburg, Pa. Nov. 20, 1903

AHLM, CHARLES EDWARD FRANS. Consulting Engineer, 1327 Williamson Bldg., Cleveland, O. Feb. 27, 1903

AITKEN, KENNETH LYNDWODE. Canadian General Electric Co., 14 King St., E. Toronto, Ont. July 28, 1903

ALBIN, HENRY ALLISON. General Manager and Electrical Engineer, Concord Street Railway, Concord, N. H. Mar 22, 1901

ALBURGER, EDWARD T., JR., Electrical Engineer, The American Bridge Co., Ambridge, Pa. July 28, 1901

ALDEN, HERBERT WATSON, Engineer, Electrical Vehicle Co., cor. Park and Laurel Sts., Hartford, Conn. Aug. 22, 1901

ALEXANDER, GEORGE L., Commercial Engineer, General Electric Co.-Schenectady, N. Y. June 18, 1903

ALEXANDER, HARRY, General Manager and Vice-Prest., Alexander-Chamberlain Electric Co., 25 West 33d St., New York City. Apr. 21, 1891

ALKINS, ALBERT EDWIN, Foreman, Special Lamp Testing, General Electric Co.; res., 192 S. Common St., Lynn, Mass. Apr. 24, 1903

ALLEN, ALBERT P., Central Union Telephone Co., Indianapolis, Ind. July 26, 1900

ALLEN, EDWIN WOOD, In Consulting Engineering Department, General Electric Co.; res., 14 Union St., Schenectady, N. Y. Mar. 27, 1903

ALLEN, GEORGE CONRAD, Supt. of Construction, N. Y. Telephone Co., 32 Gold St. New York City; res., New Rochelle, N. Y. Jan. 23, 1903

ALLEN, THOMAS SIMMONS, Electrical Engineer, Bullock Electric Mfg Co.; res., 5139 Main Ave., Norwood, Ohio Feb. 27, 1903

ALLEN, WALTER CUMMINGS, Electrical Engineer, District of Columbia, District Building, Washington, D. C. June 24, 1898

ALLEN, WYATT H., Consulting Engineer, Hunt, Meredith, Cory & Allen, 331 Pine St., San Francisco, Cal. Apr. 27, 1898

ALVERSON, HARRY BARTLETT, Superintendent, Cataract Power and Conduit Co., 40 Court St., Buffalo, N. Y. Oct. 25, 1901

AMBLER, NATHAN B., Sub-station Foreman, The Interurban Street Railway Co.; res., 134 E. 19th St., New York City. June 19, 1903

AMBLER, WILLIAM, Asst. Prof. of Electrical Engineering, Case School of Applied Science, Cleveland, Ohio. July 12 1900

AMSTUTZ, NOAH STEINER, Vice-President Amstutz Osborn Co., 716 Caxton Building; res., 27 Hillsdale Ave., Cleveland, O. Jan. 3, 1902

ANDERSON, COOPER, General Superintendent, Colorado Department, The Telluride Power Co., Telluride, Col. Nov.21,1902

ANDERSON, DOUGLAS SMITH, Associate Professor of Electrical Engineering, Tulane University, New Orleans, La. Apr. 26, 1901

ANDERSON, EDWARD H., Designing Engineer, General Electric Co.; res., 10 Gillespie St., Schenectady, N. Y. Apr. 25, 1902

ANDERSON, HENRY S., General Manager and Electrician, United Electric Light Co., Springfield, Mass. Jan. 16, 1895

ANDERSON, PAUL LEWIS, Tester, Sprague Electric Co., Bloomfield; res. 253 Renshaw Ave., E. Orange. N. J Oct. 23, 1903

ANDREWS, LEONARD, Electrical Engineer, 82 Victoria St., London, S. W. Eng. July 28, 1903

ANDREWS, WILLIAM C., Sales Department Engineer, Stanley Instrument Co., Great Barrington, Mass May 21, 1895

ANDRUS, LUCIUS BUCKLEY, Engineer, Westinghouse Electric & Mfg. Co.; res., 42 W. State St., Columbus, Ohio. May 19, 1903

ANGUS, WILLIAM GRAHAM, Electrical Engineer, The Hamilton Electric Light and Cataract Power Co., Hamilton, Ont. May 19, 1903

ANTHONY, JAMES STOWELL, General Electric Co., 44 Broad St., New York City. Apr. 25, 1902

APPERSON, ALFRED HULL, Assistant Electrician, South Eastern Tariff Association, 433 Equitable Building, Atlanta, Ga. Sept. 25, 1903

APPLER, GRAFTON WALL, Northern California Power Co., Redding, Cal Nov. 21, 1902

APPLEYARD, ARTHUR E., Treasurer and Managing Dir., Dayton, Springfield & Urbana Electric Ry. Co, Springfield, Ohio. Aug. 5, 1896

ARCHBOLD, WM. K., University Building, Syracuse, N. Y. June 20, 1894

ARCHER, GEO. F., Electrical Engineer, 150 Nassau Street, New York City. Nov. 21, 1894.

ARCHIBALD, ERNEST M., Electrical Engineer American Locomotive Co., Richmond Works, Richmond, Va. May 15, 1900

ARENDT, MORTON, Lecturer in Electrical Engineering, Columbia University; res., 1851 7th Ave., New York City. Jan. 23, 1903

ARMSTRONG, ALBERT H. (*Manager*), Electrical Engineer, General Electric Co., Schenectady, N. Y. June 24, 1898

ARMSTRONG, JAMES ROBERTS CHARLTON, in charge of installation of switchboard at Manhattan Power Station for General Electric Co.; res., 140 E. 34th St., New York City. Sep. 26, 1902

ARMSTRONG, SAMUEL GEORGE, Johannesburg, South Africa. Jan. 3, 1902

ARNOLD, CHESTER HASTINGS, Asst. Engineer N. Y. Telephone Co., 18 Cortlandt St.; res., 242 West 104th St., New York City. Jan. 3, 1902

ARNOLD, WARD S., Electrical Engineer, Stanley Electric Mfg. Co., 15 Monadnock Bldg; res., 384 E. 40th St., Chicago, Ill. Jan. 24, 1902

ASCHOFF, ADOLPHO, Partner James Mitchell & Co., Rio de Janeiro, Brazil. Feb. 27, 1903

ASH, WALTER VOORHIS, Chief Electrician, Raritan Copper Works; res., 79 State St., Perth Amboy, N. J. May 20, 1902

ASHE, SIDNEY WHITMORE, Instructor in Physics, Polytechnic Institute, Brooklyn; res., Webster Ave., Bedford Park, N. Y. June 28, 1901

ASHLEY, FRANK M., *M.E.*, Ashley & Stern, 130 Fulton St.; res., 124 W. 112th St., New York City. Nov. 21, 1894

ATKINS, CHARLES GILMAN, Consulting Engineer, Pratt & Atkins, 1001 Monadnock Building, Chicago, Ill. Oct. 25, 1901

ATKINS, HAROLD B., Assistant to H. de B. Parsons, Consulting Engineer, 22 William St., New York City. June 23, 1897

ATWOOD, GEORGE F., with Western Electric Co., New York City; res., 1030 Hudson St., Hoboken, N J. Sep. 16, 1890

AUEL, CARL B., Engineer, British Westinghouse Elec. & Mfg. Co., Ltd., Trafford Park, Manchester, Eng. July 26, 1900

AUSTIN, SYDNEY B., Consulting Engineer, 659 Maryland Ave., Pittsburg, Pa. Sep. 25, 1895

AVERRETT, ANDREW E., Engineer, General Electric Co.; res., 934 State St., Schenectady, N. Y. Jan. 3, 1902

AYLMER-SMALL, SIDNEY, Electrical Engineer, 19 W. 44th St., New York City; res., 11 Randolph St., Passaic, N. J. Oct. 24, 1900

AYLSWORTH, J. WALTER, Experimenter and Chemist, Edison Laboratory res., 223 Midland Ave., East Orange, N. J. Sept. 27, 1901

AYRES, ALBERT DOANE, Keokuk Electric Railway Co., 421 Main St., Keokuk, Iowa. Feb. 28, 1902

AYRES, MILAN VALENTINE, Electrical Engineer, Boston and Worcester Street Railway Co., South Framingham, Mass. May 19, 1903

BABBITT, HARRY D., Electrical Engineer, Thompson-Starrett Co., 51 Wall St.; res., 7 W. 108th St., New York Ctiy. Mar. 27, 1903

BABCOCK, EDWIN WILSON, Superintendent of Electrical Construction, Brooklyn Edison Co., Brooklyn, N. Y. Sept. 25, 1903

BABSON, ALBERT D., Manager, Supply Department, General Electric Co., 44 Broad St., New York City. Mar. 27, 1903

BABSON, ARTHUR C., Engineer, Portland Office, General Electric Co., 541 Worcester Building, Portland, Ore. Mar. 28, 1900

BACON, DANIEL READ, Student, Columbia University, New York City; res., Goshen, N. Y. July 28, 1903

BACOT, EUGENE CYRUS, Electrical Engineer, Great Northern Power Co., 315 Providence Building, Duluth, Minn Apr. 23, 1903

BADEAU, CHARLES CUSHING, Cutler-Hammer Mfg. Co., 319 Frick Building, Pittsburg, Pa. Apr. 25, 1902

BADEAU, ISAAC F., General Electric Co.; res., 144 Lafayette St., Schenectady, N. Y. Feb. 26, 1896

BAEHR, GEORGE, Chief Electrician, Nat. Tube Co.; res., 516 Willow Ave., McKeesport, Pa. Jan. 23, 1903

BAEHR, WILLIAM ALFRED, Engineer, Laclede Gas Light Co., St. Louis, Mo. Feb. 27, 1903

BAHNSON, FREDERIC FRIES, Chief Engineer, Florida East Hotel Co., Nassau, N. P., Bahamas. Apr. 23, 1903

BAILEY, CLIFFORD DEXTER, Student, Polytechnic Institute; res., 861 Carroll St., Brooklyn, N. Y. Mar. 27, 1903

BAILEY, LEON W., Electrical Engineer, Reliance Electric Co.; res., 2815 Brown St., Milwaukee, Wis. Sep. 27, 1901

BAILEY, THEO. P., Assistant Manager, Chicago Office, General Electric Co., 1047 Monadnock Building, Chicago, Ill. Apr. 25, 1902

BAINTON, JOHN RICHARD, Consulting Engineer, Standard Electric Elevator Co., Equitable Bldg., Sydney, N. S. W. Oct. 24, 1902

BAKER, ARTHUR O., Superintendent, Wichita Gas, Electric Light and Power Co., Wichita, Kan. July 26, 1900

BAKER, JOSEPH B., Consulting Electrical Engineer, 161 Summer St., Boston, Mass. Sep 27, 1901

BAKER, WILLIAM EDGAR, W. E. Baker & Co., Engineers, 170 Broadway, New York City. June 28, 1901

BALDWIN, CHARLES FOWLER, Chief Engineer Bell Telephone Mfg. Co., 18 Rue Bondewyns, Antwerp, Belgium. Oct. 23, 1903

BALDWIN, GEORGE PORTER, John Martin & Co., 511 Douglass Building, Los Angeles, Cal. Nov. 23, 1900

BALDWIN, JAS. C. T., American Telephone and Telegraph Co., 125 Milk St.; res., Chestnut Hill Ave., Boston, Mass. Apr. 17, 1895

BALFOUR, REGINALD, Asst. Operating Supt., Lachine Rapids Hydraulic and Land Co., 160 McCord St., Montreal, P. Q. Mar. 27, 1903

BALL, HENRY PRICE, Electrical Engineer, General Electric Co., Schenectady, N Y. May 21, 1901

BALL, WM. D., Consulting Engineer, 1105 Merchants Loan and Trust Bldg., 135 Adams St., Chicago, Ill. Nov. 20, 1895

BALLARD, FREDERICK WAYNE, Consulting Engineer, 100 Canal St.; res., 52 Wallingford Court, Cleveland, Ohio. Feb. 27, 1903

BALLOU, WARREN JAMES, Electrician, Woonsocket Elec. Machine & Power Co., Station No. 2, Woonsocket, R. I. Nov. 23, 1900

BALSLEY, ABE, Engineering Department, Georgia Railway & Electric Co., Atlanta, Ga. Oct. 27, 1897

BAMBER, WILLIAM CHILD, Electrical Engineer Rapid Transit Subway Construction Co., 13 Park Row, New York City. Oct. 25, 1901

BANCROFT, CHAS. F., Electrical Engineer, General Electric Company, 84 State St., Boston, Mass. Dec. 18, 1895

BANGS, CHAS. R., Special Agent, American Telephone and Telegraph Co. 15 Dey St., New York City. Jan. 26, 1898

BANKS, WILLIAM C., Consulting Electrical Engineer, Smith Building, 148th St. & 3d Ave., N. Y. City. May 18, 1897

BARCLAY, JOHN C., Asst. General Manager, Western Union Telegraph Co., 195 Broadway; res., Hotel Empire, New York City. Apr. 23, 1903

BARKER, ARTHUR E., Secretary Dean Electric Co., Elyria, Ohio. Mar. 27, 1903

BARKER, JAMES EDMUND, Electrical Engineer, Pacific Electric Railway Co., Los Angeles; res., Pasadena, Cal. Apr. 23, 1903

BARKER, RALPH EMERSON, Assistant Electrical Engineer, General Electric Co.; res., 24 Chase St., Lynn, Mass May 19, 1903

BARNAY, JOHN MARTIN, Designer, McCormick Division International Harvester Co., Chicago, Ill. Apr. 23, 1903

BARNES, EDWARD A., Electrical Expert, Fort Wayne Electric Co., Fort Wayne, Ind. Sep. 20, 1893

BARNES, HOWELL HENRY, Engineer, Stanley Electric Mfg. Co.; res., Beech Grove Inn, Pittsfield, Mass. Feb. 28, 1900

BARNES, WALTER CLYMER, Supt. of Electrical Construction, Interborough Rapid Transit Co., New York City. Nov. 20, 1903

BARNES, WILLARD J., Electrician, The Duncan Co., Mechanicsville, N. Y. June 19, 1903

BARNETT, CARL P., Draftsman and Engineer, with S. & S. Packing Co., Osage and Adams Sts., Kansas City, Kansas. Jan. 25, 1901

BARNUM, THOMAS EDSON, Assistant Chief Engineer, Cutler-Hammer Mfg., 648 34th St., Milwaukee, Wis. Nov. 20, 1903

BARON, MAX D., Electrical Engineer and Contractor, 125 East 23d St.; res., 61 E. 75th St., New York City. Mar. 28, 1900

BARR, FRANK ADELBUT, Manager and Electrician, Fries Mfg. and Power Co., Winston-Salem, N. C. Jan. 9, 1901

BARR, FREDERIC CROSSGROVE, Electrician, The Colorado Telephone Co., 1447 Lawrence St., Denver, Colo. Mar. 27, 1903

BARR, JOHN B., Electrical Engineer, General Electric Co., 44 Broad St., New York City. Apr. 25, 1900

BARRY, CHARLES EDWARD, Electrical Engineer, General Electric Co., Schenectady, N. Y. Sept. 25, 1903

BARRY, DAVID, Electrician and Superintendent, Amherst Gas Co., Amherst, Mass. Aug. 5, 1896

BARRY, JOHN G., General Electric Co., Schenectady, N. Y. Apr. 23, 1903

BARTON, EDWARD GUSTAVUS CAMPBELL, Managing Director, Brisbane Electric Supply Co., Ltd., Brisbane, Queensland. Oct. 23, 1903

BARTON, ENOS M., President Western Electric Co., 259 So. Clinton St., Chicago, Ill. July 12, 1887

BATES, FREDERICK C., Electrical Engineer, General Electric Co., 44 Broad St., New York City. Jan. 20, 1891

BATES, PUTNAM A., Assistant Secretary, Crocker-Wheeler Co., Ampere, N. J.; res., 113 W. 72d St., New York City. Jan. 20, 1897

BATTEY, PAUL LEON, Electrical Engineer, Arnold Electric Power Station Co., 1539 Marquette Building, Chicago, Ill. Dec. 19, 1902

BAUGHER, E. C., Resident Engineer, Westinghouse Elec. & Mfg. Co., c/o Takata & Co., Tokio, Japan. Nov. 22, 1899

BAUM, FRANK GEORGE, Asst. Electrical Engineer, California Gas & Electric Corpo., 624 Rialto Bldg., San Francisco, Cal. Nov. 22, 1899

BAUSCH, FREDERICK EMIL, Manager, Hooven, Owens Rentschler Co., 1416 Chemical Building. St. Louis. Mo. June 28 1901

BAYLEY, GUY LYNFIELD, Manager Engineering Department, The American Trading Co., Yokohama, Japan. Feb. 28, 1901

BAYLIS, JAMES ADAMS, Electrical Engineer, The Bell Telephone Co., Montreal, P. Q. Sep. 26, 1902

BAYNE, HOWARD. Assistant to Dr. M. I. Pupin, Columbia University, New York City. Sep. 27, 1901

BEACH, RALPH HAMILTON, General Electric Co., 44 Broad St., New York City. Apr. 23, 1903

BEAL, THADDEUS R., General Manager, Poughkeepsie Light, Heat and Power Co., Poughkeepsie, N. Y. Mar. 27, 1903

BEAM, ELMER E., Electrical Engineer, 62 Public Square, Cleveland, Ohio. Oct. 23, 1903

BEAM, VICTOR SHAEFFER. Electrical Engineer, 92 N. 15th St., East Orange, N. J. Oct. 24, 1902

BEAN, HORACE DOW, Whitney Elect. Inst. Co.; res., 41 High St., Penacook, N. H. Jan. 23, 1903

BEAN, HARRY JOEL, Electrical Engineer, Department of Electricity of San Francisco; res,. Alameda Ave., San Jose, Cal. July 28, 1903

BEATTY, SAMUEL ROBERT, Assistant Chief Operator, Western Union Telegraph Co.; res., 657 Pearl St., Denver, Colo. Mar. 27, 1903

BEATTYS, WILLIAM HENRY, JR., Chicago Representative, The Cutler-Hammer Mfg. Co., 1232 Monadnock Block, Chicago. May 19, 1903

BEAUCHAMP, LEON, Manager and Electrical Engineer, Standard Construction Co., Montreal, Que. Oct. 23, 1903

BEAUMONT, CHAS. W., [Address unknown] Jan. 9, 1901

BECKSTRAND, ELIAS HYRUM, Instructor, Engineering Department University of Utah, Salt Lake City, Utah. Apr. 23, 1903

BEDELL, CHARLES HAMPTON, Head of Laboratory, Electro-Dynamic Co., 224 Ionic St., Philadelphia; res., Swarthmore, Pa. May 19, 1903

BEDELL, RAYNER MONROE, 20 North Mountain Ave., Montclair, N. J. Feb. 27, 1903

BEE, WILLIAM G., Supt. Auto Battery Dept., Edison Storage Battery Co.; res., 875 Bloomfield Ave., Glen Ridge, N. J. Apr. 23, 1903

BEEBE, MURRAY C., Chemist, Nernst Lamp Co.; res., Amber Club, Pittsburg, Pa. Jan. 26, 1898

BELDON, DAVID W., Electrical Engineer and General Superintendent, The Phœnix Light & Fuel Co., Phœnix, Arizona. Sept. 26, 1902

BELL, ALONZO C., Owner and Manager, Bell Electric Motor Co., 197 Wooster St.; res., 83 E. 116th St. New York City. Sep. 27, 1901

BELL, ORA A., Electrical Engineer, Western Electric Co., 463 West St., New York; res 352 W. 117th St., New York City. Aug 5, 1896

BELLMAN JOHN JACOB, President, Bellman & Sanford, 14 Church St., New York City. Dec. 28, 1898

BELNAP, LA MONTE J., District Engineer, Bullock Electric Mfg. Co., 402 Merchants Bank Building, Montreal, P. Q. Apr. 23, 1903

BENECKE. ADELBERT O., Weston Electrical Instrument Co., Waverley Park, N. J; res., Vailsburgh, N. J. Sep. 26, 1902

BEUGLER, HUGH M., Supt. Motive Power, Elmira Water, Light & R. R. Co.; res., 620 Madison Ave., Elmira, N. Y. Jan. 23, 1903

BENJAMIN, EDGAR BRYANT, Assistant Engineer, Ideal Electric Contracting Co.; res., 409 E. 64th St., New York City. Apr. 23, 1903

BENNETT, EDWARD, Electrical Engineer, Nernst Lamp Co.; res., Amber Club, 260 Shady Ave., Pittsburg, Pa. Sep. 27, 1901

BENNETT, EDWIN H., JR., Electrician and Engineer, Diehl & Co., Elizabethport, N. J., res., 19 W. 33d St., Bayonne, N. J. June 20, 1894

BENNETT, JOHN C., Electrician, General Electric Co., 44 Broad St., New York City. Mar. 18, 1890

BENNETT, RALPH, Chief Draughtsman, Edison Electric Co., Los Angeles, Cal. Oct. 23, 1903

BENNETT, WILLARD S., Engineering Department, The S. S. White Dental Mfg. Co., 5 Union Square, West, New York City. Oct. 25, 1901

BENOLIEL, SOL. D., *B.S.*, *E.E.*, *A.M.*, General Manager, Roberts Chemical Co., Niagara Falls, N. Y. Oct. 21, 1896

BENTLEY, EDWARD M., Patent Attorney and Expert, 5 Beekman St., New York City. May 21, 1901

BENTLEY, MERTON H., Electrical Engineer, International Teleph. Mfg. Co., Chicago; res., 221 N. Scoville Ave., Oak Park, Ill. Oct. 18. 1893

BENTLEY, WILTON, Superintendent Teleph. Switchboard Installation Western Electric Co., 259 So. Clinton St., Chicago, Ill. July 28, 1903

BERAN, THEODORE, Manager, New York Supply Department, General Electric Co., 44 Broad St., New York City. July 25, 1902

BERG, ESKIL, Electrical Engineer, General Electric Co., Schenectady, N. Y. Nov. 20, 1895

BERG, GEORGE HEWES, District Manager, Bullock Electric Mfg. Co., 262 Washington St., Boston; res., Medford, Mass. Apr. 23, 1903

BERG, MAX A., Secretary, Porter & Berg, 309 Dearborn St., Chicago, Ill. May 19, 1903

BERGEN, FRANCIS PATRICK, Inspector, Western District, Commonwealth Electric Co., 1094 W. Madison St., Chicago, Ill. June 19, 1903

BERGEN, OTTO, Engineer, Daly Reduction Co., Hedley, B. C. Apr. 23, 1903

BERGENTHAL, VICTOR W., Western Sales Engineer, The Stanley Electric Mfg. Co., 15 Monadnock Block, Chicago, Ill. Jan. 9, 1901

BERNAYS, CHARLES EDWIN, Overland Representative. Noyes Bros., 45 Adelaide St., Brisbane, Queensland. Dec. 18, 1903

BERRESFORD, ARTHUR W., *B.S.*, *M.E.*, Supt., The Cutler-Hammer Mfg. Co., 12th St. and St. Paul Ave. Milwaukee, Wis. May 15, 1894

BERRY, A. HALL, General Manager, F. H. Lovell & Co., 100 William St., New York City; res., Montclair, N. J. May 20, 1902

BERRY, EDGAR HENRY, Electrical Engineer, C. W. Hunt Co.; res., 2d St., near York Ave., New Brighton, N. Y. Apr. 23, 1903

BESSEY, CARL ATHEARN, Draughtsman, General Electric Co.; res., 1219 State St., Schenectady, N. Y. May 19, 1903

BESSEY, EDWARD ATHEARN, Engineer, Stanley Electric and Mfg. Co., Pittsfield, Mass. July 28, 1903

BETHELL, FRANK HOPKINS, Contract Agent New York Telephone Co., 15 Dey St.; res., 839 West End Ave., New York City. Mar. 27, 1903

BETHELL, U. N., General Manager, The New York Telephone Co., 15 Dey St., New York City. Jan. 17, 1894

BETTS, HOBART D., *E.E.*, Room 517, 141 Broadway, New York City; res., Englewood, N. J. Aug. 5, 1896

BEVENUE-MILLER, EDWIN DAVID, Electrical and Mechanical Assistant, Kilburn & Co., 4 Fairlie Pl., Calcutta, E. India. Mar. 28, 1902

BEVERIDGE, EDMUND WALTER, Assistant Engineer, P. W. D. Ghar Canals, Larkhana, Sind. India. Jan. 24, 1900

BIBBINS, JAMES ROWLAND, Technical Editor, Westinghouse Co's Pub. Dept., Pittsburg, Pa. Dec. 19, 1902

BICKNELL, DANA EDWIN, Assistant in Inspection Dept., Western Electric Co., 57 Bethune St.; res., Lyndhurst, N. J. June 28, 1901

BIDDLE, JAMES G., Electrical and Scientific Instruments, Stephen Girard Bldg., Philadelphia; res., Wallingford, Pa. Aug. 5, 1896

BIEBEL, HERMAN MATTHEWS, Designing Electrical Engineer, Western Electric Co., Chicago, Ill. Apr. 23, 1903

BIJUR, JOSEPH, *A. B.*, President & Manager General Storage Co., 29 [Life Member.] Sullivan St., New York City. May 15, 1894

BINDEMANN, HARRY OTTO FERDINAND, Electrical Engineer Union Electricitats Gessellchaft, 43 Dorotheen Str., Berlin, Ger. Jan. 24, 1902

BINGAY, ROBERT V., Pittsburg Transformer Co., Pittsburg, Pa. Dec. 18, 1903

BIRCH, ARTHUR KNODE, Sales Department, Bullock Electric Mfg. Co. Cincinnati, Ohio. Feb. 27, 1903

BIRD, WILLIAM LISTER, The Lachine Rapids Hydraulic and Land Co., Ltd., 160 McCord St., Montreal, P. Q. Mar. 27, 1903

BISHOP, FREDERICK LENDALL, Head of Department of Physics, Bradley Institute, Peoria, Ill. Mar. 27, 1903

BISSELL, FREDERICK, President, The F. Bissell Co., 226 Huron St., Toledo, Ohio. Feb. 27, 1903

BISSELL, GEORGE WELTON, Professor of Mechanical Engineering, The Iowa State College, Ames, Iowa. Apr. 23, 1903

BISSING, WILLIAM F., Electrical Engineer and Patent Attorney, Kenyon & Kenyon, 49 Wall St., New York City. Jan. 23, 1903

BLACK, CHAS. N., Ford, Bacon & Davis, 149 Broadway; res., 43 E. 57th St., New York City. Apr. 19, 1890

BLACK, HOWARD D., With Blackall & Baldwin, 39 Cortlandt St.; res., 340 Manhattan Ave., New York, N. Y. Sep. 15, 1897

BLACK, ROBERT GIVEN, Electrical Engineer, Toronto Electric Light Co., Toronto, Ont. May 21, 1901

BLACK, ROY HARRY, Student, Cornell University, Ithaca, N. Y.; res., 441 East Santa Clara St., San Jose, Cal. July 28, 1903

BLACK, SAMUEL DUNCAN, Electrical Engineer, The Rowland Telegraphic Co., Baltimore; res., White Hall, Md. Mar. 27, 1903

BLACKALL, FREDERICK S., 39 Cortlandt St.; res., 51 Manhattan Ave., New York. Sep. 15, 1897

BLACKWELL, HENRY FIELD, Electrical Engineer, Dept. of Water Supply, etc.; res., 18 Morningside Ave., New York City. Sept. 25, 1903

BLACKWELL, HOWARD LANE, Assistant in Physics, Harvard University, 34 Thayer Hall, Cambridge, Mass. Jan. 24, 1902

BLAKE, EDWIN TYLER, 2235 Piedmont Way, Berkeley, Cal. May 19, 1903

BLAKE, HENRY M., Superintendent, The Jenkintown Light Co., Wyncote, Pa. July 28, 1903

BLAKE, HENRY W., Editor, *Street Railway Journal*, 114 Liberty St., New York City. Nov. 13, 1888

BLAKE, S. HENRY, Engineer of Arc Lighting, General Incandescent Arc Light Co., Pittsfield, Mass. April 23, 1903

BLAKE, THEODORE W., Electrical Engineer, Goodyear Insulating Co., 1955 Park Ave.; res., Engineers Club, New York. Sept. 20, 1893

BLAKEMORE, MAURICE NEVILLE, Electrical Engineer, with Westinghouse E. & M. Co., Pittsburg; res., Wilkinsburg, Pa. Jan. 25, 1901

BLAKESLEE, HENRY JONES, Electrical Inspector, Hartford Board of Fire Underwriters; res., 791 Park St., Hartford, Conn. Aug. 22, 1902

BLANCHARD, CHARLES M., Union League, Philadelphia, Pa. Sep. 19, 1894

Blanck, William A., Electrical Engineer, Arnold Electric Power Station Co., 1539 Marquette Building, Chicago, Ill. Apr. 23, 1903

Bleo, William Ericson, Inspector Elec. Dept. Dist. of Columbia; res., 464 Louisiana Ave., Washington, D. C. Jan. 23, 1903

Bliss, Donald McQueen, Electrical Engineer and Superintendent, The Holtzer-Cabot Electric Co., Brookline, Mass. June 19, 1903

Bliss, Louis Denton, Principal Bliss Electrical School, 614 12th Street Washington, D. C. July 12, 1900

Bliss, William L., *B.S., M.M.E.*, President, Bliss Electric Car Lighting Co., 138 Front St., New York City. Mar. 21, 1894

Blizard, Charles, Manager Sales Department Electric Storage Battery Co., 19th St. and Allegheny Ave., Philadelphia. Nov. 21, 1894

Blood, Grosvenor Tarbell, Electrical Engineer, The American Telephone and Telegraph Co., 125 Milk St., Boston, Mass. Mar. 27, 1903

Blossom, Francis, Sanderson & Porter, 52 William St., New York City. July 25, 1902

Blunt, William W., Assistant Manager, British Westinghouse Electric and Mfg. Co., Ltd., Westinghouse Bldg., London. Dec. 16, 1896

Bobri. Albert P., Chief Inspector, Engineering Dept., The N. Y. & N. J. Telephone Co., 81 Willoughby St., Brooklyn, N. Y. Dec. 18, 1903

Bogen, Louis E. (*Local Secretary*), Engineering Department, Bullock Electric Mfg. Co., Avondale, Cincinnati, O. May 16, 1899

Bogue, Charles J., Mfr. of Search Lights and High Candle Power Focussing Arc Lamps, 213 Centre St., New York City. Dec. 3, 1889

Bolan, Thomas V., Local Engineer, General Electric Co., 226 S. 11th St.; res., 501 N. 40th St., Philadelphia, Pa. Aug. 5, 1899

Bolles, Frank G., Business Mgr., *Cassier's Magazine*, 3 West 29th St., New York City. May 21, 1901

Bonine, Charles Edward, Chief Draughtsman and Asst. Supt. Electro-Dynamic Co.; res., 909 N. 43d St., Philadelphia, Pa. June 19, 1903

Bonney, Robert Bridge, Wire Chief, The Colorado Telephone Co., 1447 Lawrence St., Denver, Colo. Mar. 27, 1903

Booth, William Thomas, Draughtsman, The Lambert Schmidt Telephone Mfg. Co., 35 Maple St., Weehawken, N. J. June 19, 1903

Bortenlanger, Joseph A., 1614 Farnam St., Omaha, Neb. June 19, 1903

Bouché, Will Forest, Order Clerk, Production Department, Bullock Electric Mfg. Co., Norwood, Ohio. Mar. 27, 1903

Bowden, Zolly Masby, Mulberry, Fla. Sept. 25, 1903

Bowie, Augustus Jesse, Jr., Engineer, Electrical Dept. Union Iron Wks; res., 915 Hyde St., San Francisco, Cal. May 15, 1900

Bowman, Joseph H., Chief Engineer, Pan-American R. R., Tonala, Chiapas, Mexico. May 16, 1899

Boyd, John Duncan, Electrician, Palo Alto, Cal. Feb. 28, 1900

Boyer, Frank N., Manager Supply Department, General Electric Co.; res., 3805 Wabash Ave., Chicago, Ill. June 19, 1903

Brackett, Byron B., Professor of Electrical Engineering, Clarkson School of Technology; Potsdam, N. Y. Nov. 30, 1897

Brackett, Prof. Cyrus F., Princeton, N. J. Apr. 15, 1889

Braddell, Alfred E., Electrical Inspector, Underwriters Assn., Middle Department, 316 Walnut St., Philadelphia, Pa. Sep. 1, 1890

Bradfield, William Walter, Chief Electrical Engineer, Marconi Wireless Telegraph Co., of America, 27 William St., New York City. Mar. 27, 1903

BRADLEY, ALONZO B., Student Columbia University; res., 111 West 86th St., New York City. Aug. 22, 1902

BRADY, NICHOLAS F., Treasurer, The N. Y. Edison Co., 57 Duane St., New York City. May 21, 1901

BRADY, PAUL T., Manager Central, N. Y. Agency, Westinghouse Electric and Mfg. Co., Syracuse, N. Y. July 12, 1887

BRAGA, EDUARDO, JR., Juiz de Fora Minas, Brazil, South America. Feb. 27, 1903

BRAGG, CHARLES A., Manager, Philadelphia Agency, Westinghouse Electric and Mfg. Co., 708 Land Title Blg.Philadelphia, Pa. Sep. 20, 1893

BRANDAO, JULIO VIVEIROS, *C.E.*, Rua Barao do Flamengo 8, Rio de Janeiro, Brazil, S. A. Jan. 25, 1901

BRANDEIS, CHARLES, Consulting Electrical and Mechanical Engineer, 112 St. James St., Montreal, P. Q. Mar. 27, 1903

BRATNEY, JOHN FREDERICK, Assistant Engineer, Bell Telephone Co., of Mo., Telephone Building, St. Louis, Mo. Dec. 18, 1903

BRAUN, CHRISTIAN EDWARD, Draughtsman, Western Electric Co., New York City; res., 318 Classon Ave., Brooklyn, N. Y. Sep. 27, 1901

BRAY, CHARLES AYERS, Electrical Engineer, General Electric Co., Schenectady, N. Y. May 19, 1903

BRAYSHAW, J., Telegraph Superintendent Great Southern Railway, City of Buenos Aires, A. R. Aug. 5, 1896

BRECK, CHESNEY YALES, Superintendent, Telluride Electric Light Co., Telluride, Colo. July 28, 1903

BREESE, CHARLES PARKER, 180 Broadway, New York City. Mar. 27, 1903

BRETT, JAMES A., Director and General Manager, Electrical Installation Co., 1517 Monadnock Building, Chicago, Ill. Apr. 23, 1903

BREWSTER, WALTER SCOTT, Electrician, Standard Underground Cable Co.; res., 65 Kearney Ave., Perth Amboy, N. J. Apr. 26, 1901

BRIDGMAN, GREENVILLE TEMPLE, General Electric Co., Schenectady, N. Y. Dec. 18, 1903

BRIESEN, HAROLD V., Engineering Department, American Telephone and Telegraph Co., 22 Thames St., New York City. June 28, 1901

BRIGHT, GRAHAM, Designer Nernst Lamp Co.; res., 127 Roup St., Pittsburg, Pa. May 19, 1902

BRIGHTMAN, CARL GORDON, Electrical Engineer,Old Colony Street Railway Co., 147 Milk St.; res., Dorchester, Mass. Apr. 23, 1903

BRISLEY, EDWARD BETTS, Interborough Rapid Transit Co , Power House 59th St. and N. R.; res., 102 W. 75th St., New York. Apr. 25, 1902

BRIXEY, W. R., Proprietor and Manufacturer, Day's Kerite Wire and Cables, 203 Broadway, New York City. Sep. 20, 1893

BROADHURST, WM, CHANNING, Student Brooklyn Polytechnic Institute; res., 320 Green Ave., Brooklyn, N. Y. Aug. 22, 1902

BROICH, JOSEPH, Superintendent and Electrician, with F. Pearce, 18 Rose St., New York; res., 1622 8th Ave., Brooklyn, N. Y. Jan. 17, 1894

BROOKE, IRVING EMERSON, Draftsman, Chicago Edison Co., 139 Adams St.; res., 551 Jackson Boulevard, Chicago, Ill. Sept. 25, 1903

BROOKE, JAMES DILLON, Electrical Engineer, Nernst Lamp Co., Pittsburg, Pa. Oct. 23, 1903

BROOKE, ROBERT THOMAS, JR., Special Student in Electrical Testing Department, General Electric Co., Lynn, Mass. Apr. 23, 1903

BROOKS, FRANK HARRISON, General Manager, Vicksburg R. R. Power and Mfg. Co., Vicksburg, Miss. Feb. 27, 1903

BROOKS, LOUIS C., Electrical Aid to Superintending Naval Constructor at Cramps' Shipyard, Philadelphia, Pa. Aug. 22, 1902

Brooks, Orion, Manager Electric Engineering Dept., Heald's School of Mines and Engineering, San Francisco, Cal. Feb. 27, 1903

Brophy, William, Consulting Electrical Engineer, 17 Egleston St., Jamaica Plain, Mass. Mar. 5, 1889

Broughton, James Russell, Station Foreman, The Power Co., Provo, Utah. Apr. 23, 1903

Browd, Paul K., Manufacturer's Agent, W. O., 10th line 21, St. Petersburg, Russia. Feb. 15, 1899

Brown, Arthur James, Draughtsman, Bullock Electric Mfg. Co.; res., 4913 Wesley St., Norwood, Ohio. Mar. 27, 1903

Brown, Arthur Noble, The Sawyer-Man Electric Co., 510 W. 23d St.; res., 331 W. 23d St., New York City. Mar. 27, 1903

Brown, Cardella Drake, Electrical Engineer, General Electrical Co., Windsor, Conn. Jan. 23, 1903

Brown, Carlton Emerson, Assistant Works Engineer, The Canadian General Electric Co., Peterboro, Ont. Mar. 27, 1903

Brown, Charles L., General Electrical Contractor, 312 Fisher Building, Chicago, Ill. Nov. 20, 1895

Brown, Dickson Queen, Director, Tidewater Oil Co., 12 Broadway; res., 160 W. 59th St., New York City. May 19, 1903

Brown, Ellis Eugene, Electrical Engineer, Philadelphia and Reading Railway Co., 925 North 5th St., Reading, Pa. May 16, 1899

Brown, Frank Zenas, Consulting Electrical Engineer, Chamber of Commerce, Richmond, Va. Sept. 25, 1903

Brown, Garry Estep, Construction Department, Niagara Falls Power Co., Niagara Falls, N. Y. Sept. 25, 1903

Brown, Harry Curtis, Draughtsman, Westinghouse Electric & Mfg. Co., Pittsburg; res., 710 Pitt St., Wilkinsburg, Pa. Mar. 27, 1903

Brown, Hugh Auchincloss, Electrical Engineer, Crocker-Wheeler Co., Old Colony Building, Chicago, Ill. Mar. 28, 1902

Brown, Hugh Thomas, Chief Engineer, Railways and Light Co., of America, Richmond, Va.; res., Columbia, Tenn. Jan. 26, 1902

Brown, John Elliott, Electrical Engineer, Consumers' Electric Co.; res., 53 Waverly St., Ottawa, Can. Mar. 27, 1903

Brown, Robert Calthrop, Consulting Engineer, Toronto Ry. Co.; res., St. George Apartments, Toronto, Ont. June 19, 1903

Brown, Robert G., Electrician, 158 Montague St., Brooklyn, Oct. 25, 1901

Brown, Sydney William, B. C. Elec. Ry. Co., Trout Lake near Vancouver, B. C., May 19, 1903

Brown, Theodore J., Traveling Salesman, General Electric Co., 84 State St., Boston, Mass.; res., Portland, Maine. Apr. 23, 1903

Brown, Walter Everette, Engineer N. Y. & N. J. Telephone Co.; res., 1178 Degraw St., Brooklyn, N. Y. May 20, 1902

Brown, Warren Day, 79 Park Ave., New York City. Jan. 25, 1901

Browne, Morton S., Consulting Engineer, Brown-Ryan Electric Co., 27 Deshler Blk., Columbus, Ohio. Feb. 27, 1903

Browne, William Hand, Jr., Technical Editor, *Electrical Review*, 1003 Park Row Building, New York City. Apr. 25, 1900

Browne, William Henry, Treasurer, General Manager and Director, Stanley Instrument Co., Great Barrington, Mass. May 20, 1902

Brush, Frederick Farnsworth, Engineer, Societie Francaise Sprague 6 Rue de Madrid, Paris, France. Feb. 28, 1901

Bryant, Waldo Calvin, Manager, The Bryant Electrical Co., Bridgeport, Conn. May 19, 1903

BUCK, MARION ESTES, Superintendent, Generating Plant, The Power Co., Norris, Mont. Jan. 23, 1903

BUCKE, WILLIAM AUGUSTUS, Agent Canadian General Electric Co., 14 King St., East Toronto, Ont. Dec. 19, 1902

BUCKINGHAM, CHARLES L., Attorney and Counsellor-at-Law, Potter Building, 38 Park Row, New York City. Apr. 15, 1884

BUDDY, HARRY JOHN, General Selling Agent, General Electric Co., 226 So. 11th St.; res., 1523 Arch St., Philadelphia, Pa. June 19, 1903

BULL, ROBERT WILSON, Electrical Engineer, The New Jersey Zinc Co., (of Penn.), Palmerton, Pa. Mar. 22, 1901

BULLARD, ALBERT MORRISON, Engineering Dept., Western Electric Co., 463 West St., New York City. Mar. 27, 1903

BULLEN, DANA RIPLEY, General Electric Co., 84 State St., Boston; res., Winthrop, Mass. Mar. 28, 1902

BULLOCK, GEORGE, President, Bullock Electric Mfg. Co.; res., 2915 Vernon Pl., Cincinnati, Ohio. Feb. 27, 1903

BUMP, MILAN RAY, Assistant Engineer and Draughtsman, 620 Langdon St., Madison, Wis. Mar. 27, 1903

BUNCE, THEODORE, D. President, The Storage Battery Supply Co., 239 E. 27th St., New York City. May 20, 1890

BUNKER, ARTHUR CLIFFORD, Engineering Department, Stanley Electric Mfg. Co., 238 Crocker Building, San Francisco, Cal. Oct. 25, 1901

BURDICK, IRVING EDWARD, Treasurer and Engineer; res., 146 W. 104th St., New York City. Oct. 24, 1900

BURGESS, EDWIN M., General Superintendent, Colorado Telephone Co.; res., 150 W 1st Ave., Denver, Colo. June 19, 1903

BURKETT, CHAS. WATSON, Engineer, Wisconsin Telegraph Co., Milwaukee Wis. Aug. 23, 1899

BURKHOLDER, CHARLES IRVINE, Electrical Engineer, General Electric Co.; res., 108 Park Place, Schenectady, N. Y. Apr. 23, 1903.

BURNETT, DOUGLASS, *B. S.*, United Electric Light & Power Co., Baltimore, Md. Feb. 21, 1893

BURNETT, JAMES AUBREY, Engineering Dept., Montreal Light, Heat and Power Co., N. Y. Life Building, Montreal, P.Q. Apr. 26, 1902

BURNHAM, GEORGE A., Electrical Engineer, American Thread Co., Willimantic, Conn. Dec. 18, 1903

BURNS, OWEN C., Electrical Operator, Manhattan Railway Co., New York City; res., 422 Atlantic Ave., Brooklyn, N. Y. Mar. 27, 1903

BURNS, WILLIAM GIBSON, Electrical Engineer, with Jabez Burns & Sons, 542 Greenwich St., New York City. May 19, 1903

BURRITT, ALEXANDER HAMILTON, Assistant Chief Draftsman, General Electric Co.; res., 27 Stephen St., Lynn, Mass. April 23, 1903

BURROUGHS, HARRIS S., Consulting Electrical and Mechanical Engineer, 19 William St., New York City. Nov. 30, 1897

BURROWS, WILLIAM RUSSELL, Experimenter General Electric Co., Harrison; res., 86 Fourth Ave., Newark, N. J. Mar. 27, 1903

BURSCH, WILLIAM OSCAR, Assistant Foreman, Testing Department, General Electric Co.; res., 5 City Hall Sq., Lynn, Mass. Apr. 23, 1903

BURTON, CHARLES GILLETTE, Christensen Engineering Co., 1020 Old Colony Building, Chicago, Ill. Feb. 28, 1902

BURTON, FRANK VAIL, Bryant Electric Co., 142 State St.; res, 157 Coleman St., Bridgeport, Conn. Mar. 28, 1902

BURTON, PAUL G., Switchboard Dept., Western Electric Co.; res., 475 Central Park, West, New York City. Nov. 20, 1895

BUSH, ARTHUR RICHMOND, Engineer, General Electric Co., 84 State St., Boston; res., 51 Lexington Ave., Cambridge, Mass. Apr. 23, 1903

Bushnell, S. Morgan, Engineer, Chicago Edison Co., 139 Adams St.; res., Hyde Park Hotel, Chicago, Ill. Feb. 27, 1903

Bushnell, Winthrop Grant, Salesman General Electric Co., New Haven, Conn. Mar. 27, 1903

Butler, Henry Weil, Engineer, Manhattan Railway Co.; res., 56 E. 50th St., New York City. Jan. 23, 1903

Butler, John Starr, Sales Agent, General Electric Co., 84 State St., Boston; res., New Dorchester, Mass. Apr. 23, 1903

Butler, William C., President, The Puget Sound Reduction Co., Everett, Washington. Mar. 21, 1893

Butterworth, Irvin, President and General Manager, Denver Gas and Electric Co.; res., 405 17th St., Denver, Colo. Mar. 27,1903

Butterworth, Isaac Nelson, General Manager, Tri-City Electric Co.; res., 405 Brady St., Davenport, Iowa. May 19, 1903

Buys, Albert, Electrical Engineer, Ovid Electric Co., Ovid, N. Y. Feb. 7, 1890

Byrnes, Eugene A., *Ph.D.*, Byrnes & Townsend Patent Lawyers, 1918 F. St., N. W., Washington, D. C. May 21, 1901

Byrns, Robert A., Electrical Engineer, 120 Liberty St., New York City. Dec. 16, 1896

Cabot, Francis Elliott, Assistant Secy. and Electrician, Boston Board of Fire Underwriters, 55 Kilby St., Boston, Mass. Apr. 17, 1895

Cabot, Sewall, Electrical Dept., New England Tel. & Tel. Co., 101 Milk St., Boston; res., High St., Brookline, Mass. Jan. 24, 1902

Cady, Lawrence Whittredge, Student, General Electric Co.; res., 41 Main St., Lynn, Mass. Apr. 23, 1903

Calderwood, Hugh Alexander, Electrical Inspector, Underwriters' Association of the Middie Dept., Pittsburg, Pa. July 28, 1903

Caldwell, Edward, Importer and Dealer, Technical Books and Periodicals, 114 Liberty St., New York City. Jan. 20, 1891

Caldwell, Eliot Lincoln, Department Superintendent, Edison Electric Illuminating Co., 3 Head Place, Boston, Mass. Apr. 23, 1903

Caldwell, Eugene Wilson, Electrical Engineer, 315 Fifth Ave.; res., 20 E. 31st St., New York City. Jan. 24, 1902

Calisch, Julius C., Manager Buffalo Office, General Electric Co., Ellicott Square Building, Buffalo, N. Y. Dec. 19, 1902

Calvert, Richard C. M., Chief Operator, Cauvery Power Scheme, Champion Reefs, Mysore State, India. Sept. 25, 1903

Campbell, Edward, Secretary and Treasurer, The Germania Electric Lamp Co., Harrison; res., East Orange, N. J. Mar. 27, 1903

Campbell, George Ashley, Electrical Engineer, The American Telephone and Tel. Co., 125 Milk St., Boston, Mass. Mar. 27, 1903

Campbell, Henry Arthur, Electrician, Jamaica Electric Light & Power Co., Ltd., 38 Harbor St., Kingston, Jamaica, W. I. Sept. 27, 1899

Campbell, John A., Westinghouse Electric and Mfg. Co., Pittsburg, Pa. Jan. 23, 1903

Campbell, Joseph William, Canadian General Electric Co., Ltd., 14 King St., E.; res., 92 Glen Road, Toronto, Ont. July 28. 1903

Canfield, Charles Ernest, Electrical Engineer, Stanley Electric Mfg. Co.; res., 28 Hamlin St., Pittsfield, Mass. Aug. 22, 1902

Canfield, Milton C., Electrical Engineer, Railway Department, Stanley Electric Mfg. Co., Pittsfield, Mass. Feb. 21, 1893

Capuccio, Mario, Raimondo & Capuccio, Consulting Engineers and Patent Agents, Piazza Castello 22. Turin, Italy. Dec. 20, 1893

Carlebach, Walter Maxwell, Student, Columbia University; res., 136 W. 86th St., New York City. June 19, 1903

CARLIN, WILLIAM HENRY, Electrical Engineer, H. Eckstein & Co., Johannesburg, S. A. Sept. 25, 1903

CARLTON, WILLARD GILBERT, Assistant to Chief Operating Engineer, Chicago Edison Co., 139 Adams St., Chicago, Ill. Oct. 25, 1901

CARNAGHAN, E. D., M.E., Ventanas Consolidated Mining and Milling Co., Villa Corona, Do. Mexico. July 26, 1900

CARPENTER, CHAS. E., Vice-President, Carpenter Enclosed Resistance Co., 79 E. 130th St., New York City. Aug. 5, 1896

CARPENTER, HENRY CANNON, Assistant in Engineering Department N.Y. Telephone Co.; res., 113 E. 69th St., New York City. Oct. 25, 1901

CARPENTER, HUBERT VENTON, Professor of Mechanical Engineering, Washington Agricultural College, Pullman, Wash. Feb. 27, 1903

CARR, JOHN HERBERT, Chief Electrician, Arnold Print Works, North Adams, Mass. Dec. 18, 1903

CARTER, FREDERICK WILLIAM, *M.A.*, British Thomson-Houston Co., Ltd., Rugby, Eng. Sept. 28, 1898

CARTWRIGHT, CRELLIN, Tester, General Electric Co.; res., 773 State St., Schenectady, N. Y. Dec. 18, 1903

CASE, WILLARD E., 196 West Genesee St., Auburn, N. Y. Feb. 7, 1888

CASE, WILLIAM MELANCTHAN, Manager and Superintendent, Queen City Electric Light and Power Co., Clarksville, Tenn. Mar. 27, 1903

CASSIDY, JOHN, Superintendent Mutual Telephone Co., Honolulu, Hawaiian Islands, U. S. A. Nov. 23, 1898

CECIL, THOMAS, Chief Electrician, *New York Herald*, Broadway and 35th St., res., 23 Manhattan Ave., New York City. April 23, 1903

CHACE, PAUL GRISWOLD, Electrical Engineer, D. H. Burnham & Co., The Rookery; res., 5740 Rosalie Ct., Chicago, Ill. Mar. 27, 1903

CHACE, WILLIAM GREGORY, Electrical Engineer, Mitchell & Jackson, Niagara Falls; res., St. Catharines, Ont. Oct. 23, 1903

CHALMERS, CHARLES HENRY, Vice-President and General Manager, Electric Machinery Co., Minneapolis, Minn. Feb. 27, 1903

CHAMBERLAIN, AARON FRANKLIN, Westinghouse Electric and Mfg. Co.; 708 Land Title Building, Philadelphia, Pa. Dec. 19, 1902

CHAMBERS, FRANK ROSS, JR., Draftsman, with E. W. Cummings, 70 Dexter Horton Buildings, Seattle, Wash. Oct. 23, 1903

CHAPMAN, A. WRIGHT, 160 Hicks St., Brooklyn, N. Y. Mar. 25, 1896

CHAPPELL, WALTER E., Engineer, British Westinghouse Electric & Mfg. [Life Member.] Co., Ltd., Trafford Park, Manchester, Eng. May 16, 1899

CHASE, CHARLES ALBERT, Assistant Engineer, General Electric Co., 84 State St., Boston; res., Dorchester, Mass. Apr. 23, 1903

DE CHATELAIN, MIKAIL ANDREJEVITCH, Professor of Electrical Engineering, Wasily Ostrow, 10 line No. 5, St. Petersburg. Nov. 23, 1900

CHEEVER, MARKHAM, Engineering Department, The Ontario Power Co.; res., The Alexandria, Niagara Falls Centre, Ontario. Sept. 25, 1903

CHERRY, FLOYD H., 315 S. Bunkerhill Ave., Los Angeles, Cal. June 19, 1903

CHESTER, M. E., Telephone Engineer, Western Electric Co., 463 West St.; res., 296 Manhattan Ave., New York City. Feb. 28, 1902

CHETWOOD, ROBERT EDES, JR., Assistant Electrician, The American Teleph. and Tel. Co., 22 Thames St., New York City. Mar. 27, 1903

CHEYNEY, ALGERNON ROBERTS, Station Supt. The Phila. Electric Co., 26th and Callowhill St. Station, Philadelphia, Pa. Apr. 23, 1903

CHILDS, SUMNER W., Engineer, 15 Cortlandt St., New York City. May 15, 1894

CHISHOLM, FREDERICK JOHN, Special Student, Westinghouse Electric & Mfg. Co., Pittsburg, Pa. May 19, 1903

CHUBBUCK, LEONARD BURROWS, Engineering Department, Westinghouse E. & Mfg. Co.; res., 510 South Ave., Pittsburg, Pa. Feb. 28, 1902

CHURCHWARD, ALEXANDER, Electrical Engineer, General Electric Co., 44 Broad St., New York City; res., Pelham, N. Y. Mar. 27, 1903

CLACK, CHARLES WILLIAM, Telephone Engineer, Western Electric Co., N. Woolwich; res., Finsbury Park, London, Eng. May 19, 1903

CLARK, CHAS. M., *E.E.*, Clark & MacMullen, 22 Broad St., New York City. Apr. 22, 1896

CLARK, CHARLES WESTON, Agent, General Electric Co., Claus Spreckels Building, San Francisco; res., Berkeley, Cal. Apr. 23, 1903

CLARK, CLARENCE DOANE, Engineering Department, California Gas & Elec. Co., 2207 Ellsworth St., Berkeley, Cal. May 19, 1903

CLARK, FARLEY GRANGER, Electrician Westinghouse Church, Kerr & Co., 8 Bridge St., New York City. Apr. 26, 1901

CLARK, HORACE STEDMAN, Electrical Engineer, Westinghouse Electric & Mfg. Co., 621 Trust Building, Los Angeles, Cal. Jan. 23, 1903

CLARK, NORMAN FREDERIC, Electrical Engineer, Wm. E. Baker & Co.; 170 Broadway; res., 120 W. 116th St., New York City. Jan. 23, 1903

CLARK, WALLACE S., Engineer, Wire, Cable and Tube Department, General Electric Co., Schenectady, N. Y. Apr. 25, 1902

CLARK, WALTER G., Engineer and Manager, Kilbourne & Clark Co., 815 Second Ave., Seattle Wash. Mar. 27, 1903

CLARK, WM. EDWIN, Clark & Mills, Engineers and Contractors, 543 Boylston St., Boston, & 23 Church St., Cambridge, Mass. Aug. 23, 1899

CLARK, WILLIAM J., General Manager, Foreign Dept., General Electric Co., 44 Broad St., New York City. Apr. 22, 1896

CLARKE, JAMES ULRICK, Superintendent Lancaster Traction Co., Lancaster, Ohio. Feb. 27, 1903

CLARKE, LEON, Electrical Engineer, McCormick Division, International Harvester Co., Chicago, Ill. July 28, 1903

CLAYPOOLE, CURTIS, Estimating and Superintending Construction, Claypoole Electric Co., 134 E. Long St. Columbus, O. Apr. 23, 1903

CLELAND, HARRY W., 1012 Wood St., Wilkinsburg, Pa. Dec. 18, 1903

CLEMENT, EDWARD E., Patent Attorney and Electrical Expert, McGill Building, 908 G St., N.W., Washington, D. C. May 18, 1897

CLEMENT, LEWIS M., Haywards, Alameda Co., Cal. Apr. 21, 1891

CLIFT, ARTHUR S., Chief Mechanical Engineer, Siemens Bros. & Co., Ltd., Woolwich, Kent, Eng. Sept. 27, 1901

CLOHESEY THOMAS F., General Manager, Quincy Gas & Electric Co., Quincy, Ill Sept. 25, 1903

CLORAN, GERALD JOSEPH, Electrical Engineer, Interborough Rapid Transit Co.; res., 408 W. 150th St., New York City. June 19, 1903

CLOUGH, ALBERT L., Manchester, N. H. Feb. 21, 1894

CLOUGH, DWIGHT EDWARD, Electrical Engineer, Pacific Electric Railway Co., Los Angeles; res., Long Beach, Cal. April 26, 1902

CLOUGH, FREDERICK HORTON, Alternating Current Designing Office, British-Thomson-Houston Co., Rugby, Eng. June 19, 1903

COATES, CHARLES BENJ., Electrical Engineer, The Keystone Electric Co., res., 709 Liberty St., Erie, Pa. Jan. 23, 1903

COCHRAN, BERRY WYNN, 208 Liberty St., Schenectady, N. Y. June 19, 1903

COCHRAN, ROBERT BARTER, Student in Electrical Testing Department General Electric Co., Lynn, Mass. Apr. 23, 1903

CODMAN, JOHN STURGIS, Consulting Engineer, Associated with R. S. Hale. 31 Milk St.; res., 57 Marlborough St., Boston, Mass. Feb. 15, 1899

CODY, L. P., Manager and Engineer. Grand Rapids Electric Co., 9 South Division St., Grand Rapids, Mich. Aug. 5, 1896

COFFIN, CHAS. A., General Electric Co., 44 Broad St., New York City. Dec. 6, 1887

COGAN, HENRY MANNING, Electrical Engineer, The American Sugar Refining Co., Kent Ave., Brooklyn, N. Y. Sept. 26, 1902

COGHLIN, JOHN P., Electrical Engineer and Contractor, Page Electric Co. 24 Pearl St., Worcester, Mass. Sept. 27, 1901

COHO, HERBERT B., New York President, H. B. Coho & Co., 114 Liberty St., New York City; res., Mt. Vernon, N. Y. Mar. 21, 1894

COKEFAIR, FRANCIS ALBERTSON, Chief Engineer, Great Northern Power Co., Duluth, Minn. Sept. 25, 1903

COLBY, SAFFORD KINKEAD, Manager N. Y. Office, The Pittsburg Reduction Co., 99 John St., New York City. May 19, 1903

COLDWELL, ORIN B., Assistant Electrical Engineer, Portland General Electric Co.; res., 267 Grant St., Portland, Ore. Mar. 27, 1903

COLE, GEORGE MARSHALL, Engineer, Sanderson & Porter, Plattsburg, N. Y. July 25, 1902

COLE, GEORGE PERCY, Motor Designing Engineer, Wagner Electric Mfg. Co.; res., 2712 Locust St., St. Louis, Mo. Oct. 23, 1903

COLE, HENRY ERNEST, Electrical Engineer, Watts & Cole, 1200 Westinghouse Building, Pittsburg, Pa. July 28, 1903

COLEMAN, WALTER H., Supt. and Treasurer, Andover Electric Co., Andover, Mass. Sept. 28, 1898

COLES, EDMUND P., Local Engineer, General Electric Co., 214 S. 11th St., Philadelphia, Pa. Oct. 23, 1895

COLLETT, SAMUEL D., Eastern Manager, Elevator Supply and Repair Co., 136 Liberty St., New York City. Feb. 26, 1896

COLLIER, WILLIAM RAWSON, Electrical Engineer, Collier & Brown, Atlanta, Ga. May 19, 1903

COLLINS, ARCHIE FREDERICK, Elec. Engineer and Inventor, Collins Wireless Teleph. and Tel. Co., 11 Broadway, New York. June 28, 1901

COLLINS, CURTIS C., Electrical Engineer, S. A. Luz Electrica, San Juan, P. R. Oct. 24, 1902

COLLYER, ALFRED, District Manager, Bullock Electric Mfg. Co., 402 Merchants' Bank Building, Montreal, Can. Aug. 22, 1902

COLWELL, FREDERICK CHARLES, Bullock Electric Mfg. Co., Cincinnati, Ohio. Mar. 27, 1903

COMPTON, ALFRED G., Professor of Applied Mathematics, College of the City of New York, 17 Lexington Ave., New York City. Nov. 1, 1887

COMSTOCK, CHARLES WORTHINGTON, Consulting Engineer, Engineering Co. of America, 213 Boston Building, Denver, Colo. June 19, 1903

CONKLING, DEWITT C., Inventor and Model Maker; res., 14 Third St., Hoboken, N. J. Sep. 25, 1903

CONKLIN, OLIVER FRANCIS, Consulting Electrical Engineer, The Robbins & Myers Co., Springfield, Ohio. Oct. 25, 1901

CONLEE, FREDERICK MONROE, Chief Draftsman, Northern Electric Mfg. Co.; res. 1212 Spaight St., Madison, Wis. Dec. 18, 1903

CONN, FRANK, W., Superintendent, N. Y. & N. J. Tel. Co., 81 Willoughby St.; res., 77 St. James Pl., Brooklyn, N. Y. July 28, 1903

CONRAD, FRANK, Electrical Engineer, Westinghouse Electric & Mfg. Co., Pittsburg; res., Edgewood Park, Pa. Dec. 19, 1902

CONVERSE, V. G., Ontario Power Co., Niagara Falls South, Ont. Nov. 23, 1900

CONWELL, WALTER LEWIS, Westinghouse Electric and Mfg. Co., 11 Pine St., New York City; res., Upper Montclair, N. J. May 20, 1902

COOK, ARTHUR LEROY, Assistant Instructor in Applied Electricity, Pratt Institute; res., 281 Ryerson St., Brooklyn, N. Y. Dec. 19, 1902

COOK, EDWARD JEROME, Electrical Engineer, Cleveland Electric Railway Co., Western Reserve Bldg., Cleveland, Ohio. May 15, 1900

COOK, JAMES CARR, Student, Georgia School of Technology; res., Cusseta, Ga. June 19, 1903

COOKE, GEORGE A., Electrical Engineer, 519 North Oak Park Ave., Oak Park, Ill. Mar. 22 1901

COOLEY, FREDERICK EDMOND, Testing Department, General Electric Co.; res., 785 State St., Schenectady, N. Y. Nov. 20, 1903

COOPER, WILLIAM RANSOM, Consulting Engineer, with James Swinburne, 82 Victoria St., London, Eng. July 25, 1902

COPELAND, CLEM A., Office Edison Electric Co., 845 Coronado St., Los Angeles, Cal. June 23, 1897

CORA, CHARLES ANTHONY, Assistant Wire Chief, American Telephone and Telegraph Co., 261 Triangle St., Buffalo, N. Y. Dec. 19, 1902

CORBETT, LAURENCE JAY, 412 Bartlett St,, San Francisco, Cal. Mar. 27, 1903

COREY, FRED BRAINARD, Engineer, General Electric Co.; res., 1009 Nott St., Schenectady, N. Y. Dec. 20, 1893

CORNELL, JOHN B., Niles-Bement-Pond Co., 136 Liberty St., New York City. Sept. 25, 1895

CORNING, JOHN WOODSIDE, Electrical Engineer, Boston Elevated Ry. Co.; 439 Albany St., Boston; res., Brookline, Mass. Jan. 23, 1903

CORNMAN, GEORGE W. W. JR., Supt. Keystone Elec. Inst. Co., 9th & Montgomery Ave., Philadelphia, Pa. Jan. 23, 1903

CORNWALL, CLEMENT ARTHUR, Engineer in charge of shift, B. C. Electric Railway Co., Vancouver; res., Ashcroft, B. C. May 19, 1903

CORSON, WILLIAM R. C., Consulting Electrical Engineer, 36 Pearl St., Hartford, Conn. Jan. 17, 1893

COSGROVE, JAMES FRANCIS, 38 St. Andrews Place, Yonkers, N. Y. Nov. 23, 1898

COWEN, JULIAN BETTY, Manager of Export Department, General Incandescent Arc Light Co., 572 First Ave., New York City. Feb. 28, 1902

COWPER-COLES, SHERARD OSBORN, Grosvenor Mansions, 82 Victoria St., London, S. W., Eng. Aug. 22, 1902

CRAIG, THOMAS EDGAR, Salesman, General Electric Co., 84 State St., Boston; res., 256 So. Common St., Lynn, Mass. Feb. 27, 1903

CRAIN, JOHN JAY, 2000 H. St., N. W., Washington. D. C. Dec. 16, 1896

CRAIN, L. D., Assoc. Prof. Mech. Eng., The State Agri. College, Fort Collins, Colo. Jan. 23, 1903

CRAMPTON, STEWART HOOKER, First Asst. Supervising Eng., N. Y. Teleph. Co., 15 Dey St., New York City. Jan. 23, 1903

CRANDALL, CHESTER D., Manager, Western Electric Co., 259 South Clinton St.; res., 2821 Sheridan Road, Chicago, Ill. Sept. 27, 1892

CRANE, HENRY MIDDLEBROOK, Western Electric Co., 463 West St.; res., 532 Fifth Ave., New York City. Mar. 27, 1903

CRAVATH, JAMES RALEY, Western Editor, *Street Railway Journal*, 1139 Monadnock Block, Chicago, Ill. Nov. 23, 1901

CRAWFORD, DAVID FRANCIS, General Supt. Motive Power, Penn'a Co., Union Station, Pittsburg, Pa. Sept. 25, 1895

CRAWFORD, JACK RANDALL, 17 Stratton St., W. London, Eng. Dec. 19, 1902

CRAWFORD, NORMAN McDONALD, General Manager, Hartford Street Railway Co.; res., 111 State St., Hartford, Conn. Mar. 27, 1903

CREAGHEAD, THOMAS J., President and General Manager, Creaghead Engineering Co., 313 Walnut St., Cincinnati, Ohio. Sept. 20, 1893

CREELMAN, ADAM, Superintendent, Rockland Electric Co., Hillburn, N. Y. Mar. 27, 1903

CREHORE, ALBERT C., *Ph.D.*, The Crehore-Squier Intelligence Transmission Co., Lincoln Terrace, Yonkers, N. Y. Dec. 21, 1892

CREIGHTON, ELMER ELLSWORTH FARMER, Engineer of Experimental Dept., Stanley Electric Mfg. Co., Pittsfield, Mass. May 20, 1902

CROCKER, JAMES ROGER, Acker Process Co., Niagara Falls, N. Y. Dec. 19, 1902

CRONVALL, ERIK, Electrical Draftsman, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. Feb. 27, 1903

CROSBY, OSCAR T., with J. G. White & Co., 43 Exchange Place, New York City. Mar. 18, 1890

CROSS, EDMUND RUST, Dynamo Testing, Department Westinghouse Electric and Mfg. Co., Pittsburg, Pa. Feb. 27, 1903

CROSSMAN, GILBERT, Telephone Engineer, Western Electric Co., 463 West St.; res., 145 W. 10th St., New York City. Nov. 22, 1901

DE CROW, CHARLES EDWARD, In charge of Power Apparatus, Output Dept., W. E. Co., 242 S. Jefferson St., Chicago, Ill. Sept. 27, 1901

CROWELL, ROBINSON, Assistant Electrician, Sacramento Electric Gas and Railway Co., Sacramento, Cal. Dec. 28, 1898

CROZIER, ARTHUR BERTRAM, Draftsman and Engineer, Schwarzchild & Sulzberger Packing Co., 41st St., Chicago, Ill. Jan. 9, 1901

CROZIER, HERBERT WILLIAM, Electrical Engineer, S. F. Department of Electricity; res., 677 Pine St., San Francisco, Cal. Apr. 23, 1903

CRUMPTON, WILLIAM JAIRUS, Student, University of Wisconsin; res., West Superior, Mich. Sep. 25, 1903

CULLEN, EDWARD L., Chief Operator, Cauvery Transmission Scheme, Sirasamudrum, Mysore, India. July 28, 1903

CULVER, FRANK S., Salesman, Northern Electric Mfg. Co., Madison, Wis. Dec. 18, 1903

CUMMISKEY, WILLIAM MICHAEL, Draftsman, Marine Engine and Machine Co., Harrison; res., 108 James St., Newark, N. J. April 23, 1903

DA CUNHA, MANOEL IGNACIO, Manager of the Electrical Section, Emprera Industrial Gram-Para, Para, U. S. of Brazil. May 16, 1893

CUNNINGHAM, E. R., Des Moines City Railway Co., 607 Mulberry St., Des Moines, Iowa. Jan. 22, 1896

CUNNINGHAM, RICHARD H., Instructor in Electro-Physiology, Columbia University; res., 200 W. 56th St., New York City. May 21, 1901

CUNTZ, JOHANNES H., *Engineering Magazine*, 120 Liberty St., New York City; res., 325 Hudson St., Hoboken, N. J. Mar. 5, 1889

CURRIE, HARRY ALLAN, Electrician, Brooklyn Heights R. R. Co.; res., 87 South 9th St., Brooklyn, N. Y. Apr. 23, 1903

CURRIE, N. M., Electrical Engineer, Electric Light Department, Cia de Gas de Valparaiso, Valparaiso, Chili. Feb. 15, 1899

CURRIE, WILLIAM, JR., Electrical Engineer, 89 Union Ave., Montreal, Que. July 25, 1902

CURTIS, CARL CLIFTON, General Manager, The Sandusky Tel. Co., Sandusky, Ohio. Aug. 22, 1902

CUTLER, ELIHU HERBERT, Manager, The Elektron Mfg. Co., 84 Westminster St., Springfield, Mass. Apr. 23, 1903

Cutler, Henry H., Vice-President and Chief Engineer, The Cutler-Hammer Mfg. Co., Milwaukee, Wis. June 19, 1903

Cutler, James Elmer, Manager of Philadelphia Office Stanley Electric Mfg. Co., 26 So. 15th St., Philadelphia, Pa. Apr. 25, 1902

Daggett, Royal Bradford, Electrical Engineer, Electric Storage Battery Co., 43 Nevada Block, San Francisco, Cal. Jan. 25, 1899

Dahlander, Robert, Electrical Engineer, The Royal Government of the Railways of Sweden, Stockholm, Sweden. May 19, 1903

Damon, Geo. A., Electrical Engineer, Arnold Electric Power Station Co., 1540 Marquette Building, Chicago, Ill. June 24, 1898

Damon, Geo. B., Manager, Cahall Sales Dept., 1110 Farmer's Bank Building, Pittsburg, Pa. June 23, 1897

Daniels, Harold Platt, Testing Department, General Electric Co.; res., 5 So. Church St., Schenectady, N. Y. Dec. 19, 1902

Danielson, Ernst, Technical Director, Allmanna Svenska Elektriska, A. B., Westerås, Sweden. June 27, 1895

Darby, Walter Raines, Pittsburg Reduction Co., 99 John St., New York City; res., 18 Summit Ave., Westfield, N. J. May 20, 1902

Dassori, Frederick Humbert, Engineering Dept., N. Y. & N. J. Telephone Co., 81 Willoughby St., Brooklyn, N. Y. May 21, 1901

Dates, Henry B., Professor of Electrical Engineering and Physics, University of Colorado, Boulder, Colo. Dec. 28, 1898

Davenport, George W., 44 Bay St., Winchester, Mass. June 4, 1889

Davidson, Edw. C., Patent Lawyer, 141 Broadway, New York City. Feb. 7, 1890

Davidson, James Edward, Superintendent, Port Huron Light and Power Co., Port Huron, Mich. Mar. 28, 1902

Davidson, John Clarence, Electrician and Chief Engineer, S. S. White Dental Mfg. Co., Princes Bay, N. Y. May 19, 1903

Davidson, Rolland Arthur, General Manager, Newburgh Light, Heat and Power Co.; 298 Grand St., Newburgh, N. Y. Mar. 27, 1903

Davies, John Hubert, Senior Partner, Hubert Davies & Spain, Johannesburg, S. A. Oct. 23, 1903

Davis, Arthur Percy, 167 Russell St., Worcester, Mass. July 28, 1903

Davis, Charles Bridge, Local Manager of Boston Office, General Electric Co., 84 State St., Boston; res., Lexington, Mass. Apr. 23, 1903

Davis, Delamore L., Superintendent, Salem Electric Light and Power Co., 299 Lincoln Ave., Salem, Ohio. Apr. 2, 1889

Davis, Ernest Edgar, Mechanical and Electrical Engineer, Davis & Forrest, Savannah, Ga. Nov. 20, 1903

Davis, Fred Horne, Consulting Engineer, Winchester House, Loveday St., Johannesburg, Transvaal. Sept. 25, 1903

Davis, Jesse Hood, Draftsman, Motive Power Department, Pennsylvania Railroad, 1409 10th St., Altoona, Pa. June 19, 1903

Davis, Joseph P., Engineer, American Telephone and Telegraph Co., 113 W. 38th St., New York City. Apr. 15, 1884

Davis, Leslie Foster, Secretary and Manager, Jamaica Electric Light & Power Co., Ltd., 38 Harbor St., Kingston, Jamaica. Sept. 27, 1899

Davis, Philip W., Engineer of New England Office, The Electric Storage Battery Co., Boston; res., Cambridge, Mass. May 15, 1900

Davis, Solomon, Proprietor, The Conduit Wiring Co., 12 West 29th St., New York City. July 25, 1902

Davis, William Griffith, Electrical Engineer, Electric Storage Battery Co., 19th St. & Allegheny Ave., Philadelphia, Pa. Oct. 24, 1902

DAVIS, W. J., JR., Electrical Engineer, General Electric Co., Schenectady, N. Y. Mar. 20, 1895

DAWSON, JOSIAH, Contractor for Electric Light and Power, etc., Cuba Street Extension, Wellington, New Zealand. Jan. 9, 1901

DAY CHARLES. Dodge & Day, Nicetown; res., Germantown, Philadelphia, Pa. May 20, 1902

DAY. WINTERTON JAMES, Power and Mining Engineering Department, General Electric Co., Schenectady, N. Y. June 19, 1903

DEAN, WALTER CLARK, Electrical Draughtsman in charge Equipment Department, Norfolk Navy Yard, res., Norfolk, Va. Sept. 17, 1901

DEAN, WILLIAM TUCKER, Chief Electrician, Illinois Steel Co., So. Chicago; res., 748 E. 72d St., Chicago, Ill. Apr. 23, 1903

DEAN, WILLIAM WARREN, Vice-President Dean Electric Co., Elyria, Ohio. Nov. 21, 1902

DE BLOIS, LEWIS AMORY, Electrical Engineer, with Harry Alexander, Astor Court Building, W. 33d St., New York City. Sept. 25, 1903

DECKER, WARD, Manufacturing Electrical Specialties and Automobiles, Owego, N. Y. May 19, 1903

DEEDS, EDWARD ANDREW, Assistant General Manager National Cash Register Co., Dayton, Ohio. Nov. 23, 1900

DELAFIELD, CLARENCE E., District Manager, Wagner-Bullock Co., 2017 Locust St., St. Louis, Mo. Apr. 23, 1903

DELAVAL, LEON, Electrical Engineer, Westinghouse Electric and Mfg. Co., Pittsburg; res., Wilmerding, Pa. June 19, 1903

DE MARCHENO, E., Chief Engineer, Compagnie Francais, Thomson Houston, 10 Rue de Londres, Paris, France June 19, 1903

DEMPSTER, THOMAS, Electrical Engineer, General Electric Co., Schenectady, N. Y. May 17, 1898

DENN, HOWARD HARPER, Teacher in Mechanical Drawing. Drexel Institute; res., 4408 Walnut St., Philadelphia, Pa. Dec. 18, 1903

DENNISON, EDGAR WALLACE, District Manager, New York and New Jersey Telephone Co., 11 Cone St., Orange, N. J. June 19, 1903

DE WOLF, ROGER DENNISON, Electrical Engineer, Westinghouse Eletric and Mfg. Co., Pittsburg, Pa Nov. 20, 1903

DICK, WILLIAM AMZI, Designing Electrical Engineer, Westinghouse E. & M. Co., Pittsburg, Pa. Mar. 28, 1902

DICKERSON, E. N., Attorney-at-Law, 141 Broadway; res., 64 E. 34th St., New York City. Apr. 15, 1884

DICKINSON, EDGAR DRURY, Testing Dept. General Electric Co.; res., 5 So. Church St., Schenectady, N. Y. Jan. 23, 1903

DICKINSON, HARRY HAMMOND, Erecting Engineer, Arnold Electric Power Station Co., 1539 Marquette Building, Chicago, Ill. July 28, 1903

DIETERICH, ALBERT EDGAR, Solicitor of Patents, with Fred G. Dieterich, 602 F St., N. W. Washington, D. C. Jan. 23, 1903

DIETERICH, FRED G., Solicitor of Patents and Mechanical Expert, 602 F St., Washington, D. C. July 18, 1899

DILLON, EDWARD PAUL, Electrical Engineer, The Colorodo Springs Electric Co., 107 East Kiowa St., Colorado Springs, Colo. Sept. 26, 1902

DINKEY, ALVA C., Supt. Electric Dept., Homestead Steel Works, Munhall, Pa. Feb. 17, 1897

DINSMORE, SAMUEL C., Expert Nutrition Investigation U. S. D. A., Wesleyan University, Middletown, Conn. Sept. 25, 1903

DIX, WALTER S., Mechanical and Electrical Engineer, Sanderson & Porter, 52 William St., New York City. May 19, 1903

DIXON, JAMES, Electrical Engineer, Gray National Telautograph Co., 80 Broadway, New York City. Jan. 24, 1902

DIXON, WILL MONTAGUE, Foreman, Inside Wiring, World's Fair, St. Louis, Mo. May 19, 1903

DOBBELAAR, EDWARD CHRISTIAN, Assistant Engineer, New York *Sun*, 170 Nassau St., New York City. Sept. 25, 1903

DOBBIE, ROBERT S., Electrical Engineer, Riding Mill-on-Tyne, Northumberland, Eng. Feb. 5, 1889

DODD, JOHN NEVINS, Designer Electrical Machinery, English Electrical Mfg. Co., West Strand Road, Preston, Lancashire, Eng. Feb. 27, 1903

DODD, SAMUEL THOMSON, Engineer Railway Department, Stanley Electric Mfg. Co., Pittsfield, Mass. Sept. 27, 1901

DODGE, KERN, Dodge & Day, Nicetown; res., Germantown, Philadelphia, Pa. May 20, 1902

DOLPH, JOHN CLEMENT, Manager, Insulating Varnish Department, Standard Varnish Works, Brooklyn, N. Y. Sept. 25, 1903

DONALDSON, KEITH, Assistant in Construction Department, J. G. White & Co., 43 Exchange Place, New York City. May 19, 1903

DONALDSON, WM. W., Electrical Engineer, The Gould Storage Battery Co., 25 W. 33d St., New York City. May 21, 1901

DON CARLOS, HENRY C., Station Foreman, The Telluride Power Transmission Co., Telluride, Colo.; res., Clarkbsurg, Mo. Apr. 23, 1903

DONSHEA, WILLIAM ISAAC, District Superintendent, The N. Y. Edison Co., 55 Duane St., New York City. Apr. 23, 1903

DOOLITTLE, CHARLES BENJAMIN, Supt. of Traffic, The Southern N. E. Telephone Co., 118 Court St., New Haven, Conn. Apr. 23, 1903

DOOLITTLE, CLARENCE E., Manager and Electrician, Roaring Fork Electric Light and Power Co., Aspen, Colo. May 15, 1895

DOOLITTLE, THOMAS B., Engineering Department, American Telephone and Telegraph Co., 125 Milk St., Boston, Mass. May 16, 1893

DOPP, WILLIAM HUGH, Stanley Electric Mfg. Co., Pittsfield, Mass. Sept 27, 1901

DOREMUS, CHARLES AVERY, *M.D.*, *Ph.D.*, 55 West 53d St., New York City. July 7, 1884

DORNBUSCH, LOUIS CHARLES, Student, Polytechnic Institute; res., 61 Hancock St., Brooklyn, N. Y. Dec. 19, 1902

DOSTAL, JOHN FRANK, Member of Engineering Corps, Denver Gas and Electric Co., 2432 Stout St., Denver, Colo. Mar. 27, 1903

DOTY, ERNEST LAWRENCE, Assistant Engineer, Westinghouse E. & M. Co., 11 Pine St., New York City. Sept. 25, 1903

DOUBLEDAY, HARRY M., Doubleday-Hill Electric Co., 535 Wood St., Pittsburg, Pa. July 25, 1902

DOUBRAVA, HARRY WILFRED, Engineer, Bullock Electric Mfg. Co. 220 Broadway, New York City. May 20, 1902

DOUBT, THOMAS EATON, Graduate Student, The University of Chicago, 5802 Jackson Ave., Chicago, Ill. Jan. 9, 1901

DOUD, CHARLES HAMILTON, With Sawyer, Man Electric Co., 510 West 23d St.; res., 30 W. 44th St., New York City. Sept. 27, 1901

DOUGHERTY, CHARLES JAMES, Electrical Engineer, The Wm. Cramp & Sons Ship and Engine Building Co., Philadelphia, Pa. May 19, 1903

DOUGHERTY, PROCTOR L., Electrical Engineer, Treasury Department; res, 1427 Binney St., Washington, D. C. Dec. 19, 1902

DOUGLAS, EDWIN RUST, Chief Draftsman, The Crocker-Wheeler Co., Ampere, N. J.; res., East Orange, N. J. Jan. 23, 1903

DOUGLAS, EGBERT, Construction Engineer, General Electric Co., Ruggery Building, Columbus, Ohio. Apr. 23, 1903

DOW, HERBERT WILLIAM, Assistant Professor of Mechanical Engineering, Iowa State College, Ames, Iowa. May. 19, 1903

DOW, JAMES CHASE, Switchboard Attendant, Missouri River Powe Cor., 551 S. Main St., Butte, Mont. Feb. 27, 19C3

DOWIE, HORACE, With Westinghouse, Church, Kerr & Co., 8 Bridge St., New York City; 363 Jefferson Ave., Brooklyn, N. Y. Jan. 25, 1901

DOWNERD, HIROM S., Erecting Engineer, 240 Marshall Ave., Columbus, Ohio. June 19, 1903

DOWNES, LOUIS W., Vice-President and General Manager, The D. & W. Fuse Co., 407 Pine St., Providence, R. I. Nov. 22, 1899

DOWNING, P. M., Supt. of Sub-Stations, California Gas & Elec. Corp., Rialto Bldg., San Francisco, Cal. June 24, 1898

DOWNS, EDGAR SELAH, 704 Trenton Ave., Wilkinsburg, Pa. May 19, 1903

DOWNTON, CHARLES EDWARDS, Foreman of Apprentices, The Westinghouse Electric & Mfg. Co., Pittsburg, Pa. Jan. 23, 1903

DRAKE, BERNARD MERVYN, Chairman, Drake & Gorham, Ltd., 66 Victoria St., London, S.W., Eng. Apr. 23, 1903

DRAKE, DAVID E., Sales Department, Westinghouse Electric and Mfg. Co., 120 Broadway; res., 260 Sixth Ave., Newark, N. J. June 19, 1903

DRAKE, HERBERT WILLIAM, Assistant Wire Chief, American Telephone and Telegraph Co., 261 Triangle St., Buffalo, N. Y. Dec. 19, 1902

DRANE, FRANK NEAL, Secretary and Treasurer, Corsicana Gas & Electric Co., Corsicana, Tex. Sept. 25, 1903

DRESSEL, JOHN HATHAWAY, 436 S Ave., Wilkinsburg, Pa. Sept. 27, 1901

DRESSER, CHARLES A., Supt., Kohler Bros., 1808 Fisher Bldg., Chicago, Ill. May 21, 1901

DRESSLER, CHARLES E., 17 Lexington Ave., New York City. Dec. 16, 1890

DROHAN, T. E., Supt. of Shops, Northern Electric Mfg. Co., Madison, Wis. May 21, 1901

DRYER, ERVIN, Salesman and Engineer, Westinghouse E. & Mfg. Co.; 171 La Salle St., Chicago, Ill. Feb. 28, 1902

DRYSDALE, DR. W. A., Consulting Electrical Engineer, 414 Hale Building, Philadelphia, Pa. Sept. 19, 1894

DuBOIS, ALEXANDER DAWES, Motor Application Engineer, Western Electric Co., 259 South Clinton St., Chicago, Ill. July 25, 1902

DuBOIS, TUTHILL, Electrical Contractor, 891 Glenmore Ave., Brooklyn, N. Y. Aug. 23, 1899

DUDLEY, EUGENE ELMER, Asst. Elec. Eng'r., Quartermaster's Dept., Bedloe's Island, N. Y. Harbor. Oct. 24, 1902

DUFRESNE, BERNARD MAURICE, Erecting Engineer, Westinghouse E. & M. Co.; res., C27 South Negley Ave., Pittsburg, Pa. Sept. 25, 1003

DUNCAN, JOHN D. E., Engineer, with Sanderson & Porter, 31 Nassau St.,
[Life Member.] New York City. Mar. 20, 1895

DUNCAN, THOMAS, Vice-President and General Manager, Duncan Electric Mfg. Co., Lafayette, Ind. Oct. 17, 1894

DUNLOP, ROBERT ROWSE, Engineer in Electrical Department, Jeffrey Mfg. Co.; res., 272 N. 17th St., Columbus, Ohio. Apr. 23, 1903

DUNN, CLIFFORD E., Patent Attorney, Park Row Bldg., New York City; res., 12a Monroe St., Brooklyn, N Y. Feb. 15, 1899

DUNN, KINGSLEY G., With C. C. Moore & Co., 614 Pacific Block, Seattle, Washington. Oct. 17, 1894

DURANT, EDWARD, Electrical Engineer, 115 East 26th St., New York City. Nov. 15, 1892

DURANT, GEO F., General Manager Bell Telephone Co., of Missouri, Telephone Building, St. Louis, Mo. Apr. 15, 1884

DUSMAN, JOHN F., General Manager, The York County Traction Co.; res., 15 S. George St., York, Pa. May 19, 1903

DWIGHT, THEODORE, Asst. Secy. Amer. Inst. of Mining Engrs., 99 John St.; res., 103 W. 55th St., New York City. Jan. 23, 1903

DYER, ERNEST I., Engineer and Manager of the Engineering Department of the American Trading Co., Yokohama, Japan. Jan. 25, 1899

DYER, SHUBAEL ALLEN, Manager Supply Dept. Mexican Mine & Smelting Supply Co., Callé San Francisco, No. 12, Mexico City, May 15, 1900

DYKE, OWEN ARTHUR WYNNE, Electrical Contractor, 90 St. George's St.; Capetown, South Africa. Sept. 27, 1901

DYSON, ALFRED HARTWELL, Engineer, Automatic Electric Co., cor. Morgan and Van Buren Sts., Chicago, Ill. Jan. 23, 1903

DYSTERUD, EMIL, [Address Unknown.] July 26, 1900

EASTMAN, FRANK HALL, Salesman, Washington Office, Crocker-Wheeler Co.; 1417 New York Ave , Washington, D. C. May 19, 1903

EASTMAN, GEORGE NIAL, In charge of Testing Laboratory, Chicago Edison Co., 139 Adams St., Chicago, Ill. Nov. 22, 1901

EASTWOOD, ARTHUR CLARKE, Electrical Engineer, The Wellman-Seaver-Morgan Engineering Co., Cleveland, Ohio. Mar. 27, 1903

EATON, HOWARD FRENCH, Mechanical and Electrical Draftsman, Stone & Webster, 19 High St., Boston; res.. Quincy, Mass. Feb. 27, 1903

EDDY, H. C., Electrical Engineer, 924 Monadnock Building, Chicago, Ill. June 20, 1894

EDDY, HORACE T., University of Cincinnati, Cincinnati, Ohio. May 21, 1901

EDGAR, HARRY THOMAS, Manager El Paso Electric Railway Co., and International Light and Power Co., El Paso, Tex. Feb. 27, 1903

EDMANDS, I. R., Electrical Engineer and Superintendent, Union Carbide Co., Sault Ste. Marie, Mich. June 23, 1897

EDMANDS, SAMUEL SUMNER, Instructor, Applied Electricity, Pratt Institute, Brooklyn, N. Y. Mar. 22, 1901

EDMONDS, SAMUEL OWEN, Patent Lawyer, 32 Liberty St.; res., Lawrence Park, Bronxville, N. Y. July 28 1903

EDMONSTON, EDGAR DAVIS, Electrical Engineer, The Lackawanna Iron & Steel Co., res.; 401 Delaware Ave., Buffalo, N. Y. Apr. 25, 1902

EDSTROM, JOHANNES SIGFRID, General Manager, Allmanna Svenska Electric Co., Westeràs, Sweden. May 19, 1903

EDWARDS, CLIFTON V., Attorney-at-Law and Solicitor of Patents, 220 Broadway, New York. Nov. 22, 1899

EDWARDS, JAMES P., Consulting Electrician, Augusta; res , Montesano, Summerville, Ga. Apr. 19, 1892

EDWARDS, JOSEPH BLACKBURN. Supt. Kellogg Switchboard and Supply Co., Congress and Green Sts., Chicago, Ill. Jan. 23, 1903

EGLIN, JAMES MEIKLE, Chief of Electric Dept Edison Electric Light Co., 10th and Sansom Sts., Philadelphia, Pa. July 26, 1900

EGLIN, WM. C. L., Manager, Electrical Engineer, Edison Electric Lt. Co., 10th and Sansom Sts., Philadelphia, Pa. Sept. 19, 1894

EGLINTON, WILLIAM MCNICOL, Chief Constructing Engineer of Power Plant, Guanica Centrale, Guanica, Porto Rica. Feb. 27, 1903

EHRENREICH, JAMES JACOB, Contracting Electrical Engineer, 503 Fifth Ave., New York City. June 19, 1903

EHRET, CORNELIUS DALZELL, 1011 Chestnut St., Philadelphia, Pa. Jan. 24, 1902

EHRHART, RAYMOND NELSON, The Westinghouse Machine Co.; res., 7712 Edgerton Ave., Pittsburg, Pa. Mar. 27, 1903

EISENBEIS, WALTER HERMAN, Engineering Apprentice, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. Dec. 19, 1902

EKSTRAND, CHARLES, Superintending Engineer, Brooklyn Cooperage Co., North 6th St. and Kent Ave., Brooklyn, N. Y. Apr. 25, 1902

EKSTROM, AXEL, Consulting Electrical Engineer, Delaware Hudson Ry. Co., Albany, N. Y. June 17, 1890

ELDEN, LEONARD LORD, Chief Electrican, Edison Electric Illuminating Co., of Boston, 3 Head Pl.; res., Dorchester, Mass. Apr. 23, 1903

ELEY, JOSIAH NORFLEET, Electrical Engineer, Georgia Railway and Electric Co., 198 S. Prior St., Atlanta, Ga. Feb. 28, 1902

ELIAS, ALBERT B., 1310 Washburn St., Scranton, Pa. Jan. 26, 1898

ELLARD, JOHN W., J. L. Blackwell & Co., 229 East German St., Baltimore, Md. June 23, 1897

ELLINGER, EDGAR, Electrical Engineer, George A. Fuller Co., 137 Broadway; res., 164 E. 79th St., New York City. Apr. 25, 1902

ELLIOTT, ELMER G., General Electric Co., 44 Broad St., New York City. May 21, 1902

ELLIS, JOHN, Manager, The Lonsdale Co.'s Electric Light Plant, Lonsdale, R. I. Apr. 26, 1899

ELLIS, R. LAURIE, General Superintendent, Gas and Electric Departments, Natchez Gas Light Co., Natchez, Miss. Apr. 26, 1896

ELLIS, WESLEY ROSE, Student, Elec. Eng'g, Cornell Univ.; 302 Eddy St., Ithaca, N. Y.; res., Johnstown, Pa. Jan. 23, 1903

ELMER, WILLIAM, JR., Assistant Master Mechanic, Altoona Machine Shop, Altoona, Pa. Mar. 18, 1890

ELSHOFF, BERNARD, General Foreman, Bullock Electric Mfg. Co., East Norwood; res., 1522 Breman St., Cincinnati, Ohio. Feb. 27, 1903

ELY, WM. GROSVENOR, JR., Asst. Supt. Construction, General Electric Co.; res., Avon Road, Schenectady, N. Y. Mar. 21, 1893

EMERICK, LOUIS W., Vice-President and General Manager, Fulton Light, Heat and Power Co., Fulton, N. Y. Aug. 13, 1897

ENGELHORN, FRANK JOSEPH, Superintendent Nezperce Light & Power Co., Nezperce, Idaho. May 19, 1903

ENTZ, JUSTUS BULKLEY, Electrical Engineer, Electric Storage Battery Co., 19th St. and Allegheny Ave., Philadelphia, Pa. Jan. 7, 1890

ERBEN, H. F. T., Designing Engineer, General Electric Co., Schenectady, N. Y. Aug. 22, 1902

ERICKSON, F. WM., Electrical Engineer, The Erickson Electric Equipment Co., 280 Devonshire St., Boston, Mass. Sept. 19, 1894

ERWIN, FRANK BENNETT, Electrical Engineer, Westinghouse E. & M. Co., University Building, Syracuse, N. Y. Jan. 3, 1902

ESLING, ALBERT, Sales Manager, R. E. T. Pringle Co., 18, Toronto St., Toronto, Ont. Nov. 20, 1903

ESTERLINE, J. WALTER, Instructor Electrical Engineering, Purdue University; res., 401 State St., Lafayette, Ind. Mar. 28, 1900

ESTES, ORANGE A., The Chesapeake and Potomac Telephone Co., 619 14th St., N. W., Washington, D. C. Jan. 3, 1902

ETHERIDGE, HARRY, Asst. Supt. Allegheny Co. Light Co.; res., 1906 Jenny Lind St., McKeesport, Pa. Jan. 23, 1903

ETHERIDGE, LOCKE, *M.E.*, Electrical Engineer, Pullman Car Works, Pullman; res., 44 E. 50th St., Chicago, Ill. Oct. 17, 1894

EVANS, CLEMENT W., Electrical Engineer, Fogarty & Dickenson, 1a San Francisco, Mexico City, Mexico. Feb. 28, 1900

EVANS, PAUL H., Chief Engineer, Mexican General Electric Co., Mexico City, Mexico. Jan. 24, 1900

EVELAND, PORTER, 773 State St., Schenectady, N. Y. June 19, 1903

EVERIT, EDWARD HOTCHKISS, Engineer, The So. N. E. Telephone Co., 641 Whitney Ave., New Haven, Conn. Jan. 3, 1902

EWING, GEORGE CLINTON, Electrical Railway Supplies, 131 State St., Boston, Mass. Mar. 27, 1903

EYRE, MANNING K., Buckeye Electric Co., Cleveland, Ohio. Oct. 17, 1894

FAHNESTOCK, ERNEST BENJAMIN, Vice-President and G. M., Fahnestock Transmitter Co., 74 Cortlandt St., New York City. Apr. 23, 1903

FAIRBANKS, ROBERT PAYNE, Power Station Superintendent, The Logan Power Co., Logan, Utah. Apr. 23, 1903

FAIRBURN, WILLIAM ARMSTRONG, Naval Arch. & Engr., Eastern Shipbuilding Co., Quincy, Mass. Jan. 23, 1903

FAIRCHILD, WALTER LOWE, Bullock Electric Mfg. Co., 220 Broadway, New York City. Oct. 24, 1902

FAMBROUGH, WILLIAM MCINTOSH, Designing & Erecting Engineer, Moore & McCrary, Atlanta, Ga. July 28, 1903

FANSLER, PERCIVAL ELLIOT, *B.S.*, Chief Clerk, Department of Electricity, Universal Exposition, St. Louis, Mo. Mar. 28, 1902

FARMER, FRANK MALCOLM, Lamp Testing Bureau, 80th St. & East End Ave., New York ; res., 568 Pacific St., Brooklyn. Nov. 21, 1902

FARNSWORTH, ARTHUR J., Asst. Chief Engineer, Consol. Rwy, Electric Ltg. & Equip. Co., 83 W. Jackson Boul., Chicago, Ill. Jan. 16, 1895

FARRAND, DUDLEY, General Manager, United Electric Company of New Jersey, 207 Market St., Newark, N. J. July 26, 1900

FARWELL, HAROLD GILBERT, Testing Department, General Electric Co.; res., 77 Grove St., Lynn, Mass. Apr. 23, 1903

FAWCETT, WALLACE H., General Electric Co.; res., 8 Union St., Schenectady, N. Y. Aug. 22, 1902

FAY, THOMAS J., 461 55th St., Brooklyn, N. Y. June 26, 1891

FELDMAN, CLARENCE, Lecturer, The Polytechnical High School; res., Stifts St., 9, Darmstadt, Ger. May 19, 1903

FELLOWS, HENRY WALLACE, Consulting and Construction Engineer, Citizen's Electric Co., Lewistown, Mont. May 19, 1903

FERGUS, WILLIAM LOVEDAY, Partner, Chas. G. Armstrong & Co., 1510 Fisher Building, Chicago, Ill. May 19, 1903

FERGUSON, LOUIS ALOYSIUS, General Superintendent, Chicago Edison Co., 139 Adams St., Chicago, Ill.; res., Evanston, Ill. Oct. 25, 1901

FERGUSON, SAMUEL, Engineer, General Electric Co., Schenectady, N. Y. Jan. 3, 1902

FERNALD, CHARLES ARTHUR, Electrician, General Electric Co.; res., 24 Brimblecom St., Lynn, Mass. Apr. 23, 1903

FERNANDEZ, WILLIAM, TALANERA Foreman, Electrical Operating Dept., N. Y. Edison Co., 38th St. & 1st Ave., New York. May 19, 1903

DE FERRANTI, SEBASTIEN ZIANA, Managing Director, de Ferranti, Ltd.; res., 31 Lyndhurst Rd,, Hampstead, London, Eng. May 19, 1903

FERRIS, ROBERT MURRAY, JR., Engineering Dept., The N. Y. & N. J Telephone Co., 81 Willoughby St., Brooklyn, N. Y. Feb. 28, 1902

FETHERLING, HERSCHEL GEORGE, Salesman and Engineer, Northern Electric Mfg. Co., 126 E. Dayton St., Madison, Wis. Dec. 18, 1903

FIELD, ALLAN BERTRAM, General Electric Co., Schenectady, N. Y. May 19, 1903

FIELD, ARTHUR W., Secretary and Manager, 101 Hoffman Ave., Columbus Ohio. Aug. 22, 1902

FIELD, MICHAEL BIRT, Contract Engineer, Ferranti Ltd., 20 Cockspur St., London, S. W., Eng. Nov. 20, 1903

FIELDING, FRANK E., Chemist and Assayer, Virginia City, Nev. [Life Member.] Sept. 6, 1887

FIELDING, PHILIP HARRISON, Chief Electrician, B. Altman & Co.; res., 59 W. 124th St., New York City. July 28, 1903

FINCH, HERBERT ISAAC, Assist. Supt. The Emerson Electric Mfg. Co., St. Louis, Mo. Apr. 23, 1903

FINNEY, JOHN H., Manager, Southern office, The Pittsburg Reduction Co., Bond Building, Washington, D. C. Sept. 26, 1902

FINZI, GEORGE, General Manager, Brioschi, Finzi & Co., 24 Piazza Castello, Milano, Italy. Mar. 27, 1903

FIRTH, WM. EDGAR, Chief Engineer, The Midvale Steel Co., Nicetown, Phila.; res., 7203 Boyer St., Germantown, Pa. Mar. 25, 1896

FISH, FRED ALAN, Assistant Prof. of Electrical Engineering, Ohio State University; res., 241 W. 4th Ave., Columbus, O. Mar. 28, 1900

FISH, FREDERICK PERRY, President, American Telephone & Telegraph Co., 125 Milk St., Boston; res., Brookline, Mass. Mar. 28, 1902

FISHER, GEORGE EDWARD, Engineer, General Electric Co., 84 State St., Boston; res., Natick, Mass. Apr. 23, 1903

FISHER, HOWARD SHREVE, Correspondent, Westinghouse Electric and Mfg. Co., Pittsburg; res., Swissvale, Pa. Dec. 19, 1902

FISKE, WARREN HERBERT, Consulting Engineer, The Toronto Ry. Co., Street Railway Chambers, Toronto, Ont. July 28, 1903

FISKEN, JOHN BARCLAY, Superintendent Light and Power System, The Washington Water Power Co., Spokane, Wash. Apr. 23, 1903

FITTS, CLARENCE DUDLEY, Electrician, Oakville Co., Oakville, Conn. Nov. 20, 1903

FITZ, ERVIN MOUL, Electrical Engineer, M. P. Dept., Pennsylvania Lines West of Pittsburg, Columbus, Ohio. Sept. 25, 1903

FITZGERALD, THOMAS, JR., General Superintendent, Lexington Railway Co., Lexington, Ky. Jan. 3, 1902

FITZHUGH, WM. H., Supt. Bay City Electric Plant, 2230 Center Ave., Bay City, Mich. Apr. 27, 1898

FLATHER, JOHN J., Professor of Mechanical Engineering, University of Minnesota, Minneapolis, Minn. Apr. 19, 1892

FLEMING, JOHN BRECKENRIDGE, *M.M.*, Mechanical Engineer, Detroit Copper Mining Co., Morenci, Ariz. Apr. 27, 1898

FLEMING, JOHN F., Electrical Contractor, Brookline, Mass. July 12, 1900

FLEMING, RICHARD, Designing Engineer, General Elec. Co., Lynn; res., Swampscott, Mass. Jan. 24, 1902

FLETCHER, GEORGE WESLEY, Engineer, 38 Grove St., Brooklyn, N. Y. July 25, 1902

FLICHTNER, STANWOOD EDWARDS, Engineer, The Cooper-Hewitt Electric Co., 220 West 29th St., New York City. Mar. 27, 1903

FLICKINGER, JOHN TRESSLER, Head of No. 16 Test, General Electric Co., Schenectady, N. Y. Sept. 25, 1903

FLIESS, ROBERT ANTON, 55 Church St., Montclair, N. J. Mar. 23, 1898

FLINT, JAMES J., President, The Flint-Lomax Electric and Mfg. Co., 1400 Delgany St.; res., Berkeley, Denver, Colo. Mar. 27, 1903

FLOY, HENRY, Consulting Electrical and Mechanical Engineer, 220 Broadway, New York City; res., East Orange, N. J. May 17, 1892

FOG, CARL F., Electrician, General Electric Co.; res., 69 Warren St., Lynn, Mass. Mar. 28, 1900

FOOTE, FERDINAND JOHN, Erecting Engineer, Bullock Elec. Mfg. Co.; res., 4615 Montgomery Ave., Norwood, Ohio. Oct. 23, 1903

FOOTE, THOS. H., Electrical Engineer, 88 South Los Robles Ave., Pasadena, Cal. Apr. 21, 1891

FORBES, FRANCIS, Lawyer, 32 Nassau St., New York City. Sept. 16, 1890

FORD, ARTHUR HILLYER, *E.E.*, Professor of Electrical Engineering, Georgia School of Technology, Atlanta, Ga. Mar. 24, 1897

FORD, FRANK R., *M.E.*, Consulting Engineer, Ford, Bacon & Davis, 24 Broad St., New York City. Mar. 25, 1896

FORD, WM. S., Assistant to Chief Engineer, The American Telephone and Telegraph Co., 125 Milk St., Boston, Mass. June 7, 1892

FORSYTH, JOSEPH C., Chief Inspector, Electrical Dept., The N. Y. Board of Fire Underwriters, 32 Nassau St., New York City. Apr. 23, 1903

FORTESCUE, CHARLES LE GEYT, Electrical Designer, Westinghouse E. &. M Co., Pittsburg; res., Wilkinsburg, Pa. Jan. 23, 1903

FOSTER, FREDERICK HENRY, Draftsman, The Hamilton Electric Light and Cataract Power Co., Hamilton, Ont. June 19, 1903

FOSTER, GEORGE BEERS, District Manager, Bullock Electric Mfg. Co., 1625 Marquette Building, Chicago, Ill. Feb. 27, 1903

FOWLE, FRANK FULLER, Special Agent, Railway Department, American Telephone and Tel. Co., 15 Dey St., New York City. Dec. 19, 1902

FOWLER, GEO. W., Electrical Expert, The C. & C. Electric Co., Garwood, N. J. Oct. 24, 1900

FOWLER, MYRON MARSHALL, Electrical Engineer, Western Electric Co., 259 South Clinton St., Chicago, Ill. Apr. 23, 1903

FOX, WILLIAM A., Secretary, Chicago Edison Co., 139 Adams St., Chicago, Ill. May 19, 1903

FRANCISCO, M. J., President and General Manager, Rutland Electric Light Co., Rutland, Vt. June 17, 1890

FRANK, AUGUSTUS ALPHONSUS, Electrician, New York and New Jersey Telephone Co., New York City. Jan. 23, 1903

FRANK, GEO. WILLIAM, Engineer in charge Yadkin River Hydraulic Development, New London, N. C. Sept. 28, 1898

FRANKENFELD, BUDD, Eng'g Dept., Nernst Lamp Co., Pittsburg, Pa. Feb. 17, 1897

FRANTZEN, ARTHUR, Electrical Engineer and Contractor, 225 Dearborn St.; res., 662 N. Irving Ave., Chicago, Ill. Feb. 21, 1894

FRASER, JAMES WM., 745 Wallace Ave., Wilkinsburg, Pa. May 21, 1901

FREEMAN, CLARENCE E., Professor of Electrical Engineering, Armour Institute of Technology, Chicago, Ill. Mar. 27, 1903

FRENCH, THOMAS, JR., *Ph.D.*, Department of Physics, Amherst College, Amherst, Mass. Sept. 20, 1893

FREUDENBERGER, WILLIAM KAISER, 413 Price Ave., Columbia, Mo. Nov. 22, 1901

FREUND, HENRY PAUL, 796 Lexington Ave., New York City. Sept. 26, 1902

FRIEDLANDER, EUGENE, Electrician, Carnegie Steel Company, Duquesne, Pa. Nov. 20, 1895

FRITCHLE, OLIVER PARKER, Chief Chemist and Assayer, The Boston and Colorado Smelting Co., Argo; res. Denver, Colo. Mar. 27, 1903

FROMHOLZ, ANTON JOHN, Electrician in charge, U. S. Navy Yard; res., 1177 Greene Ave., Brooklyn, N. Y. May 20, 1902

FROST, HOMER ELI, Superintendent Public Works, Rocky Mount, N. C. Jan. 23, 1903

FRY, DONALD HUME, Consulting Engineer, 601 Hayward Building, San Francisco, Cal. Nov. 23, 1898

FUCHS, GEORGE ADAM, Electrical Engineer, Electric Equipment Co., Erie, Pa. Oct. 23, 1903

FUCHS, HUGO, Draftsman, Chicago Edison Co., 139 Adams St.; res., 317 Bissell St., Cnicago, Ill. Oct. 23, 1903

FULLER, ARTHUR JOHN, Borough Electrical Engineer, Corporation Electric Works, Townmead Rd., Fulham, S.W., England. Feb. 27, 1903

FULLER, EDWIN ERNEST, Representative Engineer for Scotland for The British Thomson-Houston Co., Ayr. N.B., Eng. Feb. 28, 1902

FULLER, HARRY WILLIAMS, General Manager, Washington Ry. & Electric Co., 14th and E. Capitol Sts., Washington, D. C. June 19, 1903

FULLER, HENRY JAMES, Assistant Manager and Engineer, John Fuller & Co., res.; 13 Park View, Beeston Hill, Leeds, Eng. Apr. 23, 1903

FULLER, LUCIUS B., Assistant to P. N. Nunn, The Niagara Construction Co., Ltd., Niagara Falls, Ont. Sept. 25, 1903

FULLER, WALLACE WATT, Electrical Engineer, Consolidated Railway Gas and Electric Co., Charleston, S. C. Mar. 27, 1903

FURGUESON, CORNELIUS, JR., Student, Polytechnic Institute, Brooklyn; res., 22d and Bath Aves., Bensonhurst, N. Y. Mar. 27, 1903

GAEHR, PAUL FREDERICK, Asst. in Physics, Cornell Univ., Ithaca, N. Y. Jan. 23, 1903

GAGE, ELBERT ELLSWORTH, Superintendent, St. Johnsbury Electric Co., St. Johnsbury, Vt. Apr. 23, 1903

GALLAHER, WILLIAM, Superintendent Electrical Dept., Laclede Gas Light Co., 716 Locust St., St. Louis, Mo. Dec. 18, 1903

GALLATIN, ALBERT R., Student at Columbia University; res., 58 W. 55th St., New York City. Mar. 23, 1898

GARRELS, W. L., Consulting Engineer, 1707 South 3d St.; res., 4531 West Pine Boulevard, St. Louis, Mo. Mar. 20, 1895

GARTLEY, ALONZO, General Manager, Hawaiian Electric Co., Honolulu, H. I. July 12, 1900

GASSMANN, HOWARD MAIN, Assistant Engineer, Crocker-Wheeler Co., Ampere; res., Newark, N. J. July 28, 1903

GASTON, RALPH MAYO, Draftsman, Sargent & Lundy, 46 E. Van Buren St.; res., 7152 Harvard Ave., Chicago, Ill. July 28, 1903

GATES, ARTHUR OLIVER, Draftsman, Old Dominion Copper Mining and Smelting Co., Globe, Arizona. Mar. 27, 1903

GAYLORD, TRUMAN PENFIELD, Manager, Chicago Office, Westinghouse E. & Mfg. Co., 171 La Salle St., Chicago, Ill. Feb. 28, 1902

GAYTES, HERBERT, Electrical Engineer, Oakland, Cal. Mar. 23, 1898

GEAR, HARRY BARNES, General Inspector, Chicago Edison Co., 139 Adams St., Chicago, Ill. Oct. 25, 1901

GEARY, JOHN RICHARD, Representative for Japan, General Elecrict Co.; res., Yokohama United Club, Yokohama, Japan. Mar. 27, 1903

GEORGE, JAMES ZACHARIAH, Consulting Engineer, 602 Tulane-Newcomb Building, New Orleans, La. Sept. 27, 1901

GERDES, THEODORE RICHARD NICKOLAS, Rodman, Rapid Transit Construction Co.: res., 5 Van Nest Pl., New York City. Feb. 27, 1903

GERRY, EDWARD M., Engineer, Bullock Electric Mfg. Co., Cincinnati, Ohio. Mar. 27, 1903

GHERARDI, BANCROFT, Chief Engineer, New York and New Jersey Telephone Co., 81 Willoughby St., Brooklyn, N. Y. June 27, 1895

GIBBES, THOMAS, MIDDLETON Assistant to Contract Agent, Georgia Railways and Electric Co., Atlanta, Ga. Sept. 25, 1903

GIBBONEY, WILLIAM KENT, Assistant Superintendent, The Niagara Falls Power Co., 118 Buffalo Ave., Niagara Falls, N. Y. Sept. 27, 1901

GIBBS, GEORDE SABIN, Capt. Signal Corps, U. S. A., Fort Myer, Va. Sept. 25, 1903

GIBBS, HARRY PARKER, Constructing Engineer, General Electric Co., Champion Reef, Kolan Gold Field, South India. Sept. 26, 1902

GIBBS, HARRY THURSTON, Dynamo Tester, Westinghouse Electric and Mfg. Co., Pittsburg; res., Wilkinsburg, Pa. June 19, 1903

GIBSON, GEO. H., Manager, Advertising Department, International Steam Pump Co., 114 Liberty St., New York City. Nov. 22, 1899

GIBSON, JOHN JAMESON, Sales Westinghouse E. & Mfg. Co., 171 La Salle St., Chicago, Ill. Feb. 28, 1902

GILBERT, E. E., General Electric Co., Schenectady, N. Y. Apr. 23, 1903

GILBERT, HOWARD LUDLOW, 2236 Madison Ave., Baltimore, Md. May 19, 1903

GILBERT, SWOOPE DARROW, Commercial Engineer, General Electric Co., Cincinnati, Ohio. June 19, 1903

GILCHRIST, JOHN FOSTER, Head Contracting Dept., The Chicago Edison Co., 139 Adams St., Chicago, Ill. Jan. 23, 1903

GILCREST, CHARLES F., Testing Department, General Electric Co.; res., 618 Chapel St., Schenectady, N. Y. Sept. 25, 1903

GILL, FRANK, Engineer in Chief, The National Telephone Co., Ltd., Telephone House, Victoria Embankment, London, E. C. May 19, 1903

GILLE, HENRY JOHN, General Superintendent, St. Paul Gas Light Co., St. Paul, Minn. Jan. 25, 1901

GILLETT, HARRY, Branch Manager, H. W. Johns-Manville Co., 14 So. Water St.; res., 408 Dunham Ave., Cleveland, Ohio. Apr. 23, 1903

GILLETTE, JAMES WALTER, General Manager and Resident Engineer, Phœnix Gas and Electric Co., Phœnixville, Pa. Feb. 27, 1903

GILLIAM, HOGE, Erecting Engineer, W. E. & Mfg. Co., Land Title Building, Philadelphia; res., Ardmore, Pa. Jan. 23, 1903

GILMAN, FRANCIS LYMAN, Telephone Engineer, Western Electric Co., 463 West St., New York City; res., Montclair, N. J. June 28, 1901

GILMORE, ALBERT DICKISON, Assistant in Testing Laboratory, Chicago Edison Co., 139 Adams St., Chicago, Ill. Mar. 27, 1903

GINN, EVANDER H., Railway Engineering Department, General Electric Co., Empire Bldg., Atlanta, Ga. Mar. 27, 1903

GLASGOW, CARR LANE, Engineer, Westinghouse, Church, Kerr & Co., 8 Bridge St.; res., 164 W. 50th St., New York City. Mar. 27, 1903

GLASS, LOUIS, Assistant General Manager, Pacific Telegraph and Telephone Co., Telephone Bldg., San Francisco, Cal. Oct. 24, 1900

GLASSCO, JOHN GIRDLESTONE, Demonstrator, Eng. Building, McGill University, Montreal, Que. May 19, 1903

GLENCK, IMMO ADOLPH HEINRICH, Chief Engineer, Russiche Elektricitats Ges. "Union," Riga, Russia. Jan. 23, 1903

GODDARD, HERBERT WILLARD, Westinghouse, Church, Kerr & Co., 10 Bridge St.; res., Technology Club, 36 E. 28th St., New York City. Nov. 20, 1903.

GODDARD, STEPHEN HAILE, Secretary and Manager, *Electrical Review*, 13 Park Row; res., 223 Fifth Ave., New York City. Sept. 25, 1903

GODINEZ, FRANCISCO L., Student in Electrical Engineering, Polytechnic Institute; res., 1212 Beverly Road, Brooklyn, N. Y. July 25, 1902

GOLDMARK, CHAS. J., Consulting Electrical Engineer, 66 New St., New York City. June 5, 1888

GOLDSCHMIDT, EDWARD W., District Manager, Bullock Electric Mfg. Co., 220 Broadway, New York City. July 28, 1903

GONZENBACH, ERNEST, Electrical Engineer, 302 West Rayen Ave., Youngstown, Ohio. Jan. 23, 1903

GOODELL, JOHN M., *Engineering Record*, 114 Liberty St., New York City. Feb. 27, 1903

GOODY, CORAL PAYNE, Assistant Engineer, The Telluride Power Co., Provo, Utah. Oct. 24, 1902

GORDON, GEORGE BYRON, Expert, Maintenance Dept., New York Telephone Co., 18th St. & Irving Pl., New York City. May 19, 1903

GORDON, REGINALD, Newburg, N. Y. Feb. 24, 1891

GORRISSEN, CH., Siemens Bros. & Co., Ltd., York Mansions, York St. Westminster, London, S. W. Eng. Mar. 25, 1896

GORTON, CHARLES, Civil Engineer, Belmont, N. Y. Nov. 12, 1889

GOSLIN, ERNEST THOMAS, Chief Electrical Engineer, Corporation Tramways, 88 Renfield St., Glasgow, Scotland. May 19, 1903

GOUGH, HARRY EUGENE, Assistant in Office Mechanical Engineers, Penn. R. R. Co., res., 1526 9th St., Altoona, Pa. Jan. 9, 1901

GOULD, EDWARD FREDERICK, Electrical Engineer, Aurora, Elgin & Chicago Railway Co., Wheaton, Ill. Sept. 25, 1903

GRACE, SERGIUS P., Chief Engineer, Central District and Printing Telegraph Co., Pittsburg, Pa. Mar. 27, 1903

GRADOLPH, WILLIAM FREDERICK, JR., Engineering Dep., Am. Elec. Telephone Co., 36 West Jackson Boulevard, Chicago, Ill. Jan. 23, 1903

GRAHAM, WILLIAM P., Professor of Electrical Engineering, Syracuse University, 504 University Pl., Syracuse, N. Y. Jan. 24, 1902

GRALING, VERNEY, Electrician, Niagara Falls Power Co.; res., 530 11th St., Niagara Falls, N. Y. Aug. 22, 1902

GRANBERY, JULIAN H., 561 Walnut St., Elizabeth, N. J. Aug. 5, 1896

GRANT, LOUIS T., Managing Engineer, The Michael Gaspar, Grant Co., Ltd., 84 Calle Carriedo, Manila, P. I. Nov. 22, 1899

GRANT, OLIVER REMICK, Student, Columbia University; res., 2236 Southern Boulevard, New York City. Mar. 28, 1902

GRAVES, CARLETON AUGUSTUS, Electrical Engineer, Peckham Mfg. Co., Kingston, N. Y. Mar. 27, 1903

GRAVES, CHAS. B., Marblehead, Mass. Sept. 15, 1897

GRAY, AINSLIE ALEXANDER, Assistant Editor, *Electrical Review*, 13 Park Row; res. 38 Cooper St., Brooklyn, N. Y. Aug. 22, 1902

GRAY, CHARLES FREDERICK, First Switchboardman, The Manhattan Railway Co., 74th St. and East River, New York City. Dec. 19, 1902

GRAY, CLYDE D., Assistant in Electrical Department, J. G. White & Co., 43 Exchange Pl., New York City, Apr. 25, 1902

GRAY, EDWARD WYLLYS TAYLOR, Manager, N. Y. Sales Office, Westinghouse Elec. & Mfg. Co., 11 Pine St., New York City Jan. 3, 1902

GRAY, GUTHRIE, Electrical Engineer, National Battery Co., Buffalo, N. Y. Oct. 24, 1903

GRAY, LATIMER D., Electrical Engineer, Union Pacific Coal Co., Rock Springs, Wyo. Feb. 27 1903

GRAY, ROY WILLIAM, Foreman, Division Construction, Sunset T. & T. Co., 701½ South Broadway, Los Angeles, Cal. Nov. 20, 1903

GRAY, VANCE I., Engineer and Salesman, The F. Bissell Co., Toledo, Ohio. Feb. 27, 1903

GREEN, CHARLES MAXWELL, Engineer on Brush Arc Dynamos, General Electric Co ; res., 24 Chase St., Lynn, Mass. Feb. 28, 1902

GREEN, FRED. J., Electrical and Mechanical Engineer, Springfield Troy & Piqua Railway Co., Bushnell Bldg., Springfield, O. Apr. 23, 1903

GREEN, GEORGE ROSS, Engineer Meter Dept., The Philadelphia Electric Co., N.E. cor. 10th and Sansom Sts., Philadelphia, Pa. Apr. 23, 1903

GREENIDGE, CHARLES AUSTIN, Superintendent of Electric Dept., Utica Gas and Electric Co., 86 Lafayette St., Utica, N. Y. June 19, 1903

GREENLEAF, LEWIS STONE, General Superintendent, Hudson River Telephone Co., Albany, N. Y. Aug. 5, 1896

GREGORY, JOHN PUGH, Engineer, Power and Lighting Department, The British Thomson-Houston Co., Ltd., Rugby, Eng. Sept. 25, 1903

GRIFFEN, JOHN D., Inventor, Electric Conduit and Electric Signaling Apparatus, 82 Wall St., New York City. Aug. 13, 1897

GRIFFES, EUGENE V., Manager, United Electric Co., Long Beach, Cal. Feb. 26, 1896

GRIFFIN, EUGENE, First Vice-President, General Electric Co., 44 Broad St., New York City Feb. 7, 1890

GRIFFITH, PERCY LE ROY, Electrical Engineer, 211 State St., Schenectady, N. Y. Dec. 19, 1902

GRISSINGER, ELWOOD, Engineer, The Cataract Power & Conduit Co., 40 Court St., Buffalo, N. Y. Mar. 28, 1902

GROH, BERNARD CHARLES, Supt. of Equipment, Inter-State Telephone Co., of New Jersey, Trenton, N. J. Nov. 20, 1903

GROWER, GEORGE G., Electrician and Chemist, Ansonia Brass and Copper Co., Ansonia, Conn. Mar. 18, 1890

GUERRERO, JULIO, Associated with the Durango Electric Light Co., Reresas, 97 Durango, Mex. Apr. 25, 1900

GUINLE, EDWARD, Electrical Engineer, General Electric Co., 44 Broad St.; res., 275 Central Park West, New York City. Mar. 27, 1903

GUMP, WALTER BINKERD, Electrical Engineer, 23 Marvin Ave., Shelby, Ohio. Nov. 20, 1903

GURNEY, HOWARD F., General Superintendent of Construction, Otis Elevator Co., 71 Broadway, New York City. Mar. 27, 1903

GUTBROD, FRIEDRICH WILHELM, Electrical Engineer, Reichsgerichts-Gebaeude, 4 Beethoven St., Leipzig, Germany. Feb. 27, 1903

GUTIERIEZ, MANUEL R., Professor of Physics, Normal School, Jalapa, V. C., Mexico. Apr. 25, 1900

GUY, GEORGE HELI, Secretary, The New York Electrical Society, 114 Liberty St., New York City. May 16, 1893

HAIGHT, LOUIS HENRY, Student Columbia University; res., 152 Sixth Ave., Brooklyn, N. Y. May 19, 1903

HAIGHT, MONROE GLEASON, Hartford Electric Light Co., 21 Broad St., Hartford, Conn. July 25, 1902

HAIGLER, WILLIAM HOPE, Student in Testing Department, General Electric Co., Lynn; res., 23 Pine St., Waltham, Mass. June 19, 1903

HAKONSON, CARL HAROLD, Electrical Engineer, Sodertelge, Sweden. Sept. 25, 1895

HALL, CLARENCE MORTIMER, Teacher of Physics and Electricity, Manual Training School No. 1, Washington, D. C. Mar. 28, 1902

HALL, DAVID, Assistant Engineer, Bullock Electric Mfg. Co., Cincinnati, Ohio. Mar. 27, 1903

HALL, EDWARD J., Vice-President and G. M., American Telephone and Telegraph Co., 15 Dey St., New York City. Apr. 18, 1893

HALL, FRANK WELLS, Office Engineer, The Sprague Electric Co., 222 Renshaw Ave., Orange, N. J. Oct. 24, 1902

HALL, FRED'K A., Engineer, The Johnson-Lundell Electric Traction Co. Ltd., 16 Soho Square, London, W. Eng. Aug. 23, 1899

HALL, FREDERICK JAMES, Assist. to General Manager, The India Rubber and Gutta Percha Insulating Co., Yonkers, N. Y. May 19, 1903

HALL, HARRIOTT CURTIS, Inspector, New York Edison Co., 55 Duane St., New York City; res., Glen Cove, L. I. June 28, 1901

HALL, HARRY YOUNG, JR., First Switchboardman, Manhattan Railway Co.; res., 14 W. 103d St., New York City. Mar. 27, 1903

HALL, JOSEPH BATES, Chief Engineer, McGuire Mfg. Co., 122 North Sangamon St.; res., 621 W. 65th Pl., Chicago, Ill. June 19, 1903

HALL, NEWTON LEE, Draftsman, The Colorado Telephone Co., 1447 Lawrence St.; res., 1762 Logan Ave., Denver, Colo. Mar. 27, 1903

HALL, WILLIAM ALBERT, President, The Hall Electrical Supply Co., 213 W. 4th St., Cincinnati; res., Madisonville, Ohio. Apr. 23, 1903

HALL, WILLIAM H., Head of Department of Science, Baltimore Polytechnic Institute, Baltimore, Md. Sept. 25, 1903

HALLBERG, J. HENRY, General Superintendent, Electrical Department, Cincinnati Gas and Electric Co.. Cincinnati, Ohio. Aug. 23, 1899

HALLER, WINFIELD A., Engineer, Sanderson & Porter, 52 William St.; res., 509 W. 124th St., New York City. Sep. 25, 1903

HALLOCK, WILLIAM, Professor of Physics, Columbia University; res., 417 W. 118th St., New York City. Dec. 19, 1902

HALSEY, HENRY, General Manager, Halsey Electric Generator Co.; res., 49 W. 44th St., New York City. July 28, 1903

HALSTEAD, DAVID, Electrical Engineer; res., Manheim St. and Wissahickon Ave., Philadelphia, Pa. Apr. 23, 1903

HAMBURGER, MAX, *Ph.D.*, Electrical Engineer, Union Electricitats-Gessellschaft; res., 8 Pariser St., Berlin, Ger. July 28, 1903

HAMERSCHLAG, ARTHUR A., Consulting Engineer, 41 Liberty St.; res., 330 Manhattan Ave., New York City. Mar. 25, 1896

HAMILTON, GEORGE WELLINGTON, 123 East St., Pittsfield, Mass. Jan. 23, 1903

HAMILTON, JAMES, Patent Law Specialist, Room 129 Washington Loan and Trust Building, Washington, D. C, Nov. 23, 1898

HAMILTON, JAMES HENRY, Electrical Signaling Engineer, The Cape Government Railways, Cape Town, S. A. Oct. 24, 1902

HAMILTON, RALPH BERGEN, Manager, The Packard Electric Co., Ltd., St. Catharines, Ont. Nov. 22, 1901

HAMLIN, PHILIP, Special Inspector The Colorado Telephone Co.; res., 120 East Fourth Ave., Denver, Colo. May 19, 1903

HAMMATT, CLARENCE S., Vice-President Florida Electric Co., Jacksonville, Fla. Sept. 20, 1893

HAMMOND, LYMAN PIERCE, Connecticut State Representative, Crocker-Wheeler Co., 42 Church St., New Haven, Conn. Mar. 27, 1903

HAMPSON, RICHARD BENJAMIN, Salesman, General Electric Co.; res., 86 Moulton St., Lynn, Mass. Apr. 23, 1903

HANCHETT, FRANK E., Electrical Engineer, Jamestown, N. Y. Jan. 23, 1903

HANCOCK. L. M., General Superintendent Bay Counties Power Co., 324 Pine St., San Francisco, Cal. May 19, 1891

HANCOX, SAMUEL HERBERT. Electrician, Queensland Government Railways, North Ipswich, Queensland, Aus. Sept. 25, 1903

HAND, WILLIAM, Engineer, General Electric Co., 816 Wainwright Building; res., 727 Walton Ave., St. Louis, Mo. Apr. 23, 1903

HANKS, MARSHALL WILFRED, Engineer, Nernst Lamp Co.; res., Amber Club, Pittsburg, Pa. Jan. 3, 1902

Hanna, Max Ross, Assistant Foreman in Testing Department, General Electric Co., Schenectady, N. Y. Apr. 23, 1903

Hanscom, Perry Theodore, Engineer, General Electric Co., Schenectady, N. Y. Mar. 27, 1903

Hanscom, Wm. W., Chief Electrical Engineer, Union Iron Works, 848 Clayton St., San Fancisco, Cal. Apr. 25, 1900

Hanson, Arthur James, Lawrence & Hanson, 3 Wynyard St.; res., Drummoyne, Sydney, N. S. W. Nov. 22, 1899

Harder, Edwin Partridge, The Cataract Power and Conduit Co.; res., 218 Virginia St., Buffalo, N. Y. Apr. 23, 1903

Harding, Burcham, Assisting Second Vice-President, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. Dec. 19, 1902

Harding, H. McL., 20 Broad St., New York City. May 24, 1887

Hardy, Carl Ernest, Master Electrician, U. S. Navy Yard, Norfolk, Va.; res., 206 London St., Portsmouth, Va. Dec. 27, 1899

Harisberger, John, Seattle Cataract Co., Seattle, Wash. May 20, 1902

Harper, Herbert Reah, City Electrical Engineer, Melbourne City Council, Town Hall, Melbourne, Victoria. June 19, 1903

Harries, George Herbert, Vice-President, The Washington Railway and Electric Co., Washington, D. C. June 19, 1903

Harris, Charles Orrin, Engineer, Stramburg-Carlson Tel. Mfg. Co.; res., 70 W. Jackson Blvd., Chicago, Ill. Sept. 25, 1903

Harris, George H., Superintendent of Equipment, Birmingham Railway Light and Power Co., Birmingham, Ala. June 20, 1894

Harris, Grenville A., Electrical and Mechanical Engineer, Takata & Co., 10 Wall St., New York City. Oct. 25, 1901

Harris, Samuel Clark, In charge of Storage Batteries, New York Edison Co., 47 W. 26th St., New York City. May 19, 1903

Harrison, Burt Sylvanus, Consulting Engineer, 81 Wall St.; res., 442 Lexington Ave., New York City. June 19, 1903

Harrison, James, Assistant Chief Engineer, The Kinloch Telephone Co., 1055 Century Building, St. Louis, Mo. Apr. 23, 1903

Hart, Percy E., Electrical Enigneer, Canadian General Electric Co., 14 King St. E., Toronto, Ont. Sept. 25, 1903

Harter, Bret, With E. P. Roberts & Co., Cleveland, Ohio. July 26, 1900

Harthan, Charles E., Electrical Engineer, General Electric Co., Lynn, Mass. Apr. 23, 1903

Hartmann, Francis M., Instructor of Experimental Physics and Electrical Measurements, Cooper Union, New York City. Sept. 26, 1902

Harvey, Gilbert Alexander, Electrical Engineer, General Electric Co., 677 Ellicott Square, Buffalo, N. Y. May 19, 1903

Harvey, Robert R., 20 So. Franklin St., Wilkesbarre, Pa.
[Life Member.] Sept. 25, 1895

Harvie, William James, Electrical Engineer, Utica and Mohawk Valley Ry. Co., Utica, N. Y. Apr. 23, 1903

Haselden, Harry Ariel, Electrical Engineer, The Whitin Machine Works, Whitinsville, Mass. Oct. 24, 1902

Haskell, George Myron, Selling Agent, J. G. Brill Co.; res., 32 Maple St., New Haven, Conn. May 19, 1903

Haskins, William Edgar, Chief Electrician, South Works, American Steel and Wire Co., 209 Vernon St.. Worcester, Mass. Jan. 25, 1901

Hassler, Chas T. F., Inspector of Electrical plants, Kungl Kornmerskollegium, Stockholm, Sweden. Oct. 24, 1900

Hastings, Louis Brounell, Erecting Road Engineer, Stanley Electric Mfg. Co., Pittsfield, Mass. Oct. 23, 1903

HATCH, AUSTIN SMITH, Assistant General Superintendent, Public Lighting Commission, 40 East Atwater St., Detroit, Mich. Sept. 26, 1902

HATHAWAY, JOSEPH D., JR., Superintendent, The Wire & Cable Co., Montreal, Que. Aug. 5, 1896

HATZEL, J. C., Firm Hatzel & Buehler, 114 Fifth Ave.; res., 1231 Madison Ave., New York City. Sept. 3, 1889

HAUBRICH, ALEX. MICHAEL, Electrical Engineer, Stromberg-Carlson Telephone Mfg. Co., 72 West Jackson Boul., Chicago, Ill. Apr. 26, 1901

HAVENS, ARTHUR L., Salesman and Engineer, Kilbourne & Clark Co., 815 Second Ave., Seattle, Wash. Mar. 27, 1903

HAVILAND, HENRY FIELD, with Clark & MacMullen, 20 Broad St., New York City. Feb. 27, 1903

HAWKINS, CHARLES CAESAR, Electrical Engineer, H. Allen, Son & Co., Ltd.; res., 37 Conduit Road, Bedford, Eng. Nov. 20, 1903

HAWKINS, LAURENCE A., Engineer, Stanley Elec. Mfg. Co., Pittsfield, Mass. Jan. 23, 1903

HAWKINS, WILLIAM CLARK, General Manager and Secy., Hamilton Cataract Power Lt. Traction Co., Ltd., Hamilton, Ont. June 19, 1903

HAWKS, H. D., Engineer, with General Electric Co., Schenectady, N. Y. May 21, 1901

HAYES, CLIFTON RICHMOND, Electrical Engineer, Ludlow, Mfg. Associates, Ludlow, Mass. June 19, 1903

HAYES, JAMES EDWARD, JR., Assistant in Laboratory Western Electric Co., New York City. Mar. 27, 1903

HAYES, JOHN BARTLETT, Storekeeper, Mechanical and Electrical Department, Universal Exposition, St. Louis, Mo. June 19, 1903

HAYES, STEPHEN Q., Switchboard Engineer, Westinghouse E. & M. Co.; res., 4 Brushton Ave., Pittsburg, Pa. Sept. 25, 1903

HAYS, GEORGE, Manager Edison Storage Battery Co., Glen Ridge; res., 190 Belleville Ave., Bloomfield, N. J. Apr. 23, 1903

HAYWARD, ROBERT FRANCIS, Chief Engineer, The Utah Light and Power Co., Salt Lake City, Utah. Apr. 23, 1903

HAZARD, WILLIAM JONATHAN, Assistant Professor Colorado School of Mines, Golden, Colo. Mar. 27, 1903

HEALY, LOUIS W., Treasurer, East Liverpool Railway Co., East Liverpool, Ohio. June 26, 1891

HEANY, JOHN ALLEN, Expert, Teter-Heany Developing Co., York, Pa. Oct. 25, 1901

HEATH, WILLIS HERBERT, Engineer and Draftsman, with C. O. Mailloux; res., 9 Hanson Pl., Brooklyn, N. Y. Mar. 27, 1903

HEDENBERG, WM. L., Manager and Editor, *Electricity*, 136 Liberty St., New York City. Nov. 21, 1894

HEFT, N. H., Chief of Electrical Dept., N. Y. & N. H. H. R. R., New Haven; res., Bridgeport, Conn. Aug. 23, 1899

HELLEBUCK, GUSTAVE J., Electrical Engineer, Societe Anonyne, Tramway Bologne, Italy. April 25, 1902

HELLICK, CHAUNCEY GRAHAM, 510 Northampton St., Easton, Pa. Jan. 26, 1898

HEMINGWAY, ALBERT FRANKLIN, Engineering Depart., American Electric Telephone Co., 36 W. Jackson Boul., Chicago, Ill. Sept. 27, 1901

HENDERSON, ALEX., Electrician, Sprague Electric Co.; res., 122 West 103d St., New York City. Nov. 30, 1897

HENDERSON, HENRY BANKS, Riverside, Cal. May 21, 1895

HENDERSON, ROBERT H., Detail Engineer, Westinghouse E. & M. Co., Newark, N. J. Jan. 23, 1903

HENDRY, WILLIAM FERRIS, Factory Engineer, Western Electric Co., 463 West St., New York City. Apr. 23, 1903

HENRY, ARTHUR ROBERT, General Superintendent, Canadian Electric Light Co., 12 Laporte St., Quebec, P. Q. July 28, 1903

HENRY, GEORGE CLINTON, District Manager, Bullock Electric Mfg. Co., Atlanta, Ga. Jan. 3, 1902

HENRY, GEORGE J., JR., Engineer The Pelton Water Wheel Co., 143 Liberty St., N Y., & 127 Main St., San Francisco, Cal. Apr. 27, 1898

HENRY, IRA WALTON, Vice-President, and Cable Engineer The Safety Cable Co., 114 Liberty St., New York City. May 21, 1901

HENRY, LEWIS WARNER, Superintendent, Hudson River Power Transmission Co., Mechanicsville, N. Y. Feb. 28, 1900

HERBERT, EDWARD, Western Electric Co., 259 South Clinton St.; res., 111 Loomis St., Chicago, Ill. Oct. 24, 1902

HERDT, LOUIS A., Lecturer on Electrical Engineering, McGill University, Montreal, Canada. May 16, 1899

HERMESSEN, JOHN LOUIS, Engineer, Commercial Department, Mexican Gen. Electric Co., Mexico, D. F., Mexico. Jan. 20, 1897

HERRICK, ALBERT B., Consulting Electrical Engineer, 120 Liberty St., New York City; res., Ridgewood, N. J. May 21, 1901

HERZOG, JOSEF, Chief of Installations Department, Ganz & Co., V. Elisabetplatz, 1 Budapest, Austria-Hungary. Jan. 3, 1902

HESKETH, JOHN, Electrical Engineer, Queensland Government, Post and Telegraph Dept., Brisbane, Queensland. May 21, 1901

HESS, ADOLFO G. B., 32 Seventh Ave., Brooklyn, N. Y. Nov. 20, 1903

HESS, HERBERT H., Assistant in Transformer Eng'g Department, General Electric Co., Schenectady, N. Y. Apr. 23, 1903

HESSENBRUCH, GEORGE S., *E.E.*, *Ph.D.*, Asst. Engineer to Supt. of Structure, 205 Union Station, St. Louis, Mo. June 27, 1895

HEWITT, CHARLES E., President, C. E. Hewitt & Co., Park Row Building, New York City. Sept. 25, 1895

HEWITT, PETER COOPER, 11 Lexington Ave., New York City. May 21, 1901

HEWITT, WILLIAM R., Chief, Department of Electricity, 9 Brenham Pl., San Francisco, Cal. May 15, 1894

HEWLETT, EDWARD M., Engineer, General Electric Co., res.; 27 University Pl., Schenectady, N. Y. May 19, 1891

HICKOK, FREDERICK S., Electrical Engineer, Berwyn, Ill. Apr. 23, 1903

HILDBURGH, WALTER LEO, Student, Columbia University; c/o D. H. Hildburgh, Hotel Normandie, New York. Dec. 28, 1898

HILL, ERNEST ROWLAND, Electrical Engineer, The British Westinghouse E. &. M. Co., Ltd., 2 Norfolk St., London, Eng. Jan. 25, 1899

HILL, G. HENRY, Packwood Boulevard and Union Ave., Schenectady, N. Y. Jan. 25, 1899

HILL, NICHOLAS S., JR., Consulting Engineer, 520 Equitable Bldg., Baltimore, Md., and 100 William St., New York City. Aug. 5, 1896

HILLIARD, JOHN D., JR., Electrical Engineer, Hudson River Water Power Co., Glens Falls, N. Y. June 19, 1903

HILLIARD, THOMAS WILLIAM NICHOLLS, District Manager and Engineer, The Canadian General Electric Co., Ottawa, Ont. Mar. 27, 1903

HILLMAN, H. W., General Electric Co., Schenectady, N. Y. Jan. 3, 1902

HINDERT, EDWIN GEORGE, Chief Mechanical and Electrical Engineer, The Cleveland and South Western Traction Co., Elyria, Ohio. Nov. 20, 1903

HINES, CHARLES HENRY, Electrical Engineer, Mechanical Dep., Canadian Pacific R. R. Shops, Montreal, P. Q. Apr. 25, 1902

HITNER, HARRY FERMAN, Electrical Engineer, American Window Glass Co., Farmers Bank Building, Pittsburg, Pa. Sept. 25, 1903

HITZEROTH, L. D., Engineer, Century Electric Co., 18 Second St., San Francisco, Cal. July 26, 1900

HIXSON, CLINTON JEROME, Engineer Railway Department, Allgemeine Elektricitats-Gesellschaft Ackerstrasse 71, Berlin. Nov. 21, 1902

HOADLEY, GEORGE A., Professor of Physics, Swarthmore College, Swarthmore, Pa. May 19, 1903

HOAG, GEO. M., City Electrician, City of Cleveland; res., 317 Hough Ave., Cleveland, Ohio. April 28, 1897

HOBBLE, ARTHUR CASSON. Cauvery Falls Power, Scheme Livasamudram Mysore Prov., India. Mar. 27, 1903

HOBEIN, CHARLES AUGUSTUS, JR., Power Department, St. Louis Transit Co.; res., 325 No. Boyle St., St. Louis, Mo. June 19, 1903

HODGE, CHARLES, Salesman, Westinghouse E. & M. Co., 1504 Continental Trust Bldg., Baltimore, Md. Mar. 28, 1902

HODGE, ROBERT WALTER, Prest. Hodge-Walsh Elec. Eng'g Co.; res., 623 Independence Boulevard, Kansas City, Mo. Jan. 23, 1903

HODGE, SETH EVANS, Student, Cornell University; res., 107 Edgemoor Lane, Ithaca, N. Y. June 19, 1903

HODGE, WILLIAM B., Electrical Engineer, Queen & Co., 1010 Chestnut St., Philadelphia, Pa. Dec. 28, 1898

HODGES, GEORGE HANWOOD, Electrical Engineer, The New York Telephone Co., 15 Dey St., New York City. Apr. 23, 1903

HODGES, WILLIAM LEMMON, Sales Manager, National Battery Co., 253 Broadway, New York City. Apr. 26, 1901

HODGKINSON, FRANCIS, Mechanical Engineer, The Westinghouse Machine Co., East Pittsburg, Pa. May 20, 1902

HODGSON, CECIL, Electrical Engineer with Stephens & Tyler, 960 Monadnock Block, Chicago. Sept. 26, 1902

HODGSON, JOSEPH ERNEST, Engineer, United Gas Improvement Co., Philadelphia, Pa. Apr. 23, 1903

HOEFTMANN, ALEXANDER O., Superintendent of Electric Cable Works, American Steel and Wire Co., Worcester, Mass. May 19, 1903

HOFFMAN, WILLIAM LEVI, Electrical Engineer, Columbia Improvement Co.; res., 230 C. St., Tacoma, Wash. Oct. 23, 1903

HOFFMANN, BERNHARD, New York Telephone Co., 15 Dey St., New York City. Nov. 23, 1898

HOFFMAN, FRANK, Electrical Engineer, Owl Creek, Mo. Sept. 25, 1903

HOFMAN, LOUIS, Chief Engineer, Wessell, Nickel & Gross, 457 W. 45th St., New York City. Mar. 27, 1903

HOGAN, CHARLES WILLIAM, Germania Electric Lamp Co., Harrison, N. J. Mar. 28, 1902

HOGAN, THOMAS JEFFERSON, New York Edison Co., 57 Duane St.; res., 611 E. 148th St., New York City. Sept. 25, 1903

HOGLE, CHARLES EDWARD, Acting Foreman of Testing Department, The Edison Electric Co., Los Angeles, Cal. Sept. 25, 1903

HOLBERTON, GEORGE C., General Supt., Electric Dept., Oakland Gas Light and Heat Co., 13th & Clay Sts., Oakland, Cal. May 15, 1894

HOLBROOK, FREDERICK MONTGOMERY, Electrical Engineer, Crocker-Wheeler Co., Old Colony Building, Chicago, Ill. Sept. 27, 1901

HOLCOMB, EUGENE, Representative Engineer, Westinghouse E. & M. Co., 124 Defensa, Buenos Aires, A. R. July 28, 1903

HOLDEN, EDGAR B., JR., Constructing Engineer, General Electric Co., Niagara Falls, N. Y.; res., Albany, N. Y. Sept. 25, 1903

HOLDREGE, HENRY ATKINSON, General Manager, Omaha Electric Light & Power Co., N. Y. Life Bldg., Omaha, Neb. Sept. 25, 1903

HOLLEY, CARL HIRAM, Chief Engineer, The Mt. Whitney Power Co. Brown Building, Visalia, Cal. Sept. 26, 1902

HOLLINS, GEORGE GRUNDY, Student, Stevens Institute of Technology, Hoboken; res., 119 Harrison Ave., Montclair, N. J. Mar. 27, 1903

HOLLOS, JOSEPH, Principal Engineer, Hungarian Telegraph Administration Tel. Department, Budapest, Austria-Hungary. May 19, 1903

HOLMAN, GEORGE ULYSSES GRANT, General Manager, The Canadian Electric Light Co., Ltd., 12 Laporte St., Quebec, P. Q. Apr. 25, 1902

HOLMAN, MINARD LAFEVER, General Superintendent, Missouri Edison Electric Co.; res., 3744 Finney Ave., St. Louis, Mo. Feb. 27, 1903

HOLMES, DUNCAN ARGYLE, Student, Columbia University; res., 203 W. 79th St., New York City. Mar. 27, 1903

HOLMES, GWYLLYN R., Holmes-Rose Electric Co., 215 Calvert St., res.; 2842 Parkwood Ave., Baltimore, Md. Jan. 24, 1900

HOLT, MARMADUKE BURRELL, Mining and Electrical Engineer, Silverton, Colo. Apr. 15, 1890

HOLTZER, CHAS. WM., President Holtzer-Cabot Electric Co., Brookline, [Life Member.] Mass. May 21, 1901

HOMMEL, LUDWIG, with The O. Hommel Co., 110 Market St., Pittsburg, Pa. Jan. 20, 1897

HONEY, WILLIAM, Electrical Engineer, The Mexican Gas and Electric Light Co., Station Clara No. 7, Mexico City, Mexico. Feb. 27, 1903

DE HOOR-TEMPIS, MAURICE, Professor at the Royal University of Technical Sciences, Budapest II., Zsigmondutca 9, Hungary. Nov. 20, 1903

HOPE, HARRY MILFORD, Engineering Department, Chicago Edison Co., 139 Adams St., Chicago, Ill. Apr. 23, 1903

HOPEWELL, CHAS. F., Fire Alarm and Police Telegraph, City of Cambridge, City Hall; res., Cambridgeport, Mass. Aug. 13, 1897

HOPKINS, NEVIL MONROE, *M.S.*, Instructor in Chemistry and Electrochemistry, Columbian Univ. Washington, D. C. Nov. 20, 1895

HOPKINS, N. S., Designing Engineer, Fort Wayne Electric Works, Fort Wayne Ind Apr. 27, 1898

HOPKINS, ROBERT MILNE, Assistant C. A. Chapman. 1041 Marquette Bldg., Chicago; res., 621 Foster St., Evanston, Ill. Nov. 20, 1903

HOPKINS, ROBERT S., Testing Department, Bullock Electric Mfg. Co., St. Paul Bldg., New York City. July 28, 1903

HOPTON, WALTER EDWIN, Solway Process Co., Syracuse, N. Y. Apr. 26, 1901

HORN, HAROLD J., *E.E.*, Assistant Superintendent Bare Wire Department, John A. Roebling's Sons' Co., Trenton, N. J. Mar. 22, 1899

HORRY, WILLIAM SMITH, Electrician Union Carbide Co., Niagara Falls, N. Y. Dec. 19, 1902

HOUGH, BENJAMIN KENT, Electrical Engineer, New York Edison Co., 57 Duane St., New York City; res., Westfield, N. J. Apr. 25, 1902

HOUK, RUDOLPH J., 2d Assistant Elec. Operator, Manhattan Railway Co.; res., 129 W. 67th St., New York City. Mar. 27, 1903

HOVLAND, OLE C., Automatic Telephone Switchboard Inspector, The Automatic Electric Co., Chicago, Ill. May. 19, 1903

HOWARD, ERNEST GRANT, Electrical Engineer, Chapman Valve Mfg. Co.; res., 573 State St., Springfield, Mass. Apr. 23, 1903

HOWE, JAMES CARLETON, Assistant Engineer, The American Telephone and Telegraph Co., 125 Milk St., Boston, Mass. Dec. 19, 1902

HOWE, WINTHROP KEITH, Assistant Engineer, Taylor Signal Co., 1738 Elmwood Ave., Buffalo, N. Y. Mar. 22, 1901

HOWELL, DAVID JANNEY, Secretary-Treasurer and Manager, Welch Water, Light and Power Co., Washington, D.C. Sept. 25, 1903

HOWES, ROBERT, Asst. Supt. of the Light and Power System, The Washington Water Power Co., Spokane, Wash. Jan. 25, 1901

HOWSON, HUBERT, Patent Lawyer, 38 Park Row, New York City. June 8, 1887

HOXIE, GEORGE L., Westinghouse, Church, Kerr & Co., 8 Bridge St., New York City. Feb. 28, 1901

HOXIE, HALL FARRINGTON, Electrical Engineer, 945 State St., Schenectady, N. Y. Oct. 24, 1902

HOYT, HARRY CAMPBELL, Motor repair man, St. Louis Transit Co., 1121 E. Whittier St., St. Louis, Mo. June 19, 1903

HUBBARD, ALBERT S., Gould Storage Battery Co., Astor Court Bldg., 25 W. 33d St.; res., Greenwich, Conn. Nov. 20, 1895

HUBBARD, WILLIAM C., with Westinghouse Electric & Mfg. Co., 120 Broadway, New York City. Apr. 18, 1894

HUBRECHT, DR. H. F. R., Director, Nederlandsche Bell Telephone Co., Amsterdam, Holland. Oct. 4, 1887

HUDGSON, JOHN HOWARD, Draftsman, Electro-Dynamic Co.; res., 38 N. 36th St., Philadelphia, Pa. Dec. 18, 1903

HUDSON, HARRY PRATT, Testing Department, General Electric Co.; res., 229 Liberty St., Schenectady, N. Y. Sept. 26, 1902

HUELS, FREDERICK WILLIAM, Asst. in Engineering Laboratories, University of Wisconsin; res., 115 State St., Madison, Wis. Dec. 18, 1903

HUGUET, CHAS. K., Electrical Engineer, 753 Jackson Boulevard, Chicago, Ill. June 27, 1895

HULL, MARMADUKE CURTIS, Contracting Agent, The Columbus Edison Co.; res., 332 W. 8th Ave., Columbus, Ohio. Mar. 27, 1903

HULSE, WM. S., Electrical Engineer, with Union Elektricitats Gesellschaft, Dorotheen Str. 43, Berlin, Germany. Mar. 25, 1896

HUMISTON, JOHN MEANS, The Chicago Telephone Co., 203 Washington St.; res., Berwyn, Ill. May 19, 1903

HUMPHREY, CALVIN B., Office Manager, Westinghouse Electric and Mfg. Co., 711 Neave Building, Cincinnati, Ohio. Apr. 25, 1902

HUMPHREY, CLIFFORD WANE, Engineer, The Denver Gas and Electric Co.; res., 405 17th St., Denver, Colo. Mar. 27, 1903

HUMPHREYS, C. J. R., Humphreys and Glasgow, 31 Nassau St., New York City. Sept. 6, 1887

HUNT, ARTHUR L., Harrisburg Foundry and Machine Works, 114 Liberty St., New York City. Sept. 19, 1894

HUNT, CHARLES WALLACE, President, C. W. Hunt Co., 45 Broadway, New York City. Apr. 25, 1902

HUNT, SAMUEL PARKER, Electrical Engineer, 747 Union St., Manchester, [Life Member.] N. H. Apr. 23, 1903

HUNT, WALTER SIMEON, Assistant Superintendent, Limon Electric Light and Power Plant, Port Limon, Costa Rica. Apr. 23, 1903

HUNTER, MADONE C., Electrical Engineer; St. Joseph R. R. Light, Heat & Power Co., St. Joseph, Mo. Sept. 26, 1902

HUNTLEY, CHAS. R., General Manager, Buffalo General Electric Co., 40 Court St., Buffalo, N. Y. Sept. 25, 1895

HURD, CHARLES HENRY, Consulting Engineer, Indianapolis and Chicago; res., 39 The Lexington, Indianapolis, Ind. Nov. 20, 1903

HUTCHINGS, JAMES TYLER, Electrical Engineer Assistant, The Philadelphia Electric Co., Philadelphia, Pa. Apr. 23, 1903

HUTCHINSON, FREDERICK L., Manager Electrical Sales, National Electric Company, Milwaukee, Wis. June 20, 1894

HUTCHINSON, ROLIN WILLIAM, JR., Polytechnic Institute; res., 294 Clinton Ave., Brooklyn, N. Y. Jan. 3, 1902

HYDE, JAMES CLARK, Foreman Test Department, Canadian General Electric Co., Ltd., Peterborough, Ont. Apr. 23, 1903

HYDE, J. E. HINDON, Patent Lawyer, 120 Broadway, New York City. Jan. 24, 1900

IDELL, FRANK E., Havemeyer Building, 26 Cortlandt St., New York City. July 12, 1887

IIJIMA, ZENTARO, Electrical Engineer, Shibaura Engineering Works, 1 Shinhamacho, Tokyo, Japan. Jan. 22, 1896

INSULL, MARTIN J., 2d Vice-President and G. M., General Incandescent Arc Light Co., 529 W. 34th St., New York City. Nov. 22, 1899

INSULL, SAMUEL, President, Chicago Edison Co., 139 Adams St., Chicago, Ill. Dec. 7, 1886

IWADARE, KUNIHIKO, Electrician, Nippon Electric Company, 2 Mita Shikokumachi Shibaku, Tokyo, Japan. Sept. 20, 1893

JACKSON, HENRY DOCHER, Electrical Engineer, 83 Newbury St., Boston, Mass. Apr. 23, 1903

JACOBSON, JULIUS R., Special Employee, General Electric Co., Schenectady; res., 310 Almond St., Syracuse, N. Y. Oct. 24, 1902

JACOBUS, DAVID SCHENCK, Professor Experimental Engineering, Stevens Institute of Technology, Hoboken. Sept. 25, 1903

JAEGER, CHARLES L., Inventor, Electric Recording Ship Apparatus, Laboratory, 132 Mulberry St., New York, N. Y. Dec. 20, 1893

JAMES, HENRY DUVALL, *B.S.*, *M.E.*, Engineer, Westinghouse E. & Mfg. Co., Pittsburg, Pa. Nov. 23, 1898

JAMES, TUDOR CONWAY, Electrical Engineer, Lake Superior Power Co., 1500 Grand Ave., Kansas City, Mo. Feb. 27, 1903

JAMESON, CHARLES SMITH, Assistant Foreman Installation and Meter Department, General Electric Co., Lynn, Mass. May 19, 1903

JANES, CLAUDE MINNIS, Erecting Engineer, Stanley Electric Mfg. Co.; res., 214 Second St., Pittsfield, Mass. Apr. 23, 1903

JANISCH, CHARLES, Chief Engineer, The Siemens & Halske Co.; Siegmunds No, 12, Berlin, Ger. Oct. 25, 1901

JANNEY, WILLIAM CANBY, Electrical Engineer, Dodge & Day (Nicetown); res., 3412 Hamilton St., Philadelphia, Pa. June 19, 1903

JAQUAYS, HOMER M., Canada Life Building; res., 862 Sherbrooke St., Montreal, P. Q. Dec. 27, 1899

JEFFREY, JOHN RUSSEL, Assistant General Manager Sales, Bullock Electric Mfg. Co., Cincinnati, Ohio. Dec. 19, 1902

JEFFRIES, THOMAS IRVING, Arc Lamp Testing Dept., General Incandescent Arc Light Co., 572 First Ave.,New York City. Apr. 23, 1903

JENKS, ARTHUR PERKINS, Railway Department, General Electric Co.; res., 27 Front St., Schenectady, N. Y. May 21, 1901

JENKINS, JOHN EVAN, Chief Operator, Western Union Telegraph Co., Denver, Colo. Mar. 27, 1903

JESSUP, WARREN CANFIELD, Sales Engineer, The Cutter Electric and Mfg. Co.; res., 1728 Spring Garden St., Philadelphia, Pa. Sept. 25, 1903

JEWELL, EDWARD W., Manager, Jewell Electrical Inssrument Co.; res., 1036 Park Ave., Chicago, Ill. Apr. 23, 1903

JEWETT, FRANK BALDWIN, Student, Mass. Inst. Technology; res., Technology Club, Boston, Mass. Jan. 23, 1903

JEWSON, FRANK KNIGHT, Telephone Engineer, The Western Electric Co., North Woolwich, England. May 19, 1903

JOBBINS, GEORGE GILBERT, Chief Assistant Engineer, Electric Light and Traction Co., of Australia, Melbourne, Vict. Apr. 23, 1903

JOHANN, CHARLES SHEPPARD, Electrical Engineering Student, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. Dec. 19, 1902

JOHNS, ELLWOOD C., Electrician, The United Electric Light & Power Co., of N. J.; res., 161 Virginia Ave., Jersey City, N. J. Feb. 27, 1903

JOHNSON, ALBERT C., Superintendent and Electrician, Electric Light and Water Works, Willmar, Minn. May 16, 1890

JOHNSON, CHARLES E., *C.E.*, 36 Wall St., Norwalk, Conn. May 15, 1900

JOHNSON, CHARLES WOOD, Production Manager, Bullock Electric Mfg. Co.; res., 2272 Jefferson Ave., Norwood, Ohio. Feb. 27, 1903

JOHNSON, FRANCIS PORTER, Electrical Engineer, Western Electric Co., 259 South Clinton St., Chicago, Ill. Mar. 27, 1903

JOHNSON, HOWARD S., Jeffrey Mfg. Co., 303 Kanawha St., Charleston, W. Va. Mar. 22, 1899

JOHNSON, JASON A., Electrician, Niagara Falls Power Co.; res., 544 10th St., Niagara Falls, N. Y. Sept. 25, 1903

JOHNSON, JOHN C., Electrician, Westinghouse E. & M. Co.; res., 31 West Clinton St., Cleveland, Ohio. Sept. 25, 1903

JOHNSON, MONTGOMERY HUNT, President, Johnson & Morton, 44 Whitesboro St., Utica, N. Y. Feb. 27, 1903

JOHNSON, WALLACE CLYDE, Consulting Engineer, Water Power and Transmission, Niagara Falls, N. Y. Mar. 22, 1901

JOHNSON, WARREN S., Johnson Electric Service Co., 120 Sycamore St., Milwaukee, Wis. Sept. 27, 1901

JOHNSON, WOOLSEY MCALPINE, Electro-Metallurgist, Lanyon Zinc Co., Iola, Kan. Mar. 28, 1902

JOHNSTON, HERBERT L., Electrical Engineer, The Hobart Elec. Mfg. Co., Troy, Ohio. Jan. 23, 1903

JOHNSTON, JAMES EWING, Engineer and Superintendent, Mountain Electric Co.; res., 1111 Detroit St., Denver, Colo. Sept. 25, 1903

JOHNSTON, RICHARD HARRY, Assistant, R. D. Lillibridge, 170 Broadway, New York; res., 972 Park Pl., Brooklyn, N. Y. Oct. 24, 1902

JOHNSTON, THOS. J., Counsel in Patent Causes, 11 Pine St., New York City. May 16, 1899

JOHNSTON, W. J., President, *The Engineering and Mining Journal*, 261 Broadway, New York City. Apr. 15, 1884

JOLLY, JOHN MACCALLUM, Electrical Engineer, Noyes Bros., 109 Pitt St., Sydney, N. S. W. Oct. 24, 1902

JOLY, HENRI LOUIS, Battery Expert and Chemist, The Electromobile Co., Ltd., London, Eng. Feb. 27, 1903

JONES, ARTHUR W., Managing Director, Australian General Electric Co., Equitable Bldg., Melbourne, Vict. Oct. 17, 1894

JONES, FORREST R., Professor, Cornell University, Ithaca, N. Y. May 20, 1890

JONES, FRED ATWOOD, Consulting Electrical, Mechanical and Hydraulic Engineer, 303 Binz Building, Houston, Tex. Jan. 24, 1902

JONES, G. H., Agent, General Electric Co., Casilla, 1317 Santiago, Chili. Apr. 17, 1895

JONES, GEORGE HARVEY, Assistant Engineer, Chicago Edison Co., 139 Adams St.; res., 6531 Woodlawn Ave., Chicago, Ill. Dec. 19, 1902

JONES, M. E., 443 First St., Brooklyn, N. Y. Oct. 27, 1897

JONES, ROBERT CLAY, Turnbull & Jones, Electrical Engineers and Contractors, Dunedin, N. Z. Oct. 24, 1902

JONES, WALTER J., With Hendrie & Bolthoff, 1621 17th St., Denver, Colo. May 20, 1902

JOSLIN, ARBA VANDERBURG, Transformer Inspector, Antioch, Cal. Oct. 24, 1902

JOSLYN, ROLAND ARTHUR, Student, General Electric Co., West Lynn, Mass. Apr. 23, 1903

JOURDAN, FREDERICK MORTON, Supply Agent, General Electric Co.; res., 28 Atlantic Terrace, Lynn, Mass. Apr. 23, 1903

JOYNER, ALBERT HENRY WINTER, Electrical Engineer, Edison Electric Illuminating Co., 576 Atlantic Ave., Boston, Mass. Sept. 26, 1902

JUDSON, HANFORD CHASE, Assistant Engineer General Electric Co., Dobbs Ferry, N. Y. Apr. 25, 1902

JUDSON, WM. PIERSON, Deputy State Engineer, of New York, Albany; res., Oswego, N. Y. June 8, 1887

JUHLIN, GUSTAV ADOLF, Assistant Electrical Engineer, Dick Kerr & Co., Ltd., West Strand Road, Preston, Eng. Oct. 23, 1903

JUNKERSFELD, PETER, (*Local Honorary Secy.*,) Asst. to Mechanical Engineer, Chicago Edison Co., 139 Adams St., Chicago, Ill. Oct. 25 1901

KAETKER, HENRY, Foreman of Switchboard and Controller Department, Triumph Electric Co., Cincinnati, Ohio. Feb. 27, 1903

KAMMERER, JACOB A., General Agent, The Royal Electric Co.; res., 87 Jameson Ave., Toronto, Ont. Apr. 28, 1897

KAPPELLA, ADOLPH SOMERS, Railway Engineering Department, General Electric Co.; res., 1231 State St., Schenectady, N. Y. Oct. 24, 1902

KARAPETOFF, WALDIMIR, Special Apprentice, Westinghouse E. & M. Co.; res., 804 Wood St., Wilkinsburg, Pa. Feb. 27, 1903

KATTE, EDWIN BRITTON, Electrical Engineer, N. Y. C. & H. R. R. R. Co.: Grand Central Station, New York City. Feb. 27, 1903

KEDNEY, LYNN, STEINFORT, Electrician in charge of Power House, The Jalapa Railroad and Power Co., Jalapa, Mexico. May 19, 1903

KEEFER, EDWIN S., Supt. of Electric Light Construction, Western Electric Co., 463 West St., New York City. Apr. 18, 1894

KEELER, IRVING PHELPS, Superintendent of Power and Construction, Asheville Electric Co., Asheville, N. C.

KEILEY, JOHN D., Asst. Electrical Engineer, N. Y. C. & H. R. R. R., 5 Vanderbilt Ave., New York City. July 25, 1902

KEILHOLTZ, P. O., General Manager, United Electric Light and Power Co., Continental Trust Building, Baltimore, Md. Mar. 21, 1893

KELLER, CARL A., Chicago Edison Co., 139 Adams St., Chicago, Ill. Sept. 27, 1901

KELLER, E. E., Vice-President and General Manager, Westinghouse Machine Co., Pittsburg, Pa. Sept. 20, 1893

KELLOGG, JAMES GIFFORD, Student, Cornell University; res., Sigma Phi Place, Ithaca, N. Y. Nov. 20, 1903

KELLOGG, JAMES W., *M.E.*, Manager Marine Sales, General Electric Co.; res., 10 Front St., Schenectady, N. Y. June 26, 1891

KELLY, JOHN WESLEY, JR., Superintendent of Equipment Keystone Telephone Co., 135 South 2d St., Philadelphia, Pa. Dec. 18, 1903

KELLY, THOMAS FRANCIS, Construction and Electrical Engineer, Electric Storage Battery Co., 1427 Marquette Bldg.,Chicago. Dec. 18, 1903

KELSEY, JAMES CEZANNE, Purdue University, Lafayette, Ind. Nov. 23, 1900

KENNEDY, A. P., Electrical Engineer, Yates, Tallapoosa Co., Ala. [Life Member.] Apr. 26, 1899

KENT, JAMES MARTIN, Instructor in Steam and Electricity, Manual Training High School, Kansas City, Mo. July 26, 1900

KENYON, ALFRED LEWIS, Electrical Engineer, General Electric Co., Schenectady, N. Y.; res., Lima, Peru, S. A. Sept. 25, 1903

KER, W. WALLACE, Instructor of Electricity, Hebrew Technical Institute, 36 Stuyvesant St., New York City. Sept. 25, 1895

KERR, SAMUEL ROSS, Testing Department, Bullock Electric Mfg. Co.; res., cor. Norwood Ave. & Marion St., Norwood, Ohio. Jan. 3, 1902

KERSHNER, JEFFERSON E., Consulting Engineer, The Lancaster County R. & L. Co., 445 W. Walnut St., Lancaster, Pa. Jan. 3, 1902

KETCHAM, JOHN BRYANT, Branch Manager, New York Edison Co., 207 Greene St.; res., 4196 Park Ave., New York City. Apr. 23, 1903

KEYES, CLIFT BUTTON, Erecting Engineer, General Electric Co., Schenectady, N. Y. July 28, 1903

KIER, SAMUEL MARTIN, Electrical Engineering Dept., Westinghouse E. & M. Co.; res., 5820 Callowhill St., Pittsburg, Pa. Jan. 24, 1902

KIMBALL, FRED MASON, Manager, Small Motor Department, General Electric Co., 84 State St., Boston, Mass. Apr. 23, 1903

KING, ARTHUR CHARLES, Engineer Northern Electric Mfg. Co., Madison, Wis. Nov. 20, 1903

KING, CHARLES G. Y., Mechanical Engineer, Chicago Edison Co., 139 Adams St., Chicago, Ill. Apr. 23, 1903

KING, HARRY R., Electrical Engineer, Western Electric Co., 259 S. Clinton St., Chicago, Ill. Nov. 22, 1901

KING, R. O., 32 Church St.; res., 503 Markham St., Toronto, Ont. Sept. 26, 1903

KING, VINCENT C., JR., With V. C. & C. V. King, 517 West St.; res., 110 E. 16th St., New York City. Aug. 5, 1896

KINNECOM, FRED ORRIN, General Manager, Electrical Department, Charles S. Bush Co., Providence, R. I. May 19, 1903

KINSELL, WILLIAM LEONARD, Mechanical and Electrical Engineer, Chicago Great Western Railway, St. Paul, Minn. Dec. 18, 1903

KINSLEY, CARL, Assistant Professor of Physics, University of Chicago, Chicago, Ill. May 18, 1897

KINTNER, CHARLES JACOB, Solicitor of Patents and Expert, 45 Broadway; res., 36 E. 29th St., New York City. Feb. 28, 1902

KIRKER, HARRY LEPPER, Estimating and Erecting Engineer, The British Westinghouse E. &. M Co., Ltd., London, Eng. Feb. 27, 1903

KITTLER, DR. ERASMUS, Professor at the Technical High School, Darmstadt, Germany. Dec. 16, 1896

KLAUDER, RUDOLPH H., Electrical Engineer, 41 West Philena St., Philadelphia, Pa. Aug. 13, 1897

KLEIN, RICHARD M., Electrical Expert Bureau of Equipment, Navy Department, Washington, D. C. July 28, 1903

KLINCK, J. HENRY, Electrical Engineer, Lehigh Valley R. R., South Bethlehem, Pa. Jan. 16, 1895

KLINE, JAMES JOSEPH, Engineer, Stanley Electric Mfg. Co.,; res. Beech Grove Inn, Pittsfield, Mass. Jan. 3, 1902

KLIPPHAHN, EMIL OSWALD ERNEST, Building No. 16, General Electric Co., Schenectady, N. Y. Apr. 23, 1903

KLOCK, RAYMOND A., Assistant Electrical Engineer, the U. S. Signal Corps, Signal Office, Washington, D. C. Mar. 27, 1903

KLOMAN, THEODORE W., Manager and Treasurer, The John F. Kelly Engineering Co., 149 Broadway, New York City. June 19, 1903

KLUMPP, JOHN BARTLEMAN, Assistant Inspecting Engineer, The United Gas Improvement Co., Philadelphia, Pa. Dec. 19, 1902

KNIGHT, CLIMPSON MOORE, Superintendent, Empire State Power Co., Amsterdam, N. Y. Apr. 23, 1903

KNIGHT, EARL RAWLINGS, Engineer, Bullock Electric Mfg. Co., Norwood, Ohio. Feb. 27, 1903

KNIGHT, GEORGE LAURENCE, New York Edison Co., New York City; res., 13 St. James Pl., Brooklyn. May 19, 1903

KNIGHT PERCY HENRY, 808 Broadway, Seattle, Wash. Mar. 28, 1902

KNIGHT, SEYMOUR, Designer, The General Electric Co.; res., 310 Clinton St., Schenectady, N. Y. May 19, 1903

KNOWLTON, FREDERICK KIRK, Secretary, Knowlton and Beach Co., Rochester, N. Y. Dec. 19, 1902

KNOX, FRANK H., Engineer, 811 Lewis Building, Pittsburg, Pa. June 20, 1894

KNOX, GEO. W., President, Knox Engineering Co., 1409 Fisher Building, Chicago, Ill. Nov. 18, 1896

KNOX, S. L. G., Manager and Chief Engineer, Bucyrus Co., South Milwaukee, Wis. Nov. 23, 1898

KODAMA, HAYADZUCHI, Chief Engineer, Tokyo Electric Ry., 33 Uchisauvaicho Kojimachekn, Tokyo, Japan. July 25, 1902

KOGI, TORAJIRO, Consulting Engineer, Kurumaya-Cho, Nijo, Kyoto, Japan. June 19, 1903

KONISHI, TAMENOSUKE, Investigating Engineer, Shibaura Engineering Works, Tokyo, Japan. Sept. 25, 1903

KORST, PHILIP HAROLD, Secretary and Manager, Janesville Electric Co., Janesville, Wis. June 19, 1903

KOUSNETZOFF, W. A., Mining Engineer, Vladivostock, East Siberia. Aug. 22, 1902

KRATZ, ARTHUR BRYSON, Manager, Kellogg Switchboard and Supply Co., Electric Bldg., Cleveland, Ohio. Dec. 18, 1903

KREIDLER, W. A., Editor and Publisher, *Western Electrician*, 510 Marquette Building, Chicago, Ill. Oct. 4, 1887

KROHN, SIGVALD, Electrical Engineer, Union Elektricitats-Gesellschaft, Berlin, Ger. July 28, 1903

KRUESI, AUGUST H., Designing Engineer, General Electric Co.; res., 16 Union St., Schenectady, N. Y. Jan. 9, 1901

KRUESI, PAUL JOHN, Manager, Sunlight Lava Mfg. Co., Chattanooga, Tenn. Oct. 25, 1901

KUNZE, RUDOLPH I., Electrical Engineer, Otis Elevator Co.; res., 17 Culver St., Yonkers, N. Y. Nov. 20, 1903

KYNOCH JAMES, Chief Engineer, Canadian General Electric Co., 14 King St. E., Toronto, Ont. Apr. 23, 1903

LA FEVER, CHARLES A., Assistant Superintendent and Electrical Engineer, Advance Thresher Co., Battle Creek, Mich. Sept. 25, 1903

LAFORE, JOHN ARMAND, Electrical Engineer, Overbrook, Pa. May 15, 1900

LAILE, WALTER, Erecting Engineer, Triumph Electric Co.; res., 2304 Victor St., Cincinnati, Ohio. Apr. 23, 1903

LAKE, EDWARD N., Engineer, Chicago Edison Co., 139 Adams St.; res.,227 Jackson Park Terrace, Chicago, Ill. Apr. 23, 1903

LAMB, FRANCIS JOSEPH, Electrical Engineer, Lamb & Co., 284 Lagrave St., Grand Rapids, Mich. Jan. 3, 1902

LAMB, RICHARD, Chief Engineer, Brooklyn Dock and Terminal Co., 136 Liberty St., New York City. Dec. 18, 1895

LAMY, C. A., Asst. Engineer, Lighthouse service, res., Tompkinsville, N.Y. Jan. 23, 1903

LAND, FRANK, *M.E.*, Secy. and Treas., I. A. Weston Co., ; res. 102 Highland Ave., Syracuse, N. Y. Sept. 22, 1891

LANDERS, GEORGE FOREMAN, Captain Artillery Corps, Thurmont Frederick Co., Maryland. Nov. 20, 1903

LANG, ARTHUR GORDON, Tester, Edison Storage Battery (.., Glen Ridge, N. J. Sept. 25, 1903

LANG, EDMUND, Purchasing Agent, Wheeler Condenser and Engineering Co., 120 Liberty St., New York City. Feb. 27, 1903

LANG, GEORGE STUART, Engineer, Beeché, Duval & Co., Valparaiso, Chili. Jan. 23, 1903

LANGSDORF, ALEXANDER SUSS, Asst. Prof. Elec. Eng'g, Washington University, St. Louis, Mo. Jan. 23, 1903

LANMAN, WILLIAM H., Board of Patent Control, 120 Broadway, New York City. June 6, 1893

LANPHEAR, BURTON S., Assistant Professor of Electrical Engineering, Iowa State College, Ames, Ia. Jan. 16, 1895

LANPHIER, ROBERT CARR, Superintendent and Electrician, Sangamo Electric Co., Springfield, Ill. Nov. 22, 1901

LANSINGH, VAN RENSSELAER, Electrical and Illuminating Engineer, 18 E. Adams St.; res., 5329 Kimbark Ave., Chicago, Ill. Aug. 23, 1899

LANSLEY, WILLIAM J., General Manager, Carteret Electric Light Co., Woodbridge, N. J. Apr. 23, 1903

LARKE, WILLIAM JAMES, Manager, Power and Mining Dept., British Thomson-Houston Co., Ltd., Rugby, Eng. Sept. 25, 1903

LATHAM, HARRY MILTON, With American Steel and Wire Co., Worcester, Mass. Dec. 16, 1896

LATOUR, MARIUS CHARLES ARTHUR, Electrical Engineer, 22 Rue de Vocqueville, Paris, France. June 19, 1903

LAURIE-WALKER GEORGE LIVINGSTON, Engineering Apprentice, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. May 19, 1903

LAWLER, JUSTUS CLAUDE, Assistant, Colorado Springs Electric Co., 107 East Kiowa, Colorado Springs, Colo. Dec. 18, 1903

LAWRENCE, WM. G., Manager of Light and Power Department, Town of Hudson, Hudson, Mass. Feb. 28, 1900

LAWRENCE, W. H., Assistant Superintendent, Waterside Station, The N. Y. Edison Co., 38th St. & 1st. Ave., New York . Apr. 26, 1899

LAWSON, JAMES T., Assistant to Superintendent United Electric Co., of New Jersey, 14th and Bloomfield Sts., Hoboken, N.J. Aug. 22, 1902

LAWTON, ARTHUR HAMILTON, Assistant Electrical Engineer, The Hudson River Electric Co., Glens Falls, N. Y. May 19, 1903

LAWTON, EDWIN FRANKLIN, Superintendent, Hartford Electric Light Co., res., 100 Sargeant St., Hartford, Conn. Sept. 25, 1903

LAWTON, FRANCIS N., Superintendent, The Gas and Electric Co., of Bergen Co., Hackensack, N. J. May 19, 1903

LAYTON, GORDON, Electrical Engineer, British Westinghouse E. & M. Co ; res., 48 Lancaster Park, Richmond, Eng. Jan. 3, 1902

LEAR, JOHN EMERY, Student in Testing Department, General Electric Co.; res., 86 Park St., Lynn, Mass. Apr. 23, 1903

LEARY, JOHN JOSEPH, Electrical Engineer, Marconi Wireless Telegraph Co., 27 William St., New York City. Apr. 23, 1903

LEAVITT, ROBERT PABODY, Electrical Engineer, Albany and Hudson Railroad Co., Hudson, N. Y. June 19, 1903

LEBLANC, CHARLES, Engineer, 7 Rue Meyerbeer, Paris, France. Apr. 17, 1895

LEBLANC, MAURICE, Consulting Electrical Engineer, Westinghouse Electric and Mfg. Co., Paris, France. Apr. 25, 1902

LECLEAR, GIFFORD, Electrical and Mechanical Engineer, Partner Densmore & LeClear, 15 Exchange St., Boston, Mass. Oct. 27, 1897

LECONTE, JOSEPH NISBET, Instructor in Mechanical Engineering, State University, Berkeley, Cal. Feb. 27, 1895

LEDOUX, A. R., *M.S.*, *Ph.D.*, President of Ledoux & Co. (inc.), 99 John St.; res., 39 W. 50th St., New York City. Dec. 7, 1886

LEDERER, WILLIAM, Engineering Department, Chicago Edison Co.; res., 1113 Lincoln Ave., Chicago, Ill. July 28, 1903

LEE, ALBERT W., Manager, Concord Municipal Light Plant, Concord, Mass. Apr. 23, 1903

LEE, CHARLES EUGENE, Engineer and Salesman, Electric Gas Lighting Co., 195 Devonshire St., Boston, Mass. July 28, 1903

LEE, JOHN C., Chemist and Electrician, American Telephone and Telegraph Co., 125 Milk St., Boston, Mass. Mar. 18, 1890

LEE, ROBERT MILLER, Draftsman, U. S. Army Ordnance Office; res., 1905 Pennsylvania Ave., N. W., Washington, D. C. June 19, 1903

LEEDS, MORRIS EVANS, President, The Leeds & Northrup Co., 259 North Broad St.; res., 3221 N. 17th St., Philadelphia, Pa. Apr. 26, 1901

LEEDS, NORMAN, Electrical Engineer, Forest St., Stamford, Conn. Feb. 28, 1901

LEGRAND, CHARLES, Copper Queen Consolidated Mining Co., 99 John St., New York City. Jan. 23, 1903

LEIST, WILLIAM, Member and Constructing Engineer, Jantz and Leist Elec. Co., 808 Elm St., Norwood, Cincinnati, O. Mar. 27, 1903

LEITCH, HOWARD WALLACE, Switchboard Regulator, The New York Edison Co., 38th St. & First Ave., New York City. Nov. 23, 1898

LESLEY, HUGH, Engineer, The Electric Storage Battery Co., 19th St. and Allegheny Ave, Philadelphia, Pa. Sept. 26, 1902

LETHEULE, PAUL, Electrical Engineer, Commissioned by French Government, 52 Rue de Clichy, Paris, France. May 17, 1898

LEVY, LEHMAN, Construction Supt., Schwarzschild & Sulzberger Co.; res., 157 West 118th St., New York City. Apr. 23, 1903

LEWIS, EMANUEL WILLIAM, Special Apprentice, Westinghouse Elec. and Mfg. Co., Continental Trust Bldg., Baltimore, Md. Nov. 20, 1903

LEWIS, HENRY FREDERICK WILLIAM, 25 College Hill, Cannon St., London, England. Mar. 5, 1889

LIBBY, SAMUEL BYINGTON, Richmond Borough Equipment Co., 395 Richmond Terrace, New Brighton, N. Y. Feb. 23, 1898

LIDDERDALE, ARTHUR HECTOR, Chief Assistant Erection Dept., Westinghouse Electric & Mfg. Co., Ltd., Hampstead, Eng. May 19, 1903

LIGON, WILLIAM DANIEL, Electrical Engineer, Westinghouse Electric and Mfg. Co., University Building, Syracuse, N. Y. June 19, 1903

LILLIBRIDGE, RAY D., 170 Broadway, New York City. Jan. 24, 1902

LINDMAN, GUSTAV, Chief Draftsman, St. Louis Transit Co., St. Louis, Mo.; res., Stockholm, Sweden. May 19, 1903

LINDSAY, ROBERT, General Supt., The Cleveland Elec. Ill. Co., 717 Cuyahoga Building, Cleveland, Ohio. Apr. 27, 1898

LINDSAY, SHERWOOD COLEMAN, Chief Operating Electrical Engineer, The Seattle Electric Co., Seattle, Wash. June 19, 1903

LINDSEY, LUCIUS ARTHUR, *B.E.*, Wire Chief, S. B. T. & T. Co., Raleigh, N. C. Jan. 23, 1903

LINDSTROM, KARL ARVID, Electrical Engineer, Allmänna Svenska Elektriska Aktiebolaget, Westerås, Sweden. Jan. 23, 1903

LISLE, ARTHUR BEYMER, General Representative, Narragansett Electric Lighting Co., Providence; res., East Greenwich, R. I. Jan. 9, 1901

LINZEE, ALBERT CARL, Designing Engineer, Akron Electric Mfg. Co.; Akron, Ohio. Feb. 27, 1903

LITTLE, C. W. G., Engineering Manager, The British Electric Traction Co., Ltd., Donington House, Norfolk St., London, Eng. Apr. 22, 1896

LIVERS, JOHN LEO, Electrical Contractor, Woodstock, W. Va. Oct. 24, 1902

LIVINGSTON, JOHNSTON, JR., The United Engineering and Contracting Co., 113 East 22d St., New York City. May 17, 1898

LIVSEY, J. H., Salesman and Manager Detroit Office, General Electric Co., 1005 Majestic Building, Detroit, Mich. Apr. 25, 1900

LLOYD, EDWARD WILLIAM, Assistant Superintendent of Construction, Chicago Edison Co., 139 Adams St., Chicago. Feb. 28, 1902

LLOYD, WILLIAM JOHN, Engineer of Instrument Department, Stanley Electric Mfg. Co., Pittsfield, Mass. July 25, 1902

LOBO, GUSTAVE, Office Engineer, V. M. Braschi & Bro., Callé-Cadera No. 2, Mexico City, Mexico. June 28, 1901

LOCKE, FREDERICK M., President Locke Insulator Mfg. Co., Victor, N. Y. Apr. 23, 1903

LODYGUINE, ALEXANDER, 412 Richmond Road, Stapleton, Staten Island, N. Y. Oct. 24, 1902

LOEWENTHAL, MAX, Electrical Engineer, Prometheus Elec. Co., 60 Reade St., New York City; res. 200 N. 5th St., Newark, N.J. Mar. 23, 1898

LOHMANN, ALFRED PERKINS, Manager, Engineering Department, the B. F. Goodrich Co., 37 Marshall Ave., Akron, O. Mar. 27, 1903

LOHMANN, RALPH W., Room 312, 79 Wall St., N. Y. City. Nov. 23, 1898

LOMAS, HAROLD, Washington Manager, Crocker-Wheeler Co., 535 17th St., Washington, D. C. May 19, 1903

LORIMER, GEO. WM., Secy. and Treas., The American Machine Telephone Co., Ltd., Piqua, Ohio. Aug. 5, 1896

LOTT, JOHN COOLEY, Manager, New York Office, Fort Wayne Electric Works, 40 New St., New York City, Mar. 27, 1903

LOUIS, OTTO T., Manager of New York Branch, Queen & Co., Inc., 59 Fifth Ave.; res., 100½ W. 130th St., New York City. Feb. 23, 1898

LOVEJOY, D. R., Electrical Engineer, c/o Cataract Chemical Co., Niagara Falls N. Y. Apr. 28, 1897

LOVERIDGE, IRVING, Manager, Bell Telephone Mfg. Co., 18 Rue Bondewyns, Antwerp, Belgium. Oct. 23, 1903

LOWE, ERNEST A., Electrical Engineer, Lowe & Leveridge, 183 Greenwich St., New York City; res., Plainfield, N. J. June 19, 1903

LOWSON DAVID, Electrical Inspector, N. Y. Board of Education, 59th St. and Park Ave., New York City. Feb. 28, 1902

LOWENBERG, LAURENT, Head of Specification Dept., Bullock Electric Mfg. Co.; res., 2229 Park Ave., Cincinnati, Ohio. Feb. 27, 1903

LOWTHER, CHRISTOPHER MEYER, 36 Riverside Drive, New York City. Nov. 23, 1900

LUCAS, FRED. L., Manager and Engineer, Pontiac Electric Co., Pontiac, Ill. Jan. 23, 1903

LUCAS, JAMES CLARENCE MERRYMAN, District Manager, Bullock Electric Mfg. Co., 8 South St., Baltimore, Md. May 20, 1902

LUDVIGSEN, HANS VALDEMAR, Electrochemical Engineer, Blaagaardsgade 17, Copenhagen, Denmark. Nov. 22, 1901

LUKES, GEORGE HOLT, General Superintendent, North Shore Electric Co., 1319 Orrington Ave., Evanston, Ill. Oct. 25, 1901

LUNDELL, ROBERT, Electrical Engineer, 527 W. 34th St.; res., 9 W. 68th St., New York City. Feb. 7, 1890

LUNDIE, JOHN, Consulting Engineer, 52 Broadway, New York City. Nov. 22, 1899

LUPKE, FRANZ PAUL, Chief Elec. Engineer, South Jersey Gas, Electric and Traction Co.; res., 222 East State St., Trenton, N. J: Mar. 27, 1903

LUSK, WILLIAM CLARDY, Agent, General Electric Co., c/o Chartered Bank of India, Australia and China, Calcutta, India. Sept. 26, 1902

LYFORD, OLIVER S., JR., Westinghouse, Church, Kerr & Co., 8 Bridge St., New York City. Apr. 26, 1899

LYMAN, CHESTER WOLCOTT, *M.A.*, Assistant to President International Paper Co., 30 Broad St., New York, N. Y. Sept. 19, 1894

LYNCH, JOHN COOPER, Traffic Engineer, New York Telephone Co., 15 Dey St.; res., 122 East 18th St., New York City. May 20, 1902

LYNDON, LAMAR, Consulting Electrical Engineer, Park Row Building; res., 243 W. 98th St., New York City. Sept. 27, 1901

LYNN, WM. A., Electrician, 1021 N. Commerce St., Stockton, Cal. Jan. 25, 1899

LYONS, JOSEPH, Patent Solicitor, with Gustav Bissing, 908 G. St., Washington, D. C. June 24, 1898

LYSTER, THOMAS LEE BRENT, Electrical Engineer; res., 187 Lefferts Pl., Brooklyn. Sep. 25, 1903

MACAFEE, JOHN BLAIR, 1002 Harrison Building, Philadelphia, Pa. Mar. 27, 1903

MACARTNEY, JOHN F., Managing Director, Macartney, McElroy & Co., Ltd., 53 Victoria St., London, Eng. May 16, 1899

MACCALLA, CLIFFORD SHERRON, Assistant to General Manager, The Washington Water Power Co., Spokane, Wash. June 28, 1901

MACDONALD, JAMES ENON, Electrician, Pacific Elec. Ry. Co., res.; 643½ Kohler St., Los Angeles, Cal. Jan. 23, 1903

MACFADDEN, CARL K., Consulting Engineer, Geneva, Ind. Sept. 27, 1892

MACFARLANE, WALTER LUTON, Superintendent M. P. Davis, Mille Roches, Ont. May 19, 1903

MACGAHAN, PAUL, Electrical Engineer, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. Dec. 19, 1902

MACGREGOR, WILLARD H., Westinghouse Electric & Mfg. Co., 120 Broadway; res., 235 W. 108th St., New York City. Jan. 20, 1897

MACHALSKE, FLORENTIN JOSEPH, Chemist, Brooklyn, N. Y. Sept. 25, 1903

MACHEN, CHARLES HUDSON, Electrical Engineer, 231 W. 96th St., New York City. Jan. 23, 1903

MACKAY, JAMES LESLIE, Assistant Electrical Engineer, General Electric Co.; res., 41 Market St., West Lynn, Mass. Apr. 23, 1903

MACKAY, WILLIAM, Student American Institute; res., 186 East 104th St., New York City. June 19, 1903

MACKEEN, RUPERT THOMAS, Electrical Engineer, The Canadian General Electric Co., 14 King St., Toronto, Ont. Oct. 24, 1902

MACLOSKIE, GEORGE, JR., Designer and Engineer, General Electric Co., Schenectady, N. Y. Apr. 23, 1903

MADDEN, JOHN FREDERICK SCARTH, Student, Toronto University; res., 7 Bedford Road, Toronto, Ont. Mar. 27, 1903

MALCOLMSEN, CHARLES TOUSLEY, Chief Engineer, Lanyon Zinc Co., Iola, Kan. May 19, 1903

MACOMBER, GEORGE STANLEY, Instructor of Electrical Engineering, Cornell University, Ithaca, N. Y. Aug. 22, 1902

MACOMBER, IRWIN JOHN, Westinghouse, Church, Kerr & Co., 8 Bridge St., New York City; res., Richmond Hill, N. Y. Mar. 28, 1900

MADSEN, JOHN PERCIVAL VISSING, Lecturer in Electrical Engineering, University of Adelaide, Adelaide, South Australia. May 19, 1903

MAGEE, LOUIS J., Electrical Engineer, 25 Broad St.; res., 14 E. 60th St., New York City. Apr. 2, 1889

MAGIE, LOUIS DE WITT, Works Engineer, Canadian General Electric Co., Peterborough, Ont. Sept. 27, 1901

MAGNUS, BENJAMIN, Buffalo Smelting Works, 1 Austin St., Buffalo, N. Y. Jan. 24, 1900

MAGUIRE, THOMAS F. J., Electrical Expert Aid, Bureau Yards and Docks, Navy Dept., Washington, D. C. Aug. 22, 1902

MAHAFFEY, CLAYTON BENNET, Engineer, General Electric Co., Kittredge Bldg., Denver, Colo.; res., Schenectady, N. Y. Jan. 23, 1903

MALLETT, JOHN PURINTON, Chief Engineer and Designer, Northern Electric Mfg. Co.; res., 223 N. Carroll St., Madison, Wis. Feb. 27, 1903

MAKI, HEIICHIRO, 488 Sankocho, Shirokane, Shiba, Tokyo, Japan. Aug. 5, 1896

MALLORY, WALTER SEELEY, Manager, Edison Laboratory, etc., Orange, N. J. July 25, 1902

MANGE, JOHN I., Engineer, Plattsburg Light, Heat and Power Co., Plattsburg, N. Y. Sept. 25, 1903

MANIFOLD, RICHARD GOING, Draftsman, United Gas & Electric Co., 54 Phelan Ave., San Jose, Cal. Jan. 23, 1903

MANN, WILLIAM LOWRY, Niagara Falls Power Co.; res., 250 5th St., Niagara Falls, N. Y. May 19, 1903

MANSFIELD, R. H. JR., Eastern Manager of the Cutler-Hammer Mfg. Co., Westfield, N. J. Sept. 28, 1898

MANSON, RAY HERBERT, 1st. Assistant Engineer, Dean Electric Co., Elyria, Ohio. Nov. 21, 1902

MANVILLE, CHARLES B., Electrical Engineer's Assistant, Otis Elevator Co.; res., 116 Buena Vista Ave., Yonkers, N. Y. Aug. 22, 1902

MANYPENNY, JOSEPH POPE, Eastern Shipbuilding Co., Westchester, Pa. Mar. 27, 1903

MARBLE, HARRY CURTISS, Asst. E. Eng'g, Univ. of Ill.; res., 305 W. University Ave., Champaign, Ill. Jan. 23, 1903

MARBURG, LOUIS C., Electrical Engineer, General Electric Co., Schenectady, N. Y. Feb. 28, 1902

MARKLE, HERBERT, Sales Engineer, Northern Electric Mfg. Co., Suite 15, Monadnock Building, Chicago, Ill. Dec. 19, 1902

MARLOW, WAYLAND CLINTON, Electrical Engineer, The Natural Food Co., Niagara Falls, N. Y. Jan. 23, 1903

MARSH, CHAS. J., General Manager, Eastern and N. E. Sales Dept., Standard Und. Cable Co., 56 Liberty St., New York. May 21, 1901

Marsh, Charles Mercer, 24 Front St., Schenectady, N. Y. Feb. 27, 1903

Marsh, Harry Bowman, Secretary, The Sanborn & Marsh Electric Co.; res., 1131 North Illinois St., Indianapolis, Ind. Mar. 28, 1900

Marshall, Cloyd, *E.E.*, Engineer, Universal Exposition, St. Louis, Mo. Apr. 25, 1900

Marshall, Norman, President and Manager, Marshall-Sanders Co., 301 Congress St., Boston, Mass. Aug. 22, 1902

Marshall, Frederick Joseph, City Electrician, The Corporation of the City of Kamloops, Kamloops, B. C. Sept. 25, 1903

Martin, Frank, Electrician, University Power Co., 4 South Edwards, Princeton, N. J. Oct. 21, 1890

Martin, John, Agent, Stanley Electric Mfg. Co., 69 New Montgomery St., San Francisco, Cal. July 27, 1898

Martin, Lewis George, Electrical Engineer, The Okonite Co., Ltd., 253 Broadway, New York City. Apr. 23, 1903

Martin, Sidney B., General Manager, Pittsburg Construction and Eng'g Co.; res., 236 Dinwiddie St., Pittsburg, Pa. Nov. 21, 1902

Martin, T. Commerford, (*Past-President*) Editor, *The Electrical World and Engineer*, 114 Liberty St., New York City. Apr. 15, 1884

Mason, Hobart, *B.S.*, *E.E.*, Electrical Engineer, New York New Jersey Teleph. Co., 81 Willoughby St., Brooklyn, N.Y. June 28, 1901

Masson, Charles Michael, 824 West Lake Ave., Los Angeles, Cal. Dec. 19, 1903

Masson, Raymond S., Consulting Electrical Engineer, 232 Crocker Building, San Francisco, Cal. Apr. 26, 1899

Masters, Arthur Henry, Representative of Westinghouse, Church, Kerr & Co.; res., 6213 Howe St., Pittsburg, Pa. Jan. 23, 1903

Mateer, Ross Book, Engineering Department, Denver Gas & Electric Co.; res., 1427 Clarkson St., Denver, Colo. Jan. 23, 1903

Mather, Eugene Holmes, Manager, Cumberland Ill. Co.; Treasurer, Portland Lighting and Power Co., Portland, Me. Apr. 28, 1897

Matthews, Charles P., Associate Professor, Electrical Engineering, Purdue University, Lafayette, Ind. May 16, 1893

Mauro, Philip, Counsellor-at-Law, in Patent Causes (Pollock & Mauro), 620 F. St., Washington, D. C. Dec. 21, 1892

Maxim, Hiram Percy, Electric Vehicle Co., Hartford, Conn. Jan. 3, 1902

Maxwell, Alexander, Assistant Superintendent 3d District, New York Edison Co.; res., 45 West 26th St., New York City. Nov. 20, 1903

Maxwell, Eugene, Columbia Improvement Co., 509 National Bank Building, Tacoma, Wash. Aug. 5, 1896

Maxwell, Howard, Designing Engineer, General Electric Co.; res., 832 Union St., Schenectady, N. Y. Apr. 23, 1903

Mayer, Maxwell M., Maxwell M. Mayer Electric Co., 216 Centre St.; res., 226 East 118th St., New York City. Feb. 27, 1895

McAllister, Adams Stratton, Instructor in Physics, Cornell University; res., 106 Catherine St., Ithaca, N. Y. Mar. 28, 1902

McBerty, Frank R., Telephone Engineer, Western Electric Co., Chicago, Ill.; res., Evanston, Ill. Apr. 26, 1901

McCarn, George Eastman, Chief Clerk and Head Draftsman, Engineering Dept., Col. Telephone Co., Denver, Col. Mar. 27, 1903

McCarter, Robert D., Jr., Electrical Engineer, General Electric Co., 3 Southgate St., Bath, Eng. May 16, 1899

McCarthy, E. D., McCarthy Bros. & Ford, 45 North Division St.; res. 382 West Ferry St., Buffalo, N. Y. Nov. 18, 1896

McCarthy, Francis Alexander, Electrical Engineer, Noyes Bros., Yaralla Chambers, 109 Pitt St., Sydney, N. S. W. June 28, 1901

McClain, Frank Laval, Electric Light and Power Co., Cedar Rapids, Iowa. June 19, 1903

McCaskey, William Tyndale, Manager, Societe Anonyme, Westinghouse, Atacha 32 Madrid, Spain. Sept. 25, 1903

McCleary, Ernest, Manager, McCleary & Colquitt Co., Ltd.; 213 Jefferson Ave., Detroit, Mich. Apr. 23, 1903

McClelland, William, Asst. Engineer, with C. H. Wordingham, 19 Brasenose St., Manchester, Eng. May 19, 1903

McClenathan, Robert, Engineer, with D. M. Osborne & Co.; res., 76 Mary St., Auburn, N. Y. May 16, 1899

McCluer, Chas. P., Electrical Engineer, Townsend-McCluer Engineering Co., 302 Atlantic Building, Norfolk, Va. Apr. 22, 1896

McClure, William J., Associated with H. D. Brown, Electrical Engineers & Contractors; res., 358 W. 55th St., New York City. Apr. 25, 1900

McClurg, W. A., Manager, Electrical Dept., Plainfield Gas and Electric Light Co., 217 West 2d St., Plainfield, N. J. Dec. 20, 1893

McConahey, William M., Electrical Engineer, British Westinghouse E. & M. Co., Ltd., Trafford Park, Manchester, Eng. Sept. 27, 1901

McCoy, John Angus, Supt. of Construction, The New England Teleph. & Tel. Co.; res., 62 Main St., Somerville, Mass. Apr. 23, 1903

McCoy, Walter Ehmsen, Electrical Engineer, The United Electric Light and Power Co., 410 E. 29th St., New York City. May 19, 1903

McCreary, J. L., Constructing Engineer, District Railway Co., Mexico City, Mexico. Feb. 28, 1900

McDonald, Walter D., Salesman, Westinghouse E. & M. Co., 171 La Salle St., Chicago, Ill. Sept. 25, 1903

McDuffee, Edgar Jerome, Assistant Engineer, General Electric Co.; res., 311 Summer St., Lynn, Mass. Apr. 23, 1903

McElroy, James F., Consulting Engineer, Consolidated Car Heating Co., 131 Lake Ave., Albany, N. Y. Nov. 15, 1892

McGrath, William Henry, Electrical Engineer, Houghton Co. Elec. Co.; res., Keweenaw Club, Houghton, Mich. Mar. 28, 1902

McGraw, James H., President, McGraw Publishing Co., 114 Liberty St., New York City; res., Madison, N. J. Sept. 27, 1901

McIntyre, Henry Knox, Assistant, Engineering Department, New York Telephone Co., 15 Dey St., New York City. Sept. 26, 1902

McKay, Marshall Cameron, Assistant Electrical Engineer, Vancouver Power Co., Vancouver, B. C. May 19, 1903

McKelway, George Hubbell, Assistant Electrical Engineer, Brooklyn Heights R. R., Brooklyn, N. Y. Dec. 18, 1903

McKindley, James Lampert, Construction Department, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. June 19, 1903

McLaren, William Frederick, Draftsman, Westinghouse Electric and Mfg. Co., Pittsburg; res., Edgewood Park, Pa. June 19, 1903

McLeary, Samuel Harvey, Student Cornell University; res., 325 Eddy St., Ithaca, N. Y. Nov. 20, 1903

McLellan, William, Partner, Charles H. Merz, Collingswood Buildings, Newcastle-on-Tyne, Eng. May 19, 1903

McLimont, A. W., Engineer, Federal Electric Co., 141 Broadway, New York City. July 26, 1900

McNaier, Joseph Treanor, Electrical Engineer, D'Olier Engineering Co., 119 S. 11th St., Philadelphia, Pa. Dec. 18, 1903

McNary, Charles Herbert, Assistant Engineer, Edison Electric Co., Los Angeles, Cal. Apr. 25, 1902

McPherson, Norman Crawford, Engineering Department, Westinghouse E. &. M. Co., Pittsburg, Pa. Sept. 25, 1903

McQuilkin, George, Jr., Electrical Expert, U. S. Navy Department, Quincy, Mass. Dec. 19, 1902

McVay, H. D., Superintendent, Wichita Telephone Co., Wichita, Kan. Feb. 28, 1900

Mead, George Alvin, Chief Engineer, The Ohio Brass Co., Mansfield Ohio. Sept. 25, 1903

Meadows, Harold Gregory, Associate Engineer (Elec.) with Newcomb Carlton, 432 Prudential Building, Buffalo, N. Y. Sept. 23, 1896,

Mearson, Francis, Solicitor and Estimator, Geneva Electric Co.; res., 41 W. 114th St., New York City. Nov. 20, 1903

Medbery, S. C., Jr., Electrical Engineer of Stations, Va., Passenger and Power Co., 116 N. 3d St., Richmond, Va. Oct. 24, 1902

Medina, Frank P., Electrician, Pacific Postal Telegraph Co., 878 Geary St., San Francisco, Cal. Sept. 19, 1894

ter Meer, Henry Charles, Electrical Engineer; res., 930 Hudson St., Hoboken, N. J. Feb. 28, 1901

Mees, Carl Leo, President and Professor of Physics, The Rose Polytechnic Institute, Terre Haute, Ind. May 19, 1903

Meginniss, Francis Regester, Student, Testing Department, General Electric Co.; res., 80 Park St., West, Lynn, Mass. Apr. 23, 1903

Menaugh, Robert, Chief Engineer, Honolulu R. T. & L. Co., res.; 509 Beretania Ave., Honolulu, H. I. Jan. 23, 1903

Merkle, William S., Vice-President Ewing Merkle Electric Co.; res., 2601 Louisiana Ave., St. Louis, Mo. Apr. 23, 1903

Merrill, Barrett Morris, Electrical Engineer, Puget Sound Electric Railway, Kent, Wash. Apr. 23, 1903

Merrill, E. A., Manager, New York Office, McIntosh, Seymour & Co., 26 Cortlandt St., New York City. Sept. 20, 1893

Merrill, Joseph F., Professor of Physics and Electrical Engineering, University of Utah, Salt Lake City, Utah. May 21, 1901

Merrill, Josiah L., Electrical Engineer, c/o General Electric Co., 1517 Park Building, Pittsburg, Pa. Sept. 25, 1895

Merritt, Benjamin F., Superintendent Repair Department, New York Telephone Co., 30 Gold St., New York City. Mar. 27, 1903

Merz, Chas. H., 28 Victoria St., Westminster, London S. W., and 1 Mosle St., Newcastle-on-Tyne, England. Sept. 25, 1895

Messick, Charles, Jr., Selling Engineer, United Telpherage Co., Room 92, Cotton Exchange, New York City. Dec. 18, 1903

Meston, Charles Robert, Vice-President and Superintendent, The Emerson Mfg. Co., 5619 Cates Ave., St. Louis, Mo. May 19, 1903

Meuschel, August, Supt. Power Houses, The Lachine Rapids Hydraulic & Land Co., Ltd., 160 McCord St., Montreal, P. Q. Mar. 27, 1903

Meyer, Hans S., Electrical Engineer, The British Thomson-Houston Co., Rugby, Eng. July 27, 1889

Meyer, John Wilhelm, Foreman of Wiring Inspectors, Edison Electric Light Co., of Philadelphia, Philadelphia, Pa. Apr. 23, 1903

Meyer, Julius, Consulting Engineer, 115 Broadway, New York City. Oct. 25, 1892

Meyers, Alvin, Engineering Department, The Telluride Power Co., Provo, Utah. Aug. 22, 1902

MICHOD, CHARLES LOUIS, Partner E. H. Abadie & Co., 419 Bank of Commerce, St. Louis, Mo. July 28, 1903

MIDDLETON, A. CENTER, with R. U. Strong, 25 Broad St., New York City. May 16, 1899

MIEHLING, RUDOLPH, Sales Engineer, Northern Electrical Co., 20 Third Ave., Duluth, Minn. Sept. 25, 1902

MILES, J. WALTER, Electrical Engineer, Westinghouse Electric and Mfg. Co., Irwin, Pa. Apr. 25, 1903

MILLAR, PRESTON S., Asst. to Mgr. Lamp Testing Bureau, 80th St. & East End Ave., New York City. Jan. 23, 1903

MILLER, ALPHONSUS JOSEPH, Laboratory Assistant, Western Electric Co., 463 West St., New York City. Mar. 28, 1902

MILLER, ALVIN AUGUSTUS, Salesman, Westinghouse Electric and Mfg. Co., 314 Occidental Ave., Seattle, Wash. Apr. 23, 1903

MILLER, DWIGHT DANA, Salesman, Westinghouse Electric and Mfg. Co., 120 Broadway, New York City. Apr. 25, 1902

MILLER, GEORGE E., Assistant to 2d Vice-President, Westinghouse E. & M. Co., 120 Broadway, New York City. Feb. 28, 1902

MILLER, HERBERT S., Electrical Engineer, Diehl Mfg. Co., res., 1025 E. Jersey St., Elizabeth, N. J. Mar. 22, 1899

MILLER, KEMPSTER B., Engineer Kellogg Switchboard and Supply Co,, Congress and Green St., Chicago, Ill. Sept. 28, 1898

MILLER, WALTER H. Manager Record Dept. (Phonograph), with Thomas A. Edison; res., 28 Mt. Vernon St., Orange, N. J. Sept. 27, 1901

MILLER, WM. C., *M.S.*, Electrical Engineer, 3 South Hawk St., Albany, N. Y. Oct. 21, 1890

MINOR, JOHN W., JR., Inspector, Insurance Inspection Bureau, 518 Exchange Building, Denver, Colo. Mar. 27, 1903

MISAKI, SEIZO, Chief Engineer and Superintendent, Hanshin Elec. Railway Co., Nishiumeda-cho, Osaka, Japan. Dec. 27, 1899

MITCHELL, SIDNEY Z., Manager, Tacoma Railway and Power Co., South 14th and A Sts., Tacoma, Wash. Nov. 12, 1889

MIXER, CHARLES ADAM, Civil and Hydraulic Engineer, Rumford Falls Power Co., Rumford Falls, Me. Sept. 25, 1903

MÖLLER, JACOB ALARIC, LEO Engineer, Lambert Schmidt Telephone Mfg. Co., Inc., 85 Maple St., Hoboken, N. J. Nov. 20, 1903

MONEYPENNY, NELSON NORTH, Manager, Special Work Department, Alberene Stone Co., 393 Pearl St., New York City. Mar. 27, 1903

MONRATH, GUSTAVE, Engineer and Superintendent, Grace & Hyde Engineering Co., 7 E. 42d St., New York City. Apr. 26, 1901

MONTAGU, RALPH LECHMERE, Consulting Engineer, Oroville, Butte Co., Cal. Feb. 26, 1896

MOODY, VIRGINIUS DANIEL, General Electric Co.; res., 6 Catherine St., Schenectady, N. Y. Dec. 27, 1899

MOORE, HENRY ALEXANDER, Engineer, The Canadian Bullock Electric Mfg. Co., 200 McKinnon Bldg., Toronto, Ont. June 19, 1903

MOORE, JOHN PEABODY, Engineering Department, Central Illinois Construction Co., Mattoon Ill. Apr. 25, 1900

MOORE, PERCIVAL, Vice-President and General Manager, Louisville & Eastern R. R., Anchorage, Ky. Mar. 27, 1903

MOORE, ROBERT HAWTHORNE, Asst. Electrical Engineer, Mechanical and Electrical Dept., Universal Exposition, St. Louis, Mo. May 20, 1902

MORA, MARIAN LOUIS, General Electric Co., 44 Broad St., New York City. Mar. 20, 1896

MORAN, WILLIAM M., Electrical and Mechanical Engineer, with Townsend Reed, Lebanon, Ind. July 28, 1903

MORAWECK, ALVIN H., Superintendent, The Pittsburg and Allegheny Telephone Co., Pittsburg, Pa. Apr. 23, 1903

MORDEY, WM. MORRIS, Consulting Electrician, 82 Victoria St., Grosvenor Mansions, Westminster, London, Eng. Sept. 22, 1891

MORDOCK, CHARLES T., Superintendent, Lighting and Power Department, Terre Haute Electric Co., Terre Haute, Ind. Sept. 25, 1903

MOREHEAD, J. M., Engineer, Union Carbide Co., 157 Michigan Ave., Chicago, Ill. Mar. 28, 1900

MOREHOUSE, H. H., Morehouse and Morrill, 231 Crossley Building, San Francisco, Cal. Feb. 21, 1894

MORGAN, CARL LEON, With Simplex Electric Co., 110 State St.; res., 25 St. Cecilia St., Boston, Mass. Jan. 24, 1902

MORGAN, GODFREY, General Supt., The Youngstown & Sharon Street Railway Co.; res., Sharon, Pa. Oct. 25, 1901

MORITZ, CHARLES HOLLAND, Construction Engineer, Pittsburg Reduction Co., Niagara Falls, N. Y. Dec. 19, 1902

MORLEY, EDGAR L., Supt. Hatzel & Buehler, 114 Fifth Ave., New York City. Sept. 25, 1895

MORRILL, EDWARD FRANCIS, Engineering Department, The N. Y. & N. J. Telephone Co., 81 Willoughby St., Brooklyn, N. Y. Feb. 28, 1902

MORRILL, WILLIAM CHARLES, Manager, Chas. Morrill, 277 Broadway; res., 24 W. 83d St., New York City. Jan. 23, 1903

MORRIS, GEORGE HALSTEIN, Electric Storage Battery Co., 1519 Marquette Building, Chicago, Ill. May 19, 1903

MORRIS, HARVEY L., Salesman, Northern Electric Mfg. Co., Madison, Wis. Jan. 23, 1903

MORRIS, JOHN WILLIAM, Electrical Superintendent, The Reid Newfoundland Co., St. Johns, Newfoundland. Aug. 22, 1902

MORRISON, J. FRANK, Consulting Engineer, 1201 Calvert Building, Baltimore, Md. Apr. 15, 1884

MORSE, GEORGE GLENN, Testing Department, General Electric Co.; res., 327 Germania Ave., Schenectady, N. Y. Mar. 27, 1903

MORTIMER, JAMES D., Superintendent of Power Department, Tacoma Railway and Power Co., Tacoma, Wash. Mar. 28, 1900

MOSCHKOWITSCH, MEERS S., Preobrazenska, 53, Odessa, Russia. Jan. 9, 1901

MOSES, PERCIVAL ROBERT, *E.E.*, Electrical Engineer, 35 Nassau St.; res., 235 W. 76th St., New York City. Dec. 19, 1894

MOSMAN, CHARLES TYLER, Electrical Engineer, General Electric Co.; res., 1208 Union St., Schenectady, N. Y. May 19, 1903

MOSSCROP, WM. A., *M.E.*, Electrical Engineer, 47 Brevoort Pl., Brooklyn, N. Y. May 7, 1889

MOTT, FREDERICK ALLEN, Testing Department, Keystone Electric Co.; res., 701 Liberty St., Erie, Pa. July 28, 1903

MOTT, FREDERICK RUTHERFORD, Engineer, The Bell Telephone Co., of Missouri, Telephone Building, St. Louis, Mo. Apr. 23, 1903

MOTT-TRILLE RADLEY, Electrical Engineer, United Lumber Co., Cienfuegos, Cuba. Oct. 23, 1903

MOWBRAY, WILLIAM J., Engineer, Brooklyn Edison Co., 14 Rockwell Pl.; res., 272 Classon Ave., Brooklyn, N. Y. Nov. 20, 1903

MUDGE, ARTHUR LANGLEY, Electrical Engineer, York Haven Water & Power Co., York Haven, Pa. Mar. 22, 1901

MUDGE, CHARLES A., Ober-Engineer, Direct Current Railway Department, Allegmeine Electricitats Gesellschaft, Berlin, Ger. Feb. 27, 1903

MULLEN, THOMAS JAMES, Superintendent of Construction, Bullock Electric Mfg. Co.; res., 826 Hathaway St., Cincinnati, O. Mar. 27, 1903

MULLIGAN, WALTER LYON, Assistant Manager, United Electric Light Co., Springfield, Mass. Feb. 28, 1902

MULLIN, E. H., (*Manager*), General Electric Co., 44 Broad St.; res., 1 W. 102d St., New York, N. Y. May 16, 1899

MUNDY, AMBROSE, Salesman, A. B. See Elec. Elev. Co., 220 Broadway, New York City; res., Metuchen, N. J. Jan. 23, 1903

MUNRO, DAVID M., Assistant Inspector Underwriters' Agency, Masonic Building, New Orleans, La. Mar. 27, 1903

MURDOCK, HENRY DELOS, District Engineer, Westinghouse E. & M. Co., 207 Westinghouse Bldg., Pittsburg, Pa. Jan. 23, 1903

MURPHY, EDWIN J., Engineer, Arc Lamp Dept., British Thomson-Houston Electric Co., Rugby, Eng. Mar. 28, 1902

MURPHY, GEORGE R., Engineer, Operating Dept., The Electric Storage Battery Co., 42 Nevada Block, San Francisco, Cal. Apr. 25, 1902

MURPHY, JOHN Z., Chief Engineer, Chicago Union Traction Co.; res., 1948 Lexington St., Chicago, Ill. Sept. 25, 1903

MURRAY, WILLIAM SPENCER, Engineer, Farnum & Murray, 53 State St.; res., " The Wadsworth," Boston, Mass. Jan. 23, 1903

MYERS, FREDERIC WILLIAM, Superintendent of Construction; Standard Underground Cable Co., 74 7th St., Buffalo, N. Y. Sept. 26, 1902

NAGEL, WILLIAM G., President and Manager, The W. G. Nagel Electric Co., 520 Adams St., Toledo, Ohio. Feb. 27, 1903

NAMBA, M., Professor of Electrical Engineering, University of Kioto, Kioto, Japan. Apr. 26, 1899

NAPHTALY, SAM L., Asst. Engineer, San Francisco Gas & Electric Co., 229 Stevenson St., San Francisco, Cal. Aug. 23, 1899

NASH, LUTHER ROBERTS, Electrical Engineer, Stone & Webster, 84 State St., Boston; res., 51 Ellery St., Cambridge, Mass. Mar. 27, 1903

NAUCLER, REINHOLD, Draftsman, Elektriska A. B. Magnet, Ludvika, Sweden. July 28, 1903

NAYLOR, CHARLES WILLIAM, Mechanical Engineer, Marshall Field & Co., 83 State St.; res., 1592 Lexington St., Chicago, Ill. May 19, 1903

NEALL, NEWITT JACKSON, Electrical Engineer, Westinghouse Electric & Mfg. Co., Pittsburg; res., Edgewood Park, Pa. Oct. 23, 1903

NEAVE, JOSEPH SWAN, Vice-President, Bullock Electric Mfg. Co., Grandin Road, Cincinnati, Ohio. Feb. 27, 1903

NEILSON, JOHN, Larchmont, N. Y. May 18, 1897

NELSON, GEORGE, Student, Georgia School of Technology; res., 304 N. Boulevard, Atlanta, Ga. June 19, 1903

NESBIT, JOSEPH NEWTON GRAY, Professor, Dept. Experimental Engineering, Georgia School of Technology, Atlanta, Ga. Nov. 22, 1901

NESBIT, WILLIAM, Electrical Engineer, Westinghouse E. &. M. Co., 11 Pine St., New York City.

NEURATH, MORRIS M., Electrical Engineer, A. & N. Mfg. Co., 165 Broadway, N. Y. Feb. 28, 1900

NEWBURY, F. J., Manager Insulated Wire Department, John A. Roebling's Sons Co., Trenton, N. J. Sept. 23, 1896

NEWELL, FRANK CLARENCE, Consulting Electrical Engineer, Westinghouse Air Brake Co., Pittsburg, Pa. Jan. 3, 1902

NEWELL, FRANK LORD, Electrical and Mechanical Draftsman, Ford, Bacon & Davis; res., Passaic, N. J. Mar. 27, 1903

NEWELL, FREDERICK WILLIAM, Assistant Electrical Engineer, The Otis Elevator Co., Yonkers, N. Y. Nov. 21, 1902

NEWELL, HARVEY EDGAR, India Rubber and Gutta Percha Insulating Co.; res., 101 North Broadway, Yonkers, N. Y. Sept. 25, 1903

NEWMAN, FRED JACOB, Superintendent and Chief Engineer, Woods Motor Vehicle Co., 110 East 20th St., Chicago, Ill. Sept. 27, 1901

NEWTON, SAMUEL OSCAR, North East Electric Light and Power Co., North Pitcher; res., 607 W. Water St., Elmira, N. Y. Sept. 25, 1903

NEXSEN, RANDOLPH HALLIDAY, Electrical Engineer, 34 Beekman St., New York City; res., 302 St. James Pl., Brooklyn, N. Y. Nov. 21, 1902

NICHOLS, CHARLES KETCHAM, Agent, New York Edison Co., 55 Duane St.; res., 706 Union St., Brooklyn, N. Y. Apr. 23, 1903

NICHOLS, LOUIS CHARLES, Electrical Engineer, 2267 Jefferson Ave., South Norwood, Ohio. Feb. 28, 1902

NICHOLSON, CHARLES MARION, Engineer, Test Dept., Bullock Electric Mfg. Co., Cincinnati, Ohio. Jan. 23, 1903

NICHOLSON, SAMUEL L., With Westinghouse Elec. & Mfg. Co., 120 Broadway, New York. July 26, 1900

NICOLL, GEORGE D., 1000-46 Van Buren St., Chicago, Ill. Mar. 27, 1903

NIESZ, HOMER ELDREDGE, Assistant to Second Vice-President, Chicago Edison Co., 139 Adams St., Chicago, Ill. Oct. 25, 1901

NIETHAMMER, FREIDRICH, Professor of Electrical Engineering Technische Hochschule, Brünn, Austria. Feb. 27, 1903

NIMIS, ALBERT A., Electrical Contractor, Nimis & Nimis, 138 East 73d St., New York City. Aug. 13, 1897

NISTLE, GEORGE W., Secretary, Illinois Engineering Laboratory, 319 Manhattan Builidng, Chicago, Ill. Dec. 19, 1902

NOBLE, GROVER CHESTER, Assistant in Electrical Engineering, University of California, Mechanics' Building, Berkeley, Cal. Dec. 19, 1902

NOCK, GEO. W., General Manager, H. D. & H. H. R. R., Danbury, Conn. Aug. 5, 1899

NOE, JAMES BRYAN, The New York Edison Co., 55 Duane St., New York City; res., 29 Elm St., Elizabeth, N. J. June 19, 1903

NOEGGERATH, JACOB EMIL, Engineer General Electric Co.; res., 409 Union St., Schenectady, N. Y. Mar. 27, 1903

NORDWALL CHARLES FLESCH DE,, Manager of the Export Department, Allgemeine Elektricitats-Gesellschaft, Berlin, Ger. Sept. 27, 1892

NORRIS, HENRY HUTCHINSON, Assistant Professor of Electrical Engineering, Cornell University, Ithaca, N. Y. Feb. 27, 1903

NORTH, GILBERT, Electrical Engineer, British Westinghouse E. & M. Co.; Trafford Park, Manchester, Eng. Sept. 25, 1903

NORTHRUP, EDWIN FITCH, The Leeds & Northup Co., 259 N. Broad St., Philadelphia, Pa. Sept. 27, 1901

NOXON, C. PER LEE, Manufacturer, High-Frequency X-Ray Apparatus, Dynamos & Motors, 500 E. Water St., Syracuse, N. Y. Oct. 17, 1894

NOYES, ERNEST HIGH, Manager of Chicago Office, The Pittsburg Reduction Co., 190 Monroe St., Chicago, Ill. Sept. 25, 1903

NUNN, RICHARD J., *M.D.*, 5 York St. East, Savannah, Ga. July 12, 1887

NYHAN, J. T., Superintendent and Electrician, Macon Electric Light and Railway Co., Macon, Ga. Feb. 27, 1895

OAKSHOTT, HERBERT CHARLES GORDON, *M.A.*, Professor of Electrical Engineering, Oxford Tech. College, Grahamstown, S. A. Aug. 22, 1902

OBEAR, GEORGE BARROWS, Instructor in Electrical Engineering, Lowell Textile School, Lowell, Mass. Nov. 20, 1903

O'BRIEN, ALBERT DALLAM, Westinghouse, Church, Kerr & Co., 8 Bridge St.; res., 347 West 14th St., New York City. Nov. 22, 1901

O'DONOVAN, LEO. J., Consulting Engineer, Reis & O'Donovan, 15 Cortlandt St.; res., 268 West 91st St., New York City. Apr. 25, 1902

OFFINGER, MARTIN HENRY, *E.E.*, Secy-.Treas., Van Wagoner-Linn Construction Co., 27 W. 24th St., New York City. Mar. 28, 1900

OFFUTT, ANDERSON, *B.S.*, *E.E.*, Electrician, Underwriters Agency of La. and Miss., New Orleans, La. May 15, 1900

OI, SAITARO, Chief Engineer to the Bureau of Posts and Telegraphs, The Ministry of Communications, Tokyo, Japan. Dec. 28, 1898

OKAMOTO, KEITARO, Chief Engineer, The Hiroshima, Suirioku Denki Kaisha, Hiroshima, Japan. Sep. 25, 1903

OKEY, PERRY, Superintendent, Columbus Municipal Electric Light Plant; res., 89 West Ave., Columbus, Ohio. Apr. 23, 1903

OLDHAM, WILL HAROLD, Draughtsman, Electrical Department, Cambria Steel Co., Johnstown, Pa. Oct. 28, 1903

OLHEISER, WILLIAM WEAVER, General Supt., Eastern Telephone & Telegraph Co., 3d and Federal Sts., Camden, N. J. Apr. 23, 1903

OLIN, EDWIN MASON, Engineer Foreman in charge Testing Department, Westinghouse E. & M. Co., Pittsburg, Pa. Feb. 27, 1903

OLIVETTI, CAMILLO, Ingegnere Industriale, Ivrea, Italy. Oct. 17, 1892

OLMSTED, HARRY WILLIAM, Electrical Inspector, with Fremont Wilson, Hackensack, N. J. May 19, 1903

OOLGARDT, J. J., Electrical Engineer (Foreign Dept.), General Electric Co.; res., Edison Hotel, Schenectady, N. Y. Apr. 25, 1900

ORBELL, ROBERT HUGH, British Westinghouse E. and M. Co., Paines Manor, Pentlow Cavendish, Suffolk, England. May 20, 1902

ORBIN, FRANK, Superintendent, The Pittsburg Bureau of Electricity, 431 Sixth Ave., Pittsburg, Pa. Jan. 23, 1903

O'REILLY, ANDREW J., Supervisor of City Lighting, 1507 Papin St., St. Louis, Mo. Apr. 23, 1903

ORMSBEE, ALEX. F., Electrical Engineer, with N. Y. and N. J. Telephone Co., 81 Willoughby St., Brooklyn, N. Y. June 27, 1895

OSBORNE, GEORGE FREDERICK FOLGER, Lieutenant, Royal Engineers D. A. A. G., Army Headquarters, Simla, Brit. India. Mar. 27, 1903

OSBORNE, LOYALL ALLEN, Manager of Works, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. Oct. 18, 1893

OSBORNE, MARSHALL, Engineer, British Thomson-Houston Co.; res., Avon Brae, Elsee Road, Rugby, England. Apr. 25, 1900

O'SULLIVAN, M. J., Superintendent, Electric Light, B. & O. R. R. Co., 4734 Sylvan Ave., Pittsburg, Pa. Mar. 20, 1895

OSWALD, HERMAN HENRY, Student General Electric Co.; res., 306 Lafayette St., Schenectady, N. Y. Nov. 20, 1903

OTTEN, DR. JAN D., Director, Batavia Electrische Tram-Maatschappij, Heerenqracht, 259 Amsterdam, Holland. Nov. 18, 1890

OXER, GEORGE CARROLL, 615 State St., Schenectady, N. Y. July 28, 1903

PACKARD, LEONARD WARREN, Assistant Engineer of Meter Department, res., 25 Beacon Hill Ave., Lynn, Mass. Apr. 23, 1903

PAGE, A. D., Assistant Manager, General Electric Co. Lamp Works, Harrison, N. J. Jan. 19, 1892

PALMER, D. ALONZO, Superintendent, Compania Anonima de Redes Telefonicas de Ponce; Ponce, Porto Rico. Oct. 25, 1901

PALMER, HARRY MITCHELL, Mechanical and Electrical Engineer, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. Dec. 19, 1902

PALMER, WILLIAM HENRY, JR., Electrical Engineer & Asst. to President, N. Y. Transp. Co., 815 8th Ave., New York City. May 20, 1902

PANTER, THOMAS ALFRED, Assistant Electrician, The Niagara Falls Power Co.; res., 481 19th St., Niagara Falls, N. Y. Sept. 25, 1903

PARKE, FREDERIC HUNTINGTON, Engineering Office, Westinghouse Co., Nevsky Prospect No. 11, St. Petersburg, Russia. Jan. 23, 1903

PARKE, ROBERT AUGUSTUS, Special Agent, Westinghouse Air Brake Co., 634 Endicott Building, St. Paul, Minn. Jan. 23, 1903

PARKE, RODERICK J., Consulting Electrical Engineer, 409 Temple Bldg., Toronto, Can. July 26, 1900

PARKER, CAPT. CHARLES FOSTER, In charge Instruction of Electrician Sergeants, Fort Totten, Willets Point, N. Y. May 19, 1903

PARKER, HERSCHEL C., Instructor in Physics, Columbia University, New York City; res., 21 Fort Green Pl., Brooklyn, N. Y. Apr. 19, 1892

PARKER, HOMER CHARLES, Salesman J. Martin & Co., New Montgomery, St.; res., 1601 Taylor St., San Francisco, Cal. Sept. 25, 1903

PARKER, IRVING, Electrical Inspector, Pierce Richardson and Neiler, 1410 Manhattan Building, Chicago, Ill. Mar. 27, 1903

PARKER, LINDSAY R., 345 State St., Brooklyn, N. Y. Sept. 27, 1901

PARKHURST, CHARLES WILLIAM, Superintendent of Electrical Department, Cambria Steel Co., Johnstown, Pa. Sept. 27, 1901

PARKS, COLEMAN CLYDE, Draughtsman, Electrical Dept., Homestead Works of Carnegie Steel Co., Munhall, Pa. Oct. 23, 1903

PARMLY, C. HOWARD, *S.M.*, *E.E.*, College of the City of New York, 17 Lexington Ave., New York City. Feb. 21, 1893

PARODI, HIPPOLYTE, Electrical Engineer, Francaise Thomson-Houston, 10 Rue de Londres, Paris, France. Sept. 26, 1902

PARRY, EVAN, Engineer H. F. Parshall, Salisbury House, London Wall, London, Eng. Sept. 25, 1895

PARSELL, HENRY V. A., Electrical and Mechanical Designing and Experimental Work, 129 W. 31st St., New York City. Nov. 12, 1889

PARSHALL, AUGUST, Commercial Engineer, Supply Dept., General Electric Co., 44 Broad St., New York City. Oct. 24, 1900

PATTERSON, GEORGE WASHINGTON, JR., Junior Professor of Electrical Engineering, University of Mich., Ann Arbor, Mich. Sept. 27, 1901

PATTERSON, HAROLD D., Superintendent, with Max Osterberg, 11 Broadway, New York City. Mar. 27, 1903

PATTISON, HUGH, Electrical Engineer, Westinghouse, Church, Kerr & Co., 10 Bridge St.; New York City. Sept. 25, 1903

PAULY, KARL ALMON, Engineer, General Electric Co.; res., 1 Division St., Schenectady, N. Y. May 19, 1903

PAYNE, ALBERT EDWARD, The Creaghead Engineering Co., of Cincinnati, 500 East 5th St., Cincinnati, Ohio. Mar. 27, 1903

PEARSON, FREDK. J., With D. H. Burnham, 1142 Rookery Building Chicago, Ill. July 27, 1898

PEARSON, JOHN, Superintendent St. Croix Power Co., Somerset, Wis. Sept. 26, 1902

PEASE, HAROLD CHILDS, Engineer General Electric Co.; res., 820 Union St., Schenectady, N. Y. Mar. 27, 1903

PEASE, HENRY MARK, Telephone Engineer, The Western Electric Co., No. Woolwich, E., London, Eng. May 19, 1903

PECK, EDWARD F., Manager Lighting and Power Dept., Schenectady Railway Co., 420 State St., Schenectady, N. Y. May 20, 1890

PECK, RANSOM B. W., Electrician in charge Kingsbridge Power Station, Interurban Street Railway Co., New York City. Sept. 25, 1903.

PEIRCE, ARTHUR W. K., Consulting Electrical Engineer to the Consolidated Gold Fields of S.A., Ltd., Germiston, Transvaal. June 27, 1895

PENDELL, CHAS. WILLIAM, Assistant Signal Engineer, G. C. & S. F. Ry., Cleburne, Tex. Nov. 22, 1899

PENNEBAKER, EDWIN PRESTON, 314 North Yakimer Ave., Tacoma, Wash. Jan. 23, 1903

PENTON, CARL TOWNLEY, Chief Electrician American Ship Building Co.; res., 222 Forest St., Lorain, Ohio. Feb. 27, 1903

PERKINS, HENRY A., Professor of Physics, Trinity College; res., 55 Forest St., Hartford, Conn. July 28, 1903

PERKINS, JAY H., General Superintendent, Youngstown Consolidated Gas and Electric Co., Youngstown, Ohio. Nov. 21, 1902

PERRY, CHARLES LANGDON, Designing Engineer, General Electric Co.; res., No. 1 State St., Schenectady, N. Y. Mar. 27, 1903

PERRY, FRANKLIN SANBORN, Erecting and Installing Engineer, Pittsburg Engineering Co., 207 Lewis Block, Pittsburg, Pa. Jan. 23, 1903

PERRY, JAMES WILLIAM, Manager Electric Department, H. W. Johns-Manville Co., 100 William St., New York City. Apr. 23, 1903

PERRY, LESLIE LAWRENCE, Electrical Engineer, with F. S. Pearson, 29 Broadway, New York City. Mar. 27, 1903

PESTELL, WILLIAM, J. G. White & Co., 43 Exchange Place, New York City. Apr. 23, 1903

PETICOLAS, SHERMAN GOODWIN, Westinghouse Electric & Mfg. Co.; res., 1116 South Ave., Wilkinsburg, Pa. Sept. 27, 1901

PETTY, HERBERT CLINTON, Assistant in Sales Department, Crocker-Wheeler Co., Ampere; res., East Orange, N. J. June 19, 1903

PETTY, WALTER M., Superintendent Fire Alarm Telegraph, Rutherford, N. J. May 16, 1893

PFATISCHER, MATHIAS, Chief Engineer, The Electro-Dynamic Co., of Philadelphia, Philadelphia, Pa. Apr. 23, 1903

PFEIFFER, ALOIS, J. J., Engineer, 22a College Hill, London, E.. C. Eng. Jan. 24, 1900

PFUND, RICHARD, Engineer, Marconi Wireless Telegraph Co., of America, 27 William St.; res. 601 West 69th St., New York City. Apr. 18, 1893

PHARO, HARRY ALEXANDER, 600 North Ave., Wilkinsburg, Pa. Feb. 27, 1903

PHELON, JOSEPH OLIVER, Assistant Professor of Electrical Engineering, Worcester Polytechnic Institute, Worcester, Mass. Mar. 27, 1903

PHELPS, WM. J., Manager, The Phelps Co., Makers Hylo Incandescent Lamp, 33 State St., Detroit, Mich. Mar. 25, 1896

PHILBRICK, B. W., Electrical Engineer for J. J. Astor, Rhinecliff, N. Y. May 15, 1894

PHILLIPS, EUGENE F., President, American Electrical Works, Phillipsdale, R. I. July 13, 1889

PHILLIPS, ELLIS LAURIMORE, Engineer, 45 Broadway; res., 11 West 103d St., New York City. Mar. 28, 1902

PHILLIPS, LEO A., Sanderson & Porter, 52 William St., New York City. Mar. 21, 1894

PHILLIPS, WALTER, Manager, Westinghouse Electricitats Actien Gesellschaft, 19 Jaeger Strasse, Berlin, Germany. Feb. 27, 1903

PICKARD, GREENLEAF WHITTIER, Electrical Engineer, American Telephone and Telegraph Co., 125 Milk St., Boston, Mass. Mar. 27, 1903

PIERCE, ALFRED LAWRENCE, Superintendent, General Manager and E. E. Borough Electric Works, Wallingford, Conn. Mar. 28, 1902

PIERCE, GEORGE ALBERT, JR., Assistant Supt. of Electrical Department, William Cramp & Sons, Philadelphia, Pa. May 19, 1903

PIETSCH. JAMES ANDERSON, Chief Engineer, The San Juan Light and Transit Co., San Juan, Porto Rico. May 19, 1903

PIETCZKER, EZRA JAMES, Salesman, Standard Underground Cable Co., 322 The Rookery, Chicago, Ill. Apr. 23, 1903

PIKLER, ARMIN HENRY, Engineer, Stanley Electric Mfg. Co., Pittsfield, Mass. Mar. 27 1903.

PILLSBURY, CHAS. L., Consulting and Contracting Engineering, 343 Minnesota St., St. Paul, Minn. Aug. 13, 1897

PINSON, EMILE, General Manager Cia Explobadora de las Fuerra Hydro Electricas de San Ildefonso, Mexico City, Mex. June 19, 1903

PIRTLE, CLAIBORNE, Sales Agent for North Carolina, General Electric Co., Greensboro, N. C. Mar. 28, 1902

PITCHER, FRANK HENRY, Chief Engineer, Montreal Water and Power Co., 62 Imperial Building, Montreal, P. Q. June 28, 1901

PIZZINI, ANDREW J., General Manager, Electric Construction Co., of Virginia, Richmond, Va. Aug. 22, 1902

PLUMB, HYLON THERON, Assistant Professor Alternating Currents, Purdue University, West Lafayette, Ind. June 19, 1903

PODLESAK, EMIL, President and Manager, N. J. Eng. & Const. Co., Morristown, N. J. Jan. 23, 1903

POIRIER, ALFRED E., Manager, N. Y. & N. J. Tel. Co., 160 Market St., Newark, N. J., res., 29 W. 21st St., New York City. May 21, 1901

POMEROY, JAMES G., Western Manager, Adams Bagnall Electric Co., 309 Dearborn St., Chicago, Ill. Mar. 27, 1903

POMEROY, LEWIS ROBERTS, Special Representative Railway Dept., General Electric Co., 44 Broad St., New York City. Aug. 22, 1902

POMEROY, WILLIAM D., The Bullock Electric Mfg. Co., Cincinnati, Ohio. Mar. 22, 1899

POPE, HARRY BONFIELD, Switchboard Attendant, Lachine Rapids, Hydraulic & L. Co., 160 McCord St., Montreal, P. Q. Mar. 27. 1903

POPE, HENRY WILLIAM, American Telephone & Telegraph Co., 15 Dey St., New York City. Mar. 23, 1898

POPE, RALPH WAINWRIGHT, Secretary to the American Institute of Electrical Engineers, 95 Liberty St., New York City. June 2, 1885

PORTER, CHARLES HUNTINGTON, Chase-Shawmut Co.; res., 6 Washington St., Newburyport, Mass. Dec. 19, 1902

PORTER, H. HOBART, JR., Sanderson & Porter, 52 William St., New York; res., Lawrence, L. I. Mar. 25, 1896

PORTER, JOHN WILLIAM, Partner, Porter & Berg; res., 960 Flourney St., Chicago, Ill. Mar. 27, 1903

POTT, ARTHUR HENRY, Chief Engineer, Metropolitan Electric Tramways, Ltd., London, Eng. Nov. 22, 1901

POTTER, CARROLL, Superintendent, Electric Storage Battery Co., 19th St. and Allegheny Ave., Philadelphia, Pa. Sept. 26, 1902

POTTS, LOUIS MAXWELL, Constructing Engineer, Rowland Telegraphic Co., cor. Baltimore and Holliday Sts., Baltimore, Md. Sept. 6, 1902

POWELL, EDWIN BURNLEY, Technician, The New York Edison Co., 38th St. and First Ave., New York City. May 21, 1901

POWELL, PERCY HOWARD, *M.E.*, Bridgeport Brass Co.; res., 157 Coleman St., Bridgeport, Conn. Sept. 25, 1895

POWELSON, WILFRED VAN NEST, Government Inspector, Electrical Appliances; Lieut. U.S.N., Navy Yard, Bklyn., N.Y. Jan. 24, 1900

PRATT, ALEXANDER, Supt. H. R. T. & L. Co.,; res., Matlock Ave., near Pūkoi St., Honolulu, H. T. Jan. 23, 1903

PRATT, ARTHUR C., Electrician, Missouri River Pr. Co., Canyon Ferry, Mont. Jan. 23, 1903

PRATT, CHARLES RICHARDSON, Mechanical Engineer, Marine Engine and Machine Co., Harrison; res., Montclair, N. J. May 19, 1903

PRATT, WILLIAM HEMMENWAY, Designing Engineer, General Electric Co., res., 60 Eastern Ave., Lynn, Mass. Jan. 3, 1902

PRICE, CHAS. W., Editor, the *Electrical Review*, 13 Park Row, New York City; res., 223 Garfield Pl., Brooklyn, N. Y. Sept. 19, 1894

PRICE, EDGAR F., Works Manager, Union Carbide Co.; res., 625 Buffalo Ave., Niagara Falls, N. Y. June 27, 1895

PRICE, HAROLD WILBERFORCE, Demonstrator in Electrical Engineering, School of Practical Science, Toronto, Ont. Dec. 18, 1903

PRICE, JAMES A., Inspector, New York Board of Fire Underwriters; res., 184 27th St., Brooklyn, N. Y. Apr. 23, 1903

PRICE, NORMAN I., General Electric Co.; res., 839 Union St., Schenectady, N. Y. Feb. 28, 1902

PRINCE, FREDERICK WELLES, Superintendent of Construction, Hartford Electric Light Co.; res., 821 Broad St., Hartford, Ct. Oct. 23, 1903

PRINCE, J. LLOYD, The New York Edison Co., New York City; res., 868 Flatbush Ave. (Flatbush Station), Brooklyn, N. Y. Feb. 27, 1895

PROCTOR, THOS, L., Marine Electrical Equipment, 39 Cortlandt St., New York; res., Elmhurst, L. I., N. Y. Apr. 18, 1894

PROSSER, HERMAN A., Manager, De Lamar Copper Refining Works, Cartaret, N. J.; res., Elizabeth, N. J. Jan. 26, 1898

PROUTT, FREDERICK GEORGE, Electrical Engineer, The Memphis Light and Power Co., 46 Tate St., Memphis, Tenn. May 19, 1903

PUPIN, MICHAEL, I., Adjunct Professor in Mechanics, Columbia University; res., 280 North Broadway, Yonkers, N. Y. Mar. 18, 1890

PUTNAM, JOSEPH EDWARD, Assistant on Electrolysis, Engineering Bureau of the City of Rochester, City Hall, Rochester, N. Y. Mar. 27, 1903

PUTT, HARVEY J., Chief Electrical Operator, Manhattan Railway Co., 74th St. and East River, New York City. Mar. 27, 1903

RADLEY, GUY RICHARDSON, Foreman Meter and Testing Dept., Milwaukee Electric Railway and Light Co., Milwaukee, Wis. Sept. 25, 1903

RADTKE, ALBERT AUGUSTUS, Shattuck School, Faribault, Minn. Mar. 28, 1902

RAMSEY, JAMES C., JR., Electrical Engineer, The American Woolen Co.; res., Lawrence, Mass. Apr. 23, 1903

RANDALL, JOHN E., Cleveland Lamp Factory, cor. Mason & Beldon Sts., Cleveland, Ohio. May 7, 1889

RANDALL, KARL CHANDLER, Engineer, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. Dec. 19, 1902

RANDOLPH, L. S., Professor of Mechanical Engineering, Blacksburg, Va. Feb. 21, 1893

RANDOLPH, MERVYN PAUL, District Office Manager, Westinghouse E. & M. Co., 314 Occidental Ave., Seattle, Wash. Jan. 24, 1902

RANKINE, DE LANCY, General Manager, Sec'y and Treasurer, Tonawanda Power Co., 334 Buffalo Ave., Niagara Falls, N. Y. Mar. 27, 1903

RANKINE, WILLIAM B., 2d Vice-President and Manager Niagara Falls Power Co., Niagara Falls, N. Y. Jan. 23, 1903

RANSON, ALLEN EDWARD, Electrical Engineer, Lewiston Water & Power Co., Lewiston, Idaho. Jan. 3, 1902

RAU, OTTO MARTIN, Chief Electrician and Supt., Lighting Dept., Milwaukee Electric Railway and Light Co., Milwaukee, Wis. Feb. 27, 1903

RAY, WILLIAM D., Engineer, 123 Alger Ave.. Detroit, Mich. Sept. 27, 1892

RAYMOND, EDWARD BRACKETT, Electrical Engineer, General Electric Co., Schenectady, N. Y. May 20, 1902

REA, NORMAN LESLIE, Student in Testing Department, General Electric Co.; res., 1 Hamlin St., Schenectady, N. Y. Aug. 22, 1902

READ, ROBERT H., Patent Attorney, General Electric Co., Schenectady, N. Y. Jan. 19, 1892

REED, CHAS. J., Electrician, 3313 N. 16th St., Philadelphia, Pa. Mar. 5, 1889

REED, HARRY D., Superintendent Bishop Gutta Percha Co., 420 East 25th St., New York City; res., Newark. N. J. Sept. 19, 1894

REED, HENRY A., Secretary and Manager, Bishop Gutta-Percha Co., 422 East 25th St., New York City; res., Newark, N. J. June 4, 1899

REED, ROBERT CARTER, Superintendent of Electrical Department, Carnegie Steel Co.; res., Conneaut, Ohio. Apr. 23, 1903

REED, WALTER WILSON, Electrical Engineer, New Plant Citizen's' Electric Light and Power Co., Houston, Texas. Apr. 26, 1899

REGESTEIN, ERNEST ALBRECHT, Instructor, Lehigh University; res., 215 Wall St., South Bethlehem, Pa. May 19, 1903

REGESTER, CHARLES W., Salesman, Westinghouse Electric and Mfg. Co., 171 La Salle St., Chicago, Ill. Dec. 19, 1902

REICH, WILLIAM I., Tester of Dynamos, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. May 19, 1903

REICHENBACH, FREDERICK, Electrician, The Chesapeake and Potomac Telephone Co., Washington, D. C. May 19, 1903

REICHMANN, FRITZ, Cleveland, Ohio. Mar. 23, 1898

REID, CLARENCE ERLE, 1940 5th St., N. W. Washington, D. C. May 19. 1903

REID, EDWIN S., General Supt. and Engineer, National Conduit and Cable Co., Oxford Court, Cannon St., London, Eng. Feb. 26, 1896

REID, WILLIAM, Installing Dept., Kellogg Switchboard and Supply Co., Congress and Green Sts., Chicago, Ill. May 21, 1901

REILLY, HARRY WINNE, 81 Calle de Agiar, Havana, Cuba. Jan. 3, 1902

REILLY, JOHN C., General Supt., N. Y. & N. J. Tel. Co., 81 Willoughby St., Brooklyn, N. Y. Apr. 15, 1884

REMSCHEL, CESAR WILHELM AUGUST, Electrical Engineer, Westinghouse E & M Co., 425 Market St., San Francisco, Cal. Feb. 28, 1902

RENNARD, JOHN CLIFFORD, *A.B.*, *E.E.*, Asst. Chief Engineer, New York Telephone Co., 15 Dey St., New York City. Jan. 16, 1895

RENSHAW, CLARENCE, Electrical Engineer, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. Aug. 22, 1902

RENSTROM, FRANS OSCAR, Superintendent, The Regla Power Co., Pachuca, Mexico. Feb. 28, 1900

REPLOGLE, JAMES GILLESPIE BLAINE, Electrical Engineer, Blackwood Coal & Coke Co., Blackwood, Va. Oct. 24, 1902

REUTERDAHL, ARVID, President and Chief Engineer, The Reuterdahl Electric Co., Providence, R. I. Nov. 22, 1901

REYNOLDS, EDWARD LANDSDALE, Manager of Pennsylvania Sales Office; The Electric Storage Battery Co., Philadelphia, Pa. May 19, 1903

REYNOLDS, HARRY F., Engineer and Superintendent, Marion Light and Heating Co., 413 Glass Block, Marion, Ind. Mar. 27, 1903

REYNOLDS, LOUIS EMBLEE, Electrical Engineer; res., 524 Towne Ave., Los Angeles, Cal. Mar. 28, 1902

RHODES, FREDERICK LELAND, Electrical Engineer, American Telephone and Telegraph Co., 125 Milk St., Boston, Mass. Mar. 27, 1903

RHODES, HARRY ASP, Chief Engineer, The Colorado Telephone Co., 1447 Lawrence St.; res., 905 14th St., Denver, Colo. Mar. 27, 1903

RIBON, MARTIN GERMAN, Manager, The Mexican Gas and Electric Light Co., Ltd., 7 Santa Clara, Mexico City, Mex. May 19, 1903

RICE, ARTHUR, Engineer, The New York Telephone Co., 30 Gold St.; res., 453 W. 117th St., New York City. Mar. 27, 1903

RICE, ARTHUR LOUIS, Managing Editor, *The Engineer*, Publishing Co., 355 Dearborn St., Chicago, Ill. Oct. 21, 1896

RICE, MARTIN P., Chief of Publication Bureau, General Electric Co., Schenectady, N. Y. May 21, 1901

RICH, DANIEL HENRY, Engineer, North Platte, Nebraska. Mar. 27, 1903

RICH, EDWARD BURWELL, Salesman, Westinghouse Electric and Mfg. Co., 120 Broadway, New York City. June 19, 1903

RICH, FRANCIS ARTHUR, Manager, Woodstock G. M. Co., Karangahake, Auckland, New Zealand. Jan. 20, 1897

RICHARDSON, HARRY WEBB, Engineer in Meter Department, General Electric Co., Lynn; res., Beachmont, Mass. Apr. 23, 1903

RICHARDSON, THOMAS SMITH, Member of Engineering Corps, Denver Gas and Electric Co., Denver, Colo. Mar. 27, 1903

RICHEY, ALBERT S., Electrical Engineer, Indiana Union Traction Co., 213 West 9th St., Anderson, Ind. May 18, 1897

RICHTBERG, HERMANN ANDREAS, Electrical Engineer, Westinghouse Electric & Mfg. Co., Newark Works, Newark, N. J. Sept. 27, 1901

RIDEOUT, ALEXANDER C., *LL.D.*, Consulting Elec. and Mech. Engineer, Rideout & Gage, 101 Randolph St., Chicago, Ill. Aug. 5, 1896

RIPLEY, WM. HOWE, res., 17 W. 123d St., New York City. Feb. 17, 1897

RITCHIE, THOMAS EDWARD, Business Manager, Royce, Ltd.; res., Didsbury, Manchester, Eng. May 20, 1902

RITSCHY, LEWIS JOHN, Assistant Superintendent, Station A, Laclede Gas Light Co., Main St., St. Louis, Mo. Dec. 18, 1903

RITTENHOUSE, WALTER B., Mechanical Engineer, Great Northern Power Co., 315 Providence Building, Duluth, Minn. Sept. 25, 1903

RIVET, ANTOINE RUSH ,Financial and Commercial Editor, *Globe-Democrat;* res., 7511 Pennsylvania Ave., St. Louis, Mo. May 19 ,1903

ROBB, GEORGE C., Erecting Engineer, Stanley Elec. Mfg. Co., Pittsfield, Mass. Jan. 23, 1903

ROBBINS, CHARLES, Salesman, Westinghouse Electric and Mfg. Co., 120 Broadway, New York City; res., Montclair, N. J. Apr. 23, 1903

ROBBINS, PERCY ARTHUR, Consulting Mech. & Elec. Engineer, De Beers Consolidated Mines Ltd., Kimberley, Cape Colony, S.A. June 19, 1903

ROBERSON, OLIVER R., Electrician, Glen Ridge, N. J. Dec. 20, 1893

ROBERTS, ALLEN DAVIDSON, Electrician, 12½ King St., Kingston, Jamaica, West Indies. Nov. 22, 1899

ROBERTS, SHELDON, Inspector, Columbus Edison Co., res.; 137 W. Goodall St., Columbus, Ohio. Feb. 27, 1903

ROBERTS, THOMAS MAYO, Mechanical Draughtsman and Electrical Engineer, Gen. Elec. Co., 84 State St., Boston, Mass. Dec. 19, 1902

ROBERTSON, JAS. MCCALLUM, Superintendent, Power Department, Montreal Light, Heat and Power Co., Montreal, P. Q. Apr. 26, 1901

ROBINSON, ALMON, Webster Road, Lewiston, Me. Sept. 6, 1887

ROBINSON, ARTHUR L., Manager, Eclipse Mine, Auburn, Placer Co., Cal. May 15, 1900

ROBINSON, DWIGHT PARKER, Assistant General Manager, The Seattle Electric Co., 907 First Ave., Seattle, Wash. Sept. 25, 1895

ROBINSON, FRANCIS GEORGE, With Interurban Railway Co.; res., 312 West 113th St., New York City. Nov. 21, 1894

ROBINSON, GEO. P., Pacific States Telephone and Telegraph Co., 216 Bush St., San Francisco. May 16, 1899

ROBINSON, JOHN KNOWLTON, Agent, West Coast of South America, Westinghouse Elec. and Mfg. Co., Iquique, Chili, S. A. Sept. 26, 1902

ROBINSON, LAFOREST GEORGE, Engineer and Inspector in charge of Terminal Station, Shawinegan W. P. Co., Montreal, P. Q. Feb. 27, 1903

ROCHE, PERCY, Electro Manganese Co., Ltd., Shawinigan Falls, P. Q. Mar. 27, 1903

ROCKWOOD, DWIGHT CARRINGTON, Electrical Engineer, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. Mar. 22, 1901

RODGERS, ASHMEAD GRAY, Assistant Superintendent, The Carborundum Co., Niagara Falls, N. Y. Sept. 27, 1901

ROEBLING, FERDINAND W., Manufacturer of Electrical Wires and Cables, Trenton, N. J June 8, 1887

ROEDING, HENRY ULRICH, Sales Engineer, Jno. Martin & Co., 691 New Montgomery St., San Francisco, Cal. Sep. 25, 1903

ROEHL, CHARLES EDWARD, Electrical Engineer, Brooklyn Rapid Transit Co., 168 Montague St., Brooklyn, N. Y. Jan. 23, 1903

ROETTINGER, ED. MARSH, Night Foreman Test Department, Bullock Electric Mfg. Co., Cincinnati, Ohio. Feb. 27, 1903

ROGERS, JOHN JAMES ROBERT CHARLES, Electrical Engineer, Lighting Station, Yaralla Concord, Sydney, N. S. W. May 19, 1903

ROGERS, NELSON W., Electrician, Cooper-Hewitt Laboratory, Madison Square Garden Tower, New York City. May 21, 1901

ROLF, ARTHUR F., Sales Engineer, Bullock Electric Mfg. Co., St. Paul Building, New York City. Feb. 27, 1903

ROOKE, THOMAS, Resident Engineer, Messrs. Preece & Cardew, Town Hall, Sydney, N. S. Wales. Jan. 23, 1903

ROPER, DENNEY W., Electrical Engineer, Chicago Edison Co., 139 Adams St., Chicago, Ill. June 6, 1893

RORTY, MALCOLM CHURCHILL, Assistant to Traffic Engineer, American Tel. and Tel. Co., 125 Milk St., Boston, Mass. Mar. 27, 1903

ROSEBRUGH, THOMAS REEVE, Professor of Electrical Engineering, University of Toronto, Toronto, Ont. June 26, 1891

ROSENBAUM, WM. A., Attorney in Patent Cases, Nassau-Beekman Building, 140 Nassau St., New York City. Jan. 3, 1889

ROSENBERG, E. M., *M.E.*, 138 W. 85th St., New York City. Oct. 21, 1890

ROSENBLATT, GIRARD B., Engineering Student, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. Mar. 27, 1903

ROSENBUSCH, GILBERT, Royal Societies Club, London, Eng. Sept. 28, 1898

ROSENQUEST, EUGENE H., President and General Manager, the Bronx Gas and Electric Co., Westchester, N. Y. Mar. 27, 1903

ROSENTHAL, LEON WALTER, Electrical Engineer, Columbia University; res., 240 West 137th St., New York City. Aug. 22, 1902

ROSS, TAYLOR WILLIAM, Newport News Shipbuilding and Dry Dock Co.; res., 3114 West Ave., Newport News, Va. Mar. 25, 1896

ROSSI, HAROLD J., San Marten Texmelucan, Ede Pueblo, Mexico. Oct. 24, 1900

ROSSMAN, JAMES G., President B. R. Electric Co., 52 Peachtree St., Atlanta, Ga. Sept. 25, 1903

ROUGH, GEORGE CRUIKSHANK, Manager Eastern Office, The Packard Electric Co., Ltd., Montreal, P. Q. Apr. 23, 1903

ROWE, BERTRAND PERRY, Detail Engineering Office, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. Oct. 20, 1903

ROWE, GEORGE CLARENCE, Electrical Engineer, Cia de Electridad de Cuba, Aguiar 81, Havana, Cuba. Feb. 27, 1903

ROWLAND, ARTHUR JOHN, Professor of Electrical Engineering, Drexel Institute; res., 4510 Osage Ave., Philadelphia, Pa. Sept. 19, 1894

ROWLAND, HERBERT RAYMOND, Engineering Department, Philadelphia Rapid Transit Co., Philadelphia, Pa. Sept. 26, 1902

ROYSE, WALTER A. President Rovse & Batley, 16 E. Market St., Indianapolis, Ind. May 19, 1903

RUCKER, BENJAMIN PARKS, Electrical Designer and Draftsman. Westinghouse E. & M. Co., Pittsburg, Pa. July 28, 1903

RUCKGABER, ALBERT FELIX, Rapid Transit Subway Construction Co., Park Row Building, New York City. Nov. 22, 1901

RUEBEL, ERNST, Engineer, Ruebel Schwettmann Wells, 301 Chemical Building; res., 4649 Cottage Ave., St. Louis. Mo. Apr. 23, 1903

RUFFNER, CHARLES SHUMWAY, Electrician, The Telluride Power Co.; res., Telluride, Colo. Feb. 28, 1902

RUFO, HENRY NIMIS, Traffic Department, The New York and New Jersey Telephone Co., 18 Cortlandt St., New York City. Mar. 27, 1903

RUGG, WALTER S., Engineer, Westinghouse Elec. & Mfg. Co., 11 Pine St.; res., 225 W. 83d St., New York City. Mar. 28, 1902

RUSHMORE, SAMUEL W., Proprietor, Rushmore Dynamo Works, 629 South Ave., Plainfield, N. J. Mar. 28, 1903

RUSSEL, EDGAR, Captain Signal Corps, U. S. A., War Department, Washington, D. C. Nov. 22, 1901

RUSSELL, GEORGE WILLIAM, JR., Electrical Engineer and Contractor, Russell & Co., 500 5th Ave., New York City. Jan. 23, 1903

RUSSELL, H. A., Sales Agent, General Electric Co., res.; 302 Laurel St., San Francisco, Cal. Nov. 22, 1899

RUSTIN, HENRY, Chief Electrical and Mechanical Engineer of World's Fair, St. Louis, Mo. Oct. 24, 1900

RUTHERFOORD, BRABAZON, Electrical Engineer, The Allegheny County Light Co.; res., 6327 Howe St., Pittsburg, Pa. July 25, 1902

RYAN, WALTER D'ARCY, Engineer, General Electric Co., Lynn, Mass. Jan. 24, 1902

RYDER, M. P., Supt. of Bronx Dist., New York Edison Co., 140th St. and Rider Ave., New York City. May 21, 1901

RYERSON, WM. NEWTON, Supt. Substations, Manhattan Railway Co., 215 W. 100th St., New York City. Aug. 23, 1899

RYPINSKI, MAURICE CHARLES, Superintendent of Factory, Empire Electrical Instrument Co., 654 Hudson St., N. Y. City. Mar. 27, 1903

SACCAGGIO, PIETRO CELESTINO, Leading Draftsman, Estacion Tallero (F. C. Sud), Dept. Locomotora, Buenos Aires, A. R. June 19, 1903

SAGE, DARROW, with J. E. Lewis, Ruggery Building, Columbus, Ohio Sept. 27, 1901

SAGE, FREDERICK BRITTAIN, Room 1302 Havemeyer Building, New York City. May 21, 1901

SAHULKA, DR. JOHANN, Docent of Electrotechnics, Technische Hochschule Vienna, Austria. Dec. 20, 1893

SAMMETT, MATTHEW ALEXANDER, Electrical Engineer, Lachine Rapids Hyd. & Land Co., 160 McCord St., Montreal, P. Q. Mar. 27, 1903

SAMPSON, GEORGE HENRY, JR., 595 Madison St., Portland, Ore. Dec. 19, 1902

SANBORN, FRANCIS N., 47 Brevoort Pl., Brooklyn, N. Y. Nov. 24, 1891

SANDBORGH, OLOF, ALFRED, Engineer, Westinghouse E. & M. Co., Pittsburg, Pa.; res., East Orange, N. J. Mar. 27, 1903

SANDERSON, EDWIN N., Of Sanderson & Porter, Engineers and Contractors 52 William St., New York City. Oct. 17, 1894

SANFORD, EARL L., Apprentice, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. Apr. 23, 1903

SANFORD, GEORGE EDWIN, Electrician, General Electric Co.; res., 19 Hanover St., Lynn, Mass. Apr. 23, 1903

SANGSTER, JOSHUA, Hamilton Electric Light and Cataract Power Co., St. Catharines, Ont. Jan. 23, 1903

SANVILLE, HENRY F., Electric Railway Material, 710 Girard Trust Building, Philadelphia, Pa. Feb. 28, 1901

SARENGAPANI, T. S., Head Draftsman, P. W. Karantattamkndy, Tanjore, Madras, India. Mar. 27, 1903

SARGENT, HOWARD R., Electrical Engineer General Electric Co., res.; 409 Union St., Schenectady, N. Y. Mar. 25, 1896

SATHERBERG, CARL HUGO, Chief Engineer, The Midvale Steel Co., Nicetown Philadelphia, Pa. Aug. 5, 1896

SAWIN, GEORGE ALFRED, Assistant Engineer, Meter Department, General Electric Co.; res., 41 Market Sq., Lynn, Mass. Apr. 23, 1903

SAWYER, BURTON MANSFIELD, Electrical Engineer, Westinghouse Electric and Mfg. Co.; res., 5811 Rippey St., Pittsburg, Pa. Nov. 20, 1903

SAWYER, WILLETS HERBERT, Engineer, Railway Engineering Department General Electric Co., Schenectady, N. Y. Feb. 28, 1902

SAXELBY, FREDERICK, Electrical Engineer, Bullock Electric Mfg.Co., 220 Broadway, New York: res., East Orange, N.J. June 5, 1888

SAYLOR, FREDERICK ALEXANDER, c/o Charles G. Thrall, 15 O'Reilly St. [Life Member.] Havana, Cuba. Jan. 24, 1900

SCARFE, GEORGE, Division Superintendent, California Gas and Electric Co., Nevada City, Cal. Sept. 25, 1903

SCARLETT, WILLIAM, Supervising Engineer, Eastern Electric Construction Co., of Phil.; res., 133 1st St., Troy, N. Y. July 28, 1903

SCHARF, HENRY WARREN, Engineering Department, Interurban Street Railway Co., 621 Broadway, New York City. July 28, 1903

SCHIAFFINO, MARIANO L., Chief Electrician, Compania de Luz Electrica, Guadalajara, Mexico. Feb. 28, 1900

SCHILDHAUER, EDWARD, Engineering Department, Chicago Edison Co., 139 Adams St.. Chicago, Ill. Nov. 22, 1901

SCHLOSSER, FRED. G., General Manager, Citizen's Light and Transit Co., Pine Bluff, Ark. Sept. 22, 1891

SCHLUEDERBERG, CARL GEORGE, 4203 Fifth Ave., Pittsburg. Pa. July 25, 1902

SCHLUSS, KURT, Electrical Engineer, Tacoma Railway and Power Co., Box 700, Tacoma, Wash. Feb. 27, 1903

SCHMID, ERNEST E., Arc Lamp Expert, General Incandescent Light Co., 51 Perin Building, Cincinnati, Ohio. Mar. 27, 1903

SCHMIDT, CHAS. J., Patent Solicitor, with Charles A. Brown, Attorney, 1450 Monadnock Building, Chicago, Ill. Jan. 9, 1901

SCHMIDT, HENRY FREDERICK, Student, Columbia University; res., 60 West 94th St., New York City. May 20, 1902

SCHMIDT, LAMBERT, President, The Lambert Schmidt Tel. Mfg. Co., 85 Maple St., Weehawken, N. J. Nov. 22, 1901

SCHMIDT, LOUIS MILTON, Engineer Alternating Department, General Electric Co.; res., 76 New Park St., Lynn, Mass. May 19, 1903

SCHMIDT, WALTER, Mechanical Engineer, Westinghouse Electric and Mfg. Co.; res., 4953 Center Ave., Pittsburg, Pa. Apr. 23, 1903

SCHMITT, FREDERICK E., Associate Editor, *Engineering News*, 220 Broadway, New York City. Nov. 20, 1903

SCHNUCK, EDWARD FREDERICK, General Superintendent, Arbuckle Bros.; res., 119 E. 19th St., Brooklyn, N. Y. Feb. 27, 1903

SCHÖNHEIDER, RUDOLPH CHARLES, Chicago, Burlington and Quincy R. R.; res., Highwood, Minn. Apr. 23, 1903

SCHOOLFIELD, FRANK ROBERT, Chief Engineer, Baltimore Smelting and Rolling Co., Canton, Baltimore, Md. May 16, 1899

SCHRAMM, ADOLPH WILLIAM, Assistant Professor of Electrical Engineering, University of Penn., Philadelphia. Pa. Apr. 23, 1903

SCHREIBER, HERMAN VICTOR, Chief Engineer, Augusta Railway and Electric Co., Augusta, Ga. Sept. 25, 1903

SCHREIBER, MARTIN, Assisting Engineer, Public Service Corporation of New Jersey, 29 Exchange Pl., Jersey City, N. J. Apr. 23, 1903

SCHRENK, ARNOLD, Tester, General Electric Co.; res., 243 Union St., Schenectady, N. Y. June 19, 1903

SCHUCHARDT, RUDOLPH FREDERICK, Electrical Engineer in Testing Laboratory, Chic. Edison Co., 139 Adams St., Chicago, Ill. Apr. 23, 1903

SCHUETZ, FREDERICK FABER DU FAUR, Student, Stevens Institute of Technology, Hoboken; res., Newark, N. J. Mar. 27, 1903

SCHUM, CHAS. H., Electrical Engineer, Storey Motor and Electric Co., Harrison, N. J.; res., 216 3d Ave., New York City. Feb. 23, 1898

SCHURIG, EDWARD F., City Electrician, The City of Omaha, 306 City Hall, Omaha, Neb. Apr. 26, 1899

SCHWAB, MARTIN C., Electrical Engineer, with Northern Electric Co., 15 South St; res., 1729 Madison Ave., Baltimore, Md. Nov. 18, 1896

SCHWABE, WALTER P., Supt. Rutherford Dist, The Gas and Electric Co., of Bergen Co., Rutherford, N. J. May 19, 1896

SCHWARTZ, CARL, Electrical Engineer, Chicago Edison Co., 139 Adams St.; res., 1411 Windsor Ave, Chicago, Ill. Feb 27, 1903

SCHWARZ, ELMER H., Electrical Engineer, Board of Patent Control, 120 Broadway, New York City. Dec. 18, 1903

SCHWAUHAUSSBR, FREDERICK, JR., Clerk, Charles Beseler Co.; 251 Centre St., New York City. Mar. 27, 1903

SCHWEITZER, EDMUND OSCAR, Testing Laboratory, Chicago Edison Co., 139 E. Adams St.; res., 672 Fullerton Ave., Chicago. Feb. 15, 1899

SCHWENNICKE, PAUL H., Chr. Manager of Berginhe Electric Works; res., 129 Croneuberger Sts., Solingen, Germany. May 19, 1903

SCHWERMER, FELIX THEODOR, Construction Engineer, General Electric Co., Schenectady, N. Y. Feb. 27, 1903

SCOFIELD, EDWARD H., Electrical Engineer Twin City Rapid Transit Co., 2700 Blaisdell Ave., Minneapolis, Minn. May 19, 1903

SCOTT, ARTHUR CURTIS, Professor of Electrical Engineering, University of Texas, Austin, Texas. June 19, 1903

SCOTT, JAMES CROMBIE, Manager Borough Electrical Works, Gore, Otago, New Zealand. July 19, 1903

SCOTT, QUINCY ADAMS, Electrical Engineering Department, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. Dec. 19, 1902

SCOTT, ROBERT JULIAN, Professor of Engineering and Electricity, New Zealand University, Christchurch, N. Z. Oct. 24, 1902

SCOTT, WM. M., Electrical Engineer, The Cutter Electric and Mfg. Co., 19th and Hamilton Sts., Philadelphia, Pa. June 23, 1897

SCRIBNER, CHARLES E., Engineer, Western Electric Co., 259 South Clinton St., Chicago, Ill. Mar. 28, 1902

SCRUBY, ROBINETT, Electrician, Western Electric Co.; res., 443 Washington Boulevard, Chicago, Ill. Apr. 23, 1903

SCUDDER, HEWLETT, JR., Wendell Ave. & Douglas Road, Schenectady, N. Y. Nov. 22, 1899

SEABROOK, HENRY HAMILTON, Office, Westinghouse E. & M. Co., Continental Trust Building, Baltimore, Md. Jan. 24, 1902

SEAMAN, EDWIN HOPKINS, Student, Polytechnic Institute, Brooklyn; res., Wantagh, Long Island, N. Y. Mar. 27, 1903

SEAMAN, JOSEPH B., Chief of Testing Dept., Philadelphia Electric Co., 122 Arch St., Philadelphia, Pa. May 19, 1903

SEARING, LEWIS, Vice-President and General Manager, Denver Engineering Works, Co., 901 East Tenth Ave., Denver, Colo. Apr. 3, 1888

SEARLES, A, L., Electrical Engineer, Fort Wayne Electric Works, 222 Houseman Building, Grand Rapids, Mich. Apr. 18, 1894

SEDGWICK, C. E., Agent, Fort Wayne Electric Works, 623 Marquette Building, Chicago, Ill. Feb. 23, 1898

SEE, ALONZO B., A. B. See Electric Elevator Co., 220 Broadway, New York City; res., Lake Mahopac, N. Y. Jan. 17, 1893

SELDEN, ANDREW KENNETH, JR., Assistant Engineer, Crocker-Wheeler Co., Ampere; res., East Orange, N. J. Apr. 23, 1903

SEMENZA, GUIDO, Chief Electrical Engineer, Italian Edison Co., of Milan 4 Via Paleocapa, Milan, Italy. May 20, 1902

SEMPLE, BERT ERNEST, Meter Expert, General Electric Co.; res., 408 East 43d St., Chicago, Ill. Nov. 21, 1902

SENSTIUS, SEBASTIAAN, Electrical Engineer, Bullock Electric Mfg. Co. Cincinnati, Ohio. Feb. 27, 1903

SERRELL, LEMUEL WM., Mechanical and Electrical Engineer, 99 Cedar St., New York City; res., Plainfield, N. J. Nov. 1, 1887

SESSIONS, EDSON OLIVER, Sales Engineer, Stanley E. Mfg. Co., Monadnock Block, Chicago, Ill. Mar. 28, 1902

SESSIONS, FRANK LORD, Mechanical and Electrical Engineer, The Jeffrey Mfg. Co., Columbus, Ohio. Nov. 21, 1902

SESSIONS, WALTER SAMUEL, Operator, The Pacific Electric Railway Co.; res., 618 So. Bonnie Brae St., Los Angeles, Cal. Sept. 25, 1903

SHAAD, GEORGE CARL, Instructor in Electrical Engineering Department, University of Wisconsin, Madison, Wis. Feb. 27, 1903

SHAFFNER, S. C., Supt. and Electrician, Electric Lighting Co., of Mobile, 305 St. Anthony St., Mobile, Ala. Aug. 13, 1897

SHARP, CLAYTON HALSEY, Test Officer, Lamp Testing Bureau, 80th St. & East End Ave., New York City; res., Newark, N. J. Feb. 28, 1902

SHARP, FREDERICK BASSETT, Manager, The Liberty Light and Power Co., Liberty, N. Y. May 19, 1903

SHAW, ALBION WALKER, Electrical Engineer with Stone & Webster, 84 State St., Boston; res., 25 Pierce St., Malden, Mass. Oct. 19, 1902

SHAW, ALONZO BENJAMIN, Electrician, Edison Electric Illuminating Co., of Boston; res., 46 Barry St., Dorchester, Mass. Sept. 25, 1903

SHAW, AUBREY NORMAN, Draftsman, A. B. See Electric Elevator Co.; res., 298 Carlton Ave., Brooklyn, N. Y. Mar. 28, 1900

SHAW, HOWARD BURTON, Professor Electrical Engineering, Missouri State University, Columbia, Mo. Apr. 28, 1897

SHEARER, J. HARRY, Electrical Engineer, National Electric Light Co., Mexico City, Mexico. Jan. 24, 1900

SHELDON, EDWARD ELLIS, Superintendent, F. L. Frost, 47 Hudson Ave., Albany, N. Y. Apr. 25, 1902

SHELDON, SIDNEY ROBEY, Professor of Electrical Engineering, University of Idaho, Moscow, Idaho. Nov. 21, 1902

SHEPARD, ROBERTO R., Erecting Engineer, Mexican General Electric Co., Mexico, Mex. Jan. 24, 1900

SHEPHERD, FRANK ROLAND, Assistant Engineer and Business Manager, Noyes Brothers; res., Roslyn, Dunedin, N. Z. Sept. 25, 1903

SHERWOOD, EDGAR F., Superintendent of Traffic, New York Telephone Co., 122 E. 18th St.; res., East Orange, N. J. Mar. 28, 1902

SHERWOOD, IRVING HOWARD, Electrical Engineer, E. P. Roberts & Co. 603 Electric Building, Cleveland, Ohio. May 19, 1903

SHIPMAN, BENNET CARROLL, Construction Engr., Westinghouse Elec. & Mfg. Co., Montreal, P. Q. Jan. 23, 1903

SHOCK, THOS. A W., Electrical Engineer, York Haven Water and Power Co.; res., 224 Carlisle Ave., York, Pa. Mar. 20, 1885

SHUSTER, JOHN WESLEY, Instructor in Electrical Engineering, University of Wisconsin, res., 235 W. Gilman St., Madison, Wis. Jan. 3, 1902

SIBLEY, ROBERT, Professor, Mechanical Engineering Department, University of Montana, Missoula, Mont. Oct. 23, 1903

SIEBERT, ALGERNON T., Experimentalist, Pyro Electric Co., 162 Alden St., Orange, N J. May 20, 1902

SIEGFRIED, JOSEPH HENRY, Union Electric Light and Power Co., St. Louis, Mo Nov. 20, 1903

SIGOURNEY, WILLARD HENRY, Assistant in Electrical Laboratory, Pratt Institute, Brooklyn, N. Y. Mar. 27, 1903

SILVER, EARL D., Student, Purdue University, 1806 Arrow Ave., Indianapolis; res., 212 North St., West Lafayette, Ind. May 19, 1903

SIMON, ARTHUR, Electrical Engineer, Cutler-Hammer Co., 309 21st St., Milwaukee, Wis. Sept. 25, 1903

SIMONS, IÖN, City Electrician, Charleston, S. C. June 19, 1903

SIMONTON, MARK, General Manager and Treasurer, the Electric Supply and Construction Co., Columbus, Ohio. Mar. 27, 1903

SIMPSON, ALEXANDER B., Electrical Engineer, 126 E. 41st St., New York City. May 21, 1891

SIMPSON, ERNEST LEE, Electrical Engineer, The Mexican Gas and Electric Light Co., Santa Clara, No. 7, Mexico, Mex. Sept. 27, 1901

SIMPSON, J MANLEY, Minneapolis Steel and Machinery Co., Minneapolis Minn Jan. 25, 1899

SIMPSON, THOMAS T., Gen. Supt., The Capital Power Co., Ltd., Deschenes, Que. Jan. 23, 1903

SIMPSON, WILL HOSEA, Traffic Chief, Western Union Telegraph Co., Denver, Colo. Mar. 27, 1903

SINCLAIR, ANGUS, Editor and Publisher, *Railway and Locomotive Engineering*, 174 Broadway, New York City. Dec. 18, 1903

SINCLAIR, JOHN J., Engineer, Westinghouse E. &. M Co., Pittsburg, Pa. Jan. 23, 1903

SINCLAIR, LINDLEY EDGAR, General Superintendent, Potomac Electric Power Co.; res., 3318 O St., Washington, D. C. July 28, 1903

SISE, CHARLES F., President, Bell Telephone Co., of Canada, Montreal, Can. June 8, 1887

SKELDING, ARTHUR BERTRAM, General Manager, Consolidated Railways Light and Power Co., Wilmington, N. C. June 19, 1903

SKIRROW, JOHN F., Electrician, Postal-Telegraph Cable Co., 253 Broadway, New York City; res., East Orange, N. J. Sept. 25, 1895

SLADE, ARTHUR J. *Ph.D.*, Mechanical Engineer, Grand Central Station, New York City; res., 47 E. 58th St., New York City. Sept. 19, 1894

SLATER, FREDERICK R., Electrical Engineer, 2415 Park Row, Building New York City; res., 14 Arthur St., Yonkers, N. Y. Oct 17, 1894

SLOAN, JAMES RICHARD, Electrician, Motive Power Dept., P. R. R., Altoona, Pa.: res., 607 West 61st Pl., Chicago, Ill. Feb. 28, 1902

SLOANE, THOMAS O'CONOR, JR., Assistant in Electrical Engineering, Columbia University, New Yok City. Oct. 23, 1903

SMETHURST, WILLIAM ARTHUR, Smethurst & Allen, North American Building, Philadelphia, Pa.; res., Washington, D. C. May 19, 1903

SMITH, DOW S., General Superintendent, Brooklyn Rapid Transit Co., Brooklyn, N. Y. July 28, 1903

SMITH, EMOR A., Wire Chief, Southern N. E. Telephone Co.; res., 130 Capitol Ave., Hartford, Conn. Dec. 18, 1903

SMITH, FRANCIS C., Gen. Supt. Harry Alexander, 18 West 34th St.; res., 912 Home St., New York City. Jan. 23, 1903

SMITH, FRANK WARREN, Superintendent, The Cutler-Hammer Mfg. Co., 20 Charles St., Westfield, N. J. Sept. 27, 1901

SMITH, FREDERICK B., Electrical Specialties, 170 Summer St., Boston, Mass. July 26 1900

SMITH, HARRISON ARTHUR, Salesman, General Electric Co., Fowler, Ind. Apr. 23. 1903

SMITH, HAYDEN HOBART, Manager, New York Office, The Thresher Electric Co., 8 Battery Pl., New York City. Dec 19, 1902

SMITH, HOWARD F., Assistant Mechanical Engineer, World's Fair: res., 1121 Whittier St., St. Louis, Mo. Apr. 23. 1903

SMITH, IRVING B., Partner, The Wirt Electric Co., 180 Broadway, New York City. May 15, 1900

SMITH, IRVING WILLIAMS, Electrician, Bishop Gutta Percha Co., 420 E. 25th St.; res., 5 W. 90th St., New York. Jan 9 1901

SMITH, JOSEPH ALLAN, Manager Boston Office, Fort Wayne Electric Works, 518 Exch. Bldg., Boston; res. Newton, Mass. Jan. 23. 1903

SMITH, J. BRODIE, General Manager, Manchester Traction, Light and Power Co., 46 Hanover St., Manchester, N. H. Mar. 21, 1894

SMITH, JAMES NORMAN, Electrical Engineer, Lachine Rapids Hydraulic and Land Co., 160 McCord St., Montreal, P. Q. Mar. 27, 1903

SMITH, JOHN HAYS, Engineering Department, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. Mar. 27, 1903

SMITH, JULIAN CLEVELAND, Superintendent, Shawinigan Water and Power Co. 1724 Nôtre Dame St., Montreal, P. Q. Nov. 20, 1903

SMITH, LOUIS CLARENCE, Foreman of Meter Wiremen, etc., Edison Electric Light Co., of Philadelphia; res. Woodbury, N. J. Apr. 23. 1903

SMITH, OBERLIN, President and Mechanical Engineer, Ferracute Machine Co., Lochwold, Bridgeton, N. J. May 19, 1891

SMITH, SAMUEL JAMES, Salesman and Installing Engineer, Crocker-Wheeler Co., 202 North Tryon St., Charlotte, N.C. Oct. 24, 1900

SMITH, SAMUEL NEWTON, President, North Shore Reduction Co., Ltd., of Ontario, 424 Andrus Building, Minneapolis, Minn. Oct. 25, 1901

SMITH, SAMUEL WILLIAM, Stores Department, Montreal Light, Heat and Power Co.; res., 49 Walker St., Montreal, P. Q. Sept. 27, 1901

SMITH, T. JARRARD, Manufacturers and Inventors' Electric Co., 96 Fulton St., New York City; res., Roselle, N. J. Apr. 19, 1892

SMITH, WALTER EUGENE, Electrician, The Unitd States Navy Departtment, Midvale Steel Works, Philadelphia, Pa. Feb. 28, 1900

SMITH, WALTER F., General Manager, United Gas Improvement Co.; res., 2010 Ontario St., Philadelphia, Pa. July 26, 1900

SMITH, WM. LINCOLN, Consulting Electrical and Illuminating Engineer; Concord, Mass. July 18, 1899

SMITH, WILLIAM NELSON, Electrical Engineer, Westinghouse, Church, Kerr & Co., 8 Bridge St., New York City. Mar. 28, 1902

SMITH, WM. STUART, U. S. N., 2538 Dwight Way, Berkeley, Cal. July 26, 1901

SMYTHE, EDWIN HUTCHINSON, Patent Department, Western Electric Co., 259 So. Clinton St., Chicago; res., Freeport, Ill. Apr. 23, 1903

SNOW, JOHN E., Associate Professor in Electrical Engineering Department, Armour Institute of Technology, Chicago, Ill. Mar. 27, 1903

SNYDER, NATHANIEL MARION, County Surveyor for Scotts Bluff Co., Alliance, Nebraska. Nov. 23, 1900

SOLOMON, NATHAN CLARENCE, Assistant Engineer, with Harry Alexander, 25 W. 33d St., New York City. Aug. 22, 1902

SOMELLERA, GABRIEL F., Partner, Salcedo & Co., Mexico, Mex. Apr. 25, 1900

SOREN, TOWNSEND HODGES, Electrical Engineer, General Electric Co., Schenectady, N. Y. Nov. 22, 1901

SOUTHWORTH, MARTIN O., Chief Engineer, Commercial Electric Co., Indianapolis, Ind. Feb. 27, 1903

SOWERS, DAVID W., President, H. W. Dopp Co., 1300 Niagara St.; res., 67 W. North St., Buffalo, N. Y. July 18, 1899

SPAIN, HARRY GUTHRIE, Electrician to Post Office of Colony, Telegraph and Telephone, Georgetown, British Guiana. May 19, 1903

SPALDING, PHILIP LEFFINGWELL, Engineer, The Bell Telephone Co., Philadelphia, Pa. May 20, 1902

SPAULDING, PLINY P., Foreman of Experimental R. R., General Electric Co.; res., 201 Park Ave., Schenectady, N. Y. Mar. 27, 1903

SPEIRS, CHARLES EDWARD, Manager D. Van Nostrand Co., 23 Murray St., New York City; res., 2175 83d St., Brooklyn, N. Y. Dec. 19, 1902

SPELLMIRE, WALTER B., A. W. Wychoff Co., 1723 Farmers Bank Building, Pittsburg, Pa. May 21, 1901

SPENCER, CHAS. J., Electrical Engineer, with N. Y. C. & H. R. R. R. Engineering Dept., New York City. May 21, 1901

SPENCER FREDERICK FURMON, Assistant Engineer, Mexico General Electric Co. Mexico, Mex. Feb. 27, 1903

SPENCER, FRANK BENJAMIN, with William D. Ball, 1105 Merchants Loan and Trust Building, Chicago, Ill. May 19, 1903

SPENCER, HARRY B., Assistant Engineer, General Electric Co.; res., 423 Summit Ave., Schenectady, N. Y. Mar. 28, 1902

SPENCER, PAUL, Inspector of Electric Plants, United Gas Improvement Co., Broad and Arch Sts., Philadelphia, Pa. Nov. 30, 1897

SPENCER, THEODORE, With Bell Telephone Co., N. E. Cor. 11th and Filbert Sts., Philadelphia, Pa. Mar. 21, 1893

SPENCER, THOMAS, General Superintendent and Designer Helios Upton Co., 1229 Callowhill St., Philadelphia, Pa. May 19, 1903

SPENGEL, HERMANN GEORGE, General Manager, Rand Central Electric Works, Ltd., Johannesburg, Transvaal, S. A. Sept 26 1902

SPERLING, R. H., Assistant Engineer, British Columbia Electric Railway Co., Ltd.. Victoria, B. C. Nov 23, 1898

SPIER, CHARLES L., Vice-President, S. I. Midland R. R. Co., 26 Broadway, New York City. Feb 27, 1903

SPIESE, F. P., Secretary, Treasurer and Manager, the Edison Electric Illuminating Co., Tamaqua, Penn. July 26, 1900

SPINNEY, LOUIS BEVIER, Professor of Physics and Electrical Engineering, Iowa State College, Ames, Iowa. May 19, 1903

SPOEHRER, HERMANN, Laboratorian, in charge of Test Room Equipment Department, N. Y. Navy Yard, Brooklyn, N. Y. Sept 27, 1901

SPORBORG, H. N., Electrical Engineer, British Thomson-Houston Co., Rugby Eng. July 25, 1902

SPRONG, SEVERN D., Assistant Engineer of Distribution, The New York Edison Co., 55 Duane St., New York City Mar. 27, 1903

SPURLING, OLIVER CROMWELL, Factory Engineer, Western Electric Co., North Woolwich, Eng. Feb. 27, 1903

SPURRIER, JOHN RUDOLPH, The British Westinghouse E. & M Co., 295 Urmston Lane, Stretford, Manchester, Eng. Sep. 25, 1903

SQUIER, GEORGE O., CAPT., *Ph.D.*, U. S. Signal Corps, Headquarters Department of California, San Francisco, Cal. May 19, 1891

STADERMAN, ALBERT LOE, Asst. to Supt. of Equipment, City & Suburban Telegraph Association, Cincinnati, Ohio. June 19, 1903

STAFFORD, REX THOMAS, Foreman, Electrical Construction, Lackawanna Steel Co.; res., 126 Cottage St., Buffalo, N. Y. Nov. 20, 1903

STAHL, TH., Engineer 5 Cours Morand, Lyon, France. Nov. 15, 1892

STAKES, D. FRANKLIN, Electrical Engineer; res., 5372 Morris St., Germantown, Philadelphia, Pa. Jan. 20, 1897

STALBERG, SVEN OLAF, Draftsman, General Electric Co.; res., 81 N Common St., Lynn, Mass. Apr. 23, 1903

STANSEL, NUMA REID, Electrician, U. S. Navy Yard; res., 205 London St. Portsmouth, Va. Mar. 27, 1903

STARTSMAN, CHARLES WENTWORTH, Sales Department, Crocker-Wheeler Co., Ampere, N. J. June 19, 1903

STECK, ROBERT, Designing Electrical Engineer, Western Electric Co., 259 So. Clinton St.; res., 1520 Wolfram St., Chicago, Ill. Apr. 23. 1903

STEELE, J. HERBERT, Draftsman, Bullock Electric Mfg. Co., Cincinnati, Ohio. May 19. 1903

STEELE, WALTER D., Electrical Engineer, with Westinghouse, Church, Kerr & Co., 8 Bridge St., New York City. Apr. 25. 1900

ST. GEORGE, HARRY LUXMOORE, Engineering Staff, Shawinigan Water and Power Co., Montreal, P. Q. Mar. 27, 1903

STEINMETZ, EDWARD GEORGE, Asst. Supt., The Electric Storage Battery Co., 19th St and Allegheny Ave. Philadelphia, Pa. Sept. 26 1902

STEINMETZ, WILLIAM RENRICK, Construction Engineer, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. Apr. 23, 1903

STEPHENS, ARTHUR HARLAN, Engineer, 812 West Mercury St., Butte, Mont. Nov. 21, 1902

STEPHENS, CHARLES EDWIN, Armature Winder and Meter Inspector, British Columbia Electric Ry. Co., Victoria, B. C. Apr. 23, 1903

STERN, MANN, Electrical Engineer, General Electric Co.; res., 138 Glenwood Boulevard, Schenectady, N. Y. Sept. 25, 1903

STERN, PHILIP KOSSUTH, Practising Electrical and Mechanical Engineering, 140 Fulton St., N. Y. Nov. 28, 1900

STERNEFELD, ISIDORE, Manager, Electrical Department, G. & O. Braniff & Co., Callé Cadena 19, Mexico, Mex. June 19, 1903

STEUART, WILLIAM, Partner Steuart & Fenn, Auckland, N. Z. June 19, 1903

STEVENS, CABOT, Electrical Engineer, Brooklyn Edison Electric Illuminating Co., 360 Pearl St., Brooklyn, N. Y. June 28, 1901

STEVENSON, EDWARD WILLIAM, Hazard Mfg. Co.; res., 402 South River, Wilkesbarre, Pa. Mar. 27, 1903

STEVENSON, FRANCIS LESLIE, Electrical Engineer, International Harvester Co., Fullerton & Clayborne Aves., Chicago, Ill. Sept, 25, 1903

STEWART, JOHN BRUCE, Superintendent, Electric Plant, Virginia Hot Springs Co., Hot Springs, Va. Aug. 23, 1899

STICKNEY, JOSEPH WHITE, Central Union Tel. Co., Indianapolis, Ind. Mar. 27, 1903

STILWELL, TOM KENNAN PRICE, Assistant Engineer, Alternating Department, General Electric Co., Lynn, Mass. Apr. 23, 1903

STINE, WILBUR M., Professor of Engineering, Swarthmore College, Swarthmore, Pa. May 15, 1894

STITZER, ARTHUR BOWERS, Draftsman, Philadelphia Rapid Transit Co., 9th and Dauphin Sts., Philadelphia, Pa. Oct. 24, 1900

STOCKBRIDGE, GEO. H., Patent Attorney, 120 Broadway; res., 2514 11th [Life Member.] Ave., near 187th St., New York City. May 24, 1887

STOCKWELL, JOSEPH FRANCIS, General Manager, Ontario Telephone Co., cor. West 21st and Bridge Sts., Oswego, N. Y. June 19, 1903

STONE, CHARLES A., With Firm of Stone & Webster, 84 State St., Boston, Mass. May 19, 1891

STONE, CHARLES WATERMAN, Electrical Engineer, General Electric Co.; res., 18 State St., Schenectady, N. Y. Mar. 27, 1903

STONE, CHARLES LEROY, St. Louis Transit Co., St. Louis, Mo. Oct. 24, 1902

STONE, JOSEPH P., Oficina de Talleres, Ferro Carril Oeste de Buenos Aires Estacion Linieres, F. C. O., Buenos Aires, A. R. Dec. 18, 1895

STONE, WILLIAM, Electrical and Lighting Engineer, The Victoria Railway; res., 17 Doona Ave., Melbourne, Victoria. June 19, 1903

STORER, SIMON BREWSTER, Engineer and Salesman, Westinghouse Electric and Mfg. Co., 1902 University Block, Syracuse, N.Y. Apr. 25, 1902

STORKE, HENRY LAURENS, 2d Vice-President, The Empire State Telephone and Telegraph Co., 102 Genesee St., Auburn, N. Y. May 20, 1902

STOUT, JOSEPH SUYDAM, JR., Stout & Co., 25 Broad St.; res., 574 Madison Ave., New York City. Nov. 22, 1899

STOVEL, RUSSEL WELLESLEY, Electrical Engineer, Westinghouse, Church, Kerr & Co., Pittsburg, Pa. Apr. 25, 1902

STOVER, RODERICK, Albuquerque, New Mexico. Aug. 22, 1902

STRASBURGER, EDGAR, Assistant in Cable Department, Western Electric Co., 463 West St., New York City. Mar. 27, 1903

STRAUS, THEODORE E., Electrical Engineer, 13 W. Pratt St., res.; 1213 Linden Ave., Baltimore, Md. Nov. 18, 1896

STRAUSS, HERMAN, A., Consulting Electrical Engineer, Construction Co. of America, Sheyboygan, Wis. Oct. 17, 1894

STREET, GEORGE TATUM, Station Supt., Logan Power Co., Logan, Utah. Dec. 19, 1902

STRONG, JAMES REMSEN, President, The Tucker Electric Construction Co., 35 So. William St., N. Y.; res., Short Hills, N. J. Mar. 22, 1901

STRONG, RUSH PRICE, Asst. Electrician, Southeastern Tariff Assn., 643 Equitable Bldg., Atlanta, Ga. Jan. 23, 1903

STUART, HARVE R., Electrical Engineer, With W. E. & M. Co., Pittsburg; res., 524 Wallace Ave., Wilkinsburg, Pa. Jan. 25, 1901

STUEVE, CARL A. E. G., Electrical Engineer, with C. O. Mailloux, 76 William St., New York City. Apr. 23, 1903

STURDEVANT, CHAS. RALPH, Designing Engineer, The Ohio Brass Co.; res., 179 1st St., Mansfield, Ohio. May 16, 1899

STURGES, WARD LEE, Student, Polytechnic Inst., Brooklyn; res., 16 E. 8th St., New York City. Jan. 23, 1903

STURTEVANT, CHARLES L., Patent Attorney, Atlantic Building, Washington, D. C. Dec. 20, 1893

STUTZ, CHAS. C., Assistant Chief Engineer, Pittsburg Plate Glass Co., Frick Building, Pittsburg, Pa. Mar. 28, 1900

SUDLOW, HARRY, Joseph Hull & Co., Mulberry, Florida. Sept. 27, 1901

SULLIVAN, WILLIAM VAN AMBERG, JR., Mechanical and Electrical Engineer, Washington Building, Seattle, Wash. Jan. 24, 1902

SUMAN, HARRY P., Electrical and Mechanical Engineer, Baltimore Machine & Elevator Works, 603 Water St., Baltimore, Md. Aug. 22, 1902

SUMMERS, LELAND L., Electrical Engineer, 441 The Rookery, Chicago, Ill. Feb. 16 1892

SUTTER, FREDERICK C., Member, Pittsburg Transformer Co., Pittsburg, Pa. Dec. 18, 1903

SWAREN, JOHN WILLIAM, 630 Jackson Boulevard, Chicago, Ill. Apr. 23, 1903

SWEENEY, BAYARD K., Manager of Denver Sales Office, The N. Y. Insulated Wire Co., etc., 708 Equitable Blg., Denver, Col. Mar. 27, 1903

SWEETLAND, RALPH, Electrical Inspector, New England Insurance Exchange, 55 Kilby St., Boston; res., Natick, Mass. Oct. 25, 1901

SWITZER, GEORGE H., Superintendent of Construction, Morgantown Electric and Traction Co., Morgantown, W. Va. Feb. 27, 1903

SWOPE, GERARD, (*Local Secretary*) Manager, Western Electric Co., 810 Spruce St., St. Louis, Mo. Apr. 26, 1899

SYKES, FREDERICK GEORGE, Electrical Engineer, Schenectady Railway Co., Schenectady, N. Y. May 19, 1903

SYKES, HENRY H., Gen. Supt., Southern New England Telephone Co., New Haven, Conn. Oct. 18, 1893

SZUK, GEZA, Chief Engineer, Ganz & Co.; res., Csalogany utcza 52 Budapest II., Hungary. Jan. 3, 1902

TABER, SILAS, 78 South St., Auburn, N. Y. Mar. 27, 1903

TACHIHARA, JIN, Electrical Engineer, Mining Dept., Mitsu Bishi Co., Tokyo, Japan. Jan. 26, 1898

TADA, SHIGEKANE, Electrical Engineer, Imperial Japanese Navy, Takata & Co., 10 Wall St., New York City. Mar. 27, 1903

TAHL, ALFRED ROBERT, Student, Polytechnic Institute; res., 222 Carlton Ave., Brooklyn, N. Y. Apr. 23, 1903

TAIT, FRANK M., Manager, New London, Gas and Electric Co., 29 Main St., New London, Conn. Sept. 19, 1894

TALBOT, RICHMOND, Partner, firm of Sanderson & Porter, 35 William St., New York City; res., Tuxedo, N. Y. July 25, 1902

TAMLYN, WALTER IRVING, Student, Polytechnic Institute; res., 280 Van Buren St., Brooklyn, N. Y. Mar. 27, 1903

TANNATT, EBEN TAPPAN, Managing Civil and Electrical Engineer, The Oahu College Trustees, Honolulu, H. Ty. Nov. 22, 1901

TAPLEY, WALTER H., Electrician in Government Printing Office, care of Public Printer, Washington, D. C. Oct. 25, 1892

TATUM, LEWIS LEEDS, General Storekeeper, Bullock Electric Mfg. Co., Norwood, Ohio. Feb. 27, 1903

TAYLOR, ALBERT, Manager, New York Office, Electric Storage Battery Co., 100 Broadway, New York City. May 21, 1901

TAYLOR, EDWARD R., Manufacturing Chemist Penn Yan, N. Y. Jan. 23, 1903

TAYLOR, FRANK H., Westinghouse Electric & Mfg. Co.; res., 7422 Penn Ave., Pittsburg, Pa. Jan. 3, 1902

TAYLOR, IRVING A., 390 1st St., Brooklyn, N. Y. May 17, 1898

TAYLOR, JEREMY F., Ceno de Pasco Co., Ceno de Pasco, Peru. Dec. 27, 1899

TAYLOR, JOHN B., Railway Engineering Department, General Electric Co., Schenectady, N. Y. Mar. 27, 1903

TAYLOR, NEIL, Senior Partner, Neil Taylor & Co., Hunthill, Coatbridge, Scotland. Apr. 23, 1903

TAYLOR, ROBERT CAMPBELL, Assistant General Superintendent, Brooklyn Heights R.R. Co., 168 Montague St., Brooklyn, N.Y. July 28, 1903

TAYLOR, SAMUEL NEWTON, Professor Western University of Pennsylvania; res., 2206 Perrysville Ave., Allegheny, Pa. Dec. 18, 1903

TEMPLE, WILLIAM CHASE, Consulting Engineer, 1110 Farmers' Bank Bldg.; res., 1090 Shady Ave., Pittsburg, Pa May 3, 1887

TEMPLE, WORRALL E. S., Constructing Engineer, Pocahontas Collieries Co., Pocahontas, Va. Oct. 23, 1903

TEN EYCK, PETER GANSEVOORT, Assistant Engineer of Signals, N. Y. C. & H. R. R. R. Co., 25 E. 48th St., New York City. Dec. 18, 1903

TERRY, ALBERT SLOCOMB, Treas. and Manager, The Sunbeam Incandescent Lamp Co., 463 West St., New York City. Jan. 24, 1902

TERVET, ROBERT, Technical Engineer, Western Electric Co., North Woolwich, London, Eng. Sept. 27, 1901

TESLA, NIKOLA, Electrical Engineer and Inventor, Wardenclyffe, Long Island, N Y. June 5, 1888

THALER, JOSEPH AUKEN, Professor of Electrical Engineering, Montana A. & M., College, Bozeman, Mont. July 28, 1903

THAYER, GEORGE LANGSTAFF, *M.E.*, Electrical Engineer, Weirs Building, Beaumont, Texas. Aug. 5, 1896

THOMAS, ALFRED CLARENCE, Engineer, The New York & New Jersey Telephone Co., 81 Willoughby St., Brooklyn, N. Y. Feb 28, 1902

THOMAS, DAVID RADES, Supt. and Electrical Engineer, Paulius Kill Construction Power and Teleph. Co., Columbia, N. J. Apr. 23, 1903

THOMAS, JOHN WILLIAMS, Construction Engineer, Electric Storage Battery Co., Hokendauqua, Pa. Mar. 22, 1901

THOMAS, PERCY HOLBROOK, Cooper Hewitt Electric Co., 220 W. 29th St., New York City. Oct. 24, 1900

THOMAS, ROBERT MCKEAN, *E.E.*, Member firm of Thomas & Betts, 141 Broadway, New York City. Apr. 22, 1896

THOMPSON, ALFRED J., Crocker-Wheeler Co., 39 Cortlandt St., New York City Jan. 25, 1896

THOMPSON, ERMINE JOHN, 3146 Locust St., St. Louis, Mo. Jan. 25, 1901

THOMPSON, HARRISON GILMAN, JR., Electrician, Bliss Electric Car Lighting Co., 138 Front St., New York City. Feb. 27, 1903

THOMPSON, JOHN WEST, Director, Dept. de Electricidad, Cia Industrial de Guadalajara, Guadalajara, Mexico. Sept. 28, 1898

THOMPSON, MILTON T., Constructing Engineer, Mexican General Electric Co., Mexico, Mex. Jan. 24, 1900

THOMPSON, RALPH FOWLER, Electrical Engineer, The United Power Co., E. Liverpool, Ohio. Apr. 23, 1903

THOMPSON, SILVANUS P., Morland, Chislett Road, West Hampstead, London, N. W., Eng. Oct. 27, 1897

THOMPSON, THOS. PERRIN, Consulting Engineer, Neff & Thompson, Architects and Engineers, Withers Bldg., Norfolk, Va. Jan. 25, 1899

THOMPSON, WALTER LEE, Supt. Battery Dept., New York Transportation Co., 49th St. and 8th Ave., New York City. Mar. 27, 1903

THOMPSON, WARREN RAY, Assistant in Electrical Engineering Department, British Westinghouse Co., London, W.C., Eng. Oct. 24, 1900

THOMSON, CLARENCE, Fred Thomson & Co., 774 Craig St., Montreal, P. Q. May 15, 1900

THOMSON, GEO. ANDROS, Special Agent, The Adams-Bagnall Electric Co., 136 Liberty St., New York; res., Somerville, N. J. Mar. 22, 1901

THOMSON, GEORGE HUNTINGTON, Chief Engineer, American Elevated R. R. Co.; 25 Broad St., New York City. May 20, 1902

THOMSON, WILLIAM I., Assistant Engineer, Safety Car Heating and Lighting Co., New York City; res., Newark, N. J. Mar. 27, 1903

THORNTON, KENNETH BUCHANAN, Supt Line Dept., The Montreal Light, Heat and Power Co., N. Y. Life Bldg. Montreal, P. Q. Apr. 26, 1901

THURBER, GUY PLUMMER, Engineer, Salesman and District Manager, Bullock Electric Mfg. Co., Pittsburg, Pa. Feb. 27, 1903

THURBER, HOWARD F., General Superintendent, New York Telephone Co., 18 Cortlandt St., New York City. Mar. 25, 1896

THURSTON, LOUIS STEWART, General Electric Co., Perin Building, 5th and Race Sts., Cincinnati, Ohio. Aug. 22, 1902

TIDD, GEO. N., Manager, Beacon Light Co., Chester, Pa. July 26, 1900

TILLERY, PAUL ALLEN, Student, V. M. I., Lexington, Va. June 19, 1903

TIMMERMAN, ARTHUR HENRY, Supt. Wagner Electric Mfg. Co., 2017 Locust St.; res., 2633 Park Ave., St. Louis, Mo. Mar. 27, 1903

TINGLEY, E. M., Westinghouse Elec. & Mfg. Co.; res., 431 Shady Ave., Pittsburg, Pa. July 12, 1900

TISCHNER, CHARLES FREDERICK, Draftsman, Townsend & Decker; res., 878 Lafayette Ave., Brooklyn, N. Y. May 19, 1903

TOBEY, HARRY WILLARD, Member Engineering Dept, Stanley Electric Mfg. Co.; res., 40 Oxford St., Pittsfield, Mass. Sept. 27, 1901

TOERRING, C. J., C. J. Toerring Co., 19th St. and Allegheny Ave., Philadelphia, Pa. Apr. 18, 1894

TOLMAN, CHARLES PRESCOTT, Asst. Chief Engineer, National Electric Co., Milwaukee, Wis. July 28, 1903

TOLMAN, CLARENCE M., Electrical Engineer, Public Works Co., Bangor, Me. Apr. 27, 1898

TORCHIO, PHILIP, Engineer of Distribution, New York Edison Co., 55 Duane St., New York City. June 27, 1895

TOURET, MAXIME EUGENE JEAN, Consulting Electrical Engineer, 7 Rue Meyerbeer, Paris, France. Jan. 24, 1902

TOWER, GEORGE A., V. P. Tower-Binford Electric and Mfg. Co., 7 South 7th St.; res., 102 West Grace St., Richmond, Va. May 15, 1894

TOWN, FREDERIC E., Construction Dept., Otis Elevator Co., 17 Battery Place; res., 746 St. Nicholas Ave., New York City. May 15, 1900

TOWNE, EDWARD BARNES, Eastern Manager, Burdett Rowntree Mfg. Co., 17 Battery Place, New York City; res., Orange, N. J. Mar. 27, 1903

TOWNLEY, CALVERT, General Agent, Westinghouse Electric and Mfg. Co., 11 Pine St., New York City. Feb. 28, 1901

TOWNSEND, FITZHUGH, Electrical Engineer, 116th St. and Amsterdam Ave.; res., Union Club, New York City. Jan. 20, 1897

TOWNSEND, HENRY C., Attorney and Expert in Electrical Cases, 141 Broadway; res., 354 W. 123d St., New York City. July 10, 1888

TREADWAY, WILLIAM ANDREW, Instructor of Electrical Engineering, The University of Arkansas, Fayetteville, Ark. Dec. 19, 1902

TREADWELL, AUGUSTUS, JR., *E.E.*, 100 Broadway, New York City; res., 488 3d St., Brooklyn, N. Y. Feb. 21, 1894

TREAT, ROBERT BELDEN, Electrical Engineer, Crocker-Wheeler Co., Ampere; res., 214 Dodd St., E. Orange, N. J. Jan. 3, 1902

TRIPIER, HENRI, Technical Engineer of the Societé Francaise d'Incandescence par le Gaz (Systeme Auer.), Paris, France. Sept. 28, 1898

TRIPP, GEORGE BROWN, General Manager, The Colorado Springs Electric Co., Colorado Springs, Colo. Apr. 23, 1903

TRIPP, GEORGE MASON, Assistant Superintendent, British Columbia Electric Railway Co., Victoria, B. C. Dec. 19, 1902

TROTT, A. H. HARDY, Beer, near Axminster, Devonshire, Eng.
[Life Member] Jan. 20, 1891

TRUDEAU, J. A. G., 329 Kent St., Ottawa, Can. May 15, 1900

TRUESDELL, ARTHUR E., 50 Brenton Terrace, Pittsfield, Mass. Feb. 15, 1899

TUCKER, ALBERT LINCOLN, In charge Apparatus Sales Dept., Western Electric Co., 259 So. Clinton St., Chicago. May 19, 1903

TURNER, HARRY WINTHROP, Winding and Insulation Specialist, British Thomson-Houston Co., Ltd., Rugby, Eng. Nov. 20, 1903

TURNER, MATHIAS EVERETT, Electrical Engineer, Cleveland Electric Illuminating Co., 711 Cuyahoga Bldg., Cleveland, O. Feb. 27, 1903

TURPIN, MANLY CURRY, Testing Department, General Electric Co., 218 So. 11th St., Philadelphia, Pa. May 19, 1903

TUTTLE, HORACE BURT, Engineering Chemist, 727 Cuyahoga Building, Cleveland, O. Sept. 26, 1902

TYLER, VICTOR MORRIS, Secretary, The Scuthern New England Telephone Co., New Haven, Conn. Apr. 23, 1903

TYNDALL, CHARLES H., *Ph.D.*, Minister Reformed Church, 137 South Sixth Ave., Mt. Vernon, N. Y. Sept. 27, 1901

TYNG, FRANCIS E., Manager, Eastern Engineering Co., 164 W. 27th St., New York; res., Cranford, N. J. Dec. 28, 1898

UHL, ALBERT, Member of Firm, Uhl & Elliott; res., 517 Edwards St., Shreveport, La. Apr. 23, 1903

UNDERHILL, CHARLES REGINALD, Electrical Engineer, Varley Duplex Magnet Co., Phillipsdale ; res., Providence, R. I. Sept. 25, 1903

UNDERWOOD, ALVAH WARD, Electrical Draftsman and Designer, Chatham, N. Y. Mar. 27, 1903

UNDERWOOD, ARTHUR J., Foreman Electrical Department, Triumph Electric Co., 610 Baymiller St., Cincinnati, Ohio. Apr. 23, 1903

UNDERWOOD, LOUIS EDWARD, Designing Engineer, General Electric Co., West Lynn, Mass. Apr. 23, 1903

UNDERWOOD, WALTER H., Foreman Testing Floor, Triumph Electric Co., Cincinnati, Ohio; res., Bellevue, Ky. Apr. 23, 1903

UPP, JOHN W., Engineer in charge Draughting Room, General Electric Co., res., 27 Wendell Ave., Schenectady, N. Y. Mar. 27, 1903

VAIL, THEO. N., 26 Cortlandt St., New York City. Apr. 15, 1884

VALENTINE, WALTER SCOTT, Asst. Engr., Westinghouse Church Kerr & Co., 8 Bridge St., New York City. Jan. 23, 1903

VAN BUREN, GURDON C., Enginereing Department, Hudson River Telephone Co.; res., 62 South Hawk St., Albany, N. Y. Oct. 25,1892

VANCE, J. H., Mechanical Engineer, B. F. Goodrich Co.; res., 168 Westwood Ave., Akron, Ohio. Mar. 27, 1903

VAN CLEEF, ELLIOTT EARL, Assistant to Supt. of Construction, Western Electric Co., 463 West St., New York City. Mar. 27, 1903

VANDEGRIFT, JAMES A., Treas. and Manager, The Colorado Lamp Co., 2051 California St.; res., 1960 Grant Ave., Denver, Colo. Nov. 24, 1891

VANDERVEEN, ANTHONY R., Machinist, The South India Railway Co., Holland Road, Negapatam, India. Jan. 9, 1901

VAN DEVENTER, CHRISTOPHER, Stanley Electric Mfg. Co., 15 Monadnock Block, Chicago, Ill. Feb. 17, 1897

VAN DYCK, WILLIAM VAN BERGIN, Electrical Engineer and Contractor; res., 439 Manhattan Ave., New York City. Nov. 22, 1901

VANKIRK, EDWARD POWER, Electrical Engineer, Westinghouse Air Brake Co., Wilmerding, Pa. Jan. 3, 1902

VAN NORDEN, RUDOLPH WARNER, Supt. and Engineer, Central California Electric Co.; res., 1003 K St., Sacramento, Cal. Feb. 27, 1903

VAN SLYCK, C. H., Salesman, General Electric Co., 44 Broad St.; res., 80 Washington Square, E., New York City. Mar. 27, 1903

VAN VLEET, ROY MITCHELL, Chief Electrician, Columbia Iron Works, St. Clair; res., Port Huron, Mich. Mar. 22, 1901

VAN WYCK, PHILIP V. R., JR., New York Telephone Co., 15 Dey St., res., Plainfield, N. J. Apr. 21, 1891

VARNEY, FRANK H., Electrician, San Francisco Gas and Electric Co., 2912 Mission St., San Francisco, Cal. July 26, 1900

VARNEY, WILLIAM WESLEY, City Commissioner of Baltimore, office, City Hall; res., 712 N. Carey St.. Baltimore, Md. Nov. 21, 1894

VAUGHAN, JOHN FAIRCHILD, General Engineer, Stone & Webster, 84 State St., Boston; res., 30 Walker St., Cambridge, Mass. Feb. 27, 1903

VENABLE, WM. MAYO, The National Contracting Co., 713 Hennen Bldg., New Orleans, La. Nov. 30, 1897

VESER, LUCIUS OTTO, Logan Power Co., Logan, Utah. Dec. 19, 1902

VIALL, BENJAMIN THOMAS, Construction Engineer, Los Angeles Traction Co.; res., 1052 W. 8th St., Los Angeles, Cal. July 28, 1903

VIEHE, J. S., 716 Board of Trade Building, Boston, Mass. May 15, 1900

VINTEN, ERNEST STILES, Foreman Knob. Dept. Sargent Co.; res., 89 Pearl St., New Haven, Conn. Apr. 27, 1898

VOIT, DR. ERNST., Professor of Electricity, Technical University, Schwanthalerstrasse, Munchen, Germany. Mar. 21, 1894

VOM BAUR, CARL HANS, Electrical Engineer, 18 West 130th St., New York City. Sept. 26, 1902

VON AMMON, SIEGFRIED, Designing Engineer, The British Thomson-Houston Co., Ltd., Rugby, Eng. Apr. 23, 1903

VREELAND, FREDERICK K., 46 E. 21st St., New York City. Oct. 26, 1898

WADDELL, CHARLES EDWARD, Electrician in charge Electrical Dept., Biltmore Estate, Electrical Engineer, W. F. Weaver Power Co., Biltmore, N. C. Apr. 25, 1902

WAGENHALS, EDWARD T., Superintendent, Trenton and New Brunswick R. R. Co., Trenton, N. J. Apr. 23, 1903

WAGONER, PHILIP DAKIN, Commercial Department, General Electric Co., Schenectady, N. Y. Feb. 28, 1902

WAITT, ARTHUR MANNING, Superintendent Motive Power and Rolling Stock, N. Y. C. & H R R., New York City. June 19, 1903

WAKEMAN, JAMES MEANLEY, Manager, *Electrical World and Engineer*, 114 Liberty St.; res., East Orange, N. J. Feb. 27, 1903

WALKEM, GEORGE ALEXANDER, Electrical and Mechanical Engineer, Vancouver, B. C. Nov. 23, 1900

WALKER, FRANK WILKES, Mechanical & Electrical Engr., Babcock & Wilcox, Ltd.; res., 26 Summerhill Ave., Montreal, P. Q. May 21, 1901

WALKER, MILES, Electrical Engineer, The British Westinghouse Electric and Mfg. Co., Ltd., Manchester, Eng. Sept. 27, 1901

WALLACE, CHAS. F., Engineer, Stone & Webster, 84 State St , Boston; res., Wellesley Hills, Mass Nov. 18, 1896

WALLACE, ROSS STRAWN, Supt. Peoria Gas and Elec. Co., Peoria, Ill. Jan. 23, 1903

WALLAU, HERMAN L., Assistant Electrician, Cleveland Elec. Ill Co., 711 The Cuyahoga, Cleveland, Ohio May 15, 1900

WALLER, CHAS. WAITE, Sales Agent, General Electric Co., Claus Spreckels Bldg., San Francisco, Cal Aug. 23 1899

WALLER, EDMUND PUTZEI, Electrical Engineer, General Electric Co.; res., 14 Union St., Schenectady, N. Y. Mar. 27, 1903

WALLS, JOHN ABBET, Assistant Engineer, Shawinigan Water and Power Co.; res., 1724 Notre Dame St., Montreal, P. Q. May 19, 1903

WALMSLEY, WALTER NEWBOLD, 1002 Harrison Bldg., Philadelphia, Pa. Oct. 24, 1900

WALSH, JAMES, Assistant Foreman, Meter Department, General Electric Co.; res., 41 Wall St., Lynn, Mass. May 19, 1903

WALTER, HARRY CASPER, Purdue University; res., 143 Andrew Pl., West Lafayette, Ind. Nov. 20, 1903

WARD, CHARLES ARCHIBALD, Engineering Apprentice, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. Apr. 23, 1903

WARDER, WALTER JAMES, JR., Designing Electric Engineer, Western Electric Co., 242 So. Jefferson St., Chicago, Ill. Apr. 23, 1903

WARDLAW, FRANCIS ANDREW, Electrical Engineer, R. W. Hunt & Co., Pittsburg, Pa. Jan. 23 1903

WARNER, ARTHUR P., Northern Electric Mfg. Co.; res., 4339 Berkeley Ave., Chicago, Ill. Sept. 25, 1903

WARNER, CHAS. H., Consulting Electrical Engineer, 764 Rock St., Fall River, Mass. Dec. 20, 1893

WARNER, RICHARD FRANCHOT, Electrical Engineer, General Electric Co.; Schenectady, N. Y. Jan. 23, 1903

WARREN, ALDRED KENNEDY, Asst. Engr of Line and Equipment, Brooklyn Heights R. R. Co., 2075 Broadway, Brooklyn, N.Y Nov. 20, 1895

WARREN, FREDERIC AUSTIN, General Electrician, Fuel Department, Colorado Fuel and Iron Co., Trinidad, Colo. June 19, 1903

WARREN, HARRY MUNSON, Electrical Engineer, The Coal Mining Dept., D. L. & W. Railway Co., Scranton, Pa. Mar. 27, 1903

WARREN, HENRY ELLIS, Assistant Engineer, The Lombard-Governor Co., 36 Whittier St., Boston; res., Newton Centre, Mass. Jan. 24, 1902

WARREN, HOWARD SAUNDERS, Electrical Engineer, American Telephone and Telegraph Co., 125 Milk St., Boston, Mass. Mar. 27, 1903

WARREN, WILLIAM HENRY, Electrical Engineer, Western Electric Co., 259 So. Clinton St., Chicago, Ill. Feb. 27, 1903

WASON, CHAS. W., President and Manager, Cleveland, Painesville and Eastern R R., 616 Garfield Bldg., Cleveland, Ohio. May 19, 1891

WATERMAN, MARCUS B., Assistant Electrician, United Telpherage Co., Westfield, N. J. Feb. 15, 1896

WATERS, EDWARD G., British Thomson-Houston Co., Rugby, Eng. Mar. 18, 1890

WATERS, WILLIAM LAWRENCE, Chief Engineer, National Electric Co., Milwaukee, Wis. Oct. 24, 1902

WATMOUGH, PENDLETON G., JR., Electrical Engineer, 1 Broadway, New York City; res., 32 Stuyvesant Pl., S. I., N. Y. Dec. 18, 1903

WATSON, ARTHUR EUGENE, Assistant Professor of Physics, Brown University, Providence, R. I. July 28, 1903

WATSON, GEORGE HATHON, Paterson, N. J. Feb. 27, 1903

WATSON, KENNETH, Electrical Engineer,General Electric Co.,Schenectady N. Y. May 19, 1903

WATTSON, ALONZO SABINE, Electrical Engineer and General Supt. of Electrical Apparatus, So. Penn Oil Co., Pittsburg, Pa. Dec. 19, 1902

WAY, SYLVESTER BEDELL, Superintendent Union Electric Light and Power Co., 1728 Oregon Ave., St. Louis, Mo. Sept. 25, 1903

WAYNE, JACOB LLOYD, 3d., Department Mechanical Engineering, Massachusetts Institute of Technology, Boston, Mass. Jan. 23, 1903

WEBB, HENRY STORRS, International Correspondence Schools; res., 1416 [Life Member.] Monsey Ave., Scranton, Pa. Nov. 20, 1895

WEBER, HERMAN RUDOLPH, Asst. Engineer, The Denver Gas and Electric Co.; res., 365 So. Washington Ave., Denver, Colo. Mar. 27, 1903

WEBSTER, DWIGHT EDWARD, Engineer and Salesman, Westinghouse Electric and Mfg. Co., Denver, Colo. Apr. 23, 1903

WEBSTER, EDWIN S., Firm of Stone & Webster, 84 State St., Boston, Mass. Apr. 21, 1891

WEBSTER, WALTER COATES, Asst. to 2d Vice-President Westinghouse Electric and Mfg. Co., 120 Broadway, New York City. Jan. 3, 1902

WEIDMANN, OTTO WILLIAM, Student, Polytechnic Institute; res., 73 South 9th St., Brooklyn, N. Y. Mar. 27,1903

WELCH, FRANK PHILLIP, Electrical Engineer, Ingarian Mining Co., Rebeldes No. 2, City of Mexico. Feb. 27,1903

WELCKE, CELESTIN JOHN, Electrical Inspector, U. S. Navy Yard, Brooklyn; res., 237 West 112th St., New York City. Aug. 22, 1902

WELLES, FRANCIS R., Manufacturer, 46 Avenue de Breteuil, Paris, France. Sept. 6, 1887

WELLMAN, HAROLD ROBINSON, Electrical Engineer, Motor Dept., General Inc. Arc Light Co., 529 W. 34th St., New York. Apr. 25, 1902

WELLMAN, SAMUEL THOMAS, President, The Wellman-Seaver-Morgan Engineering Co., New England Bldg., Cleveland, O. Jan. 23, 1903

WELLS, ARTHUR EDWIN, Consulting Engineer, 32 Liberty St.; res., 718 St. Nicholas Ave., New York City. May 19, 1903

WELLS, GEORGE EUGENE, Consulting Electrical Engineer, Ruebel & Wells, 1112 Chemical Building, St. Louis, Mo. Sept. 27, 1901

WELLS, JOHN ALLEN, Head of Marine Test, Testing Department, General Electric Co.; res., 15 Park Pl., Schenectady, N. Y. Apr. 23, 1903

WELLS, WALTER FARRINGTON, Supt. of Waterside Station, N. Y. Edison Co., 38th St. and First Ave., New York City Apr 26, 1899

WELZ, FRANK, Electrical Engineer, Department of Electricity, World's Fair, St. Louis, Mo. Jan. 23, 1903

WENGER, EDGAR I., Westinghouse Electric and Mfg. Co., Pittsburg, Pa. May 21, 1901

WENTZ, ROBERT FILMORE, Mechanical Designing and Constructing Engineer, Gen. Electric Co., Nazareth, Pa. Apr. 23, 1903

WESSELHOEFT, CHARLES DIETRICH, Electrical Engineer, Kohler Brothers; res., 749 So. Sawyer Ave., Chicago, Ill. Sept. 25, 1903

WESSLING, ALBERT GUSTAVE, Chief Engineer, Bullock Electric Mfg. Co.; res., 549 Milton St., Cincinnati, Ohio. Feb. 27, 1903

WEST, ERASTUS LOVETTE, Asst. to Electrical Engineer, J. G. White & Co., 22a College Hill, Cannon St., London E. C., Eng. Apr. 25, 1902

WEST, JULIUS HENRIK, Engineer, 20 Hallesche St., Berlin, S. W., Germany. Sept. 20, 1893

WESTINGHOUSE, GEORGE, President, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. May 20, 1902

WESTON, SYDNEY F., Marine Engine and Machine Co., 1123 Broadway, New York City. July 12, 1900

WETZLER, JEFFERSON, Secretary and Treasurer, Electrical Engineer Institute, 240 West 23d St., New York City. July 25, 1902

WEYMOUTH, THOMAS ROTE, Engineer, National Transit Co., 206 Seneca St., Oil City; res., Lock Haven, Pa. Nov. 22, 1901

WHEELER, WALTER SCOTT, Superintendent Franchise Dept., Board of Public Works, 711 23d Ave., Seattle, Wash. Sept. 25, 1903

WHEILDON, LOUIS B., Contractor and Expert, 1027 Exchange Building, Boston, Mass. Oct. 24, 1900

WHIPPLE, CYRUS AVERY, Student, Cornell University, 302 No. I St., Tacoma, Wash. June 19, 1903

WHITAKER, S. EDGAR, Street Railway Engineer, 43 Milk St., Boston; res., Woburn, Mass. Aug. 5, 1896

WHITAKER, JOHN SANBORN, Constructing Engineer, Rockingham County Light and Power Co., Portsmouth, N. H. Apr. 23, 1903

WHITE, CHAS. G., Public Schools Supt. and Instructor in Physics and Chemistry, Lake Linden, Mich. Sept. 23, 1896

WHITE, FRANCIS JOSEPH, Assistant in Electrical Engineering, Columbia University; res., 53 St. Johns Pl., Brooklyn, N. Y. Apr. 25, 1902

WHITE, HAROLD E., Designing Engineer, General Electric Co., res.; 128 Nott Terrace, Schenectady, N. Y. Apr. 23, 1903

WHITE, LINDEN G., Superintendent Electrical Department, The Columbus Railway and Light Co. Columbus, Ohio. Mar. 28, 1902

WHITE, RICHARD ALBERT, Electrical and Mechanical Engineer, Ford & Davis, 2104 First Ave., Birmingham, Ala. June 19, 1903

WHITE, WILLIAM WESLEY, Electrical Draftsman, The William Cramp & Sons Ship and Engine Building Co., Philadelphia. Apr. 23, 1903

WHITEHEAD, JOHN B., JR., Associate in Applied Electricity, Johns Hopkins University, Baltimore, Md. Oct. 24, 1900

WHITEHOUSE, LOUIS CAMMANN, Student, Stevens Institute of Technology, Hoboken, N. J.; res., New Brighton, N. Y. Apr. 23, 1903

WHITESIDE, WALTER HUNTER, Manager Westinghouse E. & M. Co., res.; 6843 Thomas Boulevard, Pittsburg, Pa. Jan. 24, 1902

WHITING, ALLAN H., Automobile Engineer, 120 West 55th St., New York City. Nov. 18, 1896

WHITING, S. E., Instructor in Electrical Engineering, Harvard University; res., 11 Ware St., Cambridge, Mass. May 16, 1899

WHITMORE, W. G., Electrical Engineer, General Electric Co., Edison Building, New York City. Mar. 18, 1890

WHITNEY, CLINTON EUGENE, Electrical and Mechanical Engineer, 553 South Sixth Ave., Mt. Vernon, N. Y. Nov. 22, 1899

WHITNEY, EDDY RUSSEL, Engineer, General Electric Co., Lynn; res., 7 Elmwood Terrace, Swampscott, Mass. May 19, 1903

WHITNEY, HENRY M., India Wharf, Boston, Mass. July 12, 1887
[Life Member.]

WHITNEY, WILLIS R., Asst. Prof. Theoretical Chemistry, Massachusetts Institute Technology, in charge of Electrochemical Research Laboratory, General Elec. Co., Schenectady, N. Y. May 21, 1901

WHITTED, THOS. BYRD, District Engineer, The General Electric Co., Denver, Col. Mar. 22, 1899

WHITTEMORE, GEORGE W., Engineer, Bell Telephone Co., 24 W. Seneca St., Buffalo, N. Y. Jan. 3, 1902

WHITTLESEY, JAMES THOMAS, Chief Engineer, Elec. Dept., Public Service Corporation, Newark, N. J. Nov.,20, 1903

WIARD, JOHN BULKLEY, Assistant Engineer, General Electric Co.; res., 11 Shepard St., Lynn, Mass. Apr. 23, 1903

WIDDICOMBE, ROBERT A., Engineer and Superintendent, Kroeschell Bros., Co., 55 Erie St.; res., 1651 Roscoe St., Chicago, Ill. Apr. 26, 1899

WIECHMANN, FERDINAND G., Consulting Chemist, The Sawyer-Man Electric Co.; res., 310 West 80th St., New York City. Sept. 25, 1903

WIEDERHOLD, OSCAR, Supt. Natural Light Supply Co., 90 Orange St.; res., 14 Grace St., Bloomfield, N. J. Aug. 13, 1897

WIESELGREEN, CARL EMIL, 4 Lilla torget Gothenburg, Sweden. Oct. 24, 1900

WILDER, HENRY WINDSOR, Electrical Engineer, Installation Dept., Western Electric Co., 933 Market St., Philadelphia. Sept. 27, 1901

WILDER, STUART, Westchester Lighting Co., Mt. Vernon, N. Y. May 20, 1902

WILDMAN, LEONARD D., Captain U. S. Signal Corps, Washington, D. C. Mar. 27, 1903

WILER, CARL, Electrical Engineer, Western Electric Co., Chicago, Ill. Sept. 27, 1901

WILEY, GEO. LOURIE, Manager, Standard Underground Cable Co., 56 Liberty St., New York; res., Arlington, N. J. Feb. 28, 1900

WILEY, ROY RODNEY, Electrical Engineer, The Packard Electric Co., Ltd., St. Catharines, Ont. July 28, 1903

WILEY, WM. H., Scientific Expert, 43 E. 19th St., New York City. Feb. 7, 1888

WILHOIT, FREDERIC SHELTON, Assistant Supt., The Cutler-Hammer Mfg. Co.; res., 911 State St., Milwaukee, Wis. May 19, 1903

WILKES, C. M., Engineer, D. H. Burnham & Co., 1142 The Rookery Chicago, Ill. Nov. 22, 1890

WILKINS, EDGAR MORRIS, 107 Park Ave. (East) Savannah, Ga. Dec. 19, 1902

WILKINSON, JAMES, Chief Engineer Birmingham Railway, Light and Power Co., Birmingham. Ala. Feb. 28, 1902

WILLCOX, FRANCIS WALLACE, Assistant to Manager, Lamp Sales Dept. Edison Lamp Works, G. E. Co., Harrison, N. J. Mar. 27, 1903

WILLIAMS, ARTHUR, General Inspector, The New York Edison Co., 57 Duane St., New York City. June 23, 1897

WILLIAMS, CHARLES, JR., Electrician, 1 Arlington St., East Somerville Mass. Apr. 15, 1884

WILLIAMS, HERBERT HOWARD, 442 East Michigan St., Marquette, Mich. Feb. 27, 1903

WILLIAMS, ROBERT NEIL, (*Local Secretary*), Instructor in Electrical Engineering, Union College, Schenectady, N. Y. Aug. 22, 1902

WILLIAMS, WILLIAM HENRY, Professor of Electrical Engineering, University of Illinois, Urbana, Ill. Sept. 28, 1898

WILLIAMSON, ROBERT BAIRD, Principal of School of Electrical Engineering, The International Corr. Schools, Scranton, Pa. Oct. 24, 1902

WILLIS, SAMUEL THAYER, 148 Lincoln St., Worcester, Mass. Nov. 20, 1903

WILLISTON, H. S., Manager, Peerless Electric Co., 6 Wall St., New York City. Nov. 21, 1902

WILSON, HAROLD RUDOLF, Sales Engineer, Stanley Electric Mfg. Co., 616 Century Building, St. Louis, Mo. July 28, 1903

WILSON, HENRY CLINTON, Chief Engineer, American Compound Bearing Co., 25 Broad St., New York City. Sept. 27, 1901

WILSON, HUGH HEATHLEY, General Foreman of Power House, Westinghouse Electric and Mfg. Co., Pittsburg, Pa. June 19, 1903

WILSON, JAMES A., General Electric Co., 84 State St., Boston, Mass. Apr. 23, 1903

WILSON, J. ROBERTS, Salesman, Crocker-Wheeler Co., 816 New England Building, Cleveland, Ohio. May 27, 1903

WILSON, LEONARD, Electrical Engineer, Stanley Electric and Mfg. Co.; res., Beech Grove Inn, Pittsfield, Mass. Sept. 26, 1902

WILSON, NORMAN JAMES, Electrical Engineer, British W. E. & M. Co., Ltd., Trafford Park Works, nr. Manchester, Eng. Apr. 25, 1902

WILSON, ROBERT LEE, District Engineer, Westinghouse Electric and Mfg. Co., 120 Liberty St., New York City. June 28, 1901

WILSON, ROBERT M., Supt., Montreal Light, Heat and Power Co., Richelieu Village; res., 23 Seymour Ave., Montreal, P. Q. Jan. 25, 1899

WILTBERGER, BERTRAM P., Draftsman, New York Edison Co., 55 Duane St., New York City; res., Brooklyn, N. Y. Mar. 27, 1903

WINCHESTER, SAMUEL B., Superintendent, Eleotrical Dept., Holyoke Water Power Co., 5 Laurel St., Holyoke, Mass. May 15, 1894

WINFIELD, JAMES H., General Manager, Nova Scotia Telephone, Ltd., Halifax, N. S. May 17, 1898

WINN, JOHN EDWARD, Superintendent of Meter Dept., The Cincinnati Gas and Electric Co., 220 W. 8th St.,Cincinnati, O. May 20, 1902

WINSHIP, WALTER EDWIN, Electrical Engineer, Gould Storage Battery Co., 25 W. 33d St., New York City. May 19, 1903

WINSLOW, CHARLES GARDNER, New York Central and Hudson River R.R., 5 Vanderbilt Ave.; res., Mount Vernon, N. Y. Aug. 22, 1902

WINSLOW, I. E., The General Traction Company, Ltd., 20 Bishopsgate St.,(within) London E. C., Eng. Nov. 12, 1889

WINTNER, LOUIS, Engineer Switchboard Dept., General Incandescent Arc Light Co., 527 West 34th St., New York City. May 21, 1901

WINTRINGHAM, J. P., Theorist, Mills Building, 35 Wall St., New York City; res., 135 Henry St., Brooklyn, N. Y. May 7, 1889

WIRT, HERBERT C., Engineer, Supply Department, General Electric Co., Schenectady, N. Y. June 26, 1891

WISE, JOHN SHREEVE, JR., Assistant Supt., Auburn Light, Heat and Power Co., Auburn, N. Y. Feb. 15, 1896

WOHLAUER, ALFRED, Student, Testing Dept., General Electric Co.; res., 211 Liberty St., Schenectady, N. Y. Nov. 20, 1903

WOLF, LEE H., Contracting and Engineering, Honolulu, H. T. Oct. 24, 1900

WOLFE, JOSEPH THOMAS, General Engineer and Sales Agent, Noyes Bros., 17 Queen St., Melbourne, Victoria. June 28, 1901

WOLFF, FRANK A., JR., Professor of Physics and Electrical Engineering, Columbian University, and in office U. S. Standard Weights and Measures, Washington, D. C. Dec. 27, 1896

WOLFF, SALOMON, Bullock Electric Mfg. Co.; res. 1378 Myrtle Ave., Cincinnati, Ohio. Feb. 27, 1903

WOOD, ARTHUR J., Professor of Mechanical and Electrical Engineering, Delaware College, Newark, Del. Dec. 28, 1898

WOOD, BENJAMIN FRANKLIN, Asst. Engineer, Motive Power Department, P. R. R., Altoona, Pa. July 28, 1903

WOOD, CHARLES P., Chief Draftsman, The Triumph Electric Co., 610 Baymiller St., Cincinnati, Ohio. Mar. 27, 1903

WOODBRIDGE, J. E., Railway Engineering Dept., General Electric Co., Schenectady, N. Y. Oct. 26, 1898

WOODBURY, CHARLES JEPHTA HILL, Assistant Engineer, American Telephone and Telegraph Co., 125 Milk St.,Boston,Mass. Aug. 22, 1902

WOODBURY, DANIEL CORYTON, N. Y. C. & H. R. R. R., 5 Vanderbilt Ave., New York City. Apr. 25, 1902

WOODFIELD, SYDNEY, Assistant Engineer, Brush Electrical Engineering Co., Ltd., London, S. E., Eng. Feb. 28, 1902

WOODHOUSE, ALBERT LLOYD, General Supt. of Utah Dept, The Telluride Power and Transmission Co., Provo City, Utah. Aug. 22, 1902

WOODROOFE, WILLIAM TURTON, Dynamo Tender, The B. C. Electric Railway Co., Ltd., 1423 Georgia St., Vancouver, B. C. Apr. 23, 1903

WOODWARD, CORNELIUS WENDELL, Purchasing Agt., Electric Storage Bat. Co., 19th St. & Allegheny Ave. Philadelphia. Sept. 26, 1902

WOODWARD, FREDERICK SEARLE, 240 Madison St., Brooklyn, N. Y. June 28, 1901

WOODWARD, HENRY WILMOT, Secretary, The Cleveland Engineering Co., 1210 New England Building, Cleveland, Ohio. May 19, 1903

WOODWORTH, GEO. K., Assistant Examiner, U. S. Patent Office; res., 4 R. St., N. W., Washington, D. C. Feb. 17, 1897

WOODWORTH, LEON BYRON, Electrical Engineer, New Heriot Gold Mining Co., Johannesburg, Transvaal. Nov. 23, 1900

WOODWORTH, PHILIP BELL, Professor of Electrical Engineering, Lewis Institute, Chicago; res., 5808 Ohio St., Austin, Ill. July 12, 1900

WOOLF, ALBERT E., Electrician and Inventor, The Electrozone Co., 832 West End Ave., New York City. Sept. 16, 1890

WOOLFENDEN, HENRY L., President and Chief Engineer, Gilbert Wilkes & Co., 435 17th St., Denver, Colo. Mar. 27, 1903

WOOLFORD, WILLIAM ALLEN, General Electric Co., Richmond, Va. Oct. 24, 1902

WOOLLISCROFT, JOHN HAROLD, Chief Assistant Electrical Engineer, The Sandycroft Foundry Co., Ltd., Chester, Eng. May 19, 1903

WORSWICK, A. E., V. P. and Resident Engineer, Compania Limitada de Tramvias Electricos de Mexico, Mexico City. Sept. 20, 1893

WOY, FRANK PALMER, Assistant to Electrical Engineer, J. G. White & Co., 29 Broadway; New York City. July 28, 1903

WRAY, J GLEN, Superintendent of Maintenance, Chicago Telephone Co., 510 Edoy St., Chicago, Ill. Sept. 20, 1893

WRIGHT, CHARLES HARVEY, Engineer Canadian General Electric Co., 14 King St., E., Toronto, Ont. Dec. 18, 1903

WRIGHT, FRANK THOMAS, Draftsman, Underground Electric RailwaysCo., Hamilton House, Victoria Emb. London. Oct. 23, 1903

WRIGHT, GILBERT, Electrical Engineer, The Stanley Electric Mfg. Co., Pittsfield, Mass. June 19, 1903

WRIGLEY, GEORGE, Assistant, Engineering Department. General Electric Co., Schenectady, N. Y. Dec. 19, 1902

WUNDERLICH, ADOLPH, Electrical Engineer, Johnson & Phillips; res., Blackheath, London, S. E., Eng. July 28, 1903

WURDACK, HUGO, Superintendent of Electric Station, Laclede Gas Light Co.; res., 1221 Euclid Ave., St. Louis, Mo. Dec. 18, 1903

WURSTER, FREDERICK WILLIAM, JR., Student, Polytechnic Institute; res., 170 Rodney St., Brooklyn, N. Y. Jan. 23, 1903

WYLLIE, ROBERT EDWARD, Captain U. S. Artillery Corps, Fort Terry, N. Y. Sept. 25. 1903

WYMAN, WALTER S., Manager, Messalonskee Electric Co., and Oakland Electric Co., Waterville, Me. Jan. 23, 1903

WYNN, JOHN G., Engineer Northern Electric Mfg. Co.; res., 1223 Jenifer St., Madison, Wis. Dec. 18, 1903

YAMAZAKI, SHIRO, Chief Engineer, Keihin Electric Ry Co., Kawaski, Kanagawaken, Japan. Jan. 24, 1902

YEARSLEY, EUGENE WILSON, Asst. Electrical Engineer, Otis Elevator Co., Yonkers; res., Grand Union Hotel, New York City. Mar. 27, 1903

YENSEN, PETER, General Manager, The Cleveland Telephone Co., Telephone Building, Cleveland, Ohio. Mar. 27, 1903

YORKE, GEORGE MARSHALL, Asst.Engineer, American Tele. and Telegraph Co., 15 Dey St.; res., 44 Irving Pl., New York. Apr. 25, 1902

YOUNG, CHARLES I., Electrical Engineer, Westinghouse Elec. & Mfg. Co., 11 Pine St., New York City. June 27, 1895

YOUNG, FREDERICK WILLIAM, Chief Tester, Crocker-Wheeler Co., Ampere N. J.; res., 47 William St., East Orange, N. J. Aug. 22, 1902

YOUNG, JOHN MASON, Student in Electrical Engineering, Cornell University; res., 111 Osmun Pl., Ithaca, N. Y. Sept. 26, 1902

YOUNG, JAMES WATTS, Superintendent of Lines, Bell Telephone Co.; res., 36 So. 21st St., Philadelphia, Pa. Dec. 18, 1903

YSLAS, CARLOS, Civil and Electrical Engineer, Martinez del Villar, Yslas & Co., Calle Principal, No. 8, Jalapa, V. C., Mexico. Nov. 18, 1896

ZABEL, MAX W., Metropolitan Telephone and Electric Co., 610 Wilson Ave.; res., 454 North Ave., Chicago, Ill. Jan. 24, 1900

ZABRISKIE, HENRY LYLES, Electrical Engineer, Diehl Mfg. Co., Elizabeth, N. J.; res., 28 Regent Pl., Brooklyn, N. Y. Mar. 27, 1903

ZALINSKI, EDMUND L., Captain of Artillery, U. S. A., (retired) The Century, 7 West 43d St., New York City. May 17, 1887

ZANI, ARNALDO, P. Electrical Engineer, English Electric Mfg. Co., Ltd., Preston, Lancashire, Eng. July 12, 1900

ZAPATA, J. M., Constructing Engineer, Sociedad Hidroelectrica Yberica, Bilbao, Spain. Feb. 28, 1900

ZAPP, LOUIS MILTON, Indiana Union Traction Co., 917 Jackson St., Anderson, Ind. Sept. 25, 1903

ZURFLUH, WILLIAM NICHOLAS, Superintendent Home Lighting Power & Heating Co., Arcade Building, Springfield, Ohio. Jan. 3, 1902

ZWIETUSCH, EDWARD OTTO, Electrical Engineer, Telephon Apparat Fabrik Petsch, Z. & Co., Salzufer 7, Charlottenburg, Ger. Nov. 22, 1901

(23)

Associates 2,317

OFFICIAL STENOGRAPHER.

CROSSMAN, T. E., 13 Park Row, New York City; res., 931 73d St., Brooklyn, N. Y. (Telephone, 3681 Cortlandt.)

SUMMARY.

Honorary Members	2
Members	459
Associates	2,317
Total	2,778

INDEX.

BUSINESS OF THE INSTITUTE.

PAPERS AND DISCUSSIONS.

INDEX OF AUTHORS.