# JOURNAL OF THE A·I·E·E·

MARCH 1926

PUBLISHED MONTHLY BY THE
AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS
33 WEST 39TH ST· NEW YORK CITY

# American Institute of Electrical Engineers

## COMING MEETINGS

Annual Business Meeting, New York, N. Y., May 21

Annual Convention, White Sulphur Springs, W. Va., June 21-25

Pacific Coast Convention, Salt Lake City, Utah, (Dates to be announced in subsequent issue)

**Regional Meetings**

Middle Eastern District, Cleveland, Ohio, March 18-19

Great Lakes District, Madison, Wis., May 6-7

Northeastern District, Niagara Falls, May 26-28

---

## MEETINGS OF OTHER SOCIETIES

National Electric Light Association, Atlantic City, May 17-21

Middle West Division, Ft. Des Moines Hotel, Des Moines, April 8-10

Southwestern Division, Galveston, Tex., April 13-16

Southeastern Division, Pinehurst, N. C., April 27-29

American Welding Society, New York, April 21-23

# JOURNAL

OF THE

# American Institute of Electrical Engineers

PUBLISHED MONTHLY BY THE AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS
33 West 39th Street, New York

Subscription. $10.00 per year to United States, Mexico, Cuba, Porto Rico, Hawaii and the Phillipines, $10.50 to Canada and $11.00 to all other Countries. Single copies $1.00.

Entered as matter of the second class at the Post Office, New York, N. Y., May 10, 1905, under the Act of Congress, March 3, 1879.
Acceptance for mailing at special rate of postage provided for in Section 1103, Act of October 3, 1917, authorized on August 3, 1918.

Vol. XLV — MARCH, 1926 — Number 3

## TABLE OF CONTENTS

### Papers, Discussions, Reports, Etc.



### Institute and Related Activities



A REQUEST FOR CHANGE OF ADDRESS must be received at Institute headquarters at least ten days before the date of issue with which it is to take effect. Duplicate copies cannot be sent without charge to replace those issues undelivered through failure to send such advance notice. With your new address be sure to mention the old one, indicating also any change in business connections.

# Current Electrical Articles Published by Other Societies

**Engineering Journal,** January, 1926

Power Transformers, by C. E. Sisson

**Journal of the Franklin Institute,** January, 1926

Direction and Intensity Changes of Radio Waves, by C. C. Bidwell

Standard Electrical Cells, by M. Eppley

**Journal of the Western Society of Engineers,** December, 1925

Electrical Equipment in the Chicago Union Station, by C. W. Post

**Proceedings of the Institute of Radio Engineers,** February, 1926

Some Studies in Radio Broadcast Transmission, by Ralph Bown, De L. K. Martin and R. K. Potter

Transatlantic Radio Telephone Transmission, by Lloyd Espenschied, C. N. Anderson and Austin Bailey

# Journal of the A. I. E. E.

*Devoted to the advancement of the theory and practise of electrical engineering and the allied arts and sciences*

Vol. XLV MARCH, 1926 Number 3

## Intellectual Renaissance in America*

Idealism found its clearest expression in the men who immediately after the Civil War had inaugurated a new epoch in American history, the epoch of the *intellectual renaissance in America.* It was the epoch of the new movement in the direction of higher endeavor in all intellectual, aesthetic and spiritual activities of our national soul. Joseph Henry, Barnard, White, Draper, Eliot, Lowell and many other intellectual leaders led the movement, but it took its first concrete form in Baltimore, when Johns Hopkins University was formally opened fifty years ago.

The wisdom of the trustees of the princely gift which a modest Baltimore merchant had placed into their hands was that of inspired men when they selected Daniel Coit Gilman as the interpreter of the wish of Johns Hopkins.

The quality of the men whom Gilman selected for his original faculty proclaimed this idealism. Sylvester, the mathematician; Gildersleeve, the Grecian; Morris, the classicist; Remsen, the chemist; Rowland, the physicist, and Martin, the biologist, were the members of the original faculty over which the genius of Gilman presided. This was the famous heptagon, a new constellation of seven brilliant stars in the intellectual firmament of America.

Associated with this constellation there were other young and brilliant stars like Brooks, Elliott, Adams and Scott. No finer group of idealists was ever assembled in any university faculty. But their idealism was not that of a vague and misty type.

A knowledge of the truth which uplifts the soul of man and makes it free was always a part of the gospel of Johns Hopkins University. Gildersleeve's ancient classics and Remsen's modern chemistry; Sylvester's and Cayley's abstract mathematics and Welch's concrete science of medicine; Martin's modern physiology and Haupt's language of ancient Babylon; Rowland's latest theories in physics and Johns Hopkins' inquiries into the earliest documents of the Christian creed; Lowell's discourse on Dante and Brook's story of the Chesapeake oyster; Huxley's evolution and Dean Stanley's theology; Kelvin's structure of the vibrating atom and Sidney Lanier's structure of the sonorous verse—all these sources of God's eternal truth were welcome topics to the gospel which was proclaimed in the lecture rooms of Johns Hopkins University. It thrilled the American intellect as it had never been thrilled before.

I can pass over in silence many discoveries in mathematics, physics, chemistry, physiology, biology and other branches of knowledge; they are very important and well understood by the experts. But there are three achievements which have a great national significance, and they are not all as well understood by our nation as they ought to be. These I must describe, even if briefly.

The first great achievement of national significance which I must mention is the Johns Hopkins Medical School. Thirty years ago I was told by a great medical authority in London that the Johns Hopkins Medical School is second to none and that its professors and former pupils are the prophets of the medical profession. I found out later that the names of Welch, Osler, Halstead and Kelly were household words in the medical profession.

The ideals of the university were the same as those of its medical school. Welch, the first dean of the medical school, and his colleagues were guided by the same idealism which guided Gilman and his famous heptagon.

I must now mention another achievement of great national significance. The modern American medical school did not exist before William H. Welch became the dean of the Johns Hopkins Medical School; neither did the American university exist before Daniel Coit Gilman became president of the Johns Hopkins University.

But there is an achievement which is of even greater national significance than the two that I have just mentioned. Nothing is as difficult as molding the mental attitude of men; the average mind has an enormous inertia. There was a time when the so-called practical man had little use of the idealist of the Johns Hopkins heptagon type. The movement in the direction of higher endeavor, with its lofty ideals, gave no thrill to the prosy soul of the practical man.

The American industries controlled by the stubby hand of the practical man had no points of sympathetic contact with the subtle touch of science of the research laboratory. But presently industrial problems arose which were too scientific for the practical man. The harnessing of Niagara Falls and the electrification of the New York subways, for instance, were too much for the practical man. Rowland, the idealist, and Duncan, his pupil, had something to say on this subject and they received a respectful hearing. It was found that their

*Abstract of an address at the fiftieth anniversary of Johns Hopkins University on Feb. 22, 1926.

scientific idealism had a practical side, just as Brook's idealism in biology had a practical side when he told the biological story of the Chesapeake oyster.

Pretty soon the practical man opened the door of his industries and welcomed the disciples of the John Hopkins heptagon of idealists. Their idealism gave birth to the idealism of the American university research laboratories, and from these it moved into American industries. The scientific idealism which Rowland and his colleagues preached is today the idealism of our industrial research laboratories.

The words uttered lately by three distinguished American engineers are still ringing in my ears; they are the words of Jewett, Durand and Hoover. Their ideas are accepted everywhere as the practical ideas of practical men. What is their message? It is this: The greatest need of this nation is thorough training and research in the fundamental sciences. But this was the gospel of Johns Hopkins fifty years ago, and it is today. The adoption by the practical engineer of the creed of this gospel is one of the greatest services of Johns Hopkins to our nation.

My old friend President Goodnow and his distinguished colleagues are making every effort not only to continue this national service but even to amplify it. Our nation never needed it more than it does at the present moment.

M. I. PUPIN.

## Some Leaders of the Institute

Gano Dunn, the twenty-fourth president of the Institute, was born in New York City, October 18, 1870. He attended the College of the City of New York, from which he was graduated with the B. S. degree in 1889; he also received the degree of M. S. from that institution in 1897. In 1891 he received the E. E. degree from Columbia University, and honorary M. S. from Columbia in 1914.

His professional work began in 1886, in the service of the Western Union Telegraph Company, where he remained five years. He then entered the service of the Crocker-Wheeler Company, at Ampere, N. J., and from 1898 until 1911 was vice-president and chief engineer of that company. In the latter year he was elected vice-president in charge of engineering and construction by the J. G. White Company, and in 1913, when the J. G. White Engineering Company was organized to take over the engineering and construction work of the parent company, Mr. Dunn was made president, in which position he still continues.

From 1900 until 1902, Mr. Dunn was president of the New York Electrical Society. He was president of the A. I. E. E. throughout the term 1911-12; president of the United Engineering Society from 1913 to 1916; of the John Fritz Medal Board of Award in 1914; the Engineering Foundation 1915-16, and vice-chairman of the National Research Council, 1917, afterwards becoming chairman.

He is the author of various important papers on engineering subjects, and has served on many important technical committees and boards.

Mr. Dunn was secretary of electric lighting and distribution, for the International Electrical Congress, St. Louis, 1904, and a delegate and vice-president of the International Electrical Congress, Turin, 1911. He is a member of the International Electrotechnical Commission, and in 1916-18 was a member of the Engineering Committee of the Council of National Defense; also, during the war he was chairman of the State Department Committee on submarine cables.

He is a member of several American and foreing technical and engineering societies, beside belonging to various clubs in the United States and a broad.

## Companies Encouraging Convention Attendance

More organizations are realizing the advantages of having interested members of their forces attend the meetings of professional societies such as the Institute. The benefits of such attendance are felt not only by the individuals but they are carried back to the parent companies in the form of increased information, broader viewpoint, greater enthusiasm and development of personality.

As a matter of fact many companies appreciate these benefits to such an extent that they make it the duty of some members of their staff to attend certain features of conventions. They realize the importance of encouraging the attendance of their members in order that they may gain technical knowledge from the reading and discussion of the papers and from inspection trips, and that they may develop their characters through informal conversation with others at the meeting and through the social functions.

This practise certainly indicates a healthy state of mind and shows a far-sightedness of managers and managements which is entirely commendable.

## Auxiliary Radio Language

The recently held International Conference of Radio Amateurs, at Paris, France, appointed a committee to study and report upon the problem of an auxiliary language for use in communication, correspondence and conversation between members of the International units of the organization. About twenty artificial languages were considered, including Esperanto and Ido, as well as a few national languages. After considerable debate, in which the Scandanavian representatives strongly urged the adoption of English as the approved auxiliary language, the committee reported in favor of Esperanto.

# A High-Frequency Voltage Test for Insulation of Rotating Electrical Apparatus

BY J. L. RYLANDER[1]
Member, A. I. E. E.

*Synopsis.—For many years the need for a higher test voltage between turns of individual coils or complete windings has been recognized. To obtain this higher test voltage, high frequency has been introduced. The high frequency used for this test is produced by damped oscillating discharge from a condenser and applied directly to the leads of the coil or winding. Practically any desired voltage can be applied to a coil or winding provided a sufficiently high frequency is used.*

*As a shop method for checking defects in material, or poor workmanship, the high-frequency test method has been found very effective in those classes of windings so far tried.*

*The method used for detecting short circuits on the principle of the radio receiving set are described.*

INSULATION is used on rotating electrical apparatus to insulate between its various parts which have a difference of potential and also to insulate all parts of the circuit to "ground." The "ground" insulation is thoroughly tested by the present method of applying a high potential, usually at normal frequency, between the winding and the core or frame at various stages of construction. The present methods of testing the insulation of various parts of the same circuit such as from one turn to other turns, one layer of wire to other layers of wire, are far from adequate. It is the purpose of this paper to present a method of making a thorough and practical test between various parts of a coil or winding.

## Present Method of Test

The present method of testing between turns and layers of coils consists of placing the coil over a pole piece magnetized by a primary coil which induces a voltage in this coil as the secondary coil of a transformer. The maximum voltage that can be induced by this method will not exceed 10 or 20 volts per turn in most coils as the voltage is limited by the size of pole piece that can be inserted into the opening of the coil and to the frequency of the circuit. Usually 133 or 500 cycles per second are used. This test discovers short circuits where there is actual copper to copper contact. However, it does not discover any weak or damaged insulation where there is not actual copper contact. Therefore many coils are given no insulation test.

The windings of d-c. armatures are tested by this same induction method by revolving the armature slowly and testing each coil separately. This test discovers any short circuits caused by actual copper to copper contact and also discovers open circuits. As this type of testing apparatus is only adaptable for rotating windings, induction motor primary windings are not given this test.

The completed motor or generator is given a running test with rated voltage for one-half hour to several days depending on the test data needed. This test is applied to the motor when new and operating at normal voltage and under normal conditions of operation. It makes no allowance for future deterioration of the insulation or for any abnormal conditions of operation.

In order to obtain a higher test voltage between turns of coils both before and after winding the coils in the machine, that would be considered a real insulation test, high-frequency voltage is applied directly to the terminals of the coil or windings.

## Types of High Frequency

With high frequency, advantage can be taken of the inductance of the coil or winding and thus obtain almost any voltage desired.

The use of high frequency for various test purposes is not new but as far as the author is aware it has not been applied to the commercial testing of individual coils and wound apparatus.

In general, there are two types of high-frequency voltage; (1) undamped oscillations and (2) damped oscillations. The first type includes the high frequency voltage produced by high frequency generators which is, comparatively speaking, limited as regards the range of frequency. This class may also include the high frequency produced by vacuum tubes, such as used in radio work and which has a very high range of frequency compared to any generator.

The second type is produced by the oscillating discharge of a condenser through an inductance with a comparatively low resistance.

The production and control of both types of high frequency has been known practically and theoretically for many years and is described in many text books on radio and physics so no detailed description need be given.

The oscillating discharge high frequency was chosen for commercial test purposes because of its comparative ease of production and control.

It may be of interest to enumerate briefly a few of the experiments which were made with other types of high frequency. The reason for these experiments was mainly that when the damped oscillating high frequency

1. Electrical Engineer, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

*Presented at the Midwinter Convention of the A. I. E. E., New York, N. Y., February 8-11, 1926.*

was first put in use the spark-gap was the only practical means of measuring the voltage. As is well known, the measurement of voltage with the sphere spark-gap is not very accurate under 2000 or 3000 volts. Inasmuch as there were many cases where a lower high frequency test voltage was desired attempts were made to measure the damped oscillating voltage by other means than spark-gap. Ordinary voltage measuring instruments were entirely unsuitable and it was also found, as was anticipated even before trial, that the electrostatic voltmeter would not give the correct measurements.

At this point, therefore, attempts were made to use the undamped high frequency obtained from vacuum tubes. However, the necessary frequency from this source was so high that it was difficult to screen the indicating instruments from the indirect effect, so this also was discarded for commercial reasons.

The high-frequency voltage obtained from a high frequency generator was next resorted to but the current required up to 5000 cycles was so high that serious heating occurred in the bands of banded armatures in the case of direct-current machines.

In the meantime methods of detecting short circuits on wound apparatus, including commutating machines, were developed. This development permitted the high frequency test voltage to be applied across the normal span of the brushholders on a commutating machine, so the necessity for very low voltage at high frequency was largely removed. Later, also a method of instrument measurement of damped high-frequency voltage was developed, and for this reason all efforts were finally concentrated on the damped high-frequency test voltage.

## The Principle of Operation of the Damped High-Frequency Set

A very high voltage can be applied to any winding if the frequency is sufficiently high. The voltage drop due to the inductive reactance is $E = 2 \pi f L I$ where $f$ is the frequency per second and $L$ is the inductance in henries and $I$ is the current in amperes. For example, a 15-turn circular coil with a 12-in. diameter having a d-c. resistance of 0.1 ohm and an inductance of 0.001 henry would have approximately the following voltages across its terminals with 10 amperes in the circuit: one volt d-c.; 4 volts, 60 cycles per second, and 4000 volts with 60,000 cycles per second. It is thus seen that practically any desired voltage can be placed across a coil or a winding if sufficiently high frequency is applied. The voltage is applied by connecting the two leads from the high frequency apparatus directly to the terminals of the coil or winding either partial or completely finished.

When high frequency is applied to the apparatus under test, it sets up an alternating electromagnetic field of a particular frequency in a manner similar to a radio transmitter. If a short circuit occurs in the winding, the wave length and frequency will be changed accordingly, and the strength of the outgoing signals is reduced. A wave meter is used to measure the outgoing waves and thereby determine whether any insulation failure has occurred.

The wave meter consists of a set of inductance coils, variable condenser with a vernier attachment, two variable resistances and a low reading ammeter of the thermo-element type, all connected in series with one of the inductance coils. The inductance coils are such that by changing the setting of the variable condenser, resonance may be obtained for the frequency generated by the coil or winding under test. The condenser, the ammeter and the variable resistances are mounted on a panel and a tuning coil is placed near the apparatus being tested. The tuning coils have low resistance and a minimum capacity for a given inductance. Coils with taps are unsatisfactory on account of the end-turn loss.

The wave meter is tuned to the frequency of the waves omitted by the apparatus under test and it acts in a manner similar to a radio receiving set. A current flows in the wave meter circuit which is measured by the ammeter. The variable condenser is adjusted until a maximum current is shown on the meter which thereby indicates the condition of resonance and also the frequency of the circuit. The meter reading alone does not mean anything in particular; it is the relative meter readings used in connection with the condenser readings and the distance from the tuning coil to the apparatus under test which tells the story.

The principle by which high frequency is produced by this outfit is that a condenser placed across the secondary terminals of the transformer is charged during each alternation of the 60-cycle current. The condenser is automatically discharged through rotating disks when the voltage reaches a predetermined value on each alternation. The discharge of the condenser through the apparatus under test produces a high-frequency current whose frequency is determined by the apparatus under test and the capacity of the condenser.

## Description of High-Frequency Testing Apparatus for Commercial Use

The high-frequency testing apparatus consists essentially of (1) equipment for generating the high frequency and applying it to the apparatus under test, and (2) a means of detecting any short circuits or failures in the insulation of the apparatus under test while the high frequency is being applied. A photograph of the apparatus is shown in Fig. 1. A schematic diagram of this apparatus in shown in Figs. 2A and 2B, Fig. 2A showing the generation of the high frequency and its application to the coil or winding and Fig. 2B showing the apparatus used in the detection of an insulation failure.

The power is furnished by a transformer of 10-kw. capacity with 7500-15,000 and 30,000 volts on the secondary. A 70 per cent reactance limits the current to one and a third times full-load current with the short-circuit current in the secondary. The condensers have a capacity of 0.05 microfarads at 30,000 volts. The air-gap for discharging the condenser is formed between two motor-driven rotating brass alloy disks so that the arc across the gap will not burn the metal. The sphere-gap limits and measures the voltage across the apparatus under test. A resistance of 15,000 ohms is placed in series with the sphere-gap to prevent the spheres from being burned by the arc. For voltages of 5000 and

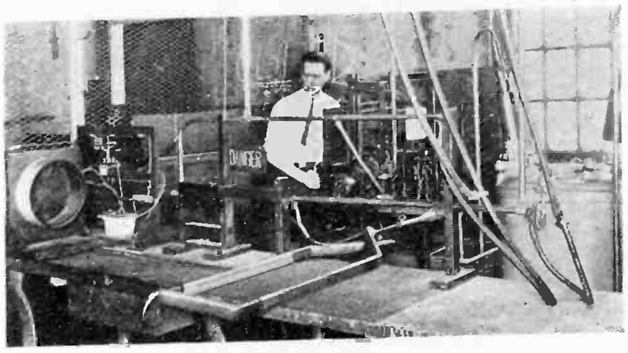


Fig. 1

higher, five-cm. spheres are used, and for lower voltages one-cm. spheres are used, also instrument measurement. A panel contains switches for the circuit breaker and plugs for tapping in different values of reactance. A hand-wheel is used for controlling the spacing of the gap of the rotating disks. Voltages ranging from 2000 to 30,000 volts can be obtained with this particular apparatus. By a combination of series and parallel connections the transformer will give 7500, 15,000 or 30,000 volts and intermediate voltages are obtained by adjustment of the rotating gap.

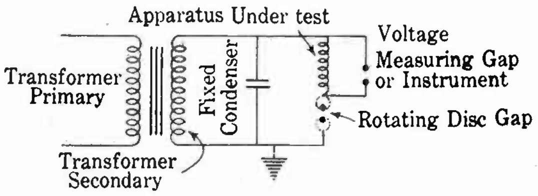



Fig. 2A

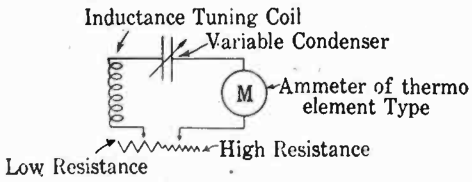



Fig. 2B

The manipulation of the test apparatus consists of connecting the leads to the coil or winding under test and setting the sphere-gap for the value corresponding to the desired test; then closing the circuit breaker and opening up the rotating disk gap until the desired voltage is obtained. This is indicated by a spark across the measuring gap. The voltages are generally applied for from 10 to 15 seconds. The frequency is determined by the apparatus under test usually within the limits of 10,000 to 200,000 cycles per sec. for individual coils and 5000 to 100,000 cycles per sec. for wound apparatus.

### The High-Frequency Voltage

The damped high-frequency voltage as produced by this set gives a somewhat more severe test on the insulation than a corresponding voltage at normal frequency. Fortunately such a test can be used to discover faults without damage to the normal insulation.

In general the voltage builds up somewhat on the end coils. At first thought this may seem to be a disadvantage, but in actual service the end coils of a group are subjected to greater voltage in the case of surges than are the other coils. The voltage on the inner coils is sufficiently high, however, to give an adequate test for defects in material or workmanship.

### Value of Test Voltages Used

The high-frequency test voltage applied to the terminals of wound apparatus corresponds closely to the regular ground test as given by the A. I. E. E. standards. This allows a liberal margin of safety over the strain due to operation at its normal voltage, and also to the momentary high voltage, high frequency surges that may be impressed in service.

The voltage which it is desirable to apply to individual coils before winding into a machine is largely a question of judgment based on experience. We have used successfully on induction regulator coils a test voltage on single coils somewhat higher than the operating voltage of the machine for voltages lower than 2500 volts while for voltages over 2500, a test voltage somewhat lower than the operating voltage, has been used.

### Methods Used in Testing with High Frequency

The methods used for various types of apparatus are somewhat different, depending on various conditions. The method of testing a single coil is shown in Fig. 1.

The method of testing the windings of a two-pole, single-phase, induction regulator is shown diagrammatically in Fig. 3 for the stator and Fig. 4 for the rotor. The two leads from the high frequency set are connected to leads *A* and *B* of one pole and the tuning coil of the wave meter is placed alongside the frame as shown at *C*. The voltage is applied for 10 to 15 seconds. The two high frequency leads are then connected to the leads *E F* of the other pole of the winding and the tuning coil placed at *G*.

The high-frequency leads can be connected to three-phase machines by either of the methods shown in Figs. 5 to 8 inclusive.

The high-frequency leads may be connected either across each pole-phase group as shown in Fig. 5, or from each lead to the star connection, as illustrated in Fig. 6 or across the leads as in Figs. 7 and 8. Each of these connections have merits for certain conditions as determined by the number of poles, the voltage of the machine, the number of turns in the winding, the number of parallel connections and the size of the machine.

On a d-c. armature the voltage is applied at two points on the commutator corresponding to the location of the brushes, and the armature is then rotated.

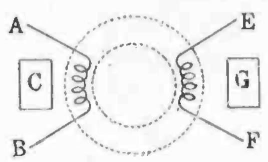



FIG. 3—TWO-POLE SINGLE-PHASE STATOR WINDING

The tuning coil of the wave meter is placed in the most advantageous position which usually is close to the outside circumference of rotors and either inside the bore or outside the frame of stators.

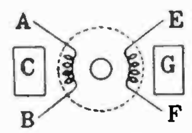



FIG. 4—TWO-POLE SINGLE-PHASE ROTOR WINDING

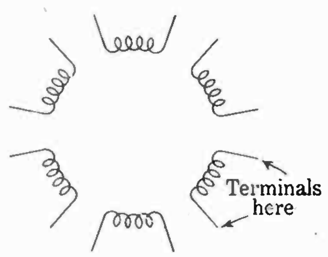



FIG. 5—VOLTAGE APPLIED TO EACH GROUP SEPARATELY

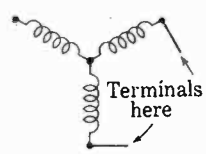



FIG. 6—VOLTAGE APPLIED TO EACH PHASE SEPARATELY

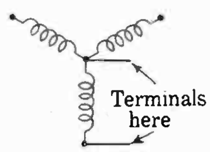



FIG. 7—VOLTAGE APPLIED ACROSS TWO TERMINALS OF A STAR CONNECTED WINDING


FIG. 8—VOLTAGE APPLIED ACROSS TWO TERMINALS OF A DELTA-CONNECTED WINDING

For each coil and winding the wave meter settings are recorded. These settings show both the frequency and the strength of signal transmitted from any particular apparatus when the winding is normal and free from faults. As each coil or winding is tested, the readings will correspond to the standard readings if the winding is free from faults, but if short-circuited, different readings will be obtained. It is thus easy to check any apparatus that has been previously tested. If new, the approximate readings can usually be estimated with sufficient accuracy by comparing the general characteristics of the windings with other known windings, and checking one part of the winding with another is an additional check. The fact that a short circuit has a deadening effect on the radiations transmitted as well as changing the wave length and frequency facilitates the discovery of any short circuits.

## SCOPE OF APPLICATION

This method of insulation testing was first applied commercially in the testing of induction regulator coils. The results were so satisfactory that the test was extended to the wound regulators, both stators and rotors of single-phase and three-phase regulators. Thousands of induction regulator coils for machines of all voltages up to 14,000 volts and hundreds of wound primaries and wound secondaries are now being tested each month with high frequency. The development has now reached a point where completely wound d-c. armatures, a-c. generator coils, turbo-generator coils and wound induction motors either partly or completely connected have been tested experimentally.

Considerable experimental work must be done before this method can be applied safely as a commercial shop test to complete windings of large alternators or induction motors. For example, sufficient information as to satisfactory test values is not yet available to apply high frequency voltage as a test to the complete windings which will be a proper measure of their ability to withstand surges in operation.

## BENEFITS DERIVED FROM HIGH FREQUENCY TESTING

Testing coils and windings with high frequency has had an effect on the insulation of the apparatus to which this test is applied. It showed that insufficient insulation for reliable operation was used in some cases, that different kinds of material should have been used in others, that certain insulating materials had been badly crushed during one of the coil forming operations, that the vacuum impregnation had not fully penetrated to all parts of the coil and that the moisture had collected into these spots and that the insulation used on certain designs was too liberal. It also furnished a good idea as to whether the insulation was sufficiently balanced between the various turns and layers to withstand the natural uneven voltage distribution that occurs in coils and windings whenever the windings are subjected to surges and line disturbances. It is thus seen that high frequency testing has enabled the improvement of the insulation of the windings by eliminating weak or defective coils, which might otherwise have been used. High frequency also checks the ability of the insulation to withstand the occasional severe dielectric strains that will occur in service and to which at present so many of the otherwise unaccountable insulation failures are attributed.

### Test Results

As induction regulator coils have been tested regularly for over four years some of the results of these tests will be of interest. During the first two years 5 per cent of all coils tested failed to stand the prescribed test but the weekly percentage of failure varied from 1 per cent to 30 per cent. During the past year the percentage failures varied from 0 to 2 per cent weekly with an average of 1 per cent. This great reduction in the number of coils that failed to stand the test was accomplished by correcting the cause of the trouble which can usually be determined by a thorough examination. However, if these coils had not been rejected on account of the high frequency test, all of the coils would otherwise have been used, as none of the coils had any defect that could have been discovered by any other method than high frequency testing.

A record of the complete windings that have been tested shows that out of 100 machines of a certain particular type there were no failures, but on other types there were as high as 10 per cent and an average of all the types of 1 per cent. It is not to be inferred that the faults detected by this test would all have resulted in service failures. The applied test has purposely been made severe in order to certainly weed out all weaknesses of this class.

There has been a distinct improvement in these machines from the service standpoint. Whereas, there was a considerable number of failures, before high-frequency testing was started on these coils, there has not been reported a single insulation breakdown in service of any machine on which high-frequency test had been applied to the coils or the winding.

### High-Frequency Testing Meets A Great Need

High-frequency testing shows up poor workmanship, checks the insulation design and the processes of manufacture. It insures that proper and adequate insulating materials are in their proper place and not missing or damaged and that no harmful foreign materials are present. It checks up such features as the elimination of moisture and the thoroughness of impregnation, undue mechanical pressure at any point and the ability of the materials to stand the mechanical operations of coil construction, and whether the various materials are sufficiently uniform.

All of the above conditions may exist but they may not be detected or discovered without the aid of high frequency testing as they are hidden from view and visual inspection is useless.

One real merit of high-frequency testing is that it invariably shows the cause of the failure, as the arc is of only such intensity as to burn out the weak insulation without burning the copper. When a machine fails in service the opposite nearly always occurs, as the copper is usually so badly burned as to destroy all evidence of the cause of the insulation failure.

High-frequency testing has now reached a stage of development where it is used as a shop test on some classes of apparatus as a check on manufacturing processes. The author does not wish to convey the idea that a point has been reached where the method may be applied as a universal commercial test.

## ULTRAVIOLET RADIATIONS

For years the scientists have attempted to make artificial sunlight and to apply it to achieve the marvels of nature; they have delved into the actual sunlight and determined its constituents; they have studied radioactivities in nature and have utilized electrical phenomena. As a result the world has a great variety of new light waves to apply. Of these the ultraviolet rays so frequently encountered from electric arcs have long been known. Much erroneous matter about the ultraviolet-ray effects has been published, but at the present time a truly astonishing list of useful applications exists.

Control of the reactions of many gases and of several chemical reactions has been achieved. In photochemical and photolytic reactions the ultraviolet ray has an important place. It is effective in halogenation reactions and in sterilization. A real field has been found in applications to biology and therapeutics, and it has come to have a very great commercial importance for industrial work in testing and bleaching.

The ultraviolet ray is applied to bring quick aging and testing of industrial materials; it detects the fastness of dyes and the quality of inks. It can be used to dry oils and leather and to determine the durability of coatings such as paints. In many bleaching operations the ultra-violet radiations are useful and they can be used to vulcanize rubber, to test the quality of paper, to waterproof paper and to detect impurities in food products.

In the field of mineral and metal fluorescent studies lie a large number of commercial possibilities, and even the cold light so eagerly sought may at last be found through the use of these radiations. Researches of many kinds are continuing, and in the near future it should be possible to reconcile and summarize a vast number of data on ultraviolet applications. It has been proved beyond doubt that this radiation from electric arcs, once considered only as an element deleterious to eyesight, is a very useful industrial and scientific tool.—*Electrical World*.

# Rating of Heating Elements for Electric Furnaces

## Test Data and Integration of Interference Between Resistors

BY A. D. KEENE[1]
Associate, A. I. E. E.

AND

G. E. LUKE[1]
Associate, A. I. E. E.

***Synopsis.***—*A study of the practical considerations involved in assigning kilowatt ratings to radiant heating elements in furnace chambers. Constants for radiation and absorption are given. Consideration is given to shape and spacing of elements with respect to shielding due to adjacent elements. A method of determining the equivalent unshielded element is worked out to provide a basis for comparing dissimilar shapes of heaters.*

* * * * *

THE failure of an electric-furnace heating element is usually due to the chaotic methods used in establishing its ratings. Frequently heating elements are given arbitrary ratings, with no analysis of the conditions under which they are to operate. Some designers have developed rule-of-thumb methods of rating elements, based on current density, or on energy dissipated per unit area. Many of these methods are further elaborated to allow for increased ratings at low chamber temperatures. These methods must be used with considerable caution as they are almost invariably based on experience with only one type of heating element, used under restricted conditions. The determination of the general constants involved has been hampered by the cost of making scientific measurements at high temperatures. A general formula must provide for the following variables:

1. The physical characteristics of the heating surfaces.
2. The relative spacing and location of the component parts of the heating surfaces.
3. The allowable difference in temperature between the element surface and the surrounding atmosphere.

Data and mathematical analysis, made available within the last year, give these constants and make it possible to determine factors of safety of various shapes and arrangements of heating elements, and so make direct comparisons. This will permit the heating engineer to select his units with greater freedom and predict the temperatures at which they will operate. The calculation is analogous to the calculation of the mechanical engineer, who determines the unit stress on the extreme fiber of the beam he is loading with a fairly accurate knowledge of the stress at which it may be expected to fail.

A conductor supported in air, and carrying electric current will increase in temperature until the heat removed by conduction, convection, and radiation, equals the heat generated within the conductor by the passage of the current. This is true whether the conductor is inclosed in a furnace chamber to act as a source of heat, or is a part of a transmission line where heat is an undesirable by-product. The relative amounts of heat removed by the three different means of transmission change rapidly with the operating temperature of the conductor.

The convection loss from a surface increases as the $1\frac{1}{4}$ power of the difference in temperature between the surface and the surrounding room, while the radiation loss increases as the fourth power. At a surface temperature of 1000 deg. cent. (1832 deg. fahr.), the loss from a conductor in free air is roughly 90 per cent by radiation and 10 per cent by convection. (Conduction through air is so small as to be negligible and will be disregarded throughout the remainder of this article.) At this temperature, it is evident that an air space is a very inefficient heat insulator, since 90 per cent of the energy travels freely and almost without loss between the enclosing surfaces.

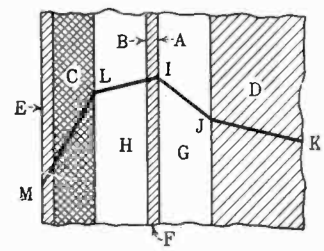



Fig. 1

The simplest heating element might be a sheet of resistance material covering an area of furnace wall and parallel to the wall, the arrangement being as indicated in Fig. 1, $F$ is the plate in which heat is generated with surface $A$ toward, and parallel to the charge $D$ which is to be heated, and surface $B$ toward, and parallel to wall $C$ which is a partial heat insulator. We will consider $F$, a large thin plate so the losses from the edges may be eliminated as negligible. Heat generated in the plate is conducted to the surfaces $A$ and $B$. We will assume that wall $C$ is of such material and thickness that 20 per cent of the heat generated in the plate escapes to the outside. Surface $B$ can then dispose of only 20 per cent of the energy, generated so surface $A$ must attain such a temperature as to dispose of the remaining 80 per cent of the energy. Surfaces $A$ and $B$ are opposite sides of a thin plate and so are at approximately the same temperature. When a state of equilib-

1. Both of the Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

*Presented at the Midwinter Convention of the A. I. E. E., New York, N. Y., February 8-11, 1926.*

rium of heat-flow is reached, the temperature-gradients will be approximately as represented by lines $I$–$J$–$K$ and $I$–$L$–$M$, the temperature at the surface of the wall $L$ will be considerably higher than the temperature $J$ at the surface of the charge because the difference in temperature between $I$ and $J$ is forcing four times as much heat across the space $G$ as the difference in temperature between $I$ and $L$ is forcing across the space $H$.

It is particularly noticeable in this example that all surfaces of an element are not equally effective in disposing of the generated heat. If we consider surface $A$ as 100 per cent effective, we can then consider the surface $B$ only 25 per cent effective because under operating conditions it disposes of only one-fourth as much of the generated heat. The surfaces of plate $F$ as located are then only 62.5 per cent as effective in disposing of heat as they would be if charge $D$ were disposed on both sides of plate $F$. The factor 62.5 per cent (in this case) may be called the "surface efficiency" since it is the factor by which the total surface area of the resistor must be multiplied to obtain the area of an equivalent resistor whose surface is 100 per cent effective.

## Theory and Experimental Data

(*a*) *Single Linear Heater.* Due to the relatively poor thermal conductivity of the supporting refractories, and to the small area of contact, very little heat is conducted away from the heater elements. Hence radiation and convection are the principal agents in the transfer of heat from the elements. The fundamental equation, expressing the rate of heat dissipated by radiation and convection from surfaces, is:

$$W = a(T_2 - T_0)^{1.25} + 36.9\, e \left[ \left\{ \frac{T_2}{1000} \right\}^4 - \left\{ \frac{T_1}{1000} \right\}^4 \right]$$

Where

- $W$ = Watts dissipated per sq. in. of surface
- $T_2$ = Absolute temperature deg. cent. of heater surface
- $T_0$ = Absolute temperature deg. cent. of room or furnace air
- $T_1$ = Absolute temperature deg. cent. of surrounding surfaces
- $a$ = Convection constant
- $e$ = Coefficient of emissivity (1.00 for a black body)

In the above equation, the convection loss is shown as proportional to the 5/4th power of the temperature rise of the heater above the ambient air. The radiation loss, however, increases at a much greater rate, since it is a function of the fourth power of the absolute temperatures. The constants ($a$) and ($e$) vary slightly with the temperatures; however, the variation is so small that it can be neglected for practical purposes. The values of these constants were determined from experimental tests. The single linear heater element was suspended in free air. The input was measured electrically and the final temperatures were determined by the use of thermo couples. An optical pyrometer was also used to check the heater temperatures. The thermo couples were 0.008-in. diameter platinum and platinum-rhodium spot welded to the conductor.

From the large number of tests made, average values of the constants were obtained as follows:

| Heater Element | Constant ($a$) | Constant ($e$) |
|---|---|---|
| ¼-in. diameter nickel chromium.......... | 0.0032 | 0.91 |
| ¾-in. wide strip nickel chromium.......... | 0.0013 | 0.90 |

Using these constants in the equation previously given, the curves shown, Fig. 2, were plotted. Experimental tests on this curve covered the range of 100 to 1100 deg. cent. The elements were tested both

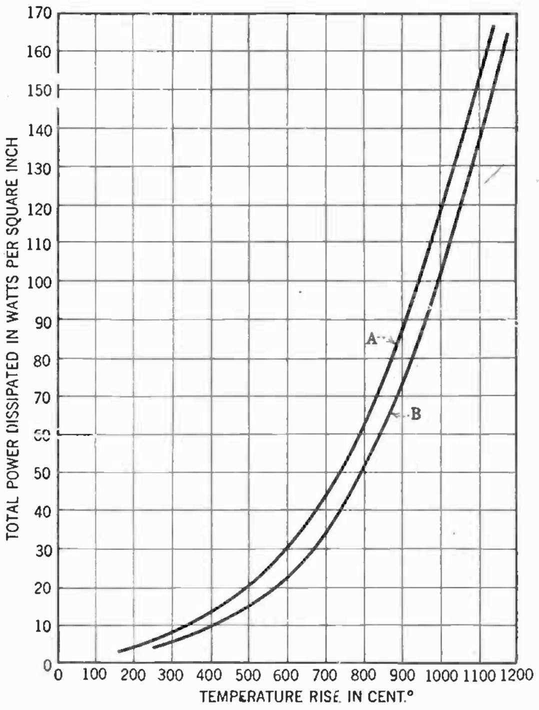



Fig. 2

$A$ = ¼-inch rod
$B$ = 1½-inch wide strip
Ambient temperature 27 deg. cent.

vertically and horizontally and very little difference was found, especially at commercial temperatures where most of the heat is transmitted by radiation.

(*b*) *Parallel Heater Elements—Single Row.* In a commercial furnace, the heater consists of a large number of parallel ribbons or rods. It is evident that the rating of such elements will not be as great as a single element, due to interference of the adjacent elements. For such parallel heater elements arranged in a row, the relative heat loss can be calculated on the basis of the angle subtended by the opposite interfering resistor. Thus, in Fig. 3 is shown a row of parallel strip resistors. The approximate radiation from any small element ($d\,x$) will be proportional to the ratio of (180 deg. $- \alpha$) per 180 deg. An integration of these elements, either mathematically or graphically, over the total surface will give the effective radiation. Results of such calculations are given in Figs. 5 and 6 for round rods and strips respectively. The curves are plotted in terms of ratios in order to be applicable to any particular arrangement and size of heating element. While these curves as calculated refer only to radiated energy, tests show that they also represent very closely the effectiveness of the surface for both radiation and convection. The reason for this primarily is due to the relatively small amount of heat lost by convection—although it is a fact that by the grouping of the elements the convection and radiation losses are reduced to about the same degree. These curves were experimentally checked throughout the range shown, both round rods and strips being used. In making these tests, three equally spaced parallel elements were used. Thermo couples were placed on all three. Means were provided for independently varying the current through the middle heater and the two outside heaters. In this way the current was adjusted so as to give equal temperatures for all three heaters. The loss from the middle conductor was measured.

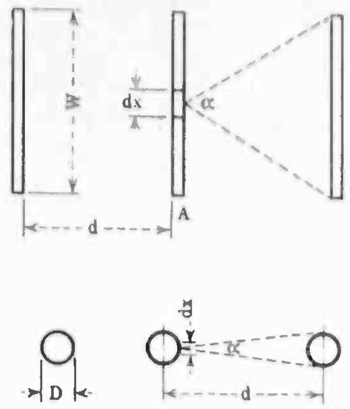



FIG. 3

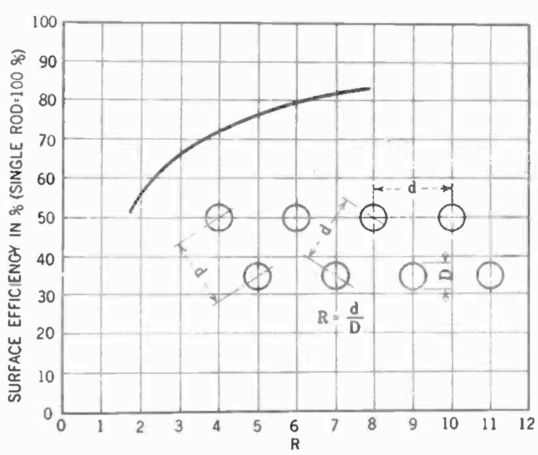



FIG. 4—CURVE OF SURFACE EFFICIENCY FOR DOUBLE BANKED RODS

(c) *Parallel Heater Elements—Double Row.* In some furnaces it is desirable to double bank the heating elements. The two rows of elements will interfere to some extent so that the rating will be reduced. The "surface efficiency" of a double bank resistor composed of round parallel rods arranged equidistant from each other, was calculated in the same manner as the single bank. The calculated curve is shown in Fig. 4.

The curves Figs. 4, 5, and 6 show values of surface efficiencies plotted against the ratios of spacings to widths and diameters respectively. The curves are not directly comparable as the abscissas are not expressed as ratios of similar dimensions.

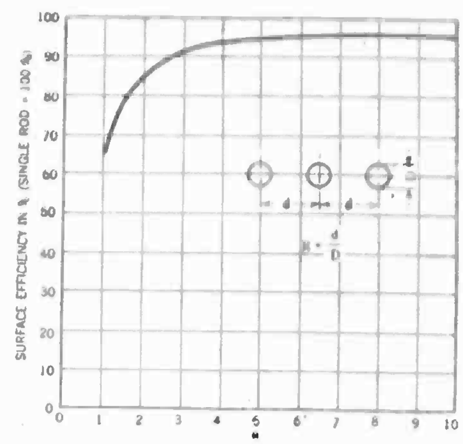



FIG. 5—CURVE OF SURFACE EFFICIENCIES FOR RODS

It is interesting to analyze commercial heating elements on the basis of the above data.

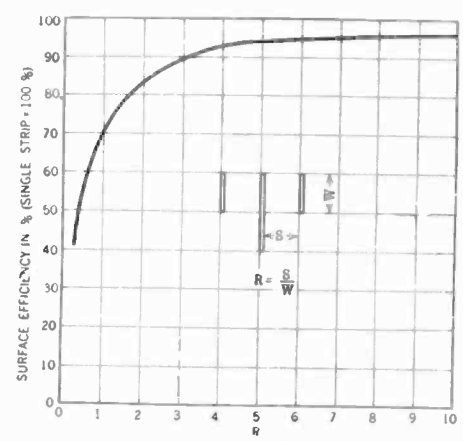



FIG. 6—CURVE OF SURFACE EFFICIENCIES FOR STRIPS

Let us assume the following conditions:

$1\frac{1}{2}$ in. wide strip 1/10 in. thick spaced, $1\frac{1}{2}$-in. centers arranged as in Fig. 3, 0.289 in. diameter rod 1-in. centers arranged in two layers, (double banked) as shown in Fig. 7, and 0.289-in. rod $\frac{3}{4}$-in. centers single layer (single banked) also shown in Fig. 3. In each case power, equivalent to 15 watts per square inch of radiating surface, is generated in the element. The furnace chamber temperature is fixed at 900 deg. cent. (1652 deg. fahr.). Room temperature 27 deg. cent.

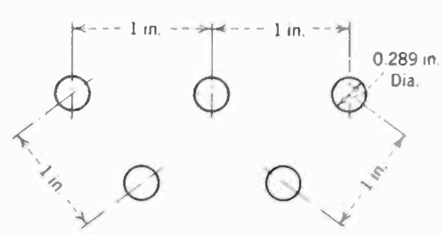



FIG. 7—ARRANGEMENT OF FURNACE HEATING ELEMENT RODS

We will assume that the resistor enters the danger zone, in which oxidation becomes progressive and, therefore, destructive at 1100 deg. cent. (2012 deg. fahr.).

*For the Case of the Double-Banked Rod*

$d$ = 1-in.

$D$ = 0.289

$R$ = 03.46

The surface efficiency from Fig. 4 is then 70 per cent.

Then 15 watts per sq. in. is equivalent to 15 ÷ 0.70 = 21.43 watts per sq. in. dissipation.

To use the curves in Fig. 2 at furnace chamber temperatures, we must transpose from 27 deg. cent. ambient temperature to 900 deg. cent. ambient temperature as follows:

900 deg. − 27 deg. = 873 deg. which corresponds to 78 watts on the Curve *A* for rods (Fig. 2).

Then 78 + 21.43 (the equivalent dissipation determined above) = 99.43 watts which corresponds to a temperature rise of 950 deg. cent. (Curve *A*, Fig. 2). The operating temperature of the rod is then 950 deg. cent. + 27 deg. cent. = 977 deg. cent.

If 1100 deg. cent. marks the entrance to the danger zone, a 12.6 per cent rise in temperature will be required to bring the temperature of this heating element up to a dangerous value. This 12.6 per cent may then be considered as the factor of safety.

*In the Case of the 1½ in. Ribbon*

$W$ = 1½

$S$ = 1½ − 1/10 = 1 4/10

$R$ = 0.933

Surface efficiency = 69 per cent from Fig. 6.

Then the dissipation equivalent to 15 watts per sq. in. = 15 ÷ 0.69 = 21.74 watts per sq. in.

900 deg. cent. minus 27 = 873 deg. cent. which corresponds to 65 watts dissipation on Curve *B*, Fig. 2.

65 watts + 21.74 = 86.74 watts per sq. in. This is equivalent to a 960 deg. cent rise. The operating temperature is then 960 deg. cent. + 27 deg. cent. = 987 deg. cent.

This gives a factor of safety as above of 11½ per cent.

*For the Single Banked Rod*

$d$ = 0.75

$D$ = 0.289

$R$ = 2.6

From Fig. 5 the surface efficiency is 89.5. Then the dissipation equivalent to 15 watts per sq. in. is 15 ÷ 89.5 = 16.65.

900 − 27 deg. cent. = 873 deg. cent. which corresponds to 78 watts on Curve *A*, Fig. 2. Then 78 + 16.65 = 94.65 watts per sq. in. which corresponds to a temperature rise of 930 deg. cent. The operating temperature of the rod is then 930 deg. + 27 deg. = 957 deg. cent. This gives a factor of safety of 14.94 per cent.

It should be noted that these factors apply only to the physical conditions specified. A narrower ribbon or smaller rod would have a higher factor of safety for this spacing. A wider strip would have a considerably lower factor of safety as we are working on the steep part of the surface efficiency curve, Fig. 6.

We may also make an analysis of the cost of metal required to generate one kilowatt of heat energy in a furnace chamber. Let us assume the same conditions of physical size and spacing as were used in the preceding illustration, the operating temperature of the resistor 1000 deg. cent. and the furnace chamber temperature 900 deg. cent.

*Considering the Double Banked Rod*

The dissipation of energy at 100 per cent surface efficiency on a rod at 1000 deg. cent. is 106 watts per sq. in. (from Curve *A*, Fig. 2). The dissipation at 900 deg. cent. (chamber temperature) = 79 watts per sq. in. correcting for 27 deg. ambient temperature in each case.

The difference is 27 watts per sq. in. or the permissible dissipation from a rod having 100 per cent "surface efficiency."

The double banked rod as before is 70 per cent efficient so the actual watts permissible dissipation is 70 per cent of 27 = 18.9 watts per sq. in.

To dissipate 1000 watts will require 1000 ÷ 18.9 = 52.91 sq. in. of rod surface.

The area of one foot of .289 in diameter rod is 10.9 sq. in.

52.91 ÷ 10.9 = 4.854 linear feet of rod required weighing 0.239 lb per foot = 1.16 lb.

At a list price of $4.05 per pound this is $4.80 for the cost of double banked rod to dissipate one kilowatt.

*For the Strip*

The watts per sq. in. dissipation at 100 per cent surface efficiency on a strip at 1000 deg. cent = 92 from Curve *B*, Fig. 2.

At 900 deg. cent. = 65 (correct for 27 deg. ambient temperature).

The difference is 27 watts per sq. in. permissible dissipation from a strip having 100 per cent "surface efficiency."

The strip as before is 69 per cent efficient so the actual watts permissible is 69 per cent of 27 = 18.6 watts per sq. in. and to dissipate 1000 watts will require

1000 ÷ 18.6 = 53.8 sq. in.

The area of one linear foot of strip is 38.4 sq. in.

53.8 ÷ 38.4 = 1.4 linear feet of strip weighing 0.81 lbs. per foot = 0.782 lbs. at $5.10 per pound = $3.99 for the cost of strip to dissipate one kilowatt.

*In the Case of the Single Banked Rod*

The dissipation from a 100 per cent surface efficiency rod as in the case of the double banked rod is 27 watts per sq. in.

The efficiency as in the earlier single banked rod example is 89.5 per cent so the actual watts permissible is 89.5 per cent of 27 = 24.16.

To dissipate 1000 watts will require 1000 ÷ 24.16 = 41.35 sq. in. of heater area.

The area of a linear foot of 0.289 inch diameter rod is 10.9 sq. in.

41.35 ÷ 10.9 = 3.793 feet of rod at 0.239 pounds per foot this weighs 0.9065 lb. at $4.05 per pound = 0$3.67 for the cost of single banked rod to radiate one kilowatt.

In computing the above costs prices have been listed for nickel chromium as quoted by a well-known manufacturer. As in the case of efficiencies, other physical dimensions will materially change the results. The dimensions used are those of heating elements in common use.

For convenience, the results of the above problems are tabulated below:

| Shape of element | Arrangement of element | Factor of safety at 15 watts per sq. in. dissipation | Cost of metal per Kw. radiated at constant factor of safety |
|---|---|---|---|
| Strip 1¼ in. wide | Single banked Fig. 3 | 11½ per cent | $3.99 |
| Rod 0.289 in. dia. | Single banked Fig. 3 | 14.94 per cent | $3.67 |
| Rod 0.289 in. dia. | Double banked Fig. 7 | 12.6 per cent | $4.80 |

The above problems serve to illustrate several important points in design.

1. A resistor element of any shape may be supported in a furnace and so rated as to give a suitable factor of safety and reasonable service.

2. The shape of the element does not inherently insure a lower first cost of material. (Low cost frequently sacrifices a part of the factor of safety).

3. The selection of the elements for any furnace is an engineering problem requiring proper analysis. It should be approached with the idea of applying a suitable heating equipment, not with the idea of adopting some specific type of element to the installation.

In the foregoing calculations, we have disregarded the effect of adjacent walls. This should not introduce a serious error where the element itself is not so located as to act as a screen preventing reradiation and reflection of heat energy from the wall. The wall would perhaps have considerable effect on convection currents, but convection plays a relatively small part in the dissipation of heat at these temperatures.

Heat radiated to the wall is either reflected or is absorbed by the wall. That absorbed is conducted away from the surface or re-radiated into the furnace chamber. For the relative values of these various heat transfers, we must again refer to test data available. Fire brick at a temperature of 1000 deg. cent. reflects 40 per cent of the radiant heat falling on its surface and absorbs the other 60 per cent. If 50 per cent of the heat generated finds its way to the wall surfaces as radiant energy, then 20 per cent of the heat generated in the furnace is reflected from the walls much as light is reflected from a mirror. Thirty per cent is absorbed by the walls. If one-half of this heat absorbed is conducted to the external surface and lost, the remainder, 15 per cent of the heat generated in the heating elements, is re-radiated from the walls into the furnace chamber.

Thus, it can be seen that with the above data, the furnace engineer can calculate with reasonable accuracy the temperatures attained by resistor elements in service and can determine the factors of safety. He can also anticipate the manner in which heat will be transmitted to the charge. These calculations are of utmost importance to the furnace buyer. The fact that the conditions in a projected furnace can be determined by competent engineers, much as the loading of a bridge is determined, is insurance against loss through furnace failure.

## A REAL CONTRIBUTION TO KNOWLEDGE OF STABILITY

System stability has been a debatable subject for several years. The advocates of transient stability and those of static stability have argued for their respective criteria for system performance in many papers and meetings. Data on an actual system, however, have been unavailable until lately, and the discussions have waxed warm on the basis of the relative importance different specialists attached to assumed factors.

It is encouraging to find that executives of the Pacific Gas & Electric Company consented to submit the system of that company to a series of stability tests for the benefit of the whole industry. In his paper before the meeting of the American Institute of Electrical Engineers this week Roy Wilkins gave the results of the tests and made available to all properties many valuable data. The executives and engineers of the Pacific Gas & Electric Company have thus contributed greatly to the development of the art, and it is to be hoped that tests by other utilities covering data needed to develop other phases of the art will likewise be published for the benefit of the industry instead of being merely placed on file on dusty shelves.

The normal limit, or even rating, of a power system is difficult to define because of the ever-changing electrical and physical conditions in lines, equipments and loads. For a specific system, however, both the static and transient stability limits can be agreed upon and determined quite accurately for given conditions. Thus progress has been made. Debates on technicalities and attempts to generalize about stability should not be permitted to obscure this fact.—*Electrical World.*

# Operating Performance of a Petersen Earth Coil-II

BY J. M. OLIVER[1] AND W. W. EBERHARDT[1]

Associate, A. I. E. E. Associate, A. I. E. E.

*Synopsis.—At the A. I. E. E. Spring Convention, Pittsburg, April 24-26, 1923, a paper was presented by the authors on the operation of a Petersen Earth Coil installed by the Alabama Power Company on its Lock 12-Vida 44,000-volt system. That paper reported an excellent performance record for the coil, although several unaccounted for bus insulator flashovers occurred at Lock 12, indicating that further investigations on the action of the coil were necessary.*

*This paper presents eleven months' additional operating experience with the Earth Coil, which shows that over-voltage disturbances can be eliminated by doing all line switching operations with the Petersen Coil out of service; that is, with the system neutral solidly grounded. It is believed that the same results can also be obtained by under-tuning the coil.*

*The Lock 12 Coil is no longer in service, as the system has outgrown the need of such equipment; additional power sources have been added to the system and reliable service can be maintained without the use of flashover suppressing devices.*

*It appears that the application of Petersen Earth Coils is limited to comparatively low voltage lines (66,000 volts and less) of moderate length with a single source of power supply. In such an application, the use of a Petersen Coil between system neutral and ground has the advantage over grounded neutral operation by reducing line outages due to flashovers and over isolated neutral operation by eliminating arcing grounds.*

* * * * *

---

The purpose of this paper is to present eleven months' additional operating experience with the Alabama Power Company's Petersen earth coil installed on its Lock 12-Vida 44,000-volt system, shown in Fig. 1. A detailed description of this installation is given in the writers' earlier paper[2] presented at the A. I. E. E. Spring Convention, Pittsburgh, April 24-26, 1923. A complete operating log of the Lock 12 coil for the period extending from October 12, 1921 to March 1, 1923 was also given in that paper, which showed an excellent performance for the coil, the number and duration of interruptions due to lightning flashovers having been reduced by 83.5 and 94 per cent respectively, by its use. There were, however, several unaccounted for bus insulator flashovers at Lock 12, which indicated that further investigations on the action of the coil were necessary.

The bus insulator flashovers in question occurred when the line switch at Lock 12 opened automatically or was opened by hand while the Petersen coil was in service. It was the consensus of opinion of those who discussed the Pittsburgh paper that the high-voltage flashovers were caused by the non-simultaneous opening of the three poles of the line breaker. This is a very plausible explanation of the trouble because at that time the coil was overtuned,—that is, it had excess reactance—and the disconnection of one line conductor ahead of the other two would change the line capacitance in the right direction to produce a condition of resonance in the series circuit, in which case there would be nothing to limit the rise of voltage except the system losses. Assuming that this is the correct explanation for the high-voltage disturbances, there are two remedies which can be applied; namely (a) to undertune the coil, and (b) to electrically interlock the control circuit of the grounding switch with the overload protective relay scheme on the line switch so that the grounding switch is always automatically closed before the line switch opens to clear phase-to-phase short circuits.

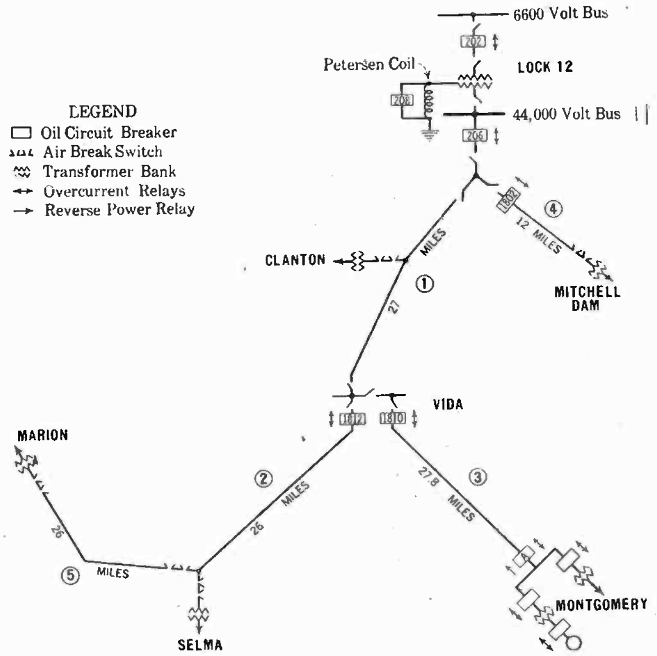



Fig. 1—Lock 12—Vida 44, 00-Volt System

Of these two methods, (a), if successful, would prove the more advantageous since no change in the normal control connections is required. Method (b) has the disadvantage of introducing complications in the control scheme and also slows up the relay operations on phase-to-phase short circuits, since additional timing must be allowed for the closing of the ground switch. Method (b), however, had already been applied and was in operation when the theory of undertuning was advanced so it was decided to continue operation with the interlocking feature between the ground and line

1. Both of the Alabama Power Co., Birmingham, Ala.
2. A. I. E. E. Transactions, 1923, page 435-45.

*Presented at the Midwinter Convention of the A. I. E. E., New York, N. Y., February 8-11, 1926.*

switches during the 1923 lightning season, and then perhaps operate the coil under-tuned during the 1924 season. Unfortunately, the coil had to be taken out of service before the 1924 lightning season for reasons stated in the latter portion of this paper, and the under-tuning principle of operation thus far has not been given a trial.

### Operation with Interlock Between Line and Ground Switches

Fig. 2 is a connection diagram of the complete control equipment on the Lock 12 Petersen coil, the interlocking of the grounding switch control circuit with the protective relay scheme on the line switch being accomplished by the use of the two type *H G* auxiliary relays shown in the lower left hand corner of the diagram. Operators were also given instructions to always close the neutral grounding switch; that is, to take the Petersen coil out of service before doing any line switching. The Lock 12 coil operated under this new operating procedure from February 24, 1923 to January 26, 1924, during which time no further high-voltage disturbances were experienced, indicating that a satisfactory solution to the problem had been found.

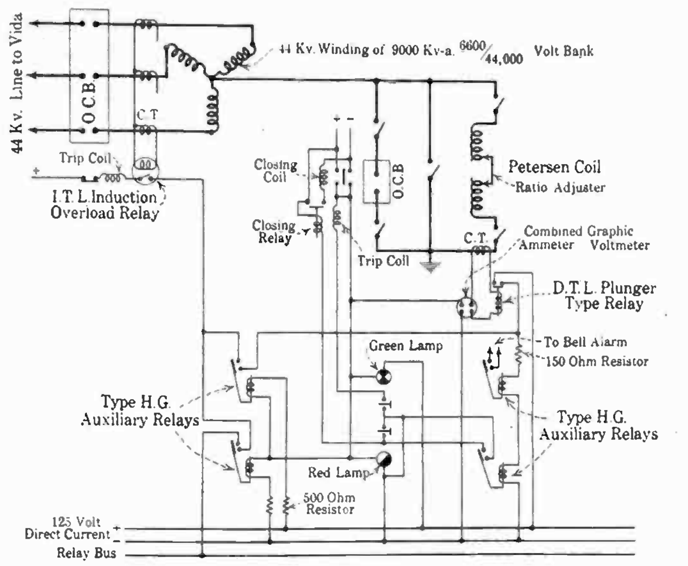



Fig. 2—Lock 12—Petersen Coil Installation—Schematic Diagram of Connections

A complete log of all the operations was taken during the period mentioned and summary of these operations is given in Table I which shows the following results:

*Flashovers.* There was a total of 109 insulator flashover indications recorded on the combined graphic ammeter and voltmeter, 94 of which, or 86 per cent, did not result in line interruptions and are considered perfect operations of the Petersen coil.

On the remaining fifteen flashover indications the line switch opened causing an interruption to service. In each case, however, the line was promptly put back into service, O. K., indicating that the trouble was not a solid ground, but rather a flashover which the Petersen coil failed to clear. These operations are therefore considered faulty.

*Solid Grounds and Phase-to-Phase Short Circuits.* There was a total of five solid grounds and 21 phase-to-phase short circuits, due to line and transformer troubles. These cases of trouble were outside of the operating sphere of the Petersen coil, but in each case the line overload relays functioned properly and promptly to clear the disturbance.

*Interruptions to Lock 12-Vida Line Due to all Causes.* Table II is a classification of service interruptions to the Lock 12-Vida line from March 1, 1923 to January 26, 1924, exclusive of prearranged interruptions and those due to trouble on other parts of the Alabama Power Company's system. This tabulation shows that there was a total of 40 interruptions to service with a total outage of 221 minutes for this eleven months' period, which is a far better service record than was obtained for any previous period of similar duration.

TABLE I
SUMMARY OF PETERSEN COIL OPERATIONS.[1]

| Month | Flashover Indications | | | | Transformer Trouble | | Line Trouble | |
|---|---|---|---|---|---|---|---|---|
| 1923 | Under 6 Amperes | Over 6 Amperes | Faulty Operation of Coil Line Switch Opened | Switch 208 Closed but no Interruption | Phase-to-ground | Phase-to Phase | Phase-to-Ground | Phase-to-Phaso |
| March | — | 2 | 1 | – | 1 | – | – | – |
| April | — | 2 | 2 | — | – | 1 | – | 2 |
| May | 4 | 5 | 3 | 6 | – | – | 1 | 5 |
| June | — | 4 | — | — | – | 1 | – | 3 |
| July | — | 4 | — | — | – | – | 2 | 3 |
| August | 15 | 22 | 7 | — | – | – | – | 5 |
| Sept. | 2 | 9 | 1 | 4 | – | – | – | 1 |
| Oct. | — | 4 | — | 4 | – | – | – | – |
| Nov. | — | — | 1 | 1 | – | – | – | – |
| Dec. | 2 | 2 | — | — | – | – | – | – |
| 1924 | | | | | | | | |
| Jan. | — | 1 | — | 1 | – | – | 1 | – |
| Total | 23 | 55 | 15 | 16 | 1 | 2 | 4 | 19 |

Total number of operations...........135

1. Copies of the complete log from which this Summary was compiled may be obtained from the authors on request.

This service record is especially remarkable for a long radial feeder when it is taken into consideration that 144 minutes of the total time out were due to a single case of trouble when a tree fell into the line.

Since the function of the Petersen coil is to reduce the interruptions due to lightning, a comparison of service interruptions to the Lock 12-Vida line chargeable to lightning for the years 1922, 1923 and 1924 proves very interesting as the following tabulation will show:

TABLE II

INTERRUPTIONS ON LOCK 12-VIDA 44-KV. SYSTEM MARCH 1, 1923 TO JAN. 26, 1924.
(Exclusive of Interruptions due to Trouble on Other Parts of Alabama Power Cmpany's System.)

| Month | Lightning | | Trees Falling Into Line | | Insulator on Lightning Arrester | | Transformer | | Unknown | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. of Cases | Time Out Min. | No. of Cases | Time Out Min. | No. of Cases | Time Out Min. | No. of Cases | Time Out Min. | No. of Cases | Time Out Min. | No. of Cases | Time Out Min. |
| 1923 | | | | | | | | | | | | |
| March | 1 | 2 | – | – | – | – | 1 | 2 | – | – | 2 | 4 |
| April | 3 | 5 | 1 | 6 | – | – | 1 | 2 | – | – | 5 | 13 |
| May | 1 | 2 | – | – | 1 | 2 | – | – | 7 | 11 | 9 | 15 |
| June | 2 | 4 | 1 | 2 | – | – | 1 | 2 | – | – | 4 | 8 |
| July | 2 | 3 | 1 | 2 | – | – | – | – | 2 | 3 | 5 | 8 |
| Aug. | 11 | 23 | – | – | – | – | – | – | 1 | 2 | 12 | 25 |
| Sept. | 2 | 2 | – | – | – | – | – | – | – | – | 2 | 2 |
| Oct. | – | – | – | – | – | – | – | – | – | – | – | – |
| Nov. | – | – | – | – | – | – | – | – | 1 | 2 | 1 | 2 |
| Dec. | – | – | – | – | – | – | – | – | – | – | – | – |
| 1924 | | | | | | | | | | | | |
| Jan. | – | – | 1 | 144 | – | – | – | – | – | – | 1 | 144 |
| Total | 22 | 41 | 4 | 154 | 1 | 2 | 3 | 6 | 11 | 18 | 41 | 221 |

| Year | Method of Operation | Number of Lightning Storms Over Line | Interruptions due to Lightning: Number | Interruptions due to Lightning: Total Time Out |
|---|---|---|---|---|
| 1922 | System neutral solidly grounded | 82 | 43 | 230 minutes |
| 1923 | Neutral grounded through Petersen Coil | 97 | 7 | 14 minutes |
| 1924 | Ditto | 80 | 22 | 41 minutes |

This tabulation shows that although approximately the same number of lightning storms have occurred in the vicinity of Lock 12 each year, the interruptions due to lightning were greatly reduced while the Petersen coil was in service, proving its effectiveness in suppressing flashovers.

## Limitations in Use of the Lock 12 Coil

The Lock 12 coil was taken out of service and the system neutral solidly grounded January 26, 1924, because

(a) At that time the line mileage of the Lock 12-Vida system was practically doubled by the addition of new lines, making the total line charging current greater than the Petersen coil was designed for and to take care of which would have required new taps on the coil, and

(b) A generating station was added at Upper Tallassee which was connected to the system through a delta-star transformer bank with a solidly grounded neutral on the 44,000-volt winding.

Of course, a second Petersen coil could have been introduced between the Upper Tallassee neutral and ground since on a Petersen coil system a reactor must be installed at each grounding point; but with two sources of power supply to Lock 12-Vida system, it was felt that reliable service could be maintained at Montgomery without the use of Petersen coils and their expense was, therefore, not justified. It was also foreseen

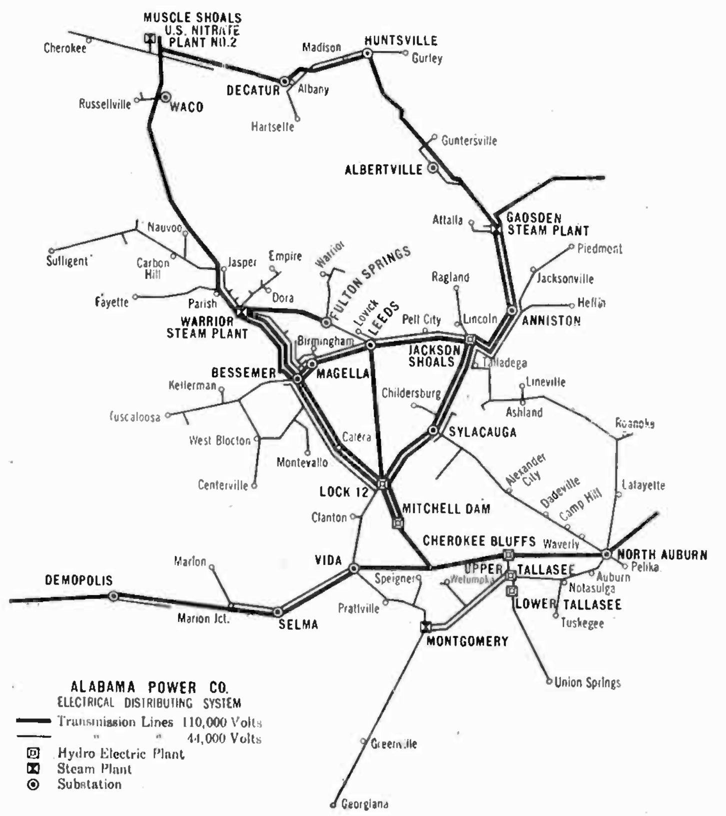



Fig. 3

that the Lock 12-Vida system would be further extended and linked with the Alabama Power Company's main 44,000-volt network, which is solidly grounded at Warrior, Bessemer, Leeds, Jackson Shoals and Anniston substations. This interconnection was completed in the latter part of 1924 and the 44,000-volt system network now exists, as shown in Fig. 3.

CONCLUSIONS

The Alabama Power Company's experience with the Petersen earth coil indicates that it will greatly reduce the number of interruptions due to insulator flashovers during lightning storms.

All high-voltage disturbances which were experienced when the coil was first placed in service have been entirely eliminated by making provisions to do all line switching, both hand and automatic, with the coil out of service—that is, with the system neutral solidly grounded.

The application of Petersen coils appears to be limited to comparatively low-voltage lines (of 66,000 volts and less) of moderate length, with a single source of power supply. On an interconnected network, such as the Alabama Power Company now operates, several sources of supply are maintained to all principle load centers and good service can be carried on without the use of flashover suppressing devices. In other words the expense and complications of a Petersen coil installation are justified only on radial feeder systems where it is desired to improve service to an important load center which is connected to the power source by only a single line. The Petersen coil in such an application has the advantage over grounded neutral operation by reducing line outages due to flashovers and over isolated neutral operation by eliminating arcing grounds.

## LAKE MERRIT HAS SPECIAL LIGHTING

Equipping streets and exteriors of public buildings with special electric lighting is now quite common, but doing this to a lake is a different story. In fact, Lake Merritt, Oakland, Cal., is probably the only one of its kind which has such electric lighting.

Around the shore of the lake there are now special electric lamp posts from each of which hang Gothic lanterns provided with amber glass. Each of the lanterns has a reflector so adjusted that a large portion of the lantern light will fall on the surface of Lake Merritt. In addition to these, electric floodlight units have been placed around the lake to illuminate clumps of shrubbery and groups of trees and also between the lamp posts, concrete sockets have been put in place so that for special celebrations poles carrying festoons of streamer lights may readily be put in place.

All of this electric lighting is controlled from a single central switch house where there is equipment which makes it possible to dim the light of the various lamps to such an extent that the filament of each is only a dull red. Then within a minute by turning the gears these lamps are once more producing their full candlepower of light. With all this lighting Lake Merritt on ordinary nights is a sight worth seeing and when dressed up for special occasions it is a veritable fairyland that attracts people from far and wide.

## THE COMPARISON OF NATURAL AND ARTIFICIAL LIGHTING

In connection with the efforts that are now being made to trace the relation between better lighting and higher efficiency of work, it is natural that experimenters should try to base their conclusions on the results achieved by daylight.

The greater part of the work of the world is still done by natural light, and a comparison between natural and artificial lighting conditions affords much interesting information. It is doubtful, however, whether all investigators realize the complexity of the factors involved in such a comparison. The illumination available by the best daylight conditions is far greater than is usually furnished by artifiical means. On the other hand, daylight is a highly variable quantity. Photometric measurements show that remarkable changes may occur even during a relatively short working period. In making comparisons, the experimenter is usually driven to adopt as a measure the *average* daylight illumination during the working period. But it is questionable whether an average between illuminations varying, perhaps, in a ratio of 10 to 1 can be regarded as a measure of the effective daylight illumination. The eye is inevitably affected by these changes, and it would seem better, in making comparisons, to devise some method (*e. g.*, by adjustment of blinds) by which the actual daylight illumination can be kept practically constant during the test period.

Again, the *nature* of daylight illumination, as well as the intensity, may be quite different from artificial light. The presence of the bright sky overhead out of doors causes corresponding adaptation of the eye, and leads it to demand illuminations much higher than might otherwise be required. Even in a room the presence of a window near at hand, through which the sky can be seen, has a similar effect.

Taking all these facts into consideration, it is not surprising that quite different answers are often received to the simple question: "Does one require more or less illumination by natural light than by artificial light?" The whole subject is one that deserves careful investigation, and would furnish material for an interesting discussion. Meantime there is one obvious lesson—investigators who attempt to make comparisons between artificial and natural lighting should be careful to specify as exactly as possible the daylight conditions in the room in which the comparison is made. Daylight illumination is not under our control, but an increase in artificial lighting involves corresponding increased cost. If standards recommended to consumers are unnecessarily high, a reaction towards economy and a set-back to future progress may occur. Supply undertakings could, however, materially smooth the path towards higher illuminations by closer co-operation and reduced rates.—*The Illuminating Engineer.* (London).

# Mechanical Force Between Electric Circuits

BY R. E. DOHERTY[1] and R. H. PARK

Associate, A. I. E. E. Non-member

*Synopsis.—A general equation is developed for the mechanical force exerted by a system of n electric circuits, upon any part of that system. The electric circuits are assumed to contain resistances, and the reluctance of the several magnetic circuits is assumed to be a function of both the currents and the relative positions of the circuits. The equation is therefore applicable to circuits involving saturated iron.*

*Special cases of a single circuit and of n circuits are treated, in which a method of graphical solution is given. Also an approximation is made, which results in fairly simple analytical expressions for the force in the case of circuits involving saturated iron.*

*The results are preliminary to an investigation of the forces existing in synchronous machines under the condition of short circuit, which subject will be treated in a forthcoming paper.*

## I—Discussion of Problem and Method of Solution

ALTHOUGH methods have been available for calculating the force of an electromagnet, or between simple circuits of constant inductance, such as reactance coils containing no iron, nevertheless general methods have not, to the authors' knowledge, been developed for calculating the force exerted between dissimilar circuits which contain iron and which therefore have magnetic reluctances that may vary both with the magnetic density and the relative position of the circuits. It is the purpose of the present paper to offer methods for these cases. The work presented here, as well as that in a forthcoming paper in the near future, is largely the result of an investigation made by one of the authors in 1922 on the mechanical forces in synchronous machines under short circuit conditions.

### Historical

The basic contributions regarding the mechanical force exerted by electro-magnetic circuits were, of course, made by Ampere[2], Kelvin and Maxwell[3]; and the greater part of the subsequent development of the subject has been the application of their fundamental equations to particular cases.

Maxwell's equation for the "mechanical action between two circuits" is, in different notation,

$$f_x = \frac{1}{2} I_1^2 \frac{d L_1}{d x} + I_1 I_2 \frac{d M}{d x} + \frac{1}{2} I_2^2 \frac{d L_2}{d x} \tag{56}$$

where $I_1$ and $I_2$, $L_1$ and $L_2$ are the respective currents and inductance coefficients of the two circuits; $M$, the mutual inductance; $f_x$, the component of force in the direction of $x$, "one of the geometrical variables on which the form and relative position depend."

Quoting Maxwell, "If the motion of the system corresponding to the variation of $x$ is such that each circuit moves as a rigid body, $L_1$ and $L_2$ will be independent of $x$ and the equation will be reduced to the form,"

$$f_x = I_1 I_2 \frac{d M}{d x} \tag{57}$$

Although it is clear from the above statement and his original assumptions, that the electrical circuits are not considered to be in proximity to iron or other magnetic material, nevertheless the equation holds, as will appear later, for circuits which do enclose, or are near, iron provided there is no saturation.

If there is a single circuit only, such as an electromagnet, all terms of (1) drop out except the first, thus reducing to the well-known expression,

$$f_x = \frac{1}{2} I^2 \frac{d L}{d x} \tag{58}$$

Thus for any circuit or pair of circuits in which the inductances are functions of shape or position only, Maxwell's equation applies.

Now there is another classical method of analysis according to which the force is obtained by integrating over the circuit member in question, the force on each current element, due to the magnetic density in which the element exists. In some cases this is more convenient to apply than the foregoing equations. It depends, of course, upon the nature of the problem. An excellent example of the application of the latter method is Dwight's[4] work regarding the electromagnetic force on switches.

Other authors, as listed in the bibliography, have also treated special cases, and in one or two of these, where saturation is considered, an additional step of fundamental nature has been taken. In 1911, Steinmetz[5] treated the special cases of electromagnets and transformers in accordance with existing theory, but in addition, considered the case of a single-circuit electromagnet containing iron and involving saturation. While his results were not carried further than the detailed expression of the *energy* relations which obtain during a change in position[6], this nevertheless consti-

1. Consulting Engineer, General Electric Co., Schenectady, N. Y.

2. Clerk Maxwell, Electricity and Magnetism, Vol. II, Arts. 502 to 528.

3. Clerk Maxwell, Electricity and Magnetism, Vol. II, Art. 583.

*Presented at the Midwinter Convention of the A. I. E. E., New York, N. Y., February 8-11, 1926. Complete copies containing apendixes here omitted, available upon application.*

4. H. B. Dwight, "Magnetic Force on Disconnecting Switches," TRANS. A. I. E. E., 1290, Vol. 39, Part II, pp. 1337-1355.

5. Mechanical Forces in Magnetic Fields, TRANS. A. I. E. E., 1911, Vol. 30, pp. 357-413.

6. This case is reviewed by Rudolph Richter in his *Elektrische Maschinen*, in which the equations are interpreted graphically.

tuted the initial step toward the derivation of a general equation for *force* of a single circuit.

## Scope of Paper

Thus, the development to the present appears to include the solution of the cases of one and two circuits involving inductances which are not functions of the current, and of the case of a single circuit involving saturation, to the extent of the mathematical expressions for the various terms in the energy equation. It is the purpose here to give the general equation for a system of $n$ circuits which may contain iron, either saturated or not, but assumed to have no hysteresis,

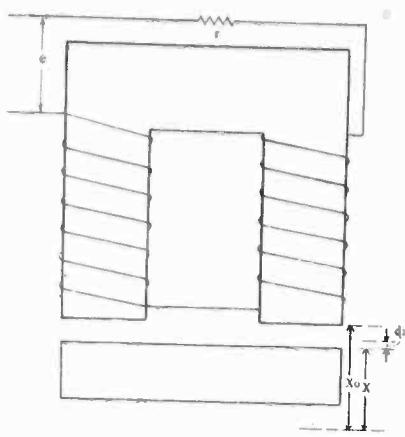


Fig. 1

and thus having inductances which are functions of both position and current; and in a subsequent paper in the near future, to apply the results to the case of mechanical forces in synchronous machines under short-circuit condition.

Two cases will be taken up in order; single circuit, and $n$ circuits.

## Single Circuit

The magnet in Fig. 1 is assumed to be excited to a point $a$ on the saturation curve Fig. 2.

Let

$\omega$ = magnetic linkages $\times 10^{-8} = L\,i$

$\Omega$ = value of $\omega$ at which the force is to be determined; viz., $\Omega = L\,I$

$L$ = inductance in henrys, defined as *linkages-per-ampere* $\times 10^{-8}$, and is a function of the current.

$i$ = current in amperes.

$I$ = value of $i$ at which force is to be determined.

$f_x$ = mechanical force exerted *on* the armature *by* the magnetic field, in the direction of $x$.

$x$ = distance in cm. from arbitrary reference.

Although the electromagnet in Fig. 1 is a special case involving, as a result of symmetry, only one space coordinate, the general case is fully treated in Appendix A, equations (5) and (6).

Applying the principle of *virtual displacement* to the system in Fig. 1, let there be a displacement $d\,x$ of the armature, thus allowing the force $f_x$ to do work. Then, referring to Fig. 2, the curve $o\,a$ corresponds to position $x$; curve $o\,b$, to position $x + d\,x$:

(a) Energy increment from electrical source during the position change $d\,x$ ($I$ and $\Omega$ being variable during the change) $= I\,d\,\Omega$ = area $a\,b\,c\,d$, where $d\,\Omega$ is the increment due to the change $d\,x$.

(b) Total energy storage at position $x$ and current $I = \int_0^\Omega i\,d\,\omega$ = area $o\,a\,d$ where $d\,\omega$ is the increment in $\omega$, due to increment in current at constant $x$.

By conservation of energy, the increment in energy received from the electrical source during the change $d\,x$ must equal the sum of the mechanical work plus increment in stored magnetic energy. Thus,

$$I\,d\,\Omega = f_x\,d\,x + d\int_0^\Omega i\,d\,\omega$$

from which, by equations in Appendix A,

$$f_x\,d\,x = -\int_0^\Omega \frac{\partial i}{\partial x}\,d\,x\,d\,\omega \qquad \text{joules} \qquad (59)$$

In Fig. 2,

$$\frac{\partial i}{\partial x}\,d\,x = h$$

Thus,

(c) Mechanical work $= f_x\,d\,x = o\,a\,b'$

In equation (59), $d\,x$ is a constant in the integration. Hence

$$f_x = -\int_0^\Omega \frac{\partial i}{\partial x}\,d\,\omega \qquad \text{joules/cm.} \qquad (60)$$

which is the same as equation (5), Appendix A. Or,

$$f_x = -\,22.5\int_0^\Omega \frac{\partial i}{\partial x}\,d\,\omega \qquad \text{lb.} \qquad (60a)$$

This is the *general equation* for force by a single

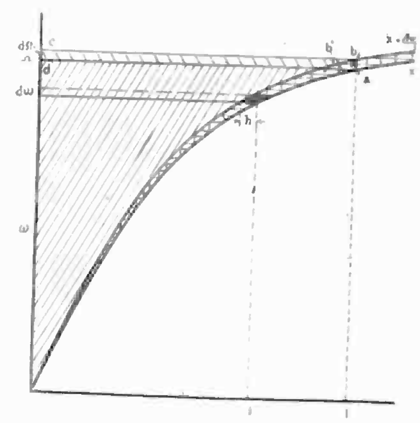


Fig. 2

circuit in which the inductance is a function of both position and magnetic flux, and is therefore applicable to electromagnets involving saturation.

Equation (60) is applied as follows:

Let,

$$i = f(\omega, x)$$

With $\omega$ as parameter, plot

$$i = F(x)$$

as in Fig. 3.[7] From this, plot

$$\frac{\partial i}{\partial x} = \varphi(\omega)$$

corresponding to $X$, as in Fig. 4. Then by equation (**60**), the force corresponding to the position $X$, current $I$, and linkages $\Omega$, is the shaded area in Fig. 4.

*Special Case.* An interesting and important simplification is made possible by an assumption which will apply approximately to many actual cases. In Fig. 3, if no saturation exists, and neglecting the magnetic reluctance of the iron.

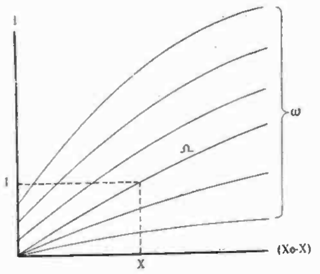


FIG. 3

$$i = 0 \text{ at } x = x_0$$

that is, when the air-gap $(x_0 - x) = 0$, since obviously no current would be required for zero reluctance. However, at values of $\omega$ which involve saturation, $i$ has a definite value when the air-gap $(x_0 - x) = 0$, namely, the value required to sustain the magnetic flux in the saturated iron. But if, as in Fig. 3, the change in $x$ is made at constant flux linkages, that is at approximately constant magnetic flux, the magnetic reluctance of the iron path should remain unchanged. Under this assumption *there is no change in that component of current which sustains the flux in the iron.* Thus the change in current due to such a change in $x$ would be due wholly to the change in reluctance of the air path. This increment is indicated by $h$ in Fig. 2, and corresponds to a change from $x$ to $x + dx$, at a constant value of $\omega$[8].

These relations will now be written into equation (**60**).

By definition,

$$i = \frac{\omega}{L} \text{ amperes} \tag{61}$$

and

$$L = \frac{N^2}{\mathcal{R}} \text{ henrys} \tag{62}$$

where

$N$ = number of series turns.

$$\mathcal{R} = \mathcal{R}_o + \mathcal{R}_i \text{ turns}^2/\text{henry} \tag{63}$$

$\mathcal{R}$ = magnetic reluctance coefficient, which is made up of $\mathcal{R}_0$, applying to the air portion of the magnetic circuit; $\mathcal{R}_i$, to the iron portion.

Substituting (**62**) and (**63**) in (**61**) and differentiating partially with respect to $x$, taking $\omega$ constant,

$$\frac{\partial i}{\partial x} = \frac{\omega}{N^2} \frac{\partial}{\partial x} (\mathcal{R}_0 + \mathcal{R}_i)$$

But under the assumption,

$$\frac{\partial \mathcal{R}_i}{\partial x} = 0$$

Hence,

$$\frac{\partial i}{\partial x} = \omega \frac{\partial}{\partial x} \left( \frac{\mathcal{R}_0}{N^2} \right)$$

$$= \omega \frac{\partial}{\partial x} \left( \frac{1}{L_0} \right)$$

Thus,

$$\frac{\partial i}{\partial x} = - \frac{\omega}{L_0^2} \frac{\partial L_0}{\partial x} \text{ amperes/cm} \tag{64}$$

Substituting (**64**) in (**60**),

$$f_x = \int_0^\Omega \frac{1}{L_0^2} \frac{\partial L_0}{\partial x} \omega \, d\omega$$

Making the assumption that in this integration

$$L_0 \text{ and } \frac{\partial L_0}{\partial x}$$

are not functions of $\omega$, they may then be placed outside of the integral sign[9]. The integral then becomes

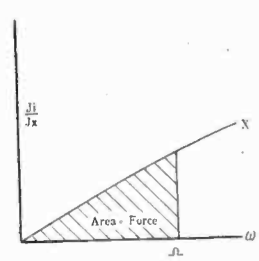



FIG. 4

$$f = \frac{1}{2} \frac{\Omega^2}{L_0^2} \frac{\partial L_0}{\partial x} \text{ joules/cm} \tag{65}$$

Thus, for those cases where the above assumptions approximately hold, the force is expressed in the following known and convenient terms: the actual magnetic

7. It is more convenient in the particular case of Fig. 1 to plot $i$ as $F(x_0 - x)$ instead of $F(x)$.

8. In calculating force, it makes no difference in the value whether it is assumed that the change $dx$ is made at constant linkages, as above, or at constant current. Referring to Fig. 2, the difference in mechanical work is represented by the second order area $a\,b\,b'$, which vanishes in the limit.

9. Thus, equation (**65**) holds only in so far as $R_0$ and the ratio $\dfrac{d\,\mathcal{R}_0}{d\,x}$ are independent of $\omega$.

linkages corresponding to the existing current $I$ and position $X$; the constant (with respect to $\omega$) inductance $L_0$ corresponding to the straight part of the $(\omega, i)$ curve, Fig. 1; and the rate at which that inductance changes with respect to $x$.

Equation (65) can be written in the following form:

$$f = \frac{1}{2} I_f^2 \frac{\partial L_0}{\partial x} \text{ joules/cm.} \qquad (66)$$

where $I_f$ is the fictitious current,

$$I_f = \frac{\Omega}{L_0} = I \frac{L}{L_0} \text{ amperes} \qquad (67)$$

thus smaller than the actual current $I$ by the ratio of the inductance at the actual current, to the inductance corresponding to no saturation.

Or in still another form,

$$f = \frac{1}{2}\left(\frac{L}{L_0}\right)^2 I^2 \frac{\partial L_0}{\partial x} \text{ joules/cm.} \qquad (68)$$

Or, in pounds

$$f = 11.25\left(\frac{L}{L_0}\right)^2 I^2 \frac{\partial L_0}{\partial x} \text{ lb.} \qquad (66a)$$

Thus if,

$$L = L_0$$

that is, with no saturation,

$$f = \frac{1}{2} I^2 \frac{\partial L_0}{\partial x} \qquad (69)$$

This is the well-known expression for a single circuit with no saturation. Comparison of (68) and (69) shows that saturation decreases the force, at the same current $I$, by the ratio

$$\left(\frac{L}{L_0}\right)^2$$

It is interesting to note that under the assumptions contained in equation (65), equation (60) also reduces to the familiar form

$$f_x = \frac{\beta^2 A}{8\pi} 10^{-7} \qquad \text{joules/cm.}$$

when applied to the special case of a magnet with relatively small uniform air-gap.

Let the total magnetomotive force for the magnetic circuit corresponding to the linkages $\omega$ be,

$$N i = F(\omega) + \frac{\omega (x_0 - x) 10^8}{0.4 \pi N A}$$

where $A$ is the cross section in sq. cm., $\beta$ is the magnetic density in lines per sq. cm. of the air path, and $F(\omega)$ represents the saturation curve of the iron alone. Thus, differentiating partially with respect to $x$,

$$\frac{\partial i}{\partial x} = - \frac{\omega 10^8}{0.4 \pi N^2 A}$$

Substituting this in (60) and integrating,

$$f_x = \frac{10^8}{0.8 \pi A}\left(\frac{\Omega}{N}\right)^2 = \frac{\beta^2 A}{8\pi} 10^{-7} \text{ joules/cm.}$$

## $n$ Circuits

*General Case.* From Appendix B, the general equation for $f_x$ for the case of $n$ circuits is given in the following two forms:

$$f_x = - \sum_1^n \int_0^{\Omega_u} \frac{\partial i_u}{\partial x} d\omega_u \qquad \text{joules/cm.} \qquad (9)$$

and

$$f_x = \sum_1^n \int_0^{I_u} \frac{\partial \omega_u}{\partial x} d i_u \qquad \text{joules/cm.} \qquad (11)$$

The application of (9) may be illustrated as follows: As discussed in Appendix B, any functional relation between the currents, or between the linkages may be assumed during the integration indicated, provided that relation brings all currents to their given values, which are the limits of the integrals. Thus, assume the currents are brought up, proportional to each other, the proportionality constants being the ratios of the final values $I_1, I_2, I_3$, etc. Then, for any value of $i_u$, all other currents and values of $\omega$, at a given value of $x$, are fixed. Thus, for each circuit, following the same procedure as indicated for the case of a single circuit, equation (60), Figs. 3 and 4,

$$i_u = f_u(\omega_u, x)$$

with $\omega_u$ as parameter, plot

$$i_u = F_u(x)$$

for each circuit. From these, plot the corresponding curves,

$$\frac{\partial i_u}{\partial x} = \phi_u(\omega)$$

corresponding to the particular value of $x$. Then the force is the sum of the areas corresponding to that in Fig. 4.

A similar procedure may be followed in the application of the other form, equation (11).

*Special Case: Inductance Independent of Current.* From Appendix C, one of the two equations derived for $f_x$, under the assumption that $L$'s and $M$'s are independent of the current is

$$f_x = \sum_1^n {}_u \sum_1^n {}_v \frac{I_u I_v}{2} \frac{d M_{uv}}{d x} \text{ joules/cm.} \qquad (21)$$

where $M_{uv}$ = mutual inductance in henrys of circuit $v$ upon circuit $u$.[10]

Thus for $n = 3$, for illustration,

$$f_x = \frac{1}{2} I_1^2 \frac{d L_1}{d x} + \frac{1}{2} I_2^2 \frac{d L_2}{d x} + \frac{1}{2} I_3^2 \frac{d L_3}{d x}$$

10. When $u = v$, self induction is indicated. Thus $M_{11} = L_1$, $M_{22} = L_2$, etc.

$$+ I_1 I_2 \frac{d\, M_{12}}{d\, x} + I_1 I_3 \frac{d\, M_{13}}{d\, x} + I_2 I_3 \frac{d\, M_{23}}{d\, x}$$

$$\text{joules/cm.} \qquad (70)$$

For two circuits only, equation (**70**) reduces to Maxwell's equation, as given in (**56**).

The other equation for $f_x$ for this case is

$$f_x = - \sum_1^n{}_u \sum_1^n{}_v \frac{\Omega_u\, \Omega_v}{2} \frac{d\, K_{uv}}{d\, x} \text{ joules/cm.} \qquad (26)$$

where $K_{uv}$ is a "coefficient of magnetization," discussed in Appendix C, and defined in general by

$$I_u = \sum_1^n{}_v K_{uv}\, \Omega_v \text{ amperes} \qquad (24)$$

*Approximation.* Making the same simplifying assumptions as contained in equations (**64**) and (**65**), discussed under "SINGLE CIRCUIT," saturation may be approximately taken into account in the equations.

As explained in Appendix *D*, the above mentioned assumptions reduce equation (**9**) to the form,

$$f_x = - \sum_1^n{}_u \sum_1^n{}_v \frac{\Omega_u\, \Omega_v}{2} \frac{d\, K_{uv}}{d\, x} \qquad (32)$$

where $\Omega_u$ and $\Omega_v$ are the linkages of circuits $u$ and $v$ corresponding to the actual currents $I_1, I_2, I_3$, etc., under the existing condition of partial saturation of the iron paths of the magnetic circuit; and where $K_{uv}$ is the coefficient of magnetization, discussed in Appendix C, applying to the *non-saturated* condition. In other words, equation (**32**) is of exactly the same form—indeed, the same equation—as (**26**), which applies to the *non-saturated* case. Thus, under the assumptions, different expressions for the force are encountered for the saturated and non-saturated conditions, only when the force is expressed in terms of *currents*; but the same equation is obtained for either case when it is expressed in terms of linkages.

In Appendix E, expressions have been worked out for $K_{uv}$ for 1, 2, 3, and 4 circuits in terms of the self and mutual inductances without saturation, namely $L_u$ and $M_{uv}$.

To illustrate the application of (**32**), take the case of a single circuit. Here,

$$K_{uv} = K_{11} = \frac{1}{L_0}$$

Then

$$f_x = \frac{\Omega_1^2}{2} \left( \frac{d}{d\, x} \frac{1}{L_0} \right)$$

or

$$f_x = \frac{1}{2} \frac{\Omega_1^2}{L_0} \frac{d\, L_0}{d\, x}$$

It will be noted that this is the same as equation (**65**). Thus, under the assumption, if the values of $\Omega_1, \Omega_2, \Omega_3$, etc., are known in any system involving saturated iron, the force is approximately determined by (**32**), using $K_{uv}$ as given in Appendix E.

It is possible to express the force, in the case of $n$ circuits, and under the above assumptions, as follows: Equations (**21**) and (**26**) express exactly the same result for the non-saturated case. But equation (**32**), which is the same as equation (**26**), gives the force for the saturated case. Therefore, equation (**21**) *will apply also to the saturated case, under the assumptions, provided such fictitious current values are used as will cause the actual existing values of* $\Omega_1, \Omega_2, \Omega_3$, etc.

Thus, knowing the values of $\Omega_1, \Omega_2$, etc., $n$ simultaneous equations may be written for the $n$ values of current, in terms of $L$'s and $M$'s as follows:

$$\left.\begin{aligned} \Omega_1 &= I_1 L_1 + M_{12} I_2 + M_{13} I_3 + \ldots \\ \Omega_2 &= I_2 L_2 + M_{21} I + M_{23} I_3 + \ldots \\ \Omega_2 &= I_3 L_3 + M_{31} I_1 + M_{32} I_2 + \ldots \end{aligned}\right\} \frac{\text{Linkages}}{10^8} \qquad (71)$$

The force is then obtained by substituting in equation (**21**) the fictitious values of current $I_1, I_2, I_3$, etc., as found by solving equation (**71**). The solution for these currents may be readily obtained by substituting in

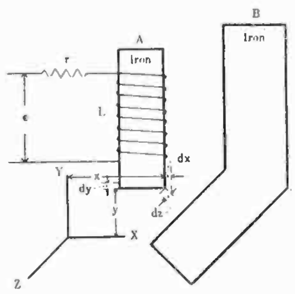



FIG. 5

equation (**24**) the known values of linkages $\Omega_v$ and the values of $K_{uv}$ as determined by the equations given in Appendix E.

The authors gratefully acknowledge the valuable suggestions and encouragement of V. Karapetoff, and the assistance of J. M. Bryant, D. S. Snell and R. M. Ryan.

## PHOTOELECTRIC CELL SPOTS FOREST FIRES

A new use has been found for the photoelectric cell, that delicate electrical device that has made sending pictures by wire possible. This unusual application is the detecting of forest fires. Strung between two points in a mountainous and heavily timbered region, a cable carries a car upon which is mounted a powerful electric searchlight.

The car travels back and forth on this cable and the beam of the searchlight is constantly focused upon the photoelectric cell mounted upon the platform of the forest fire lookout tower. Nothing happens until the beam of the searchlight has to pass through smoke arising from a forest fire. Then the photoelectric cell, because the beam of light is dimmed, comes into action and sounds an alarm and the forest rangers are "turned out" to fight the fire.

# Theory of Absorption in Solid Dielectrics

VLADIMIR KARAPETOFF[1]
Fellow, A. I. E. E.

*Synopsis.*—*Most solid dielectrics are imperfect in the sense that when a constant d-c. voltage is suddenly applied, a displacement of electricity first takes place almost instantly to a certain value, and then continues to increase asymptotically towards an ultimate magnitude. Accordingly, an initial electric charge and a greater final charge may be distinguished, with the corresponding values of initial and final permittivities. The purpose of the present investigation is to establish certain general properties of the function which expresses the increase in the initial electric displacement with the time. The initial and the final leakage conductivities of the material are also taken into consideration.*

*An assumption is made that the law of relaxation of electric displacement in the individual particles of the dielectric is a simple exponential function of time, but that the exponent varies from particle to particle. In some "non-viscous" particles the final displacement takes place instantly, in some others it occurs infinitely slowly, while for a great majority of the particles the relaxation proceeds at various finite rates. A "distribution function" for the numbers of different particles is introduced and the general conditions which this function must satisfy are established.*

*The results are then applied to a particular form of distribution function which has a large enough number of parameters for representing experimental data on a given dielectric with sufficient accuracy. Integrations are carried out for the cases of direct and sinusoidal applied voltages. With direct voltage, expressions are deduced for the permittivity and conductivity as functions of time. Since experimental curves of these two quantities can be obtained, a comparison with the theoretical formulas will permit a determination of the numerical values of the parameters in the assumed distribution function. With alternating voltages, the apparent permittivity and the apparent conductivity are expressed as functions of the frequency. Since experimental values of these quantities may be computed from measurements of capacitance and dielectric loss, another possibility is thus afforded for checking an assumed distribution function.*

*The ultimate aim of the theory (as now developed and as may be improved in the future) is to make it possible to correlate and to mutually check a vast amount of experimental data on absorption and on dielectric loss, and to enable one to predict these quantities within the range of voltages and frequencies for which no test figures are available.*

* * * * *

WHEN a constant continuous voltage is suddenly applied to an imperfect solid dielectric, a phenomenon, shown in Fig. 1, takes place. Let the piece of dielectric be in the form of a slab of thickness $a$ and let the applied voltage be $E$. Then the *voltage gradient* in the material is

$$G = E/a \tag{1}$$

By assumption, this gradient remains constant, as shown by a horizontal line in Fig. 1. Let the cross-section of the slab in the plane normal to the lines of force be $A$, and let the total quantity of electricity displaced through the slab be $Q$. Then the density of displacement, or the *dielectric flux density*, is

$$D = Q/A \tag{2}$$

Experiment shows that $D$ does not reach its final value $D_f$ at once, but continues to increase from an initial value $D_0 = O\,a$ to $D_f = O\,b$ over an appreciable interval of time. Accordingly, a charging current is produced,

$$i = d\,Q/d\,t \tag{3}$$

which continues to flow into the dielectric. Since $D$ refers to unit cross-section of the slab, we shall also introduce the *current density*

$$u = d\,D/d\,t \tag{4}$$

instead of the total current $i$. At $t = o$, the density $u$ is equal to zero; then it rapidly rises to a value $O\,c$ determined by eq. (4), and begins to decrease. We are not interested in the part $O\,d$ of the curve, since it is determined by the inductance of the circuit, and we shall assume that point $d$ is reached practically at $t = o$. If the applied voltage is of very high frequency instead of being continuous, the inductance of the circuit, including the magnetic field in the dielectric itself, may become a factor of appreciable magnitude. If the conductivity of the dielectric is zero, the current finally becomes equal to zero. Otherwise, the current density asymptotically reaches a steady small value, $u_f = h\,f$.

The above described phenomenon is known as *dielectric absorption*, and is present to some degree in most solid dielectrics, especially in those whose molecular structure is non-homogeneous or complicated. Absorption affects both the charge and the discharge of a condenser, causes the true capacitance to be a somewhat indefinite quantity and, with alternating voltages, causes dielectric loss.

A study of absorption is of interest not only from the point of view of the nature of dielectric phenomena, but also in application to charge and discharge of condensers and to dielectric loss.

In view of our meager knowledge of the atomic structure and electronic forces in solids, the time for a rational theory of dielectric absorption has not arrived. It is therefore necessary to establish a semi-empirical theory, with functions chosen by trial to represent the general character of the curves shown in Fig. 1 and with constants determined by tests. Nevertheless, such a theory is useful in permitting us to interpret some observed phenomena and to predict numerical values not actually measured. The theory given below is a further extension of that given by K. W. Wagner.[2] A

1. Professor of Electrical Engineering, Cornell University, Ithaca, N. Y.

*Presented at the Midwinter Convention of the A. I. E. E., New York, February 8-11, 1926. Complete copies including Section 5, here omitted available upon request.*

2. *Annalen der Physik*, 1913, Vol. 40, p. 817. Wagner's work is based on earlier investigations by Pellat, von Schweidler etc., references to whose writings will be found in his article.

somewhat different approach to the problem, based on the idea of "stratified" dielectrics, was given by Maxwell[3] and recently further developed by Grünewald.[4]

The character of the curves shown in Fig. 1 suggests the presence of three kinds of paths or "fibers" between the electrodes (Fig. 2); namely, (a) portions of a perfect dielectric, in which an electric displacement faithfully

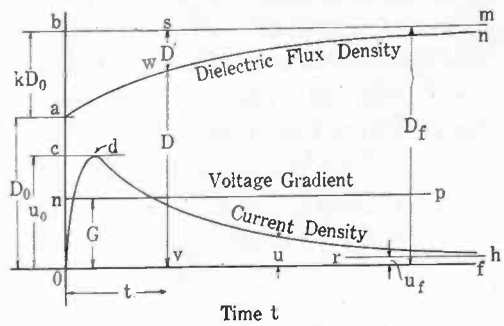



FIG. 1—VARIATIONS IN THE DIELECTRIC FLUX AND CURRENT DENSITY WITH THE TIME

When a constant d-c. voltage is applied suddenly

and instantly follows the applied voltage; (b) portions of an imperfect dielectric in which the final orientation of molecular charges requires some time and is opposed by some kind of viscous reactions; and (c) conducting paths. Of course, all these portions are of irregular shapes and intermingled in series and in parallel, the three distinct fibers being shown merely for the sake of convenience. Such a dielectric would behave as indicated in Fig. 1.

A mechanical analog to the behavior of an imperfect dielectric is shown in Fig. 3. $A\,B$ is a stationary plate and $C\,D$ is an identical plate connected to it by two springs, $S_1$ and $S_2$. A vessel $V$, filled with viscous liquid, is attached to $A\,B$. A plate $q$, supported by the

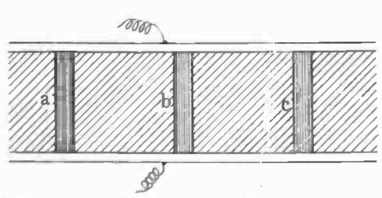



FIG. 2—THREE ASSUMED KINDS OF FIBERS OR PARTICLES IN AN IMPERFECT DIELECTRIC

*Viz.*, a. perfectly elastic, b. viscously elastic, c. conducting

spring $C$, is immersed in the liquid. Two weights, $G_1$ and $G_2$, rest on supports $h_1$ and $h_2$, and are attached to $C\,D$ by strings over the stationary pulleys $P_1$ and $P_2$. The lower ends of the springs $S_1$ and $S_2$ are attached to the stems $K_1$ and $K_2$ fitted into the board $A\,B$ with considerable friction.

Assume the apparatus to be initially in equilibrium with no tension in the springs and with the weights resting on their supports. Now let $h_1$ and $h_2$ be suddenly withdrawn, causing the weights to pull $C\,D$ upward and to stretch the springs $S_1$, $S_2$ and $C$. Consider the stems $K_1$ and $K_2$ to be so tight as not to move, and assume the motion of $q$ to be negligible at first, due to the viscosity of the liquid. The tension is then initially taken up by the three springs. As the pull continues, the plate $q$ moves upward, relieving the tension of $C$ so that ultimately the whole tension is taken up by $S_1$ and $S_2$ only. This subsequent increase in the tension and displacement of the springs $S_1$ and $S_2$ illustrates the effect of absorption. Let now the supports $K_1$ and $K_2$ be slightly yielding. Then the motion of $C\,D$ will never stop, thus giving a picture of a conduction current.

If the stress be suddenly changed before the final stage has been reached, the additional stress put on $C$ depends upon the position of the plate $q$. Thus, the amount of absorption depends upon the previous history of the sample.

If the weights be suddenly removed (corresponding to

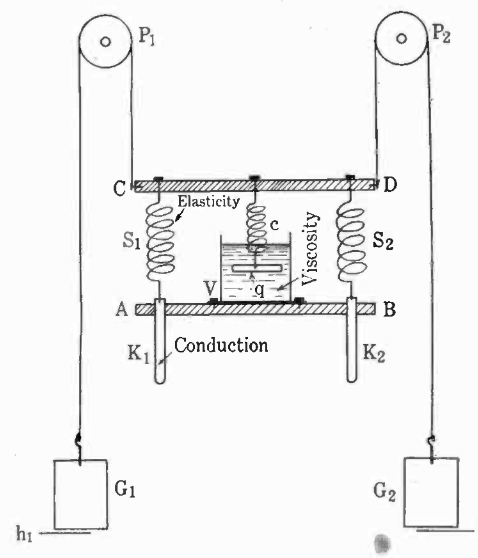



FIG. 3—A MECHANICAL ANALOG OF AN IMPERFECT SOLID DIELECTRIC

a short-circuit), there will be an instant position of equilibrium at which the tension of the springs $S_1$ and $S_2$ will balance the compression of the spring $C$. Then, gradually, the bar $C\,D$ will go down to a final position of equilibrium. If, however, the short-circuit be removed before the final position has been reached, and the bar $C\,D$ locked (to correspond to an open circuit) a readjustment of stresses will take place, with a residual charge. Thus, later, upon releasing $C\,D$, another movement will take place without an application of the weights.

The influence of temperature can be taken into account by changing the viscosity of the liquid in $V$; for instance, by heating it.

Of course, this analog cannot be followed in detail, but it may facilitate an understanding of the general nature of phenomena taking place in an imperfect dielectric. The writer has also designed a kinematic

3. Electricity and Magnetism, Vol. 1, p. 452.
4. Archiv für Elektrotechnik, 1923, Vol. 12, p. 96.

linkage with a spring and a dashpot, to illustrate the ideas discussed in the above mentioned article by Grünewald. See also Maxwell's model, *ibid.*, p. 462.

## 2. The Fundamental Equations

The phenomenon shown in Fig. 1 is primarily determined by the ratio of $D_0$ to $D_f$ and by the shape of the curve $a\,n$. Let the final displacement be $1 + k$ times the original displacement. Then, in Fig. 1, $a\,b = k\,D_0$, and the *absorption coefficient* $k$ may be defined by the equation

$$k = (D_f - D_0)/D_0 \qquad (5)$$

For a perfect dielectric, $k = 0$; the greater $k$, the more absorption manifested by the material.

Assume $a\,b = 1$ and let the equation of the curve $a\,n$, referred to the axis $b\,m$, be $\phi\,(t)$. The function $\phi\,(t)$ may be called the *relaxation function*, as it characterizes the rate at which the absorbed charge is being released with the time. Let $\kappa_0$ be the *initial permittivity* of the material; that is, the permittivity that would be obtained from a ballistic test at the first instant of voltage application. In other words, let

$$D_0 = \kappa_0\,G \qquad (6)$$

and

$$D_f = (1 + k)\,\kappa_0\,G \qquad (7)$$

At any instant, $t$, the *deficiency* $D' = w\,s$ between the final displacement $D_f$ and the actual displacement $D$ is

$$D' = k\,D_0\,\phi\,(t) = k\,\kappa_0\,G\,\phi\,(t) \qquad (8)$$

Hence

$$D = D_f - D' = \kappa_0\,G\,[(1 + k) - k\,\phi\,(t)] \qquad (9)$$

According to eq. (4),

$$u = -\,\kappa_0\,\kappa\,G\,d\,\phi\,(t)/d\,t \qquad (10)$$

In these equations, the function $\phi\,(t)$ is as yet arbitrary, except that it must correspond to a curve the general shape of which is that of the curve $a\,n$, and must satisfy the terminal conditions

$$\phi\,(o) = 1 \text{ and } \phi\,(\infty) = 0 \qquad (11)$$

The factor $k$ may be expressed through the *final permittivity* of the material, $\kappa_f$, as follows: After the sample has been subjected to a constant d-c. voltage for a long time, we have, by analogy with Equation (6):

$$D_f = \kappa_f\,G \qquad (12)$$

so that

$$(D_f - D_0)/D_0 = (\kappa_f - \kappa_0)/\kappa_0 \qquad (13)$$

Comparing this expression with equation (5), it will be seen that

$$k = (\kappa_f - \kappa_0)/\kappa_0 \qquad (14)$$

and

$$\kappa_0\,k = \Delta\,\kappa = \kappa_f - \kappa_0 \qquad (14a)$$

where $\Delta\,\kappa$ is the apparent increase in the permittivity, due to absorption.

The next step is to generalize Equations (9) and (10) for the case when the applied voltage is not constant but varies with the time in a prescribed manner. Let us begin with the simplest case when a constant stress $G_1$ (Fig. 4) is applied from $t = 0$ to $t = \tau$, and is then increased by an amount $G_2$. The new stress, $G_1 + G_2$, may be assumed to last indefinitely. The flux density curve, $a\,w$, is similar to that in Fig. 1 as long as $G_1$ is acting alone. At the instant of application of $G_2$ the flux density is suddenly increased by an amount $w\,w'$ and then continues to increase asymptotically towards a new limit $b'\,m'$.

It is impossible to deduce, theoretically, the relationship between the displacement $p\,w$, existing at the instant $\tau$ and the resultant displacement $p\,w'$ an instant later, due to a suddenly increased voltage. We shall therefore make the simplest assumption; namely, that the added voltage $G_2$ produces its own displacement curve, just as if $G_1$ did not exist, and that the displacements due to $G_1$ and $G_2$ are simply added together.

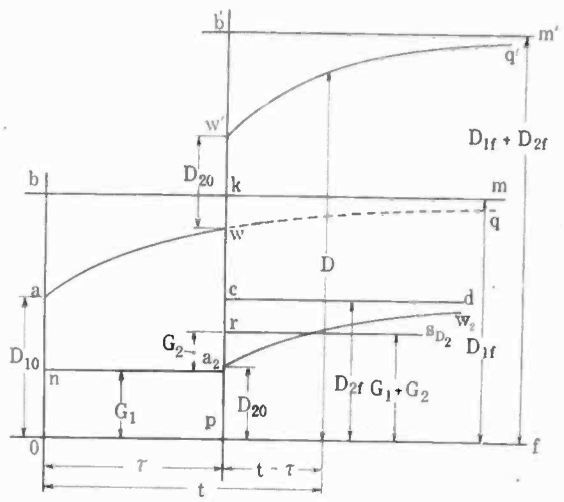



Fig. 4—Variations in the Dielectric Flux Density

When a constant d-c. voltage is applied in two steps

According to this principle of superposition (due to Hopkinson), the curve $a\,w$ continues in the range $w\,q$ as if $G_2$ did not exist, while the stress $G_2$ causes a new curve, $a_2\,w_2$, the initial ordinate of which is $D_{2o} = \kappa_0\,G_2$, and the final value is $D_{2f} = (1 + k)\,\kappa_0\,G_2$; equations (6) and (7). The ordinates of the curve $a_2\,w_2$ added to those of $w\,q$ will give the curve of resultant displacement, $w'\,q'$. This is a mathematical hypothesis, justified only by the possibility of deducing on this basis a set of formulas which can be made to fit observed curves to a sufficient degree of accuracy. From a physical point of view, we know that the $a$ fibers (Fig. 2) satisfy the law of superposition because, in a perfect condenser, the charge is strictly proportional to the voltage. The $c$ fibers also satisfy the law of superposition in that a current is proportional to the applied voltage. Therefore, it is only necessary to grant that the viscous or $b$ fibers also obey this law. In a viscous fluid, at low velocities, the velocity is proportional to the applied force, so that the superposition hypothesis seems reasonable for these fibers as well.

Thus, for any instant $t > \tau$, we may write

$$D = \kappa_0 (1 + k) (G_1 + G_2) - \kappa_0 k [G_1 \phi (t) + G_2 \phi (t - \tau)] \qquad (15)$$

Let now the total stress $G_t$, which exists at the instant $t$, be gradually built up in small increments $\Delta G_\tau$, each of which is applied at a different instant $\tau$. Generalizing equation (15), we get

$$D = \kappa_0 (1 + k) G_t - \Delta \kappa \Sigma \Delta G_\tau \phi (t - \tau) \qquad (16)$$

where

$$\Sigma \Delta G_\tau = G_t \qquad (17)$$

and $\Delta \kappa$ is used in place of $\kappa_0 k$, according to equation (14a).

In the limit, let the applied voltage vary continuously; then, equation (16) becomes

$$D = \kappa_0 (1 + k) G_t - \Delta \kappa \int_{t_0}^{t} \left( \frac{d G_\tau}{d \tau} \right) \phi (t - \tau) \, d \tau \qquad (18)$$

where $t_0$ is the instant at which the voltage is first applied to the sample. In changing from equation (16) to equation (18), $\Delta G_\tau$ is divided and multiplied by $\Delta \tau$, and, in the limit, $\Delta$ is replaced by $d$.

In equation (18), $\phi$ is an assumed function, while $G_\tau$ is the impressed stress. It is more convenient to have a derivative of $\phi$ than of $G_\tau$. Integrating in parts, we get

$$\int_{t_0}^{t} \left( \frac{d G_\tau}{d \tau} \right) \phi (t - \tau) \, d \tau = G_\tau \phi (t - \tau) \Big|_{t_0}^{t} - \int_{t_0}^{t} G_\tau \, d_\tau \, \phi (t - \tau) \qquad (19)$$

But

$$G_\tau \phi (t - \tau) \Big|_{t_0}^{t} = G_t \phi (0) - G_{t0} \phi (t - t_0) \qquad (20)$$

According to equation (11), $\phi (0) = 1$; moreover, $G_{t_0} = 0$, since, by assumption, $t_0$ is the instant at which the voltage begins to be applied. Hence, the value of the right-hand side of equation (20) is simply $G_t$. Using this value in equation (19) and substituting the value of the integral in equation (18), gives

$$D = \kappa_0 G_t + \Delta \kappa \int_{t_0}^{t} G_\tau \, d_\tau \, \phi (t - \tau) \qquad (21)$$

Using this expression for $D$ in equation (4), we get the following expression for the current density:

$$u = \kappa_0 \left( \frac{d G_t}{d t} \right) + \Delta \kappa \int_{t_0}^{t} G_\tau \left[ \frac{d^2 \phi (t - \tau)}{d t \, d \tau} \right] d \tau + \Delta \kappa G_t \left[ \frac{d \phi (t - \tau)}{d \tau} \right]_{\tau = t} \qquad (22)$$

When taking a total derivative of the definite integral in equation (21), with respect to $t$, two terms are obtained; viz., one assuming $t$ to be a parameter under the sign of integral, and the other assuming $t$ to be a variable upper limit. Equations (21) and (22) are the fundamental equations in the theory under consideration. In so far as no particular form has been ascribed to the function $\phi$, these equations are perfectly general. The next step is to specify the function $\phi$ in accordance with the observed behavior of solid dielectrics.

## 3. An Exponential Law of Relaxation

In Fig. 1, the simplest assumption which can be made regarding the shape of the curve, $a\,n$, is that the "deficiency" $w\,s$ is an exponential function of time; that is

$$\phi (t) = \epsilon^{-\alpha t} \qquad (23)$$

where $\alpha$ is a *relaxation factor* which characterizes the sample under consideration. Equation (23) proposed by Pellat[5], satisfactorily represents the general shape of the curve $a\,n$ and also satisfies equations (11). On the other hand, substances which show considerable absorption are usually too complicated to be characterized by a single parameter $\alpha$. Therefore, von Schweidler proposed a generalization of the foregoing formula to

$$\phi (t) = (\Sigma N \epsilon^{-\alpha t}) / \Sigma N \qquad (24)$$

Here the material is supposed to be heterogeneous and to consist of $N_1$ particles of constant $\alpha_1$, $N_2$ particles of constant $\alpha_2$, etc.

Wagner has further extended this idea and proposed for the relaxation function an expression of the form

$$\phi (t) = \int_0^\infty F (\alpha) \epsilon^{-\alpha t} d \alpha \qquad (25)$$

the integration being with respect to $\alpha$, and not $t$. His idea was that a piece of heterogeneous dielectric may have some particles with a relaxation constant $\alpha = 0$ (perfect dielectric, no relaxation) and others with $\alpha = \infty$ (conducting particles, instant relaxation). For most particles, $\alpha$ lies between zero and infinity, and the number of particles which have a definite value of $\alpha$ is a function of $\alpha$. In other words, for a fairly uniform material, $\alpha$ ranges within rather narrow limits for a great majority of particles, and there are comparatively few particles with very large or small values of $\alpha$, due to admixtures and impurities. A specific form of $F (\alpha)$ will be considered in the next section. We shall first deduce some general expressions which hold true for any function of $\alpha$. The function $F (\alpha)$ may be called the distribution function, because it shows the relative number of particles having different values of $\alpha$.

From the physical significance of $F (\alpha)$, we judge that this function remains finite between $\alpha = 0$ and $\alpha = \infty$. Therefore the second equation (11) is satisfied. In order that the first equation (11) be satisfied, the function $F (\alpha)$ must satisfy the condition

$$\int_0^\infty F (\alpha) \, d \alpha = 1 \qquad (26)$$

We shall now apply expression (25) to equations (21) and (22) and deduce some special cases.

*General Case of Variable Voltage.*

Equation (25) gives

$$\phi (t - \tau) = \int_0^\infty F (\alpha) \epsilon^{-\alpha (t - \tau)} d \alpha \qquad (27)$$

5. For literature references see the above mentioned article by Wagner.

so that

$$d_\tau \phi (t - \tau) = \int_0^\infty \alpha F(\alpha) \epsilon^{-\alpha(t-\tau)} d\alpha \, d\tau \quad (28)$$

and

$$[d^2 \phi (t - \tau)/d t \, d \tau] \, d\tau = - \int_0^\infty \alpha^2 F(\alpha) \epsilon^{-\alpha(t-\tau)} d\alpha \, d\tau \quad (29)$$

Substituting expression (28) in equation (21), gives

$$D = \kappa_0 G_t + \Delta \kappa \int_{to}^{t} G_\tau \, d\tau \int_0^\infty \alpha F(\alpha) \epsilon^{-\alpha(t-\tau)} d\alpha \quad (30)$$

The integration with respect to time is independent of that with respect to $\alpha$. Changing, therefore, the order of integration, the foregoing equation becomes

$$D = \kappa_0 G_t + \Delta \kappa \int_0^\infty \alpha F(\alpha) \epsilon^{-\alpha t} \left[ \int_{to}^{t} G_\tau \epsilon^{\alpha \tau} d\tau \right] d\alpha \quad (31)$$

Substituting expressions (28) and (29) in equation (22), gives

$$u = \kappa_0 \frac{d G_t}{d t} - \Delta \kappa \int_{to}^{t} \int_0^\infty G_\tau \alpha^2 F(\alpha) \epsilon^{-\alpha(t-\tau)} d\alpha \, d\tau + \Delta \kappa G_t \int_0^\infty \alpha F(\alpha) \, d\alpha \quad (32)$$

Equation (32) may also be deduced directly from equation (31) by differentiation; see equation (4).

*Continuous Constant Voltage.* In this case, $G_t = G_\tau = G$; assume also $t_0 = 0$. We then have for the second integral in equation (31)

$$\int_{to}^{t} G_\tau \epsilon^{\alpha\tau} d\tau = G \int_0^t \epsilon^{\alpha\tau} d\tau = \left( \frac{G}{\alpha} \right) (\epsilon^{\alpha t} - 1) \quad (33)$$

Therefore, the first integral in equation (31) becomes

$$G \int_0^\infty F(\alpha) \epsilon^{-\alpha t} (\epsilon^{\alpha t} - 1) \, d\alpha = G \int_0^\infty F(\alpha) \, d\alpha - G \int_0^\infty F(\alpha) \epsilon^{-\alpha t} d\alpha \quad (34)$$

According to equation (26), the value of the first integral on the right hand side is 1. Substituting from equation (34) in equation (31) and dividing by $G$, gives

$$\kappa_t = \frac{D}{G} = (\kappa_0 + \Delta \kappa) - \Delta \kappa \int_0^\infty F(\alpha) \epsilon^{-\alpha t} d\alpha \quad (35)$$

Here $\kappa_t$ may be considered to be the *apparent permittivity* of the sample at the instant $t$. When $t = 0$, $\kappa_t = \kappa_0$; when $t = \infty$, $\kappa_t = \kappa_0 + \Delta\kappa = \kappa_f$.

The current density $u$ may be obtained directly by differentiating the right-hand side of equation (35) with respect to $t$, and multiplying the result by $G$. We then get

$$u = \Delta \kappa G \int_0^\infty \alpha F(\alpha) \epsilon^{-\alpha t} d\alpha \quad (36)$$

Let $\gamma$ be the final conductivity of the sample, that is, the conductivity of the fibers $c$ in Fig. 2. Then the *apparent conductivity* at the instant $t$ is

$$\gamma_t = \frac{u}{G} + \gamma_f \quad (37)$$

The first term on the right-hand side corresponds to the displacement current and the second to the real conduction current. Substituting in equation (37) the value of $u$ from equation (36), gives

$$\gamma_t = \Delta \kappa \int_0^\infty \alpha F(\alpha) \epsilon^{-\alpha t} d\alpha + \gamma_f \quad (38)$$

The initial conductivity, at $t = 0$, is

$$\gamma_0 = \Delta \kappa \int_0^\infty \alpha F(\alpha) \, d\alpha + \gamma_f \quad (39)$$

Thus the function $F(\alpha)$ must satisfy the condition

$$\int_0^\infty \alpha F(\alpha) \, d\alpha = \frac{\gamma_0 - \gamma_f}{\kappa_f - \kappa_0} \quad (40)$$

where the four quantities on the right-hand side characterize the material.

*Alternating Voltage.* For a sinusoidal applied voltage we can generally put

$$G_\tau = G_m \epsilon^{j\omega t} \quad (41)$$

More particularly, at the instant $t$,

$$G_t = G_m \epsilon^{j\omega t} \quad (41a)$$

where $G_m$ is the amplitude of the stress and $\omega$ its frequency. It is convenient to put $t_0 = -\infty$ because then the transient term disappears. The second integral in equation (31) becomes

$$G_m \int_{-\infty}^{t} \epsilon^{(j\omega + \alpha)\tau} d\tau = \frac{G_m \epsilon^{(j\omega+\alpha)t}}{(j\omega + \alpha)} \quad (42)$$

so that, using in equation (31) the value of $G_t$ from equation (41a), we get

$$D = G_m \epsilon^{j\omega t} \left[ \kappa_0 + \Delta \kappa \int_0^\infty \frac{\alpha F(\alpha)}{(j\omega + \alpha)} d\alpha \right] \quad (43)$$

Multiplying the numerator and the denominator of this equation by $(\alpha - j\omega)$, and separating the real from the imaginary part, we get

$$D = G_m \epsilon^{j\omega t} \left[ \kappa_0 + \Delta \kappa \int_0^\infty \frac{\alpha^2 F(\alpha) \, d\alpha}{(\alpha^2 + \omega^2)} - j \omega \Delta \kappa \int_0^\infty \frac{\alpha F(\alpha) \, d\alpha}{(\alpha^2 + \omega^2)} \right] \quad (44)$$

The sample under consideration may be thought of as a combination of an ideal capacitance, $C$, in parallel with a conductance, $g$. The latter is *not* the conductance due to leakage, but the apparent conductance caused by absorption. For such a combination, the current

$$I = E \epsilon^{j\omega t} (j \omega C + g) \quad (45)$$

Consequently, the charge varies according to the law

$$Q = E \epsilon^{j\omega t} \left( C - \frac{j g}{\omega} \right) \quad (46)$$

because a derivative of equation (46) with respect to $t$ gives equation (45). Equation (44) corresponds to equation (46) for unit volume of the dielectric. Therefore, comparing the two equations term by term, we find that

$$\kappa_\omega = \kappa_0 + \Delta\,\kappa \int_0^\infty \frac{\alpha^2 F(\alpha)\, d\,\alpha}{(\alpha^2 + \omega^2)} \tag{47}$$

$$\gamma_\omega = \Delta\,\kappa\,\omega^2 \int_0^\infty \frac{\alpha F(\alpha)\, d\,\alpha}{(\alpha^2 + \omega^2)} + \gamma_f \tag{48}$$

In the latter expression, the term $\gamma_f$ is added to account for the actual leakage conductivity (fibers $c$ in Fig. 2). Thus, with alternating voltages, a dielectric with absorption shows a permittivity and a conductivity both of which are functions of the frequency. Equations (47) and (48) show that the relationship between $\kappa_\omega$, $\gamma_\omega$, and $\omega$ is quite involved. Nevertheless, it is this relationship that should permit to compare the theory with observed results.

Differentiating equation (44), or directly on the basis of equation (45), we may write for the current density $u$:

$$u = G_m\, \epsilon^{j\omega t} (j\,\omega\,\kappa_\omega + \gamma_\omega) \tag{49}$$

where $\kappa_\omega$ and $\gamma_\omega$ are determined by equations (47) and (48).

In equation (47), $\kappa_0$, by definition, is the initial or instant permittivity; therefore, it is the permittivity which the dielectric should show at an infinite frequency. In fact, by putting $\omega = \infty$, equation (47) gives

$$\kappa_\infty = \kappa_0 \tag{50}$$

At zero frequency, that is, when $\omega = 0$, equation (47) gives

$$\kappa_{\omega=0} = \kappa_1 + \Delta\,\kappa = \kappa_f \tag{51}$$

which also agrees with the assumptions made above.

The variable term in equation (48) becomes equal to zero both at $\omega = 0$ and at $\omega = \infty$. This agrees with the physical conception of this term, as giving the apparent time effect of absorption. The power loss per unit volume is $G_{eff}^2\,\gamma_\omega$. Subtracting from this the true conduction loss $G_{eff}^2\,\gamma_f$, gives the dielectric loss per unit volume at frequency $\omega$:

$$P_\omega = G_{eff}^2\,(\gamma_\omega - \gamma_f) \tag{52}$$

Thus, the observed power loss corrected for true conduction and plotted against $\omega$ as abscissas gives some information in regard to the shape of the function $F(\alpha)$.

For the circuit represented by equation (45), we have

$$\tan\psi = \frac{g}{\omega\, C} \tag{53}$$

where the *loss* or *imperfection angle* $\psi$ is complementary to the phase angle between the voltage and the current. Knowing $\psi$, the value of $\sin\psi$ can be found, and this value is the power factor of the condenser. Applying equation (53) to our case, we have

$$\tan\psi_\omega = \gamma_\omega/(\omega\,\kappa_\omega) \tag{54}$$

where $\kappa_\omega$ and $\gamma_\omega$ are determined by equations (47) and (48). Knowing $\psi_\omega$, we find,

$$\text{Power factor} = \operatorname{Sin}\psi_\omega \tag{55}$$

Dielectric loss increases considerably with temperature[6]. In the present investigation, the temperature of the sample is assumed to be the same throughout its thickness and, in checking experimental data with theoretical formulas, it is of importance to see that this condition has been at least approximately fulfilled during the tests.

*Transient Voltages.* The theory developed above for an established direct voltage may be extended to include a short d-c. impulse, or a combination of such impulses, by using the principle of superposition. For example, if a voltage $E$ is applied at the instant $t_1$ and removed at the instant $t_2$, the conditions are the same as if the voltage $E$ were continued from $t = t_1$ to $t = \infty$ and a voltage $-E$ applied from $t = t_2$ to $t = \infty$. It is also possible that the Heavisidian operational calculus may be applied to the solution of this problem.

If the applied transient voltage is of the nature of a decremental sine wave, equation (41) may be used for $G_\tau$, in which $\omega$ is a complex quantity. The lower limit of $\tau$ is no longer $-\infty$ and equation (42) has to be integrated anew. Of course, equations (31) and (32) can be used directly for any transient voltage provided that $G_\tau$ is given as a function of $\tau$.

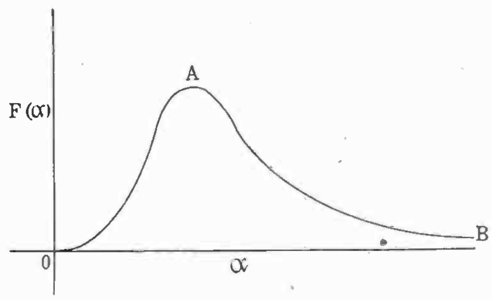



FIG. 5—THE GENERAL CHARACTER OF THE DISTRIBUTION FUNCTION $F(\alpha)$

## 4. A DISTRIBUTION FUNCTION $F(\alpha)$ AND THE CONDITIONS WHICH ITS PARAMETERS MUST SATISFY

A reasonable shape of the function $F(\alpha)$ for a fairly homogeneous dielectric is shown in Fig. 5. A large number of particles have values of $\alpha$ within the range near the maximum of the curve. There are fewer and fewer particles as one chooses values of $\alpha$ more remote from this range. The curve passes through the origin and may or may not be tangent to the axis of abscissas there; it should approach the axis of abscissas asymptotically at infinity. Probably several analytical functions would give a curve of this shape, and the selection of a particular function, in so far as there are no more valid theoretical grounds, is mainly determined by the following considerations:

a. General simplicity.

b. Ease in the integration of various expressions such as equations (38), (47), etc.

c. A sufficient number of parameters to fit the observed behavior of a given dielectric.

6. See, for example, L. Dreyfus, Mathematische Theorien für den Durchschlag fester Isoliermaterialien; *Schweiz. Elektrot. Verein, Bulletin*, 1924, Vol. 15, p. 321.

As a fundamental empirical expression, we shall take

$$F(\alpha) = H\,\alpha^{m-1}\,\epsilon^{-n\alpha} \qquad (56)$$

where $H$, $m$, and $n$, are constants independent of $\alpha$. These constants are different for different materials and, for a given material, are functions of temperature.

The physical dimension of $\phi(t)$ is a numeric; see its definition, equation (**8**). According to equation (25), the physical dimension of $\alpha$ is (time)$^{-1}$, because the product $\alpha\,t$ must be a numeric. Consequently, the physical dimension of $F(\alpha)$ must be "time," because the product $F(\alpha)\,d\,\alpha$ must be a numeric. In equation (**56**), $n\,\alpha$ must be a numeric, hence the dimension of $n$ is "time." The exponent $m$ is a numeric, and the dimension of $H$ is (time)$^m$. It will be seen later that $H$ is eliminated from the final computations.

Taking a derivative of $F(\alpha)$ with respect to $\alpha$, we get

$$d\,F(\alpha)/d\,\alpha = H\,\alpha^{m-2}\,\epsilon^{-n\alpha}\,(m-1-n\,\alpha) \qquad (57)$$

With the aid of equations (**56**) and (**57**), the limiting values of $m$ and $n$ may be determined as follows:

(a) As $\alpha$ approaches zero, $\epsilon^{-n\alpha}$ approaches unity for any finite value of $n$. Hence, $\alpha^{m-1}$ should approach zero in order that the curve pass through the origin. This gives the first limiting condition, namely, $m > 1$. But for values of $m$ less than 2, equation (**57**) gives infinite values of the slope, showing that the curve is tangent to the axis of ordinates. This does not agree with the assumed character of the phenomenon. At $m = 2$, the value of the right-hand side of equation (**57**) is $H$.

This may be accepted (at least provisionally) as a possible value, so that

$$m \geqq 2 \qquad (58)$$

(b) At infinity, the term $\alpha^{m-1}$ tends to an infinitely great value, while $\epsilon^{-n\alpha}$ tends to zero, provided that $n$ is positive. Moreover, since an exponential expression $\epsilon^{\alpha}$ tends to infinity at a higher rate than any positive power of $\alpha$, the ratio $\alpha^{m-1}/\epsilon^{n\alpha}$ approaches zero when $\alpha = \infty$.

Equation (**57**) gives a zero slope at $\alpha = \infty$. Thus, the second limiting condition is

$$n > 0 \qquad (59)$$

(c) The last factor in expression (**57**) becomes zero when

$$\alpha = (m-1)/n \qquad (60)$$

At this value of $\alpha$, the function $F(\alpha)$ reaches its maximum. Equation (**60**) may have some bearing upon the selection of values of $m$ and $n$, or upon the interpretation of experimentally obtained values.

(d) Substituting expression (**56**) in equation (**26**) and integrating, we get[7]

$$H\int_0^\infty \alpha^{m-1}\,\epsilon^{-n\alpha}\,d\,\alpha = H\,\Gamma(m)/n^m = 1 \qquad (61)$$

from which

$$H\,\Gamma(m) = n^m \qquad (62)$$

7. B. O. Peirce, Short Table of Integrals, formula 493.

where $\Gamma$ stands for the so-called Gamma Function[8].

Thus, the quantities $H$, $m$, $n$, are not entirely independent of one another, but must satisfy equation (**62**).

(e) Substituting expression (**56**) in equation (**40**) and integrating gives

$$H\int_0^\infty \alpha^m\,\epsilon^{-n\alpha}\,d\,\alpha = H\,\Gamma(m+1)/n^{m+1}$$
$$= (\gamma_0 - \gamma_f)/(\kappa_f - \kappa_0) = \Delta\,\gamma/\Delta\,\kappa \qquad (63)$$

from which

$$H\,\Gamma(m+1) = n^{m+1}\,(\gamma_0 - \gamma_f)/(\kappa_f - \kappa_0)$$
$$= n^{m+1}\,\Delta\,\gamma/\Delta\,\kappa \qquad (64)$$

This condition imposes another limitation upon the choice of the quantities $H$, $m$, and $n$. There is an additional connection between equations (**62**) and (**64**) because

$$\Gamma(m+1) = m\,\Gamma(m)\,^9 \qquad (65)$$

Dividing equation (**64**) by equation (**62**), and using expression (**65**), we get

$$m/n = (\gamma_0 - \gamma_f)/(\kappa_f - \kappa_0) = \Delta\,\gamma/\Delta\,\kappa \qquad (66)$$

The function (**56**) is different from that chosen by Wagner. He used the so-called probability function for the distribution of values of relaxation time[10]. There is no valid theoretical reason for selecting this function in preference to any other, even for a chemically simple and strictly homogeneous material. With actual substances, of complicated molecular structure and with impurities, such a function is totally inadequate, since it has not a sufficient number of parameters to fit experimental curves. Therefore, Wagner had to form a function consisting of a sum of a "finite number" of probability functions of different parameters, each giving a different most probable value of the relaxation time. However, if one has to resort to such a summation, then any other function of reasonable shape, such as equation (**56**), will do just as well.

The probability function leads to quite complicated integrations, and equation (**56**) offers considerable advantages in this respect, although two of the integrals also lead to infinite series when $m$ is not an integer. In any event, it seems advisable to carry the theory through on the basis of equation (**56**), for such practical applications and interpretations of tests as it may lead to.

## LIST OF SYMBOLS

$A$ cross-section of a slab of dielectric, perpendicular to the lines of force

$a$ thickness of a slab of dielectric

$A$, $B$, values of the integrals defined by equations (**67**) and (**68**)

8. For properties and tables of numerical values of Gamma Function see an advanced treatise on the Integral Calculus, for example B. Williamson's.

9. Equation (**65**) may be extended as follows:

$$\Gamma(m+1) = m\,(m-1)\,\Gamma(m-1)$$
$$= m\,(m-1)\,(m-2)\,\Gamma(m-2) = \text{etc.} \qquad (65a)$$

10. Loc. cit. p. 831.

$C$ ideal capacitance
$C\,i$ integral cosine
col defined by equation (**86**)
$D$ dielectric flux density, or charge per unit area
$D'$ deficiency in the density of displacement
$E$ applied voltage
$e$ a subscript meaning "even"
$F(\alpha)$ distribution function defined by equation (**25**)
$f$ a subscript meaning "final" or at the time $t = \infty$
$G$ voltage gradient or stress
$g$ apparent conductance due to absorption
$H$ a parameter defined by equation (**56**)
$I, i$ current
$j$ $= \sqrt{-1}$
$k$ absorption coefficient
$m$ a subscript meaning "maximum value" or amplitude
$m$ an exponent in equation (**56**)
$N$ number of particles
$n$ an exponent in equation (**56**)
$o$ a subscript meaning "initial," or at the instant $t = t_0$; in application to $R$ means "odd"
$P$ dielectric loss per unit volume
$p, q$ quantities defined by equation (**74**)
$p^1, q^1$ quantities defined by equation (**81**)
$Q$ dielectric flux or electric charge
$R$ an integral defined by equation (**77**)
$S\,i$ integral sine
sil defined by equation (**87**)
$t$ time
$u$ current density
$V, W$ values of the integrals defined by equations (**69**) and (**70**)
$x$ an auxiliary variable which first enters in equation (**90**)
$\alpha$ relaxation factor defined by equation (**23**)
$\Gamma$ gamma function
$\gamma$ conductivity of the material
$\Delta$ a finite increment
$\theta$ an auxiliary quantity defined by equation (**79**)
$\kappa$ permittivity or dielectric constant
$\tau$ instant of application of a new stress
$\phi(t)$ relaxation function of time
$\psi$ loss angle or imperfection angle, defined by equation (**53**)
$\omega$ electric angular velocity, that is, $2\pi$ times the frequency.

# Methods of High Quality Recording and Reproducing of Music and Speech based on Telephone Research

BY J. P. MAXFIELD[1] and H. C. HARRISON[1]
Member, A. I. E. E. Associate Member, A. I. E. E.

*Synopsis.—The paper deals with an analysis of the general requirements of recording and reproducing sound, with the nature of the inherent limitations where mechanical records are used, and a detailed description of a solution involving, first, the use of electrical equipment for the purposes of recording and, second, the use of mechanical equipment based on electric transmission methods for reproducing.*

*Probably the most useful feature of the paper is the complete description of the application of electrical transmission theory to mechanical transmission systems. A detailed analysis is made of the analogies between the electrical and the mechanical systems.*

## Introduction

The problem with which this paper is concerned, in its broadest sense, may be stated as that of taking sound from the air, storing it in some permanent way and reproducing it again without appreciable distortion. It is immaterial from the general standpoint whether the means used are mechanical or electrical or a combination of the two. The choice of which method to use will depend largely upon the commercial requirements accompanying the specific purpose for which the reproduction is being made. For instance, it is quite probable that the means chosen for reproduction in residences would differ materially from those used in large ballrooms or in the presentation of synchronized motion pictures.

Before considering the methods and results referred to in the title of this paper, it may be well to make a rough division of the problem. The storing or recording of sound requires, first, a mechanical system which will respond faithfully to the sound waves which are to be recorded. Then, there is required some material in or on which this sound may be recorded and an intervening system which permits the sound waves to make the record in this material. In the usual case, and in that with which we are particularly concerned here, there is a mechanical system which will vibrate in response to the sound which is to be recorded and

1. Both members of the technical staff, Bell Telephone Laboratories.

*Abridgment of a paper presented at the Midwinter Convention at the A. I. E. E., New York, N. Y., February 8-11, 1926. Complete copies available upon request.*

directly through some mechanical linkage or less directly through an electrical linkage, drive a cutting mechanism which will impress a wax record.

The first consideration, therefore, is the character of the sound which is to be recorded including all of the effects of reverberation and the general questions of studio design. Next to be considered is the manner in which the cutting instrument shall impress this speech or musical record upon the constantly rotating wax disk, which disk is commonly called the wax master. In this connection, there will be discussed also the relative value of the electrical and mechanical linking of the cutting knife with the mechanism which receives the sound waves. Following the discussion of these problems and a brief reference to the state of the prior art, there remains to be considered the reproduction of the sound which is stored in the cuts or grooves of the wax record.

In the case of reproduction also, there is required a mechanical system which will respond to these cuts in the wax and a system which will set up in the air-sound waves essentially identical to those picked up by the first mechanism of the recording system. Between these two systems, a mechanical linkage intervenes in the case under discussion, but reference is made to the relative advantages of this system compared with the use of an electrical linkage.

First to be described, is the character of the sound which is to be recorded and reproduced and the effects of reverberation and transients upon the listener's sensation of this sound.

## Studio Characteristics and Transients

Phonographic reproduction may be termed perfect when the components of the reproduced sound reaching the ears of the actual listener have the same relative intensity and phase relation as the sound reaching the ears of an imaginary listener to the original performance would have had. Obviously, it is very difficult, if not impossible, to fulfill all of these requirements with a single channel system, that is, with a system which does not have a separate path from each ear of the listener to the sound source.

The use of two ears, that is, two-channel listening, gives the listener a sense of direction for each of the various sources of sound to which at a given moment he may be listening, and, therefore, he apprehends them in their relative distribution in space. It has been found possible with a single channel system, however, by controlling the acoustic properties of the room in which the sound is being recorded, to simulate to a considerable degree in the reproduced music the effective space relationships of the original. In this case, with a one-channel system, the directional effect is, of course, entirely absent, and the spatial relationship which is apprehended is probably due to the increased apparent reverberation of the instruments situated at the far end of the room as compared with those in the near foreground.

In recording work, therefore, one of the important acoustic characteristics of a room is its time of reverberation. Although it is probable that this is the most comprehensive single factor, experiment has shown that the shape of the room and the distribution and character of the damping surfaces play a part in the excellence of music in such a room.

It has been shown by Sabine[2] that for piano music, studios should have a time of reverberation measured by his method of 1.08 seconds. Experience has indicated that this figure is also very closely correct for other types of music. This figure of Sabine's assumes binaural listening. With single-channel systems, such as most of the present reproduction systems, whether for radio or the phonograph, the ability of the listener to separate the reverberation from the direct music by means of the sense of direction is completely removed and there is thrust upon his attention an apparently excessive amount of room echo. Experiment has shown that a time of reverberation for the recording room ranging from slightly more than ½ to slightly less than ¾ of Sabine's figure affords in the reproduced music the effect of a room with proper acoustics. When this effect is accomplished, the person listening to the reproduced music has the consciousness of the music being played in a continuation of the same room in which he is listening and also has a sense of spatial depth.

Experiment has indicated further that any transients set up by the recording or reproducing system constitute a second cause of apparent increased reverberation. The data obtained thus far are insufficient to permit assignment of quantitative values to the importance of these two factors.

At the present state of the art, the most important requirement of a recording or reproducing system is its frequency characteristic. This involves two factors—intensity versus frequency, and phase distortion versus frequency. The effect of the second of these factors is not thoroughly understood but as it is closely related to the production of transients it has to be considered, as mentioned above. The system to be described is, however, relatively free from violent phase shifts within most of the range covered, but does have some undesirable phase-shift characteristics with small accompanying transients near its limiting cut-off frequencies.

## Frequency Requirements

The frequency range which it would be desirable to cover if, it were possible, with relatively uniform intensity for the transmission of speech and all types of music including pipe organ is from about 16 cycles per second to approximately 10,000.

2. Collected papers of W. Sabine.

It may be interesting to examine the record requirements for a band of frequencies this great. For the purpose of this illustration, a lateral cut record will be assumed although in all the factors except the time which the record will run, the arguments apply in a similar manner to the hill-and-dale cut. Since, for mechanical reproduction, the sound at a given pitch is radiated by means of a fixed radiation resistance, it is necessary that the record must be cut with a device the square of whose velocity is proportional to the sound power. Under these conditions, it is seen that for a given intensity of sound the amplitude is inversely proportional to the frequency of the tone, and that a point will be reached somewhere at the low end of the sound spectrum where this amplitude will be great enough to cut from one groove into the adjacent groove, or in case of vertical cut, to cut so deeply that with present materials the wax will tear instead of cut away with a clean surface. This means that there is an inherent maximum amplitude beyond which it is not commercially feasible to go. Similarly the minimum radius of curvature of sine waves of various frequencies cut at constant velocity is inversely proportional to the frequency, so that as higher and higher frequencies are reached the radius of curvature becomes smaller and smaller until finally it becomes too small for the reproducing needle to follow. There is, therefore, an inherent limit at the upper end.

In order to extend these limits, it is necessary in the case of the low end to make the spiral coarser and in the case of the high end to run the record at a higher speed. Both of these changes tend to decrease the time which a record of a given size can be made to play. The only alternative of these methods is to cut the record less loud than is the present standard practise and make the reproducing equipment more sensitive. This could easily be done if it were not for the "record noise" or "surface noise," as it is commonly called. Since this surface noise is already loud enough in comparison with the reproduced music to be somewhat objectionable, no appreciable gain in this direction can be made until the technique of record manufacture has been distinctly improved.

In this connection, there is one other interesting point. It has been suggested that if electric reproduction were used, it would be possible to cut the record with a characteristic other than uniform velocity sensitiveness and correct for the error by an electrical system whose characteristic is the inverse of the characteristic of record. If the change which is made in the recording characteristic tends toward cutting at uniform acceleration sensitiveness, the amplitude varies inversely as the square of the frequency and hence the difficulties at the low end of the scale are greatly enhanced. Similarly, if the records are cut more nearly at constant amplitude, the radius of curvature of the sine waves decreases as the square of the frequency, hence the difficulties are placed at the upper end. In the process which is being described in this paper, these limitations have been met commercially by having a frequency characteristic of the uniform velocity type between the frequencies of 200 and approximately 4000 cycles per second. Below 200 it has been necessary to operate at approximately constant amplitude with a resulting loss in intensity which loss increases as the frequency decreases. Above 4000 it has been necessary to operate at approximately constant acceleration with its consequent slight loss in intensity at the very high overtones. With a characteristic of this type, a range of frequencies from 60 cycles to 6000 can be recorded with reasonable success although the very low and very high range are slightly deficient. (See Fig. 14) With a record having such a frequency characteristic, the inherent limitations are divided between the two ends of the frequency band and where electrical reproduction methods are used, it is possible to employ a reproduction system whose frequency characteristic compensates for that of the record.

It should be pointed out that an attempt to record notes lower than the low cutoff of the above mentioned apparatus would result in recording only those harmonics of the notes which lie above the cut-off. This in no way prevents the listener from hearing the notes, reproduced by means of the harmonics only, as notes with the pitches of the missing fundamentals although it does somewhat change the quality of the tone.[3] If it were not for this ability of the ear to add the fundamental pitch of a note, of which only the harmonics are being reproduced, most of the older phonographs and loud speakers would have been totally useless for the reproduction of speech and music.

## Mechanical Versus Electrical Recording

In attacking the recording part of the problem, two ways at once present themselves; first, the direct use of the power, of the sound being recorded, to operate the recording instrument; and second, the use of high quality electric apparatus with vacuum tube amplifiers in order to give more freedom to the artists and better control to the process. The amount of power available to operate the recorder directly from the sound in the recording room is so small as to make it extremely difficult to make records under natural conditions of speaking, singing, or instrumental playing. As the use of high quality electric apparatus with associated amplifiers has a very distinct advantage over the acoustic method, they have been adopted for the recording part of the process. Fig. 1A shows a picture of a group of artists recording by means of the sound power directly, while Fig. 1B shows a record being made by the same artists with the electric process.

3. Physical Criterion for Determining the Pitch of a Musical Tone, H. Fletcher, *Phys. Rev.*, Vol. 23, No. 3, March, 1924.

It will be noticed in Fig. 1A that the artists are grouped very closely about the horn. In the case of the weaker instruments such as violins, it has been possible to use only two of standard construction. The rest of the violins are of the type known as the "Stroh" violin which is a device strung in the manner of a violin but so arranged that the bridge vibrates a

Fig. 1A—Picture of an Orchestra Recording for the Acoustic Process. This Picture was Furnished through the Courtesy of the Victor Talking Machine Company, Camden, New Jersey

diaphragm attached to a horn. This horn is directed toward the recording horn, as shown by the player in the foregound.

With such an arrangement of musicians, it is very difficult to arouse the spontaneous enthusiasm which is necessary for the production of really artistic music.

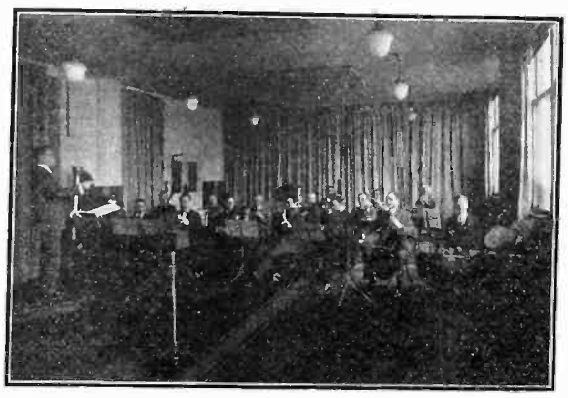


Fig. 1B—Picture of the Same Orchestra Shown in Fig. 1A, but Recording for the Electric Process. This Picture was Furnished through the Courtesy of the Victor Talking Machine Company, Camden, New Jersey

In Fig. 1B the musicians are sitting at ease more nearly in their usual arrangement and all are using the instruments which they would use were they playing at a concert. Furthermore, the microphone is now sufficiently far away from the orchestra to receive the sound in much the manner that the ears of a listener in the audience would receive it. In other words, it picks up the sound after it has been properly blended with the reflections from the walls of the room. It is in this way that the so-called "atmosphere" or "room-tone" has been obtained.

In the old process, it sometimes happened that after the instruments had been arranged in such a manner that the relative loudness of the various parts had been balanced correctly, it was found that the whole selection was either too loud or too weak. This usually meant a complete rearrangement of the players. With the flexibility introduced by the use of electrical apparatus including amplifiers, the control of loudness is obtained by simple manipulation of the amplifier system and is in no way related to the difficulties of the relative loudness of one instrument to another. The only problem for the studio director in this case is to obtain the proper balance among the various musical instruments and artists. The advantages derived from this added ease of control are also made manifest in that it is much easier and less tiresome for the artists and it is usually possible to make more records in a given time.

## Mechanical Versus Electrical Reproducing

Where the question of reproduction is concerned, the same two alternatives mentioned for recording present themselves, namely, direct use of power derived from the record itself versus the use of electromechanical equipment with an amplifier. In this case, however, the situation is a little different as the power which can be drawn directly from the record is more than sufficient for home use. Since any method of reproducing from mechanical records by electrical means involves the use of a mechanical device for transforming from mechanical to electrical power and a second such device for transforming from electrical back to mechanical power, that is, sound, it is necessary to use two mechanical systems, one at each end of an electrical system. Where the power which can be supplied by the record, is sufficient to produce the necessary sound intensity, as in the case of home use, it is in general simpler to design one single mechanical transmission system than it is to add the unnecessary complications of amplifiers, power supply and associated circuits. In cases where music is to be reproduced in large auditoriums, the power which can be drawn from the record may be insufficient and some form of electric reproduction using amplifiers becomes necessary.

## Brief Description of Recording System

The system used for recording consists of a condenser transmitter, a high quality vacuum tube amplifier and an electromagnetic recorder. Fig. 2 shows the calibration of the condenser transmitter and the associated amplifiers. The condenser transmitter and amplifiers are so designed that the current delivered to the recorder circuit is essentially proportional to the sound pressure at the transmitter diaphragm. The electromagnetic recorder, which will be described later, is designed to work with this type of system.

With the exception of this electromagnetic recorder, apparatus of this type has already been described in the literature.[4] In addition to this equipment which might be called the recording amplifier system, there is a volume indicator for measuring the power which is being delivered to the recorder and also an audible monitoring system. The audible monitoring system consists of an amplifier whose input impedance is high compared with the recorder impedance and a suitable loud speaking receiver. The monitoring amplifier is bridged directly across the recorder and operates the loud speaking receiver so that the operator may listen to the record as it is being made.

In the design of the recording and reproducing systems each part of the system has been made as nearly perfect as possible. Errors of one part have not been designed to compensate for inverse errors in another part. Although this method is the more difficult, its flexibility, particularly as regards the commercial possibilities of future improvements justifies the extra effort.[5] There is, therefore, no distortion in the record whose purpose is to compensate for errors in the reproducing equipment; the only intended dis-

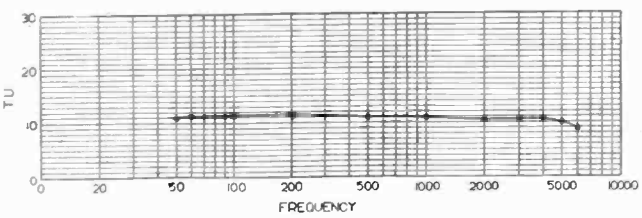



Fig. 2—Calibration of the Condenser Transmitter and Associated Amplifiers

This curve shows merely the relative frequency sensitiveness of the system, the zero line having been chosen arbitrarily

tortion in the record being that required by the inherent limitations mentioned above. See Figs. 2, 14 and 20.

## General Basis of Design

An interesting feature of the development of the mechanical and electromechanical portions of the recording and reproducing system is their quantitative design as mechanical analogs of electric circuits. Both the recording and reproducing systems are good examples of the use of this type of analogy.

The economic need for the solution of many of the problems connected with electric wave transmission over long distances coupled with the consequent development of accurate electric measuring apparatus has led to a rather complete theoretical and practical knowledge of electrical wave transmission. The advance has been so great that the knowledge of electric systems has surpassed our previous engineering knowledge of mechanical wave transmission systems. The result is, therefore, that mechanical transmission systems can be designed more successfully if they are viewed as analogs of electric circuits.

While there are mechanical analogs for nearly every form of electrical circuit imaginable, there is one particular class of electrical circuits whose study has led to ideas of the utmost value in guiding the course of the present development. This class of circuits consists of infinitely repeated similar sections of one or more lumped capacity and inductance elements in series and shunt and are commonly known as filters. The study of filters began with the work of Campbell[6] and a recognition of their importance as frequency selective systems in telephone repeaters, carrier systems, radio, signalling systems, etc., led to their intensive study. In the available literature is to be found a fairly complete statement of their properties and details of their design.[6]

It will be recalled in the case of the telephone circuit that the introduction of inductance coils at regular intervals in the circuit produced a remarkable change in the transmission characteristic. Over a broad band of frequencies the attenuation was reduced and made fairly uniform over that range while beyond a critical frequency called the cut-off frequency the attenuation became very high. In the ideal filters with zero dissipation the transmission characteristics are of the same nature but more clear cut. Structures of this type with infinitely repeated sections will have one or more transmission bands of zero attenuation and one or more bands having infinite attenuation. The impedance characteristics of such a structure measured from certain characteristic points will be pure resistance more or less uniform in the transmission bands, and pure reactance in the attenuation bands. These terminations are

4. Wente, E. C., "Condenser Transmitter as a Uniformly Sensitive Instrument for Measuring Sound Intensity," *Phys. Rev.*, Vol. 10, 1917.

Crandall, I. B., "Air-Damped Vibrating Systems," *Phys. Rev.*, Vol. 11, 1918.

Wente, E. C., "Electrostatic Transmitter," *Phys. Rev.*, Vol. 19, 1922.

Martin, W. H. and Fletcher, H., "High Quality Transmission and Reproduction of Speech and Music," Trans. A. I. E. E., Vol. 43, 1924, p. 384.

Green, I. W. and Maxfield, J. P., "Public Address Systems," Trans. A. I. E. E., Vol. 43, 1923, p. 64.

5. Green, I. W. and Maxfield, J. P., "Public Address Systems," Trans. A. I. E. E., Vol. 42, 1923, p. 64.

6. Campbell, G. A., "On Loaded Lines in Telephonic Transmission," *Phil. Mag.*, March 1903.

Campbell, G. A., U. S. Patents 1,227,113; 1,227,114; "Physical Theory of the Electric Wave Filter," *Bell System Technical Journal*, November 1922.

Zobel, O. J., "Theory and Design of Uniform and Composite Electric Wave Filters," *Bell System Technical Journal*, January 1923.

Peters, L. J. "Theory of Electric Wave Filters Built up of Coupled Circuit Elements," Trans. A. I. .E. E., May 1923.

Carson, J. R. and Zobel, O. J., "Transient Oscillations in Electric Wave Filters," *Bell System Technical Journal*, July 1923.

Zobel, O. J., "Transmission Characteristics of Electric Wave Filters," *Bell System Technical Journal*, October 1924.

Johnson, K. S., and Shea, T. E., "Mutual Inductance in Wave Filters with an Introduction on Filter Design," *Bell System Technical Journal*, January 1925.

Johnson, K. S., "Transmission Circuits for Telephonic Communication," D. Van Nostrand, 1925.

mid-series; that is, the entering element being a series one of half the normal series element; or mid-shunt; that is, the entering element being twice the impedance of the normal shunt element. The corresponding impedances are called the mid-series and mid-shunt characteristic or iterative impedances.

If we retain the first few sections of such a structure

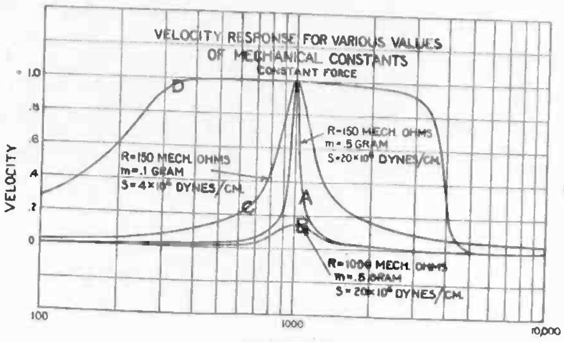



Fig. 9—Velocity Response for Various Values of Mechanical Constants

and terminate them with a resistance which is equal to the resistance impedance of the infinite line from which they were taken, the characteristics are substantially unchanged. It is understood, of course, that this resistance equals approximately the resistance impedance of the remainder of the infinite line at most of the frequencies in the transmission band in which we are interested.

The presence of small amounts of damping in the various elements also has but slight effect on the general characteristics. These results could in general be readily applied to the various telephone transmission problems because the source and load between which the filter system was inserted generally had or could be made to have a nearly resistance impedance equalling the mid-series or mid-shunt impedance of the filter within the transmission band. The filter and terminating impedances may then be said to be matched. Where adjacent sections in the filter have impedances similar in character but different in absolute magnitude they may be joined by a suitable transformer.

Many early attempts were made to design mechanical transmission systems having a wide frequency range in which highly damped single or multi-resonant systems were employed. In these attempts both of the obvious methods of increasing the damping were used, namely, that of adding a resistance to the system and that of increasing the value of the compliance and decreasing mass in such proportion as to maintain the same natural frequency. The former of these methods reduces the sensitivity of the system at the point where it is most efficient, (See Fig. 9), while the second method increases the response at the points where the system is less sensitive, namely, away from its resonance point. Fig. 9 shows four curves—first, a singly resonant system, Curve $A$; second, the same system with friction added, Curve $B$; third, the same system without the added friction but with an increase in compliance and a decrease in mass such that the natural period remains the same; Curve $C$, and fourth, a band pass type of circuit whose resistance impedance is the same as that of the system shown in Curve $A$. (See Curve $D$.)

The results of filter theory have shown how these resonances should be coordinated so that when a proper resistance termination is used high efficiency and equal sensitivity are obtained over a definite band of frequencies by elimination of response to all frequencies outside the band. With the electrical case of a repeated filter, each section considered by itself resonates at the same frequency but when combined into a short-circuited filter of $n$ sections, there will be $n$ natural frequencies. However, when such a system is terminated with a resistance which equals the nominal characteristic impedance in the transmission band, uniform response in the terminating resistance is obtained over the entire band.

## Detailed Analysis of Mechanical and Electrical Analogs[7]

Before going on with a detailed treatment of the electrical analogues of the mechanical structures used in the problem of phonographic reproduction, a list of the corresponding quantities used in the two systems will be given, together with the symbols employed.

| Mechanical | | Electrical | |
|---|---|---|---|
| Force | = $F$ (dynes) | Voltage | = $E$ (volts) |
| Velocity | = $v$ (cm./sec.) | Current | = $i$ (amperes) |
| Displacement | = $s$ (cm.) | Charge | = $q$ (coulombs) |
| Impedance | = $z$ (dyne sec./cm. or mechanical ohms) | Impedance | = $Z$ (ohms) |
| Resistance | = $r$ (dyne sec./cm.) | Resistance | = $R$ (ohms) |
| Reactance | = $x$ (dyne sec./cm.) | Reactance | = $X$ (ohms) |
| Mass | = $m$ (gms) | Inductance | = $L$ (henries) |
| Compliance | = $c$ (cm./dyne)[8] | Capacity | = $C$ (farads) |

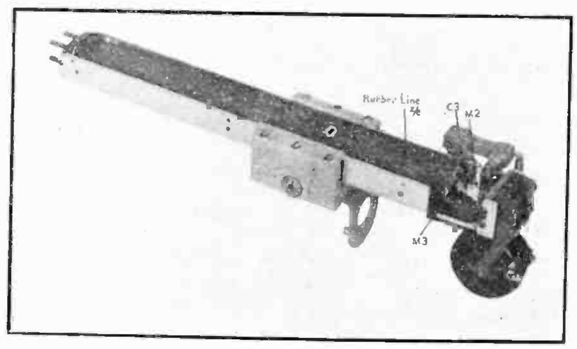


Fig. 10—This Figure Shows an Electromagnetic Recorder Complete except for the Bottom of the Case

7. The authors wish to express their appreciation to Mr. E. L. Norton for his courtesy in working out the mathematics of the mechanical and electrical analogs which are shown in this paper.

8. H. W. Nichols, "Theory of Variable Dynamical Electrical Systems," *Phys. Rev.* Vol. 10, 1917.

## General Design of Mechanical Systems

In designing mechanical systems of the band pass type, the problem is three fold—first, that of arranging the masses and compliances such that they form repeated filter sections; second, determining the magnitude of these quantities so that with or without transformers the separate sections all have the same cut-off frequencies* and characteristic impedances; third, to provide the proper resistance termination. Where the transmitted mechanical power has not been radiated as sound this third part has been one of the most difficult to fulfill.

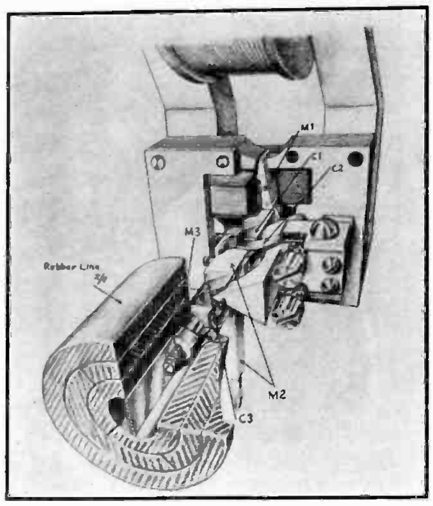



Fig. 11—Detailed Drawing of the Mechanical Filter of an Electromagnetic Recorder. (Lettering Same as in Fig. 12)

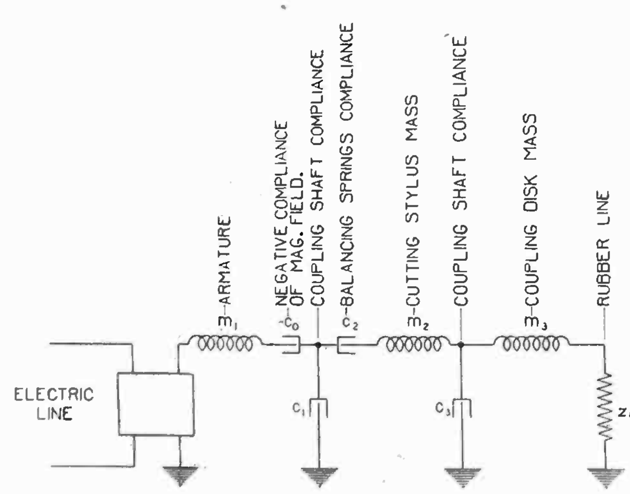



Fig. 12—Equivalent Electric Circuit of the Electromagnetic Recorder

In designing these systems, practical difficulties arose—first, the difficulty of insuring that the parts vibrated in the desired degrees of freedom only, and second, the difficulty of determining the magnitudes of the various effective masses, compliances and resistances. Before the work to be described could be carried out practically it became necessary to develop a method of measuring mechanical impedances[10]. This method of measurement has been very useful not only in determining the magnitudes of the impedances in the degrees of freedom in which it is desired that they shall operate, but in determining the impedances to motion of the various parts in directions in which they should not be permitted to vibrate. In connection with the measurement of the magnitudes of the parts in the desired degrees of freedom this method enables us to determine the constants of the mechanical networks under their conditions of operation. Experience so far has indicated that when all the degrees of freedom have been taken into account and when the dynamic axes of vibration have been properly chosen, the static and dynamic constants of the parts are the same, and it is then possible to check the parts by simple static measurements. In the early attempts to build these systems very large discrepancies between the static and dynamic characteristics were found.

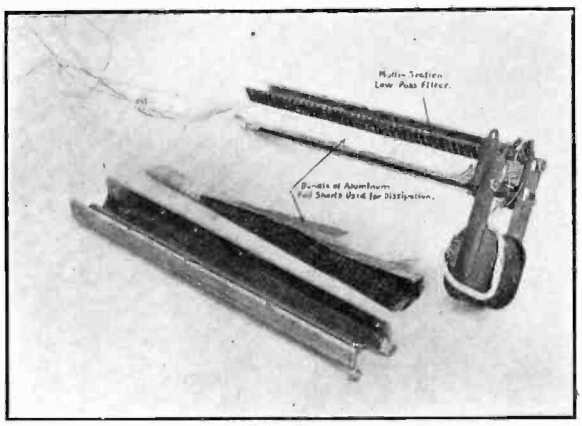


Fig. 13—Electromagnetic Recorder using Lumped Loaded Termination

The method of furnishing dissipation to the lumped loaded line is shown

## The Recorder

One of the early practical phonographic applications of electric filter design to mechanical problems was the development of an electromagnetic recorder. The instrument as finally constructed is essentially a properly terminated three-section mechanical filter in which the recording stylus and its holder constitute the series mass in the second section. Since a filter of this type appears at its input end as approximately a pure resistance within the transmission band, the current in the series inductances, that is, in the mechanical

*It is of course permissible to have a section having a higher cut-off than the others provided its characteristic impedance is the same as that of the others over the transmission band of those having the lower cut-off.

10. Kennelly, A. E. and Affel, H. A., "The Mechanics of Telephone Receiver Diaphragms, as Derived from their Motional Impedance Circles," *Proc.* A. A. A. S., Vol. 51, No. 8, November, 1915.

Kennelly, A. E. and Pierce, G. W., "The Impedance of Telephone Receivers as Affected by the Motion of their Diaphragms," *Proc.* A. A. A. S., Vol. 48, No. 6, September, 1912.

case, the velocity of the series masses is proportional to the driving force.

Figs. 10, 11 and 12 show respectively, a complete recorder, a drawing of the mechanical filter of such a recorder and a diagram of the equivalent electric circuit.

Referring to Figures 11 and 12, all of the equivalents can readily be seen with the exception of the terminating resistance and the negative compliance, $c_0$. The reason for using the type of termination shown lies in the fact that most of the known mechanical resistances have values which are functions of frequency or of amplitude or of both. Also in most cases, the mechanical resistance is accompanied by either a mass or compliance reactance. By using a continuous transmission line (shown completely in Fig. 10 and partially in Fig. 11) which line is sufficiently long so that a wave entering it will be essentially absorbed before it has reached the far end, been reflected and returned to the entering end, it has been possible to use imperfect types of damping for this line and still

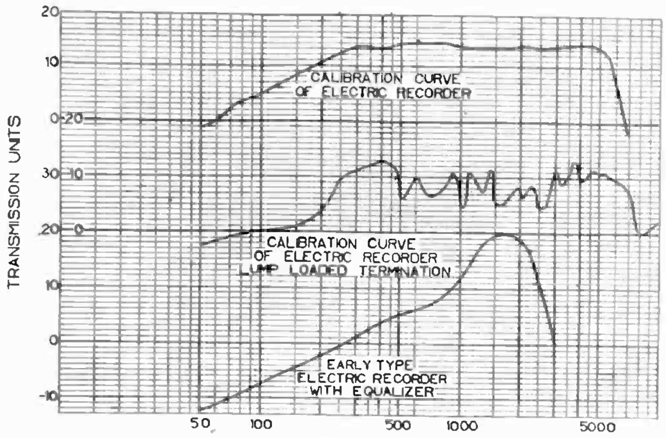



FIG. 14—CALIBRATION CURVE OF THREE TYPES OF ELECTROMAGNETIC RECORDERS

obtain over the desired band, an essentially pure resistance at the input end.

Fig. 14 shows calibration curves of three types of recorders. The bottom curve shows an early type of highly damped singly resonant system. The middle curve is a calibration of a low pass mechanical filter type using lumped loading in the resistance line.* The upper curve shows the calibration of the recorder shown in Fig. 10.

The compliance $-c_0$ is a mechanical quantity for which there is no simple electric analog. In a balanced armature type of structure such as that shown in Fig. 11, the action of the field on the armature, when it is at its center point, is balanced. If, however, the armature be deflected, a small distance from this equilibrium, there is exerted by the magnetic field a torque tending to pull the armature further away from its center position. The value of this torque for small amplitudes is proportional to the angular displacement. It is therefore seen that this quantity is of the nature of a compliance but that the back force is in a reverse direction to that required for a positive compliance.

*For a description of this, see the complete paper available in pamphlet form upon request.

## DESIGN OF THE REPRODUCING APPARATUS

As the analogy between the mechanical and electrical filter is more perfectly shown in the case of the reproducing equipment, the detailed quantitative description will be given in this connection. Figs. 15 and 16 show respectively a diagram of the reproducing system and its equivalent electric circuit. From these diagrams it is evident which units in the mechanical system correspond to the various electrical parts. As the series compliances $c_2$, $c_4$ and $c_6$ have been made so large that the low frequency cut-off caused by them lies well below the low frequency cut-off of the horn, an inappreciable error is introduced in using for design

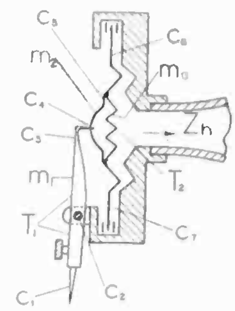


FIG. 15—DIAGRAMMATIC SKETCH OF THE MECHANICAL SYSTEM OF THE PHONOGRAPH

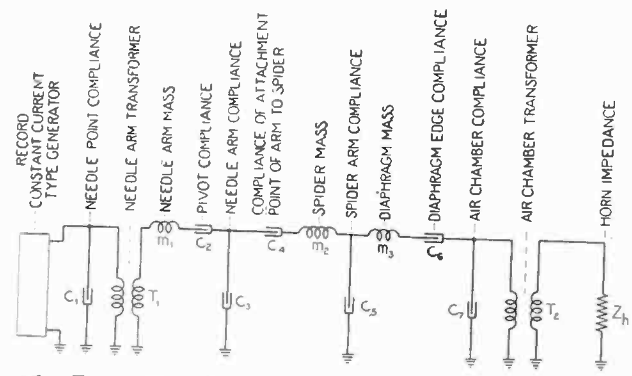



FIG. 16—ELECTRIC EQUIVALENT OF THE SYSTEM SHOWN IN FIG. 15

purposes formulas of low pass filters[11]. The two formulas which will be used are as follows:

$$f_c = \frac{1}{\pi}\sqrt{\frac{1}{m\,c}} \qquad (12)$$

Where

$f_c$ = cut-off frequency of a lumped transmission system in cycles per second

11. Campbell, G. A., "On loaded lines in Telephonic Transmission," *Phil. Mag.*, March, 1903.

$c$ = shunt compliance per section in centimeters per dynes

$m$ = series mass per section in grams

$$z_0 = \sqrt{\frac{m}{c}} \qquad (13)$$

Where $z_0$[12] is the value of characteristic impedance over the greater part of the band range.

Equations (**12**) and (**13**) which form the basis of the design work contain four variables, $f_c$, $c$, $m$ and $z_0$. It is, therefore, necessary to determine two of them by the physical requirements of the problem after which the other two are determined. The upper cut-off frequency $f_c$ was arbitrarily chosen at 5000 pps. as a compromise between the highest frequency occurring on the record and the increase in surface noise as the cut-off is raised. The choice of the other arbitrarily set variable came after considerable preliminary experimenting and was fixed by the difficulty of obtaining a diaphragm which is light enough and has a large enough area. Hence the effective mass of the diaphragm $m_3$, (Figs. 15-16) was fixed at 0.186 grams which value can be obtained by careful design. The effective area can be made as large as 13 square centimeters. For convenience let the arbitrary value chosen for $f_c = \bar{f}_c$ and the value of $m = \bar{m}_3$.

Solving Equations (**12**) and (**13**) for $c$ and $z_0$, we get

$$c = \frac{1}{\pi^2 \bar{f}_c^2 \bar{m}_3} \qquad (14)$$

$$z_0 = \pi \bar{f}_c \bar{m}_3 \qquad (15)$$

also

$$z_0 = \frac{1}{\pi c \bar{f}_c} \qquad (16)$$

In order to obtain the low value of mass mentioned, with a large enough area, it was necessary to make the diaphragm of a very stiff light material. An aluminum alloy sheet 0.0017 in. thick was chosen and concentrically corrugated as shown in Figs. 17 and 18. These corrugations are spaced sufficiently close so that the natural periods of the flat surfaces are all above $\bar{f}_c$. To insure that this central stiffened portion should vibrate with approximate plunger action, which is more efficient than diaphragm action, it is driven at six points near its periphery.

Reference to Figs. 15 and 16 and Equation (**14**) shows that the compliance of the air chamber $c_7$, of the spider legs $c_5$ and shunt tip of the needle arm $c_3$ are determined. Also the mass of the spider $m_2$ and the effective mass of the needle arm $m_1$, as viewed at the point where it is attached to the spider, are determined.

The impedance looking into the system from the record is determined by the rate at which it is necessary to radiate energy in order that the reproduction may be loud enough. The power taken from the record is approximately $v^2 z_0$ since $z_0$ is a resistance over most of the band. Experiment has shown this value of $z_0$ to be approximately 4500 mechanical ohms.

But substituting in Equation (**13**) the value of $\bar{m}_3$, and from Equation (**14**) the value of $c_5$, we find that the impedance is only 2920 mechanical ohms. It is, therefore, necessary to use a transformer whose impedance ratio is $\frac{4500}{2920}$. From this and a knowledge of filter structures the needle-point compliance can be determined. The value obtained is easily realized with commercial types of needle.

It will be noted that the record is shown in Fig. 16 as a constant current generator, *i. e.*, a generator whose impedance appears high as viewed from the needle point. That this is necessary is obvious when it is remembered that, if the impedance looking back into the record were to equal the impedance of the filter system, the walls of the record would have to yield an amount comparable with one-half the amplitude of the lateral cut. This would cause a breakdown of the record material with consequent damage.

The design of the system is, therefore, complete except for the resistance termination which is supplied by the horn for all frequencies above its low frequency cut-off. The characteristics of the horn will be dealt with later. The resistance within the band looking in at the small end of the horn is $G\,A_2$ where $G$ = mechanical ohms per square centimeter of an infinite cylindrical tube of the same area, and $A_2$ = area in square centimeters of the small end of the horn.

Let $A_1$ = the effective plunger area of the diaphragm (as previously mentioned this is 13 sq. cm.). The impedance looking back at the diaphragm is

$$z_0 = \pi \bar{f}_c \bar{m}_3 = 2920 \text{ mechanical ohms}$$

from Equation (**15**), and the impedance looking at a horn whose small end area equals $A_2$ is

$$z_h = r_0 = A_2 G \qquad (17)$$

Substituting

$A_2$ = 13 sq. cm.

$G$ = 41 ohms per cm.$^2$ we get

$z_h$ = $r_0$ = 533 mechanical ohms

This is entirely insufficient so that the air-chamber transformer becomes necessary.

To calculate the necessary ratio of areas on the two sides of the air-chamber transformer, the following formula is needed. The formula assumes the chamber to be relatively small compared with all wave lengths of the

12. $z_0$ may be called nominal mid-shunt or mid-series impedance. Their actual values in the transmission band being at any frequency $f$.,

$$\text{mid-series} = z_0 \sqrt{1 - \left(\frac{f}{f}\right)^2}$$

$$\text{mid-shunt} \quad \frac{z_0}{\sqrt{1 - \left(\frac{f}{f_c}\right)^2}}$$

sound to be transmitted, that is, the pressure changes throughout the chamber are substantially in phase.

$$\frac{z_0}{z_h} = \frac{A_1^2}{A_2^2} \qquad (18)$$

Where

$z_0$ = the impedance of the primary side of the transformer in mechanical ohms

$z_h$ = the impedance on the secondary side of the transformer in mechanical ohms, *i. e.*, the horn impedance

Solving this equation with the aid of Equations (15) and (17), we get

$$A_2 = \frac{G\,A_1^2}{\pi\, f_c\, m_3} \qquad (22)$$

(A more complete description of this part of the

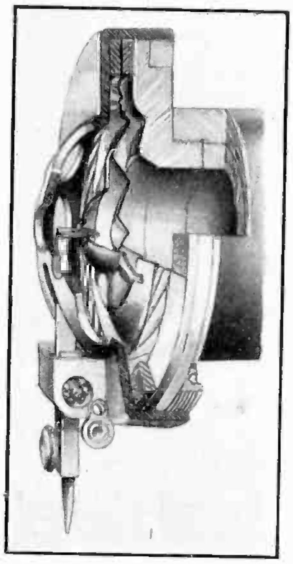


FIG. 18—SECTIONAL DRAWING SHOWING CONSTRUCTION OF THE SYSTEM SHOWN IN FIG. 17

design is given in the complete paper which will be published in the A. I. E. E. TRANSACTIONS for 1926.)

The horn which has been used as a terminating resistance to the mechanical filter structure is a logarithmic one. The general properties of logarithmic horns have been understood for some time.[13]

There are two fundamental constants of such a horn—the first is the area of the large end and the second the rate of taper. The area of the mouth determines the lowest frequency which is radiated satisfactorily. The energy of the frequencies below this is largely reflected if it is permitted to reach the mouth.

From the equations given by Webster,[13] it can be shown that all logarithmic horns have a low frequency cut-off which is determined by the rate of taper. If the rate of taper is so proportioned that its resulting cut-off prevents the lower frequencies from reaching the horn mouth, the horn will then radiate all frequencies reaching its mouth and very little reflection will result.[14] It is, therefore, possible to build a horn having no marked fundamental resonance.

Since the characteristics of the horn are determined

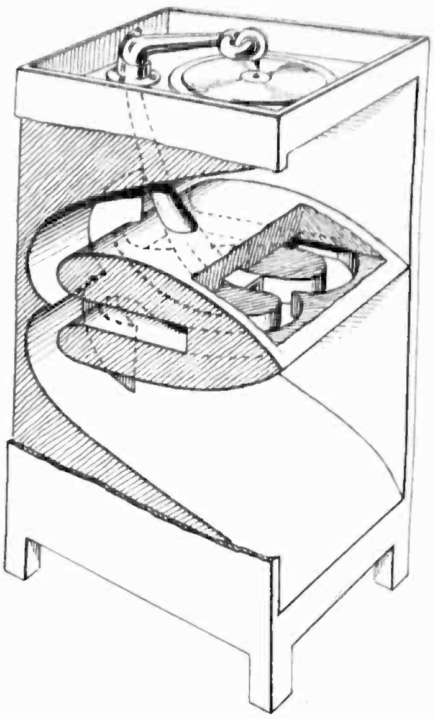


FIG. 19—SECTIONAL VIEW OF THE FOLDED HORN SHOWING THE AIR PASSAGE

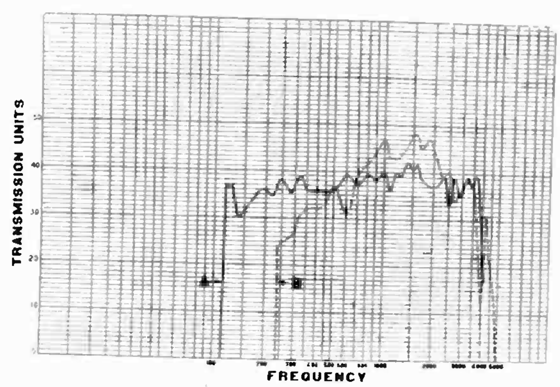



FIG. 20—RESPONSE FREQUENCY CHARACTERISTIC OF TWO PHONOGRAPHS. CURVE *A* SHOWS THE CHARACTERISTIC OF THE BAND PASS FILTER TYPE DESCRIBED. CURVE *B* SHOWS THE CHARACTERISTIC OF ONE OF THE BEST COMMERCIAL MACHINES PREVIOUSLY ON THE MARKET

by the area of its mouth and by its rate of taper the length of the horn is determined by the area of the small end. This area is determined in turn by the mechanical impedance and effective area of the system

13. Webster, A. G., "Acoustical Impedance and Theory of Horns and Phonograph," *Proc.* Nat. Acad. of Sci., 1919.

14. The authors wish to express their appreciation in this connection of the work of Mr. P. B. Flanders who carried out the mathematical investigation of these relationships and to Mr. A. L. Thuras who checked experimentally the mathematical theory.

which it is terminating, as shown in Equation (22). It is seen, therefore, that the length of the horn should not be considered as a fundamental constant. A paper describing the design of horns based on these principles is being prepared.

An interesting feature of the horn which has been built commercially is its method of folding. The sketch in Fig. 19 shows a shadow picture of the horn. It will be noticed that the sound passage is folded only in its thin direction, which permits the radius of the turns to be small and thereby makes the folding compact.

Fig. 20 shows the frequency characteristic of a phonograph designed as shown above with a logarithmic horn whose rate of taper and area of mouth opening place the low cut-off at about 115 cycles. It also shows the characteristics of one of the best of the old style phonographs. Curve *A* represents the new machine, while Curve *B* represents the old style standard machine.

---

# Development and Application of Loading for Telephone Circuits

BY THOMAS SHAW[1] and WILLIAM FONDILLER[2]
Member, A. I. E. E. Member, A. I. E. E.

*Synopsis.—A review of the art of loading telephone circuits as practised in the United States. The introductory section briefly reviews the theory of coil loading, and summarizes the principle characteristics of the first commercial standard loading coils and loading systems, thereby serving as a background for the description of the various improvements of outstanding importance which have been made in the loading coils and loading systems during the past fifteen years to meet the new or changing requirements in the rapidly advancing communication art.*

*These major improvements are described in detail under the appropriate headings (1) Phantom Group Loading, (2) Loading for Repeatered Circuits, (3) Incidental Cables in Open-Wire Lines, (4) Cross-talk, (5) Telegraphy over Loaded Telephone Circuits, (6) Loading for Exchange Area Cables, and (7) Submarine Cables. The discussion of these various developments sets forth the relations between the loading features and the associated phases of telephone development, such as the cables, repeaters, telegraph working, and carrier telephone and telegraph systems.*

*The concluding part of the paper gives some general statistics regarding the extent of the commercial application of loading in the United States, and a brief statement indicative of the large economic importance of loading to the telephone using public.*

## INTRODUCTION

The purpose of this paper is to present a review of the art of loading telephone circuits by means of inductance coils inserted at periodic intervals, as practised in the United States. In a paper[3] presented before the Institute in 1911, Mr. B. Gherhardi described the developments in loading up to that time and gave a comprehensive statement of the results obtained. The present paper, therefore, deals primarily with the subsequent developments in the art and their application. The more important improvements which will be considered here, are as follows:

Phantom Group Loading
Loading for Repeatered Circuits
Incidental Cables in Open-Wire Lines
Crosstalk
Telegraphy over Loaded Telephone Circuits
Loading for Exchange Area Cables

1. American Telephone & Telegraph Company, New York, N. Y.

2. Bell Telephone Laboratories, Inc., New York, N. Y.

3. *Commercial Loading of Telephone Circuits in the Bell System*, B. Gherardi, TRANS. A. I. E. E., Vol. XXX, 1911.

*Abridgment of paper presented at Midwinter Convention of the A. I. E. E., February 8-11, New York, N. Y. Complete copies to members on application.*

## THEORY

Viewed from the standpoint of the power engineer, the general effect of loading is to raise the line impedance and improve the power factor. This makes it possible to transmit a given amount of power corresponding to speech sounds at a higher line potential and with a lower value of line current than would be possible without the loading. In the non-loaded line, which is inherently a low impedance line, the series dissipation losses which are proportional to the square of the line current are ordinarily very large relative to the shunt dissipation losses which are proportional to the square of the line potential. Consequently, when the line impedance is increased by a suitable amount, the reduction in series losses is much greater than the increase in shunt losses, and a substantial improvement in line efficiency is obtained. The optimum impedance for minimum line loss is that which results in the shunt and series losses being equal. Ordinarily, it is not economical to apply a sufficient amount of loading to reach this condition.

In general, commercial power lines are electrically short in terms of the wave length of the transmitted frequency, and consequently the sending-end impedance is very largely influenced by the receiving-end impedance. This allows high impedance lines to be obtained by using high ratio transformers at the receiving end to step up the terminal impedance. On the other hand, telephone lines which are of interest from the loading standpoint are electrically long, and their sending-end impedance is practically unaffected by the terminal impedance. Consequently, the addition of series inductance to the line is the most

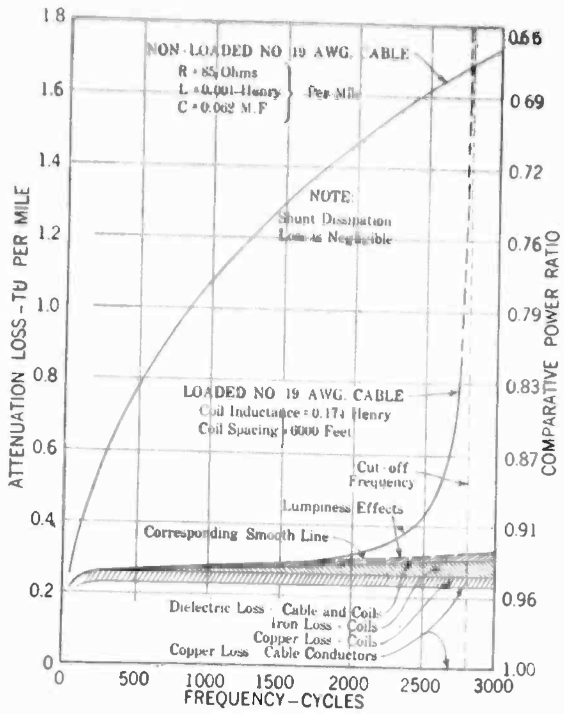



FIG. 1—ATTENUATION-FREQUENCY CHARACTERISTICS OF LOADED AND NON-LOADED NO. 19 A. W. G. CABLE

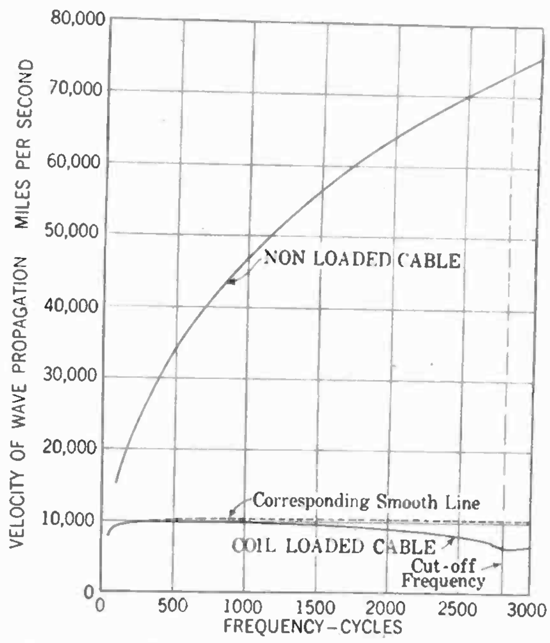



FIG. 2—VELOCITY-FREQUENCY CHARACTERISTICS OF LOADED AND NON-LOADED NO. 19 A. W. G. CABLES OF FIG. 1

practical way of increasing the telephone line impedance.

Besides reducing the line losses and the velocity of propagation, the addition of series inductance makes the attenuation and velocity substantially independent of frequency over the frequency range where the inductive reactance is large relative to the line resistance. This reduction of frequency distortion is especially important in cable circuits, since non-loaded cables have a negligible amount of distributed inductance.

Investigating the question of concentrating the line inductance at uniformly spaced intervals, Professor Pupin gave his famous solution in a paper[4] presented before the Institute in May 1900. Doctor G. A. Campbell, in his paper[5] of March 1903, also gave a mathematical development of the loading theory along somewhat different lines. These early investigations showed the beneficial effects of the lumped inductances and pointed out that these desirable effects hold up to a certain critical frequency which is known as the cutoff frequency, since at this frequency and higher frequencies the attenuatian loss amounts practically to a suppression, due to internal reflection effects. The cutoff

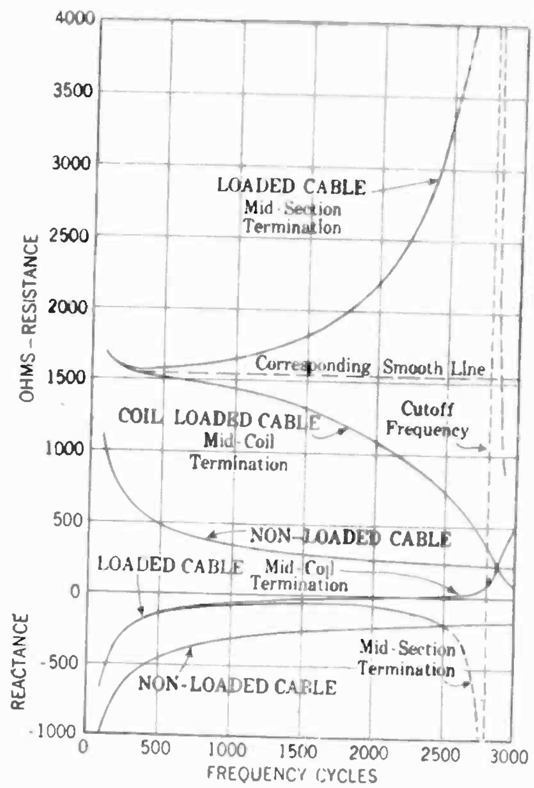



FIG. 3—IMPEDANCE-FREQUENCY CHARACTERISTICS OF LOADED AND NON-LOADED NO. 19 A. W. G. CABLES OF FIG. 1

frequency of a coil loaded line having zero distributed inductance is given by the expression:

$$f_c = \frac{1}{\pi \sqrt{L s C}}$$

in which

$f_c$ = cut-off frequency
$L$ = coil inductance
$s$ = coil spacing
$C$ = line capacitance per unit length

At the cut-off frequency there are two coils per actual

4. *Wave Transmission over Non-Uniform Cables and Long Distance Air Lines*, M. I. Pupin, TRANSACTIONS A. I. E. E., Vol. XVII, 1900, p. 445. Refer also to Pupin U. S. Patents Nos. 652, 230 and 652, 231, June 19, 1900.

5. *On Loaded Lines in Telephone Transmissions*, G. A. Campbell, *Philosophical Magazine*, March 1903.

wave length, and $\pi$ coils per wave length in terms of the velocity of the corresponding smooth line. At frequencies above 75 per cent. of the cut-off frequency, the internal reflection effects, sometimes known as "lumpiness effects," are of appreciable magnitude and increase rapidly with rising frequency as the cut-off frequency is approached. At the cut-off frequency, abrupt changes also occur in the velocity and impedance characteristics.

Figs. 1, 2 and 3 illustrate the differences in attenuation, velocity, and impedance characteristics of a typical telephone cable, with and without loading. It is interesting to note that the standard type of loading illustrated in these diagrams so increases the transmission efficiency of No. 19 A. w. g. cable wires that the loaded circuits can be used for distances four times the permissible length of the non-loaded circuits. To obtain this increased transmission range without loading would require wires about eight times as heavy; *i. e.*, No. 10 A. w. g.

## Phantom Group Loading

*Loading Methods.* The Bell System standard methods[6] for loading phantom circuits and side circuits of phantoms are illustrated in Fig. 4.

The loading problem is to introduce the desired inductance into each of the three circuits of a phantom group without causing unbalances which would result in objectionable overhearing or crosstalk effects. The method illustrated in Fig. 4 involves individual loading coils for each telephone circuit, the designs being such that the side circuit coils are substantially non-inductive to the phantom circuit, while the phantom loading coil is substantially non-inductive to each of the side circuits.

*Cable Loading.* Data regarding the general characteristics of the first phantom group loading systems standardized for use on quadded telephone cables are given in Table V, as follows:

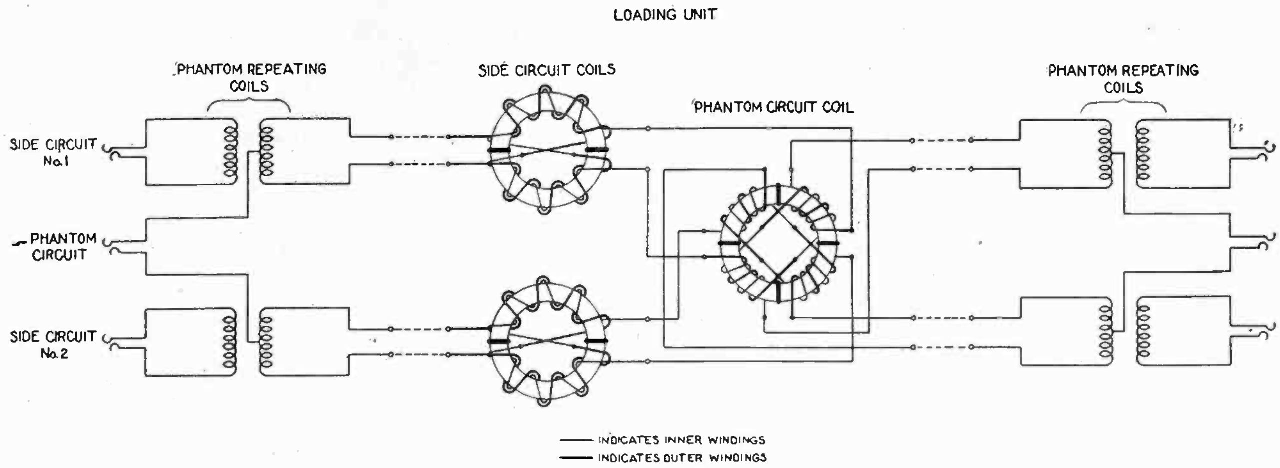



Fig. 4—Bell System Standard Method of Loading Phantom Circuits and Their Side Circuits

TABLE V
FIRST LOADING STANDARDS FOR QUADDED TOLL CABLES

| Item | Loading Designation | Type Circuit | Coil Inductance (Henrys) | Coil Spacing (Miles) | Nominal Impedance (Ohms) | Attenuation Loss—TU per mile 19 A. w. g. | 16 A. w. g. | 13 A. w. g. | 10 A. w. g. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Medium-Heavy | Side | 0.210 | 1.4 | 1500 | | | 0.085 | 0.050 |
| 2 | " " | Phantom | 0.130 | 1.4 | 950 | | | 0.069 | 0.040 |
| 3 | Heavy | Side | 0.250 | 1.25 | 1850 | | | 0.081 | 0.050 |
| 4 | " | Phantom | 0.155 | 1.25 | 1150 | | | 0.066 | 0.042 |
| 5 | Heavy | Side | 0.250 | 1.25 | 1850 | 0.24 | 0.14 | | |
| 6 | " | Phantom | 0.155 | 1.25 | 1150 | 0.20 | 0.12 | | |
| 7 | Medium | Side | 0.175 | 1.75 | 1300 | 0.31 | 0.17 | | |
| 8 | " | Phantom | 0.106 | 1.75 | 800 | 0.26 | 0.14 | | |

Notes: A capacitance of 0.062 $\mu f$. per mile is assumed in side circuits and 0.100 $\mu f$. per mile in the phantom circuit. The pair capacitance value is smaller than that assumed in Table II, due to improvements in the cables.

All of the above loading systems have a cut-off frequency of about 2300 cycles.

*Loading Coils.* Table VII gives general information regarding the first standard side circuit and phantom coils used in the phantom group loading systems listed in Table V. The coils designed for No. 10 A. w. g. cable had 65-permeability wire cores and stranded copper windings. The coils designed for No. 13 A. w. g. cables had 65-permeability wire cores and non-stranded copper windings. The coils for Nos. 16 and 19 A. w. g. cables had 95-permeability wire cores.

## Loading for Repeatered Circuits

*General.* In the development of telephone repeaters to the point where they could be used for commercial

6. U. S. Patents No. 980,021, *Loaded Phantom Circuit*, G. A. Campbell and T. Shaw, and No. 981,015, *Phantomed Loaded Circuit*, T. Shaw.

service in extending the range of telephone transmission, the adaptation of the lines to the requirements of repeater operation was secondary in importance only to the development of satisfactory repeater elements and circuits for associating the repeater elements with the lines[7].

TABLE VII
FIRST STANDARD LOADING COILS FOR PHANTOM WORKING

| Type Line | Inductance (Henrys) | Coil Code No. | Type Circuit | Average Resistance-Ohms D-C. | Average Resistance-Ohms 1000 cycles | Overall Dimensions Diameter (In.) | Overall Dimensions Height (In.) |
|---|---|---|---|---|---|---|---|
| Open-Wire | 0.265 | 512 | Side | 5.0 | 8.4 | 9.0 | 4.0 |
| | 0.163 | 511 | Phantom | 2.5 | 4.4 | 11.0 | 4.9 |
| 10-A. w. g. Cable | 0.210 | 520 | Side | 3.8 | 6.6 | 8.5 | 3.5 |
| | 0.130 | 519 | Phantom | 1.9 | 3.4 | 10.4 | 4.0 |
| | 0.250 | 532 | Side | 4.1 | 7.8 | 8.5 | 3.5 |
| | 0.155 | 531 | Phantom | 2.1 | 3.9 | 10.4 | 4.0 |
| 13-A. w. g. Cable | 0.205 | 538 | Side | 6.0 | 9.2 | 5.7 | 2.5 |
| | 0.130 | 521 | Phantom | 3.0 | 4.5 | 7.9 | 3.0 |
| | 0.250 | 534 | Side | 6.6 | 10.7 | 5.7 | 2.5 |
| | 0.155 | 533 | Phantom | 3.3 | 5.3 | 7.9 | 3.0 |
| 16 and 19-A. w. g. Cable | 0.250 | 515 | Side | 8.9 | 23.1 | 4.6 | 2.4 |
| | 0.155 | 530 | Phantom | 4.4 | 11.9 | 5.9 | 2.9 |
| | 0.175 | 514 | Side | 5.4 | 14.4 | 4.6 | 2.4 |
| | 0.106 | 513 | Phantom | 2.7 | 7.1 | 5.9 | 2.9 |

NOTE. The resistance data apply to circuits of a complete phantom group; *i. e.*, the side circuit data include effects of the phantom coils, and phantom circuit data include effects of the side circuit coils. Effective resistance values correspond to line current of 0.002 ampere.

*Early Work—Reduction of Line Irregularities.* Commercial telephony, requiring two-way transmission, imposes severe balance requirements on repeater circuits over the entire band of frequencies which the repeater is designed to transmit. The solution of this problem required (a) the construction of lines having extremely regular impedance features, (b) the development of balancing networks[8] capable of accurately simulating the impedance characteristics of the improved lines throughout the working frequency range, and (c) the use of electric wave filters[9] in the repeater sets which cut off somewhat below the cutoff frequency of the loading.

In loaded lines, the uniformity requirements call for the loading coils to have very closely the same inductance value and to be capable of resisting the magnetizing effects of abnormal service conditions; also the sections of line between loading coils should have closely the same value of capacitance.

*Transcontinental Lines—High Stability Loading Coils.* The inauguration of commercial transcontinental telephone service over the New York-San Francisco line in January 1915 marked the first commercial application of the general improvements in regularity of line construction, including the use of an improved type of loading coil having a very high degree of magnetic stability.

In the development of the improved coils the requirement laid down was that the inductance to speech currents should not be changed more than about two per cent when a magnetizing current of two amperes was passed through any of its line windings. In the older types of coils, this severe magnetization condition caused a drop of about 30 per cent in the coil inductance: The new design which was adopted involved the use of two air gaps at opposite points in the (iron wire) cores of loading coils[10], suitable clamping means being provided to hold the coil halves in proper alignment. Data regarding these coils are given in Table VIII. To assist in getting a maximum degree of line regularity, these coils were adjusted in the factory to meet ± 1 per cent inductance limits. In the older types of coils ± 5 per cent deviations had been allowed.

In the case of coarse gage cable circuits, installed prior to the advent of repeaters, the new requirements were met by the design of an air-gap type of wire core coil on which data are given in Table VIII.

TABLE VIII
HIGH STABILITY COILS HAVING WIRE CORES WITH AIR GAPS

| Type Loading | Coil Code No. | Type Circuit | Inductance henrys | Average Resistance Ohms D-C. | Average Resistance Ohms 1000-Cycles | Overall Dimension Inches Diameter | Overall Dimension Inches Hgt. |
|---|---|---|---|---|---|---|---|
| Open Wire | 550 | Side | 0.245 | 5.4 | 11.1 | 8.1 | 3.9 |
| " " | 549 | Phantom | 0.150 | 2.7 | 6.4 | 10.0 | 4.0 |
| 10 and 13 A. w. g. Cable | 556 | Side | 0.255 | 7.0 | 14.0 | 5.6 | 2.9 |
| | 555 | Phantom | 0.155 | 3.5 | 7.0 | 7.5 | 3.6 |
| 10 and 13 A. w. g. Cable | 558 | Side | 0.200 | 6.2 | 10.9 | 5.6 | 2.9 |
| | 557 | Phantom | 0.135 | 3.1 | 5.9 | 7.5 | 3.6 |

NOTES. Open-wire coils used in Loading Systems, Tables III and VI. Cable coils used in Loading Systems, Table V.

Resistance data apply to side circuits and phantom circuits of complete phantom groups. Effective resistance values are for 0.002 ampere line current.

*Compressed Powdered Iron Core Loading Coils.* The use of telephone repeaters made it possible in new cable installations to supersede the No. 10 and No. 13 A. w. g. gage conductors by No. 16 and No. 19 A. w. g. conductors. This development greatly increased the need for an efficient and stable loading coil of lower cost than the air-gap wire core coil. To meet this need there was standardized early in 1916 a new magnetic material, compressed powdered iron, which has been of the utmost value in loading coil design[11]. Briefly,

7. *Telephone Repeaters*, B. Gherardi and F. B. Jewett, TRANS. A. I. E. E., Vol. XXXVIII, 1919.

8. R. S. Hoyt "Impedance of Loaded Lines and Design of Simulating and Compensating Networks," Bell System *Technical Journal*, July, 1924.

9. U. S. Patent Nos. 1,227,113 and 1, 227,114, G. A. Campbell.

10. U. S. Patents Nos. 1,289,941 and 1,433,305, Shaw and Fondiller.

11. U. S. Patents Nos. 1,274,952 B. Speed, 1,286,965 G. W. Elmen, 1,292,206 J. C. Woodruff.

the method of production consists of grinding electrolytically deposited iron to the desired fineness, insulating the particles, and finally compressing these insulated particles in steel dies at very high pressures. The compressed powdered iron core by virtue of its very numerous, though extremely small distributed air gaps, has a very high degree of magnetic stability[12].

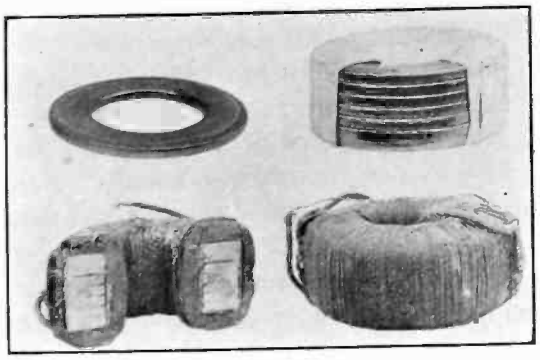


FIG. 6—COMPRESSED POWDERED IRON CORE LOADING COIL

Fig. 6 gives photographs of (a) a standard compressed iron powder core ring such as is used in the cores of toll cable loading coils: (b) a completely assembled core with part of the core taping removed: (c) a completely wound coil of the side circuit type: and (d) a coil in cross-section.

The first standard powdered iron cores had an

TABLE IX
TYPICAL COMPRESSED POWDERED IRON CORE LOADING COILS

| Coil Code No. | Core Permeability | Inductance (henrys) | Type Circuit | Resistance Ohms D-C. | Resistance Ohms 1000-Cycles | Dimensions Inches Diameter | Dimensions Inches Height |
|---|---|---|---|---|---|---|---|
| 562 | 60 | 0.250 | Side | 11.4 | 25.8 | 4.5 | 2.1 |
| 561 | 60 | 0.155 | Phantom | 5.7 | 11.7 | 6.3 | 3.0 |
| 564 | 60 | 0.175 | Side | 6.6 | 15.4 | 4.5 | 2.1 |
| 563 | 60 | 0.106 | Phantom | 3.3 | 6.7 | 6.3 | 3.0 |
| 582 | 35 | 0.250 | Side | 15.9 | 21.8 | 4.7 | 2.4 |
| 581 | 35 | 0.155 | Phantom | 8.0 | 10.0 | 6.7 | 3.1 |
| 584 | 35 | 0.175 | Side | 10.8 | 14.1 | 4.7 | 2.4 |
| 583 | 35 | 0.106 | Phantom | 5.4 | 6.6 | 6.7 | 3.1 |
| 584 | 35 | 0.175 | Side | 12.1 | 15.3 | 4.7 | 2.4 |
| 587 | 35 | 0.063 | Phantom | 6.1 | 7.0 | 4.7 | 2.8 |
| 590 | 35 | 0.044 | Side | 4.0 | 4.6 | 4.7 | 2.4 |
| 591 | 35 | 0.025 | Phantom | 2.0 | 2.0 | 4.7 | 2.8 |

NOTE. Resistance values apply to side circuits and phantom circuits of complete phantom groups. Effective resistance corresponds to 0.002-ampere line current.

These coils are used in the loading systems listed in Tables V and X.

effective permeability of about 60. Further developments resulted in the standardization of an improved grade of compressed powdered iron core having a permeability of 35. Coils having this new material 60-permeability compressed core coils were restricted to interoffice trunks and to short toll cables operated without superposed telegraph. Data on these two types of coils are given in Table IX.

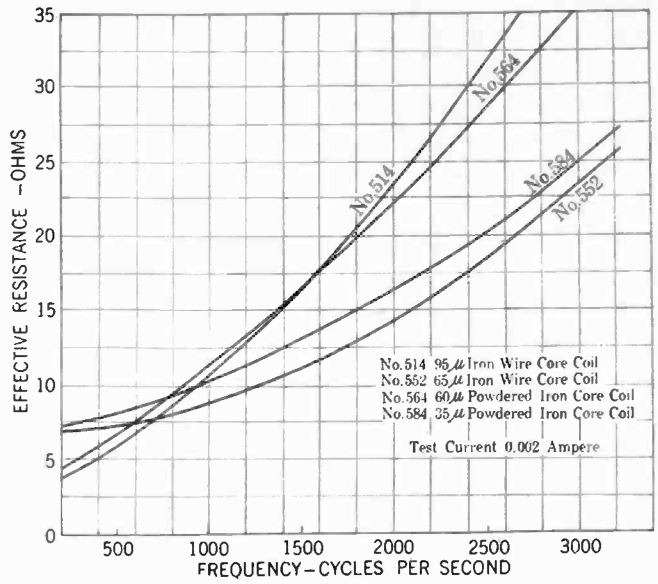



FIG. 7—EFFECTIVE RESISTANCE-FREQUENCY CHARACTERISTICS TOLL CABLE LOADING COILS

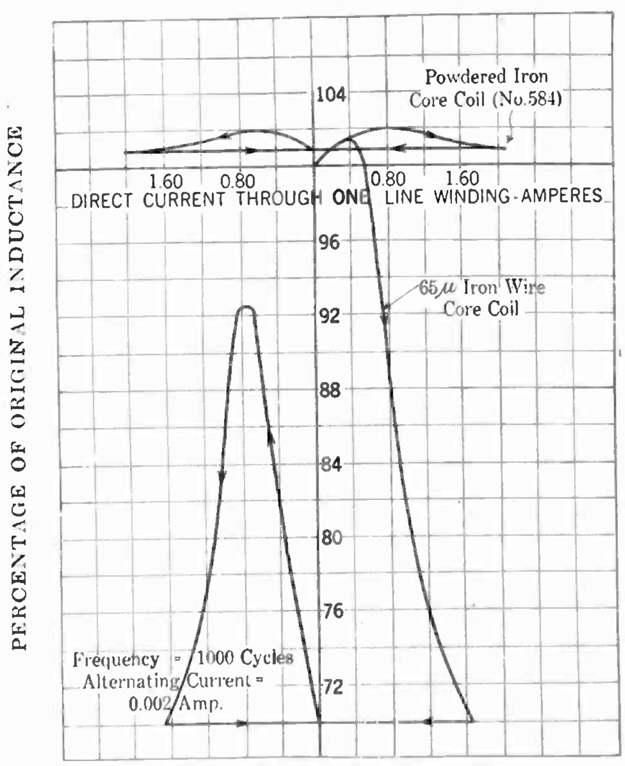



FIG. 8—RESIDUAL MAGNETIZATION CHARACTERISTICS OF COMPRESSED POWDERED IRON CORE AND IRON WIRE CORE LOADING COILS

The effective resistance-frequency characteristics of 60-permeability and 35-permeability compressed powdered iron core coils and the older 95-permeability and 65-permeability wire core coils having the same inductance (0.175 henry) and the same overall size, are given in Fig. 7. The large improvement as to freedom from residual magnetization effects afforded by the 35-

12. *Magnetic Properties of Compressed Powdered Iron*, B. Speed and G. W. Elmen, TRANS. A. I. E. E., Vol. XL, 1921.

permeability powdered iron core, compared with the old standard 65-permeability wire core coil is evident from the curves of Fig. 8.

The value of the compressed powdered iron core coil in the modern loading art has been recognized to the extent of its adoption as an international standard for repeatered circuits[13].

*New requirements for Cable Loading Systems.* The completion of the development of a satisfactory commercial type of telephone repeater marked the beginning of a long period of experimental work for the purpose of determining the commercial possibilities of the use of repeaters over long cable circuits. During these experiments, as the lengths were increased, echo and velocity distortion effects became increasingly troublesome, and it became apparent that improved loading would be necessary in order to realize the full possibilities of the use of repeaters.

*Echoes.* Echoes are due to unbalance currents, *i. e.*, to reflections of electrical energy at points of impedance irregularity in the circuits. When the circuit is so long that the time of transmission from the point of reflection to the disturbed subscriber station is appreciable, there will be echo effects, unless the losses in the circuit are so large as to cause the reflected energy to become inappreciably small.

*Velocity Distortion.* The velocity distortion in long lines is noticeable during the building up and dying down periods, when it manifests itself as transient distortion. The duration of transient distortion depends, among other factors, upon the length of the line, the nominal velocity, and the cut-off frequency of the loading. A substantial reduction in the transient distortion has been obtained in the new standard loading systems by raising the cutoff frequency as well as the velocity of the loading.

Experimental data regarding transient distortion is given in an Institute paper[14] by Mr. A. B. Clark and the results of theoretical studies are given in an earlier Institute paper[15] by Mr. J. R. Carson.

*Characteristics of Improved Cable Loading Systems.* The principal electrical features of the H-44-25 and H-174-63 phantom group loading systems which have been developed primarily for use on long repeatered cables are given in Table X, which also includes corresponding details of the older standard loading systems developed for non-repeatered cables. Typical attenuation-frequency curves of the old and new loading systems are given in Fig. 10.

Table XI lists the combinations of loading, conductor gage and type of repeater circuit which are used in meeting the wide range of commercial requirements. The position of the facility item in the table indicates the sequence of transmission excellence, item (*i*) being the highest grade facility in this respect.

For a further discussion of the use of repeatered loaded lines the reader is referred to recent papers presented before the Institute by Mr. J. J. Pilliod[16] and Mr. H. S. Osborne[17].

*Attenuation—Frequency Distortion.* In addition to their improved velocity and cut-off frequency characteristics, the H-44-25 and H-174-63 loading systems

TABLE X

LOADING SYSTEMS—SMALL GAGE REPEATERED TOLL CABLES

| Item | (a) Loading System | Circuit | (b) Coil Code No. | Nominal Impedance (Ohms) | Nominal Cut-off Frequency (Cycles) | Trans-mission Velocity Miles-per Second | (c) Attenuation Loss TU per Mile at 1000 Cycles 19 A. w. g. | 16 A. w. g. | (d) Maximum Geographical Length (Miles) |
|---|---|---|---|---|---|---|---|---|---|
| (1) | H- 44-25 | Side | 590 | 800 | 5600 | 19000 | 0.48 | 0.25 | 5000 |
| (2) | " | Phantom | 591 | 450 | 5900 | 20000 | 0.40 | 0.21 | 5000 |
| (3) | H-174-63 | Side | 584 | 1550 | 2800 | 10000 | 0.28 | 0.16 | 500 |
| (4) | " | Phantom | 587 | 750 | 3700 | 13000 | 0.28 | 0.16 | 1500 |
| (5) | H-174-106 | Side | 584 | 1550 | 2800 | 10000 | 0.28 | 0.16 | 500 |
| (6) | " | Phantom | 583 | 950 | 2900 | 10000 | 0.22 | 0.13 | 500 |
| (7) | H-245-155 | Side | 582 | 1850 | 2400 | 8000 | 0.25 | 0.16 | 250 |
| (8) | " | Phantom | 581 | 1150 | 2400 | 8000 | 0.20 | 0.12 | 250 |

Notes: (*a*) Nominal coil spacing is 6000 feet in cable having a capacitance of 0.062 $\mu f$ per/mile in the side circuits and 0.100 $\mu f$ per mile in the phantom circuit.

(*b*) The loading coil data are given in Table IX.

(*c*) These attenuation values apply at 55 deg. fahr. Under extreme temperature conditions, the actual attenuation may be approximately 12 per cent larger or smaller, due principally to changes in conductor resistance with temperature. In long repeatered cable circuits these variations of attenuation with temperature require special corrective treatment by means of automatic transmission regulators.

(*d*) The length limitations are set by transient distortion effects; echo currents may limit circuit lengths to lower values, depending on the grade of balance of the lines and the permissible over-all loss.

13. Minutes of Second Conference of Permanent Commission, Le Comité' Consultatif Internationale de Communications Telephonique a Grande Distance, Page 55 (Page 119 of English Version.)

14. *Telephone Transmission over Long Cable Circuits*, A. B. Clark, TRANS. A. I. E. E., Vol. XLII, 1923.

15. *Theory of the Transient Oscillations of Electrical Networks and Transmission Systems*, J. R. Carson, TRANS. A. I. E. E., Vol. XXXVIII, 1919.

16. *Philadelphia-Pittsburgh Section of New York-Chicago Cable*, J. J. Pilliod, TRANS. A. I. E. E., Vol. XLI, 1922.

17. "Telephone Transmission over Long Distances" H. S. Osborne, TRANS. A. I. E. E., Vol. XLII, 1923.

have an important advantage from the standpoint of attenuation-frequency distortion effects, as is illustrated in Figs. 10 and 11. The heavy line curves in Fig. 11 apply to a 500-mile No. 19 A. w. g. cable circuit, assuming that repeaters which give the same gain at all frequencies are used in each case to reduce the total line loss to 10 *T U* at 1000 cycles. The dotted lines in Fig. 11 give corresponding curves for non-repeatered cables (No. 19 A. w. g.) having the same types of loading as before, in each case the length being chosen so that the circuits have a 10 *T U* loss at 1000 cycles.

TABLE XI
TYPES OF TOLL CABLE FACILITIES

| Item No. | Length Circuit | Cable Gage | Type of Loading | Type Circuit | Type Repeater |
|---|---|---|---|---|---|
| (a) | (short) | 19 | H-174-63 | 2-wire | — |
| (b) | | 16 | " | " | — |
| (c) | | 19 | " | " | 21 |
| (d) | | 16 | " | " | 21 |
| (e) | | 19 | " | " | 22 |
| (f) | | 16 | " | " | 22 |
| (g) | | 19 | " | 4-wire | 44 |
| (h) | | 16 | H- 44-25 | 2-wire | 22 |
| (i) | (very long) | 19 | " | 4-wire | 44 |

In very long lines, the line losses, even with the best grade of loading, may cause sufficient distortion to require the use of correcting devices. The improvement obtainable by suitably designed repeaters is illustrated by an appropriately marked dot-dash curve in Fig. 11 which gives the attenuation-frequency characteristic of a 500-mile H-44-S circuit (No. 19 A. w. g.) as set up for commercial service.

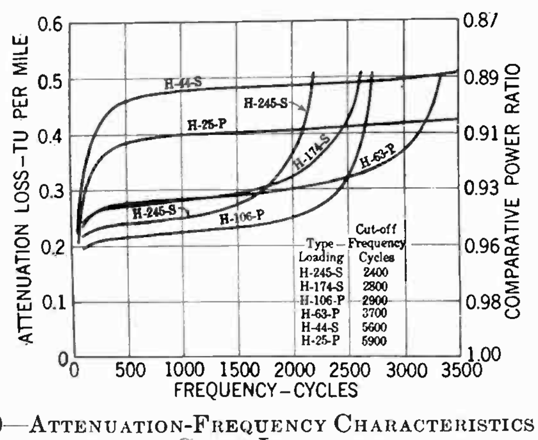



Fig. 10—Attenuation-Frequency Characteristics of Toll Cable Loading

In connection with the foregoing discussion, it is important to keep in mind the fact that coil loading substantially improves the attenuation and substantially reduces the frequency distortion at a cost which is much lower than the cost of the additional repeaters and distortion corrective networks which would be required to give the same grade of transmission without using loading.

Cost considerations make it desirable to use aerial cable in the long toll cable installations. On the main trunk cables an aerial fixture capable of supporting 4 or 6 large coil pots is required. A fixture of this type is illustrated in Fig. 12.

*Long Repeatered Open-Wire Lines.* The use of improved types of repeaters now makes it economical to secure better transmission results in long open-wire circuits without loading, than can be secured in loaded repeatered lines. This is because in non-loaded open-wire lines the distributed inductance is sufficiently large to keep the frequency distortion low; also, the transmission velocity is relatively very high.

Loading is now being removed from the important lines and it is expected that new applications of loading will generally be limited to isolated cases of short lines, where carrier telephone or telegraph systems are not contemplated or where the maintenance and operating conditions are unfavorable to the use of telephone repeaters.

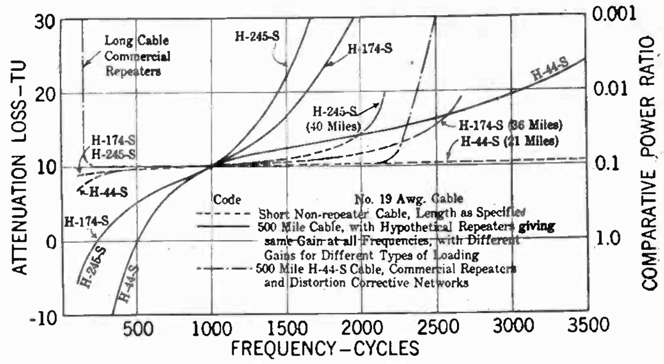



Fig. 11—Attenuation-Frequency Characteristics of Short and Long Loaded Toll Cable Circuits having a Net Attenuation Loss of 10 *TU* at 1000 Cycles

## Loading for Incidental Cables in Open-wire Lines

In the loading application discussed in the other sections, the primary purpose of the loading is to reduce line attenuation losses and frequency distortion effects. In the case of incidental pieces of cable in open-wire lines, however, the primary function of the loading is to give the inserted cable approximately the same characteristic impedance as the open-wire line, in order to minimize junction reflection effects. This particular type of loading is becoming increasingly important because of the rapidly increasing use of repeaters on open-wire lines.

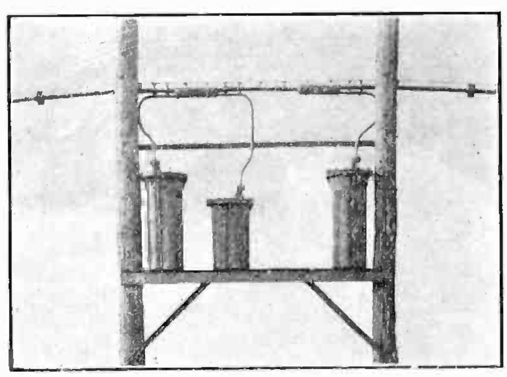


Fig. 12—Installation of Aerial Toll Cable Loading on 4-Case "H" Fixture

In incidental cables associated with loaded open-wire lines, the primary requirements for matching impedance, are that the nominal impedance ( $\sqrt{L/C}$ ) and the cut-off frequency of the loaded cable and of the loaded line should be closely the same. The E-248-154 phantom group cable-loading system listed in Table XII meets these general requirements.

The loading problem for an incidental cable in a non-loaded open-wire line requires an impedance match between a smooth line and a lumpy line, and therefore involves some degree of compromise, because

TABLE XII

TYPICAL LOADING SYSTEMS FOR TOLL ENTRANCE AND INTERMEDIATE CABLES

| Loading System Designation | Type Circuit | Coil Inductance Henrys | Coil Spacing Miles | Nominal Impedance Ohms | Cut-off Frequency Cycles | Attenuation Loss TU per Mile at 1000 Cycles | |
|---|---|---|---|---|---|---|---|
| E-28-16 | Side | 0.028 | 1.09 | 650 | 7200 | 0.15 | (13 A.w.g.) |
| | Phantom | 0.016 | 1.09 | 400 | 7800 | 0.13 | |
| CE-4.1-12.8 | Side | 0.0041 | 0.176 | 600 | 45000 | 0.22 | (13 A.w.g.) |
| | Phantom | 0.0128 | 1.09 | 400 | 8500 | 0.19 | |
| M-44-25 | Side | 0.044 | 1.66 | 650 | 4600 | 0.29 | (16 A.w.g.) |
| | Phantom | 0.025 | 1.66 | 400 | 4900 | 0.24 | |
| E-248-154 | Side | 0.250 | 1.09 | 1950 | 2400 | 0.081 | (13 A.w.g) |
| | Phantom | 0.155 | 1.09 | 1200 | 2500 | 0.070 | |

NOTE. Cable capacitance is assumed to be 0.062 $\mu f$ per mile for side circuits, and 0.100 $\mu f$ per mile for phantoms.

of the dependence of the impedance of a coil-loaded cable upon the loading termination, as illustrated in Fig. 3. At frequencies above approximately 500

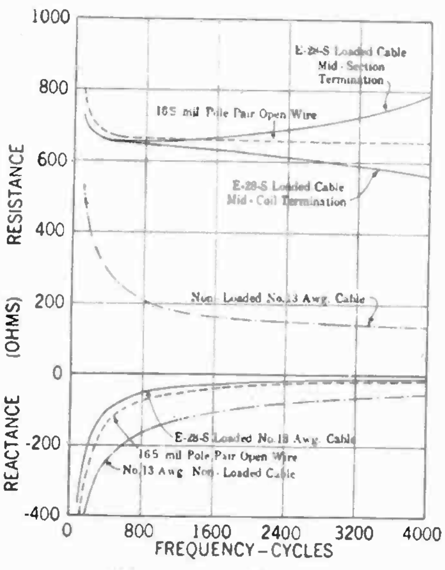



FIG. 14—TYPICAL IMPEDANCE-FREQUENCY CHARACTERISTICS OF LOADED AND NON-LOADED ENTRANCE CABLE AND NON-LOADED OPEN-WIRE LINE

cycles, the impedance of the non-loaded open-wire line is practically a non-inductive resistance, constant with frequency. On the other hand, with mid-section and mid-coil terminations, the impedance of the coil-loaded cable is substantially that of a non-inductive resistance as illustrated in Fig. 3. The higher the cut-off frequency of the loading, the more closely do these resistance-frequency curves approach the flat resistance-frequency curve of the non-loaded line, over the range of frequencies which the telephone repeaters are designed to transmit; provided, of course, that the cable loading also has the same nominal impedance as the non-loaded line. For plant simplicity and economy, it is desirable to use the same coil spacing in the different types of incidental cable-loading systems.

The above general considerations have led to the standardization of the E-28-16 loading system for use on cables associated with non-loaded open-wire lines. General data regarding this system are given in Table XII, and impedance frequency curves are given in Fig. 14.

*Carrier-Frequency Loading.* Special types of loading typified by the "CE-4.1-12.8" system in Table XII have been developed for use on incidental cables in non-loaded open-wire lines on which carrier telephone or carrier telegraph systems are superposed. The

TABLE XIII

CARRIER FREQUENCY LOADING

| Frequency Kilocycles | Attenuation Loss - TU per Mile (13 A. w. g. Cable) Non-Loaded | C-4.1 Loading | Resistance-Ohms per Carrier Loading Coil |
|---|---|---|---|
| 1 | 0.49 | 0.23 | 1.5 |
| 5 | 0.78 | 0.27 | 1.6 |
| 10 | 0.90 | 0.33 | 1.9 |
| 20 | 1.14 | 0.52 | 4.1 |
| 30 | 1.37 | 0.90 | 8.1 |

present standard carrier telephone systems operate up to frequencies of the order of 30,000 cycles.[18] Data regarding attenuation losses in a No. 13 A. w. g. cable with and without carrier loading are given in Table XIII.

The high-frequency loading is used only on the side circuits, since at the present time it is not customary to operate carrier telephone systems over phantom circuits. Carrier operation imposed upon the carrier-frequency coils involves new requirements as regards freedom from intermodulation between channels, and low energy losses at carrier frequencies. These requirements were met by using toroidal-type wood core coils with finely stranded copper windings. Typical resistance-frequency data are included in Table XIII.

## CROSS-TALK

One of the greatest practical difficulties which has been encountered in extending the commercial range of long distance telephone service is that of keeping at a tolerably low value the speech overhearing known as cross-talk which occurs between adjacent telephone circuits whenever there is an appreciable amount of

18. "Carrier Current Telephony and Telegraphy," Colpitts and Blackwell, TRANS. A. I. E. E., Vol. XL, 1921, p. 205.

electromagnetic or electrostatic coupling between them. This difficulty is in part due to the fact that as the length of the line increases, there are more and more opportunities for unbalances in the lines and in the associated apparatus. Moreover, the repeaters amplify the cross-talk as well as the speech transmission. From the service standpoint, however, it is necessary that the cross-talk in the very long lines should be within the limits set for the shorter lines.

The problem of keeping cross-talk low between the individual circuits of a phantom group is by far the most difficult phase of the general cross-talk problem in long repeatered cables. The unbalances in the cable quads are reduced to small values by exercising great care in manufacture and by selective splicing at the time of installation. By design, the loading coils are substantially free from inherent unbalances, and great care is exercised in manufacture to realize the benefits of this inherent symmetry of design.

When repeaters came into general use it was found necessary to obtain much more refined adjustments than those previously made; so further improvements were worked out in several manufacturing processes. As a result of these various improvements, the unbalances in the loading coils are now only about one-fourth of the earlier values. For instance, the average cross-talk in the coils used for H-44-25 loading is now about 20 millionths of the disturbing current. This corresponds to an attenuation of about 95 *T U*.

To assist in visualizing the real achievement which this minute value of phantom-to-side cross-talk represents, Table XIV gives information regarding the cross-talk effects of different elementary types of unbalance in H-44-25 loading coils:

TABLE XIV
CROSSTALK DUE TO UNBALANCE IN H-44-25 LOADING COILS

| Type of Unbalance | Amount of Cross-talk | | |
|---|---|---|---|
| 1 ohm resistance | 400 | millionths | ( 68 TU) |
| 1 micro-henry inductance | 2.5 | " | (112 TU) |
| 1 turn of winding | 280 | " | ( 71 TU) |
| 1 micro-microfarad capacitance | 0.94 | " | (121 TU) |

The cross-talk current caused by electromagnetic unbalances flows around the two ends of the disturbed circuit in series. On the other hand, the cross-talk current caused by electrostatic unbalances divides and flows from its point of origin in opposite directions around the two ends of the circuit in parallel. Consequently, when electrostatic and electromagnetic cross-talk currents are in phase at one end of the circuit, they tend to be in phase opposition at the other end of the circuit. The special cross-talk adjustments are made in such a way as to obtain the maximum benefit from the phase-opposition effects at the particular end of the circuit where these reductions are more important, *viz.*, at the "near-end" for two-wire circuits and at the "far end" for four-wire circuits.

Unbalances in loaded circuits which contribute to noise due to induction from power transmission and distribution circuits are similar in nature to those contributing to cross-talk. The precautions which are taken in the design, manufacture, and installation of loaded circuits to reduce unbalances have the effect, therefore, of reducing both cross-talk and noise.

## Telegraphy Over Loaded Telephone Circuits

After the introduction of loading it was desirable to continue superposing d-c. ground return telegraph currents on telephone circuits. As the lengths of the loaded circuits increased, the interaction between the telegraph and telephone currents which has been designated in an Institute paper[19] as "flutter," was aggravated and serious distortion of speech resulted. Considerable study was given to the flutter problem, and important improvements were made by changes in the design of the magnetic circuit and improved core materials.

The increasing use of long repeatered toll cables brought about a need for further reduction in flutter distortion which was met by the development of a metallic telegraph system in which the amplitude of telegraph currents is of the same order of magnitude as the telephone current[20].

More recently the development of a voice-frequency carrier telegraph system[21] providing ten or more independent channels over a loaded four-wire cable circuit has made it economical to concentrate a large part of the telegraph service over the long repeated cables on a special group of wires which is not used simultaneously for telephone purposes.

## Recent Improvements in Loading for Exchange Area Cables

The first important change in the exchange area loading standards occurred about 1916, when compressed powdered-iron core coils came into general use in place of the old standard wire core coils. In the period 1922-24, the use of new types of fine wire cables had reached a point which required changes in the loading systems and accordingly, a new series of improved loading systems having a considerably higher cut-off frequency, were developed.

*Cable Development*. Notable advances have been made in the art of cable manufacture during the last decade, including the standardization of 450-pair No. 19 A. w. g. cable, 900-pair No. 22 A. w. g. cable, and 1200-pair No. 24 A. w. g. cable, all within standard full-

19. "Hysteresis Effects with Varying Superposed Magnetizing Forces," W. Fondiller and W. H. Martin, TRANS. A. I. E. E. Vol. XL, 1921, p. 553.

20. "Metallic Polar-Duplex Telegraph System for Cables," Messrs. Bell, Shanck and Branson, presented at Midwinter Convention of the A. I. E. E., Feb., 1925, Abridgment published in JOURN. A. I. E. E., April, 1925, p. 378.

21. "Voice-frequency Carrier Telegraph Systems for Cables," Messrs. Hamilton, Nyquist, Long and Phelps, JOURN. A. I. E. E., March, 1925, p. 213.

sized sheaths (2 5/8 in. outside diameter). The 50 per cent increase in the number of circuits over the older cable designs was accompanied by a substantial increase in the mutual capacitance.

The use of the old standard loading systems on the new types of cables would have resulted in an objectionable impairment of quality, due to the reduction of the cut-off frequency resulting from the increased cable capacitance. Also the types of loading coils available were more expensive than could be justified for permanent standards on the low cost fine wire cables.

*Determination of New Cut-off Frequency Standard.* A coil design cost-balance study was taken up as one phase of a general transmission-cost study of exchange area transmission, which also included a theoretical investigation of cut-off frequency standards.

It was found that an increase in the cut-off frequency of exchange area loading up to about 3000 cycles could be justified; the increased costs for materially higher cut-off frequencies would have been unduly large in proportion to the resultant improvement in transmission.

*New Standard Loading System.* The new standard exchange area loading systems make as much use as is practicable of the old standard coil spacings and inductance values, in order to minimize the expense of rearranging the existing loading to conform to the new standards, and at the same time make full use of the large number of available loading vaults and manholes. General data regarding these new standards are given in Table XV.

TABLE XV
NEW LOADING STANDARDS FOR EXCHANGE AREA TRUNKS

| Loading Designation | Coil Spacing Feet | Coil Code Nos. | Approx. Cut-off Frequency Cycles | |
|---|---|---|---|---|
| | | | High Capacitance Cable | Low Capacitance Cable |
| M-88 | 9000 | 602 | 2900 | 3200 |
| H-135 | 6000 | 603 | 2800 | 3200 |
| H-175 | 6000 | 574 | —— | 2800 |
| D-175 | 4500 | 574 | 2900 | 3200 |

NOTE. High capacitance cable has approximately 0.083 $\mu$ per mile. Low capacitance cable has approximately 0.066 $\mu f$ per mile.

The M-88 system is especially suitable for the shorter lengths of fine wire trunk cables which will constitute the bulk of the exchange area trunk mileage. In longer trunks, the other more expensive loading systems find their field of service. The H-175 system is limited to low capacitance cables because of the lower cut-off effects on high capacitance cables, but has considerable commercial importance because of the large number of low capacitance cables now in the plant.

Table XVI gives some general transmission data on typical exchange area trunks using the new loading systems, including also non-loaded trunks. Attenuation-frequency curves of some of these trunks are given in Fig. 15, which includes also a dotted line curve for the old standard medium loading when used on 0.065 m. f., No. 19 A. w. g. cable.

In the application of the new standard loading systems, the same standards of over-all attenuation loss are adhered to, as in the older loading systems.

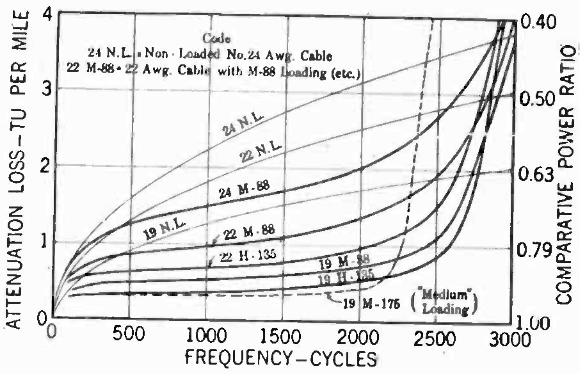



FIG. 15—ATTENUATION-FREQUENCY CHARACTERISTICS OF TYPICAL EXCHANGE AREA LOADED AND NON-LOADED CABLES

In consequence, there is an appreciable improvement in the intelligibility of transmission, due to the ability of the new loading systems to transmit efficiently a range of high-frequency voice over-tones which were suppressed by the old standard 2300-cycle cut-off systems. Along with this improvement in service,

TABLE XVI
TRANSMISSION CHARACTERISTICS OF TYPICAL EXCHANGE AREA TRUNKS

| Cable Conductor A. w. g. | Capacitance $\mu f.$/Mile | System | Coil Code No. | Cut-off Frequency Cycles | Circuit Impedance Ohms | Attenuation Loss TU per Mile |
|---|---|---|---|---|---|---|
| 24 | 0.079 | Non-loaded | — | — | 740 | 2.2 |
| 22 | 0.083 | " " | — | — | 570 | 1.8 |
| 24 | 0.079 | M-88 | 602 | 2900 | 900 | 1.48 |
| 22 | 0.083 | M-88 | 602 | 2900 | 990 | 0.96 |
| 22 | 0.083 | H-135 | 603 | 2800 | 1300 | 0.68 |
| 19 | 0.085 | Non-loaded | — | — | 400 | 1.27 |
| 22 | 0.083 | D-175 | 574 | 2900 | 1690 | 0.53 |
| 19 | 0.083 | M-88 | 602 | 2800 | 860 | 0.51 |
| 19 | 0.085 | H-135 | 603 | 2800 | 1280 | 0.38 |
| 19 | 0.066 | H-175 | 574 | 2800 | 1640 | 0.29 |
| 19 | 0.085 | D-175 | 574 | 2800 | 1680 | 0.30 |
| 16 | 0.066 | M-88 | 602 | 3200 | 960 | 0.24 |
| 16 | 0.066 | H-135 | 603 | 3200 | 1420 | 0.20 |
| 16 | 0.066 | H-175 | 574 | 2800 | 1640 | 0.17 |

NOTE. The impedance and attenuation figures hold at 1000 cycles. Impedance values for loaded circuits assume mid-section termination.

the new loading systems substantially reduce the plant cost, partly due to the economies which result from the extension of the transmission range of the new types of fine wire cables and partly because of the use of materially less expensive types of loading coils.

*Loading Coils and Cases.* Table XVII gives general data for the coils used in the new exchange area loading systems.

The standardization of the small size Nos. 602 and 603 loading coils has made it possible to design containing cases and assembly methods which permit larger numbers of coils—up to 300—to be enclosed in the loading cases. Fig. 17 illustrates the operation of assembling the loading coils, previously spliced to the cable stub, into a 300-coil pot. The use of these larger potting capacities will be of considerable value in reducing the space congestion in the loading vaults in "downtown" districts of the larger metropolitan areas.

TABLE XVII
COILS FOR LOADING EXCHANGE AREA CABLES

| Coil Code No. | Inductance (Henrys) | Core Permeability | Resistance-Ohms D-C. | Resistance-Ohms 1000 Cycles | Over-all Dimensions Inches Diameter | Over-all Dimensions Inches Height |
|---|---|---|---|---|---|---|
| 602 | 0.088 | 35 | 8.9 | 10.5 | 3.6 | 1.3 |
| 603 | 0.135 | 35 | 12.8 | 14.1 | 3.6 | 1.3 |
| 574 | 0.175 | 60 | 4.6 | 10.6 | 4.5 | 2.1 |

Effective resistance values are for a line current of 0.001 ampere.

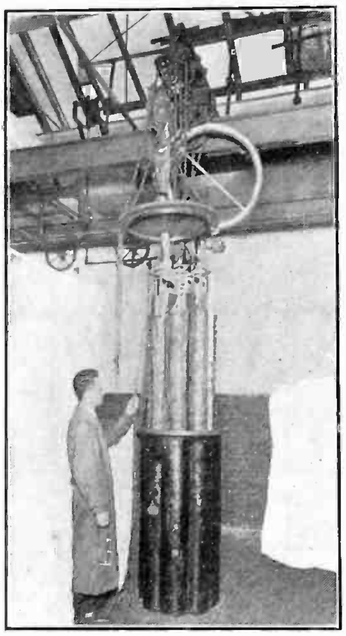


Fig. 17—Assembly of 300-Coil Case

Lowering loading coils into case after coil spindles have been mounted on frame and coil terminals spliced to stub cable conductors

In general, exchange area loading is installed in underground vaults or manholes. Fig. 18 shows a typical installation in a "double-deck" vault in New York City.

### Extent of Commercial Application

Conservative estimates set the total number of loading coils in service in the Bell System, as of January 1, 1926, at 1,250,000. These coils provide loading for about 1,600,000 miles of cable circuits and 250,000 miles of open-wire. In round numbers, 500,000 coils are installed on non-quadded local area trunk cables and 700,000 in toll entrance and toll cables (the bulk of these being quadded cables). Nearly two-thirds of the total number of coils have compressed-iron powder cores, all of these being installed on cable circuits. Recent estimates of the loading coil requirements for the next five years indicate an annual demand which will double the total number of loading coils in service by about 1930.

### Conclusion

It will be appreciated from the foregoing account that the invention of coil loading was the beginning of an era of intensive development which has been marked by enormous advances in the design of telephone transmission lines, nor is there any slackening of the inventional or development activity devoted to this subject.

In conclusion, it may be of interest to note what the

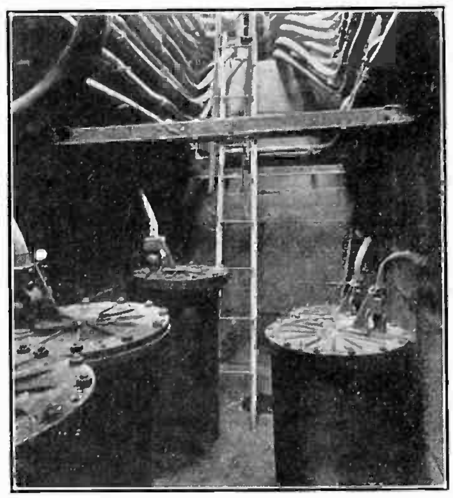


Fig. 18—Underground Cable Loading Coil Installation in Metropolitan Area. Double-Deck Vault having Ultimate Capacity of 14 Large Coil Cases

development and use of loading has meant to the telephone using public from an economic standpoint. Leaving out of consideration altogether loading on long toll cables—where the interdependence of repeaters and loading is such that it is impracticable to assign to each its share of the savings—and taking into consideration only the loading of interoffice trunks and toll open-wire circuits, it has been estimated that the larger wires which would have been required to give the present grade of transmission if loading had not been available, together with the heavier pole lines and additional underground ducts, would have entailed an additional investment in Bell System telephone plant of over $100,000,000.

## METHODS OF HARDENING HIGH-SPEED ROUGHING TOOLS

Since the discovery some 20 years ago of the benefits derived by subjecting certain chormium-tungsten or so-called high-speed steels to exceedingly high temperatures in hardening, much discussion has centered upon the best procedure and equipment for this heat treatment.

Some roughing lathe tool tests were recently made at the Bureau of Standards to determine whether or not such claims were justified. It was found that comparable performance was obtained when tools were raised to approximately equal temperatures for equal times in hardening.

# No-Load Copper Eddy-Current Losses

BY THOMAS SPOONER[1]

Member, A. I. E. E.

***Synopsis.***—*One of the factors which is sometimes responsible for very considerable losses in rotating machines is that of eddy-current losses in the copper conductors resulting from slot leakage flux produced by the main flux. These losses occur at no-load as well as under load and should not be confused with the copper losses resulting from the slot leakage flux produced by the load current. These no-load copper losses occur in salient pole machines, both d-c. and a-c., and in induction motors.*

*This paper is an attempt to remove the calculation of no-load copper eddy-losses from the field of empiricism where it has previously been and to place it on a firm theoretical foundation. Test results are presented which show that the theoretical formulas which have been developed are correct.*

*Some of the consequences of this analysis are rather unexpected where the frequencies are sufficiently high to produce large skin effect. For instance, laminating the copper may produce increased or decreased losses, depending upon the conditions.*

* * * * *

## Introduction

The design of electrical apparatus is becoming so standardized, and the efficiencies so high, that further improvements in performance will probably come largely through attention to details which previously have been considered of somewhat minor importance. This paper considers one of these details which has, perhaps, not received as much attention as its importance under certain conditions would warrant.

When a copper conductor in the slot of a rotating machine carries alternating current there are produced slot leakage fluxes which may induce sufficiently large eddy currents in the conductor copper to result in very appreciably increased losses. This type of loss has been quite adequately dealt with by Field, Gilman, and others. The type of copper eddy-current loss with which this paper deals has a different origin and is the result of slot leakage fluxes caused by the main flux. These losses are often nearly as large at no-load as at full load, and are of importance in connection with both salient pole machines and induction motors.

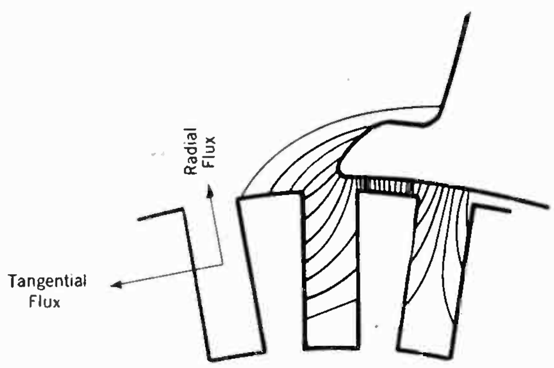



Fig. 1—Slot Leakage for Salient Pole Machine

## Cause and Nature of Losses

Fig. 1 illustrates the nature of the slot-leakage flux for a salient pole machine. As a slot comes out from under the pole tip there is a rapid decrease in the radial component of slot-leakage flux and a rapid generation and then dying out of the tangential component of slot-leakage flux as shown by Fig. 2, which is from test data obtained on a small d-c. railway motor with unsymmetrical pole tips. It will be seen that the radial leakage flux consists chiefly of the fundamental, while the tangential flux has a larger third harmonic than it has fundamental. Some of the other harmonics for the tangential flux are also quite large. These results are typical.

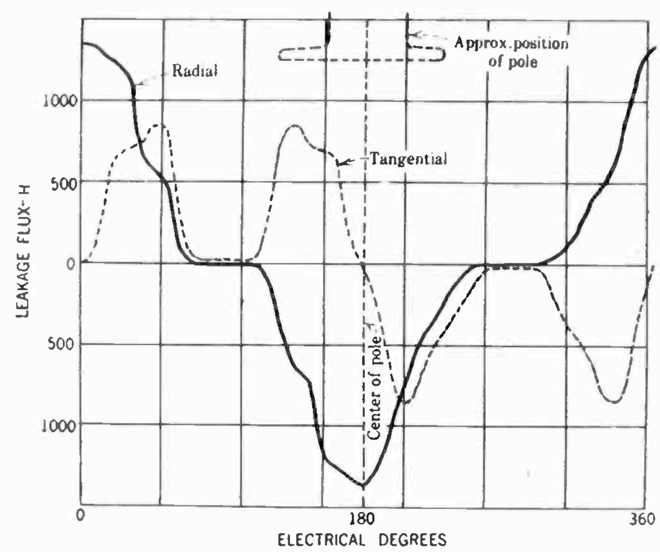



Fig. 2—Slot Leakage Fluxes for D-C. Railway Motor

Fig. 3 shows the nature of the slot-leakage fluxes for an induction motor. It will be seen that there are leakage fluxes in the rotor slots having both radial and tangential components. The radial components pulsate in amplitude but do not change sign while under a given pole. The tangential components reverse in sign twice during the interval required for a rotor tooth to

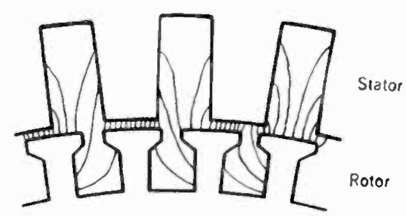



Fig. 3—Slot Leakage for Induction Motor

1. Research Engineer, Westinghouse Electric & Mfg. Co.

*Presented at the Midwinter Convention of the A. I. E. E., New York, N. Y., February 8-11, 1926.*

pass over a distance equal to one stator slot pitch. The slot-leakage fluxes, both tangential and radial, therefore, have a frequency equal to the number of stator teeth per pair of poles, multiplied by the rotor frequency, the latter frequency being in general nearly equal to the applied fundamental frequency. These leakage fluxes are small in magnitude but high in frequency and are often of importance. In the ordinary construction, consisting of nearly closed rotor slots, the pulsations of leakage flux in the stator slots are usually negligible.

These slot-leakage fluxes are appreciable only when the teeth begin to saturate. In salient pole machines, tooth inductions of the order of 120 kilolines per sq. in. are necessary before noticeable eddy losses in the copper conductors begin to be produced. For induction motors the tooth inductions must reach about 70 kilolines per sq. in. before copper eddy losses of noticeable magnitude appear. The reason for the lower inductions for the induction motors is because of the much higher frequency of the slot-leakage fluxes. In the case of the salient pole machines the radial fluxes produce very little loss as a rule, because the frequency is so low and because the copper is usually narrow tangentially. The tangential leakage fluxes, however, may produce very considerable losses, and consequently heating, due to their higher-frequency components and the fact that the radial dimensions of the copper are usually fairly large. In the induction motor, both components of the leakage flux may be quite effective in producing copper eddy losses.

## Calculation of Copper Eddy Losses

A number of formulas have been devised for calculating this type of loss, but they all contain empirical constants and all neglect certain essential factors. For instance, one of Mr. Lamme's formulas,[2] which was designed for use with large salient pole machines and was very satisfactory for the particular conditions, gave calculated losses which were from 6 to 10 times the true values when applied to a certain small railway motor. The formulas which will be proposed in this paper are based on fundamental considerations only and were devised without reference to any test data.

If the copper bars in a slot are narrow radially or the frequency is sufficiently low, the no-load eddy losses in the copper may be calculated by the following simple formula:

$$W_e = \frac{\pi^2}{6} \times \frac{W^2}{\rho} f^2 H^2 10^{-7} \qquad (1)$$

(See list of symbols below.)

If, however, the bars are wide (this refers to radial width when considering tangential slot leakage flux) or the frequency high, the above formula will no longer apply, due to the fact that the eddy currents in the copper produce a damping effect on the flux, thus making the losses less than would otherwise occur. This is the well-known skin effect. Under these conditions the flux in the region of the center of the bars is damped out. (See Fig. 4.) The eddy currents are greater in magnitude as the bottom and top of the bars are approached and there are no appreciable currents in the center; that is, if the center portions of the copper were removed there would be no change in the eddy losses.

Some time ago we developed the following formula for calculating eddy losses under the conditions of appreciable skin effect:

$$W_e = \frac{\pi^2 f^2 H^2}{m^3 \rho W 10^7} \quad \frac{\sinh m W - \sin m W}{\cosh m W + \cos m W} \qquad (2)$$

The method of developing this formula was similar to that used by Latour for his formulas dealing with losses in laminated steel at radio frequencies.[3] Dr. J. Slepian assisted in the development of this formula. For no skin effect the results are identical with those obtained

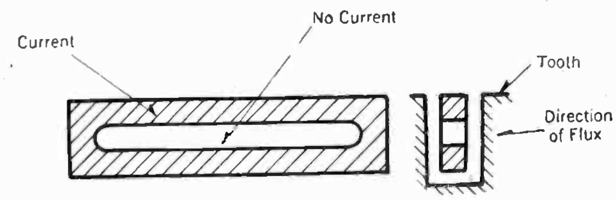



Fig. 4—Copper Eddy-Current Losses, Illustrating Skin Effect

by the simple formula (1). In the use of either formula, the eddy losses have to be calculated for each frequency; namely, for salient pole machines the magnitude of the various important harmonics has to be determined by test and analysis or estimated in some way from the machine design and the losses corresponding to each harmonic calculated as if the others did not exist. The sum is the total eddy loss. In the case of the induction motor, it is generally satisfactory to consider only the pulsating frequency corresponding to the number of stator teeth, without considering harmonics.

When it was attempted to apply formula (2) to actual machines it was found that in many cases the experimental and calculated results did not correspond as closely as was expected. In order to determine whether the discrepancies were due to inaccuracies in the formula or to the neglect of certain factors having to do with the conditions in the actual machines, the fundamental tests which are about to be described were made.

2. Iron Losses in Direct Current Machines. Electrical Engineering Papers by B. G. Lamme, p. 499.

3. Notes on Losses in Sheet Steel at Radio Frequencies; Marius Latour. Inst. of Radio Engineers *Journal*, February 1919, p. 61.

### Test Methods and Apparatus

The method of test was suggested by a similar method devised by Churcher.[4] As shown by Fig. 5, a laminated yoke was constructed having pole pieces which were adjustable to the right and left in order that the air-gap could be varied. This air-gap was about 6 inches by 2 inches and its width between pole pieces could be adjusted from ⅞ inch to 0. The yoke was provided with windings as shown. High-frequency current up to 1000 cycles was obtained from a generator through an ammeter $A$. In general, the samples consisted of two copper bars as indicated. Two small holes were drilled near the center of one of the bars about ⅛ inch apart and thermocouple wires of copper and advance soldered into the holes. The bars were separated from each other by a small distance and the couple wires were insulated from the bars except at the junction. The wires were brought out from between the bars at one end, thus keeping a considerable length adjacent to the copper in order to prevent loss of heat at the junction. An exploring coil wound on a rectangular bakelite form was provided for determining the flux density in the air-gap. The coil was approximately 6 inches by ½ inch and had 21 turns.

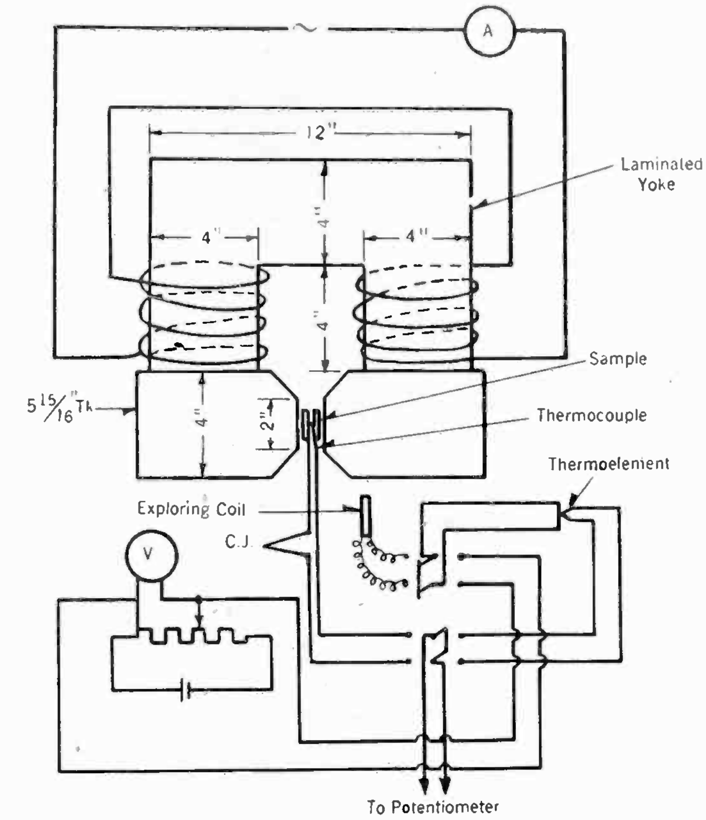



Fig. 5—Copper Eddy-Current Losses—Diagram of Connections

The method of test was as follows: The air-gap was adjusted to the desired width and alternating-current of the desired frequency applied to the field winding. Assuming a sine wave of flux in the air-gap, the voltage which would be induced in the exploring coil for the desired induction was calculated. The voltmeter $V$ was then adjusted to this value, the current element of a sensitive vacuum thermo couple was connected to the terminals of the voltmeter by a suitable manipulation of the switches and the terminals of the thermo-element connected to a Wolff potentiometer. The e. m. f. of the thermo-element was then read. Next the exploring coil was placed in the air-gap, the switches manipulated, and the magnetizing current adjusted by control of the high-frequency generator field until the thermo-element produced the same reading on the potentiometer as was obtained from the d-c. voltage. This gave the required induction in the air-gap. The thermo couple attached to the sample was then connected to the potentiometer. The cold junction of this couple was placed in a thermos bottle which was at any convenient temperature, preferably near room temperature. A copper sample which should be at or below the temperature in the air-gap was then placed in the gap, the high-frequency current switched on, and the ammeter adjusted to its original value without the sample. The potentiometer was set to some convenient reading corresponding to a value slightly above room temperature. Due to the eddy losses in the sample the temperature immediately began to rise. When this temperature corresponded to the setting on the potentiometer, the potentiometer galvanometer went through $O$ and a stop-watch was started. The potentiometer was then set to a higher reading. When the galvanometer went through $O$ again the watch was stopped and another started by means of a simple arrangement of levers. This was repeated five or six times in order to obtain sufficient data for plotting a curve between millivolts and time interval. By extrapolating back to the millivolts corresponding to the temperature at the air-gap (with corrections for cold junction temperature) the rate of temperature rise in seconds ($\Delta T_i$) for a given change in millivolts could be obtained. Knowing the millivolts per degree for the thermo couple at this temperature, the rate of temperature rise per degree could be calculated.

The eddy losses were calculated as follows, assuming a temperature of 25 deg. cent.,

$$W = Q \frac{d\,t\,e}{d\,t} \text{ watts}$$

$$Q = 4.186 \times .0917 \times G$$

where

$Q$ is the thermal capacity of the conductor in watt-sec. per deg. cent.,

$G$ is the weight of conductor in grams

$\frac{d\,t\,e}{d\,t}$ is the rate of temperature rise, namely the deg. cent. rise per sec. on the assumption that there is no heat lost or gained from the outside. Since the rate

4. The Measurement of Temperature in a Rotating Armature by Means of Thermocouples, B. G. Churcher. *Journal of Sci. Inst. V. I.*, July, 1924, p. 310

was determined corresponding to the temperature of the surroundings, there was no correction for dissipated heat; 4.186 is the thermal capacity of water in joules per gram calorie; 0.0917 is the specific heat of copper with reference to water at 25 deg. cent.

## Test Results

In order to keep the rate of temperature rise down to a reasonable value, very low air-gap inductions were used; namely, of the order of a few hundred gausses. Under these conditions there was no appreciable heating of the yoke material and the reluctance of the iron path was practically negligible. Therefore, for a given air-gap the induction was practically constant for a definite exciting current for a wide range of frequencies as shown by test results not given here.

If the sample had appreciable skin effect, the counter magnetomotive force of the eddy currents in the copper had the effect of increasing the reluctance of the air-gap. Therefore, when the copper was introduced into the gap

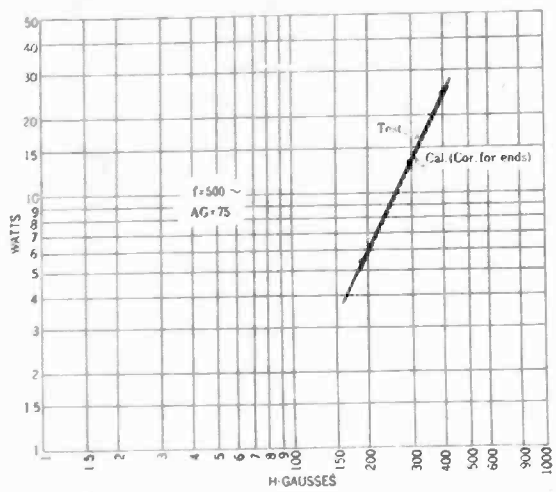



Fig. 6—Copper Eddy-Current Losses, Two Bars ¾-in. x ¼-in. x 10-in.

the exciting current increased. It was found that if the exploring coil was placed in the air-gap just above the copper, the magnetizing current had to be brought back to its original value in order to bring the air flux in the gap above the copper back to its original value. Provided the current was so adjusted, it was immaterial whether the m. m. f. was measured with or without the sample in position.

In order to obtain data for the purpose of determining the validity of our method of calculating eddy losses, a number of copper samples were tested under various conditions. Fig. 6 shows the results of the first set of tests. Two bars ¼ by ¾ by 10 inches long were placed in the air-gap (0.75 inches) with the shortest dimension parallel to the flux. Losses were determined at 500 cycles for three values of m. m. f., namely, 190, 291 and 395 gausses, and the results plotted on double log paper. The m. m. f. and flux density, namely, gilberts per centimeter and gausses are used interchangeably since in the c. g. s. system they are identical. For comparison, values as calculated by formula 2 are shown. The test and calculated values check very well with respect to magnitude and slope. As indicated by theory, the losses increased as $H^2$.

The next set of tests are shown by Fig. 7. The results are for the same set of bars but in this case $H$ was held

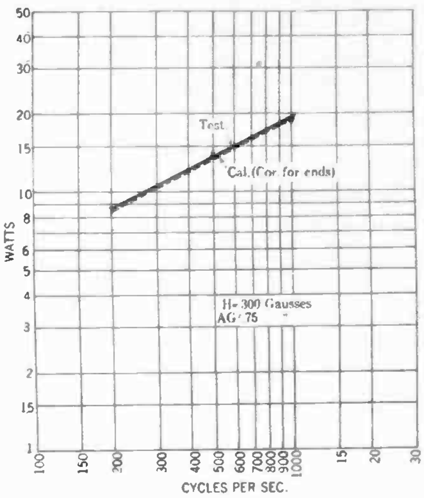



Fig. 7—Copper Eddy-Current Losses, Two Bars ¾-In. x ¼-In. x 10-In.

at 300 gausses and the frequency changed from 200 to 1000 cycles. Under the particular conditions of frequency and copper dimensions there was large skin effect. According to theory, the losses should, in this

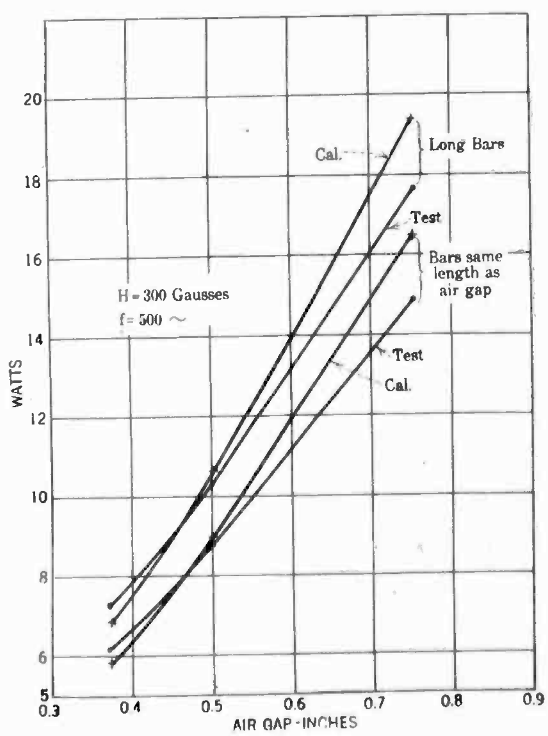



Fig. 8—Copper Eddy-Current Losses, Two Bars ⅛-In. x 1.0-In. x 10-In., Two Bars ⅛-In. x 1.0-In. x 5 15/16-In.

case, increase as the square root of the frequency. It will be seen that within the experimental errors this was the case.

It will be noted that in the case of Figs. 6 and 7 the copper bars were considerably longer than the length of the air-gap. This is, of course, the condition in rotating machines. In several cases tests were made with long bars and then the bars were cut off to the length of the air-gap and again tested in order to determine the amount of the end effect. It was found in all cases tried that if the effective length of the bar for the long bars was taken as equal to the air-gap length plus a length equal to the vertical dimension of each bar (see Fig. 5) the end effects would be very closely compensated for. This explains the notation in Figs. 6 and 7 ("corrected for ends").

Fig. 8 shows the relation between air-gap and loss for an $H$ of 300 gausses and a frequency of 500 cycles. In this case there were two bars, ⅛ by 1 by 10 inches. The results are also given for the same bars cut to the length of the air-gap. The test results follow the theoretical values within reasonable limits, the test values being a little less for the large air-gaps and a little

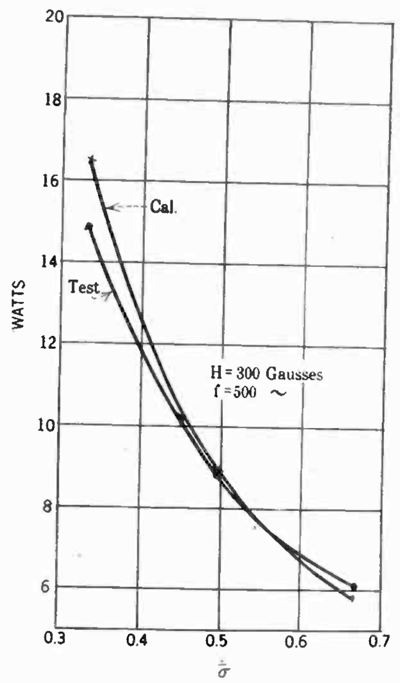



Fig. 9—Copper Eddy-Current Losses, Two Bars 1/8-In. x 1/10-In. x 5 15/16-In.

greater for the small air-gaps. Obviously for solid copper in the gap (100 per cent space factor) the gap would be 0.25 inch.

Fig. 9 shows the same data for the short bars only plotted against $t/\sigma$ (ratio of copper thickness to gap width or the space factor of the copper).

Table I gives some further comparisons between test and calculated results and includes the data of the previously mentioned curves. In most cases the average test values have been converted to a standard m. m. f. of $H = 300$ according to the square law, although the tests were made at other m. m. fs. The dimensions in the table for the copper are approximate values. The actual values were used for the calculations.

## Discussion of Results

Except in two or three cases the test and calculated results are as close as could be reasonably expected. When the space factor is low and the bars are wide, there is a tendency for the calculated results to be high. In the case of the four bars side by side with the larger cross sectional dimension vertical there is a tendency for the calculated values to be low. We may say that for all practical purposes and under the conditions of these experiments the calculated values are sufficiently

TABLE I

| $H$ gausses | $f$ | $A\ G$ | Watts Test | Watts Cal. | | Remarks |
|---|---|---|---|---|---|---|
| 2 Bars ¼ in. by ¾ in. by 10 in. (Approximate Dimensions). | | | | | | Flux |
| 395 | 500 | 0.75 | 23.8 | 23.0 | | |
| 291 | 500 | 0.75 | 12.9 | 12.5 | | |
| 190 | 500 | 0.75 | 5.31 | 5.35 | | |
| 300 | 200 | 0.75 | 8.5 | 8.4 | | |
| 300 | 500 | 0.75 | 13.7 | 13.3 | | |
| 300 | 1000 | 0.75 | 18.3 | 18.8 | | |
| 2 Bars ¼ in. by ¾ in. by 5-15/16 in. | | | | | | |
| 300 | 500 | 0.75 | 11.9 | | | |
| 2 Bars 1/8 in. by 1 in. by 10 in. | | | | | $t/\sigma$ | |
| 300 | 500 | 0.75 | 17.6 | 19.4 | 0.333 | |
| 300 | | 0.50 | 10.33 | 10.6 | 0.497 | |
| 300 | | .375 | 07.33 | 6.88 | 0.665 | |
| 2 Bars 1/8 in. by 1 in. by 5-15/16 in. | | | | | | |
| 300 | 500 | 0.75 | 14.82 | 16.5 | 0.333 | |
| 300 | | 0.50 | 8.77 | 9.00 | 0.497 | |
| 300 | | 0.375 | 6.09 | 5.85 | 0.665 | |
| 2 Bars 0.299 in. by 0.484 in. by 9.281 in. | | | | | | |
| 300 | 500 | 0.75 | 10.95 | 11.75 | | |
| 300 | 200 | 0.75 | 7.35 | 7.45 | | |
| 300 | 200 | .75 | 4.54 | 5.10 | | |
| 4 Bars 1/8 in. by ½ in. by 8 in. | | | | | | |
| 300 | 500 | 0.75 | 30.1 | 36.4 | | |
| 300 | 500 | 0.50 | 20.1 | 19.8 | | |
| 300 | 500 | 0.75 | 14.9 | 12.8 | | |
| 300 | 500 | 0.75 | 5.26 | 5.11* | | |
| 300 | 1000 | 0.75 | 20.2 | 18.1 | | |
| 300 | 1000 | 0.75 | 20.5 | 19.3 | | |

*5.25 by formula (1)

reliable. All ranges have been covered from the simple case of no skin effect (formula 1) to the case of large skin effect. Moreover multiple bars have been used and the results check practically as well as for a single pair of bars.

Unfortunately, in the case of rotating machines, the conditions are not as simple as in the ideal case. In the present tests the effective width of air-gap is the actual width of gap. In the case of rotating machines the corresponding actual width of slot is not the effective width which has to be used in the formula. By eferring to Fig. 8 or 9, for instance, it will be seen that the larger the width of the gap the greater the copper loss for a given air-leakage flux, (assuming the conductors have large skin effect). For no skin effect the losses are independent of the gap width. Now in the case of rotating machine teeth the teeth themselves are saturated to some extent, at least, or there would be no appreciable slot leakage fluxes. This means that their permeability is low and that an appreciable m. m. f. is required to force the flux through them. Again the applied m. m. f. which causes the leakage flux to pass across the slot may partly, at least, traverse a second slot and the machine air-gap. This means that due to the higher actual m. m. f. applied over that necessary to cause flux to cross the particular slot in question, the eddy currents in the copper would not be as effective in damping out the flux as would otherwise be the case, and therefore the losses are higher. This means that the value of $\sigma$ in formula (2) should be increased by some more or less uncertain amount.

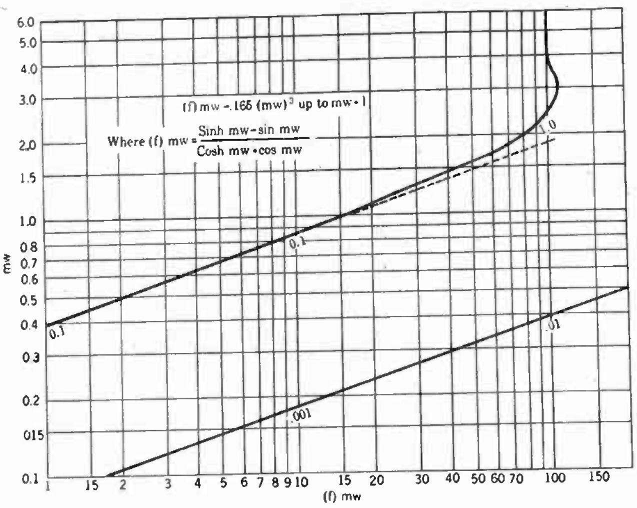



Fig. 10—Copper Eddy-Current Losses, Showing Hyperbolic Function in Exponential Form

In the majority of machines which we have tested, $\sigma$ should be multiplied by 1.5 on the average, but in some cases it has to be much higher than this and in a few cases lower. Before it would be possible to accurately predict the necessary corrections for all types of machines, much more experimental data must be obtained.

## Characteristics and Calculation of Eddy Losses

An analysis of the test results and of formulas (1) and (2) reveal some interesting relations. If the function

$$\frac{\sinh m\,W - \sin m\,W}{\cosh m\,W + \cos m\,W}$$

is plotted against $m\,W$ on double log paper, there is obtained the relation shown by Fig. 10. It will be seen that for any value of $m\,W$ up to 1, the function increases approximately as the cube of $m\,W$. Above 2 the function is nearly equal to 1. The reason that the function reduces to 1 is that for large values the sinh and cosh terms are practically equal and increase very rapidly in magnitude, thus making the sine and cosine values negligible. When this function reduces to 1, the losses are obtained from the first part of formula (2), namely

$$W_e = \frac{\pi^2 f^2 H^2}{m^3\,\rho\,W\,10^7} \tag{3}$$

In order to further simplify this expression, assume that $\rho =$ 1.8 by $10^3$ (1.8 microhm centimeters corresponds to 31 deg. cent).

$$W_e = 1.688 \times 10^{-7}\,\frac{f^{1/2} H^2}{\left(\frac{t}{\sigma}\right)^{\frac{3}{2}} W} \tag{4}$$

(when $\rho = 1.8$ by $10^3$)

The variations of the watts per cu. cm. with frequency, air-gap, space factor and radial width of copper are now evident. It has been shown experimentally that these relations are approximately correct. They apply only when the product $m\,W$ exceeds 2 (large skin effect). Using this relation, care must be taken to note the causes of the changes in $\frac{t}{\rho}$ and $W$ and the fact that this formula gives the watts per cu. cm. and not the total watts. If $t/\sigma$ is changed by increasing the width of gap (or slot for the machine), but with the copper the same, the total eddy losses will vary as $(t/\sigma)^{-3/2}$ for a given $H$ as shown by the formula or as $\sigma^{3/2}$ (slot width). Now if $t/\sigma$ is altered by changing the total thickness of copper the weight is also changed and therefore the total loss varies at $(t/\sigma)^{-1/2}$, namely, for a given slot the total loss varies inversely as the square root of the tangential copper thickness per slot.

Again suppose the width of the copper ($W$) is changed by increasing the width of the individual bars then, since an increase in width means an increased total volume of copper, the losses are independent of the copper width $W$ (for large skin effect). This is obvious from the fact that there are no eddy currents near the middle of the bars (see Fig. 4). If, however, $W$ is changed by laminating but keeping the total weight of copper the same, the total losses are, as shown by the formula, inversely proportional to $W$; but as the laminating is continued the skin effect is reduced and soon the losses begin to decrease as the square of $W$ or according to formula (1). Fig. 11 illustrates such a condition. It will be seen that for the particular conditions the losses increase rapidly with increasing lamination and then decrease. These are calculated values but test results would show the same thing. The main point is that laminating may increase or diminish copper eddy losses depending upon the conditions.

Now in using this formula, $m$ should first be calculated as shown above, namely $m = 2\pi\sqrt{\dfrac{f\,t}{\sigma\,\rho}}$ or $m = 0.148\sqrt{f \times \dfrac{t}{\sigma}}$ for $\rho = 1.8 \times 10^3$. Then if the product $m\,W$ is less than $I$, formula (1) or some modification may be used, or if desired formula (2) may be used. If $m\,W$ is over 2, or for accurate work over 4, formulas (3) or (4) may be used. For intermediate values use formula (2) or use formulas (3) or (4) and multiply by $(f)\ m\,W$ as obtained from Fig. 10.

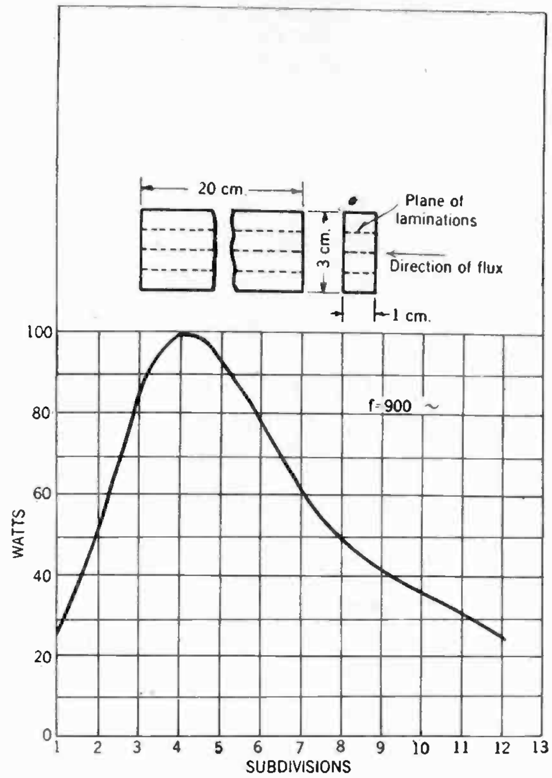



Fig. 11—Copper Eddy-Current Losses—Variation of Loss due to Laminating

Assuming

$$\rho = 1.8 \times 10^3 \text{ formula (1) becomes}$$

$$W_\epsilon = 0.915 \times 10^{-10} f^2 W^2 H^2 \quad (\text{when } \rho = 1.8 \times 10^3) \qquad (5)$$

and may be used for approximate results up to values of $m\,W$ of 1.5.

## Application of Formulas

As pointed out above, formula (2) or its modifications will, in general, give results which are of the right order of magnitude if $\sigma$ the slot width is increased by 50 per cent before using in the formula. This method of calculation may be used for salient pole machines. In this case the tangential slot-leakage curves must be analyzed into their harmonics and the copper losses calculated for each harmonic. For low frequencies, formula (1) will usually apply, but for the higher harmonics some form of formula (2) must be used. In the case of wound-rotor induction motors the no-load copper eddy losses may be calculated by assuming a single frequency corresponding to the tooth-pulsation frequency. The radial as well as the tangential slot-leakage fluxes may be of importance in this case.

As a first approximation if test data are not available the radial slot-leakage flux may be assumed to be equal to the m. m. f. necessary to magnetize the teeth adjacent to the slot and the tangential slot-leakage flux to the difference in m. m. f. between the two adjacent teeth. Of course, tooth taper introduces complications but this can readily be taken care of approximately. As pointed out, the chief difficulty is in determining the total effective m. m. f. where skin effect is large. In calculating the total loss the volume of copper is that in the slot plus an amount corresponding to an added length of copper equal to $W$.

## Summary of Formulas

For $m\,W$ less than 1 (approximately correct to 1.5).

$$W_\epsilon = \frac{\pi^2}{6} \times \frac{W^2}{\rho} f^2 H^2 10^{-7} \qquad (1)$$

$$W_\epsilon = 0.915 \times 10^{-10} f^2 W^2 H^2 \quad (\text{when } \rho = 1.8 \times 10^3) \qquad (5)$$

For $m\,W$ between 1 and 4.

$$W_\epsilon = \frac{\pi^2 f^2 H^2}{m^3 \rho\, W\, 10^7} \; \frac{\sinh m\,W - \sin m\,W}{\cosh m\,W + \cos m\,W} \qquad (2)$$

For $m\,W$ greater than 4 (Approximately correct for $m\,W$ above 2).

$$W_\epsilon = \frac{\pi^2 f^2 H^2}{m^3 \rho\, W\, 10^7} \qquad (3)$$

$$W_\epsilon = 1.688 \times 10^{-7} \frac{f^{1/2} H^2}{\left(\dfrac{t}{\sigma}\right)^{\frac{3}{2}} W} \quad (\text{when } \rho = 1.8 \times 10^3) \qquad (4)$$

The above formulas, when $\rho$ is included in the constant, are based on copper at 31 deg. cent. For copper at 65 deg. cent. $\rho$ should be taken as $2.0 \times 10^3$ instead of $1.8 \times 10^3$. For copper or aluminum alloys, use the formulas with $\rho$.

For cool machines on no-load test, formulas (4) or (5) will, in general, be satisfactory. For hot machines they may be modified, as indicated above but this refinement will usually be found unnecessary due to other much larger uncertainties. Formula (4) is to be used when $m\,W$ is greater than 2 and formula (5) when $m\,W$ is less than 1.5. For intermediate values of $m\,W$ corrections according to Fig. 10 may be applied or Fig. 10 may serve merely to indicate the possible errors which will result by neglecting this correction.

The above assumes that the effective slot-leakage flux is the tangential component. For the radial component, copper dimensions at right angles must be used.

### Symbols

$$m = 2\pi\sqrt{\frac{f\,t}{\rho}}$$

$$= 0.148\, f \times \frac{t}{\sigma} \quad (\text{when } \rho = 1.8 \times 10^3)$$

$W_e$ = eddy loss in watts per cu. cm. of bar material.
$f$ = cycles per second.
$t$ = thickness of copper bar (tangential) multiplied by the number of bars side by side in a slot.
$\sigma$ = slot width
$\rho$ = resistivity of bar material in abohms (equals microhm – cm. by $10^3$).
$W$ = radial width of individual bars in cm.
$H$ = slot leakage m. m. f. in gilberts per cm. or slot leakage flux in gausses (no bars).

### Conclusions

The above-described experiments indicate that the formulas for no-load copper eddy-current losses due to the slot-leakage fluxes are correct to within 10 or 15 per cent for all of the conditions tried which cover a wide range. In the case of rotating machines, however, we have the saturation of the teeth, other gap reluctances and other factors which make it very difficult sometimes to estimate accurately the total m. m. f. applied to the slot-leakage magnetic circuit. In general, fairly reliable corrections may be made by adding 50 per cent to the slot width. When skin effect is small no appreciable errors will result since the loss is independent of the gap reluctance, assuming a given leakage flux. This analysis gives the following interesting relations.

For small skin effect, $m\,W$ less than 1, (low frequency or narrow bars) the eddy losses for a unit volume of copper vary as $f^2\,W^2$. For large skin effect, $m\,W$ greater than 2, (high frequency or wide bars) the eddy losses for a unit volume of copper vary as $f^{1/2}$, $(t/\sigma)^{-3/2}$, $W^{-1}$ and $H^2$. For variations in total copper eddy current losses consideration must be given, as previously mentioned, to the way in which $t/\sigma$ and $W$ are varied.

In the case of salient pole machines the wave shape of the slot leakage fluxes must be analyzed or the components estimated and the losses calculated for each component frequency. In the case of induction motors the tooth-pulsation frequency is to be used.

Even though these formulas often can not be used directly without considerable labor, they should serve a very useful purpose in indicating quickly the result of changing the laminating of the copper and changing the slots. The interesting fact has been pointed out that in some cases increased laminating of the copper may increase the losses, while in others it decreases them.

### Summary

Check tests are presented, showing that our theoretical formulas for calculating no-load copper eddy-current losses are reliable provided all of the conditions are known. The actual application to rotating machines may yield erroneous results due to difficulties in estimating the total reluctance of the flux-leakage paths. These formulas in their present form should be useful for calculating roughly the amount of no-load copper eddy losses in salient pole machines and induction motors. They should also be useful for determining the effect of changes in the section of the individual copper bars in the slot with reference to eddy losses. Later it is hoped that more reliable and simpler methods for using these formulas will be devised.

---

## AUTOMOBILE HEADLIGHTING

For several years the bureau has been working with technical societies, State officials, and others in the attempt to improve the headlighting of automobiles. This question has been revived more actively than ever during the past year as the result of discussions following the National Conference on Street and Highway Safety called by Secretary Hoover in December, 1924. In order to obtain more complete and reliable information regarding the actual status of headlighting and the possibility of its improvement, a joint committee representing the Society of Automotive Engineers and the Illuminating Engineering Society has recently been formed and is attempting to lay out a program of research on this subject. Members of the bureau's staff have been appointed as representatives of both societies on this committee. The bureau has also been called on for technical advice in connection with the requirements of the proposed uniform vehicle code which is to be considered at the next meeting of the national conference. In this connection the bureau has advocated the general plan of making laws and regulations as simple as possible and depending upon education of motor-car manufacturers and users for the betterment of actual road conditions. With this in view, Circular No. 276, Motor Vehicle Lighting, was issued some time ago and has found extensive circulation. This circular is not available for free distribution, but can be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C., for 20 cents per copy.

# Electrification of Paper-Making Machines

BY STEPHEN A. STAEGE[1]

Fellow, A. I. E. E.

*Synopsis.—The ever increasing speeds of paper making machines has made necessary the replacement of the inadequate mechanical drive with electrical sectional drive, and the perfection acquired in modern electrical sectional paper machine drive has made possible unlimited paper speed in so far as the drive and control is concerned.*

*Not only is electrical sectional drive necessary for high speed machines but it is highly economical for even the slowest speed machines on account of the saving in power over mechanical drive, the great saving in maintenance, and the greater precision with which the section speeds can be maintained thereby greatly reducing the number of paper breaks and increasing production.*

*This paper outlines the several trends of development in an historical sketch of progress in the art up to the present time, devoting special attention to a unique system of direct current drive in which the section driving motors through a differential electrical field control means, cause the several section driving motors to operate in synchronous relation at any desired relative speed values, which speed relations are at the same time adjustable at the will of the operator.*

## INTRODUCTION

THE production of a continuous sheet of paper, 12 to 18 ft. wide and 250 to 1000 mi. long without a break on the machine—a paper speed of 1000 ft. per min. or more—has been made possible by electrical sectional paper-machine drive and control.

The frail web of paper, about three mils thick, passes without support from section to section of the machine, passing between heavy press rolls, tons in weight; threading around 30 or 40 steam-heated dryer rolls; through the eight or ten-roll calender stack weighing a hundred tons or more, and onto the reel.

In the travel of the sheet through the paper machine from the "wire" where it is formed to the calender where it is finished, the sheet usually increases in length from five to ten per cent. Therefore, the sheet is actually traveling faster when it leaves the machine than at the beginning of its travel. In fact, there is usually a progressive increase in the speed of travel of the sheet as it goes from section to section, on account of its stretch.

There are two principal types of paper-making machines, known as cylinder machines and Fourdrinier Machines. The fundamental differences are in the wet or forming-end of the machine.

The Fourdrinier Machine is the type always used for high speed, in making newsprint and kraft paper and in the manufacture of book, writing and the higher grade papers.

The Cylinder machine is inherently a slower speed type and is used chiefly in the manufacture of box and container board, roofing felt, and the heavier sheets.

The paper-making machine in its usual form consists of a number of sections independently driven but which must be maintained in operation at the proper speed relations to each other. Not only must the proper speed relation be maintained between sections, but these speed relations must be adjustable at the will of the operator so that they can be adapted to the requirements of the sheet of paper. These may change slightly in elongation or shrinkage on account of variations in the condition of the stock, temperature, atmospheric conditions and a number of other factors; the stretch or shrinkage of the sheet depending largely upon the thickness, quality, condition of stock and amount of pressure used in removing the water.

In addition to the requirement of adjustability of speed between sections to take care of variations in elongation and shrinkage, it is essential that the entire machine be adjustable in speed over a wide range, without disturbing the speed relation of the several sections.

The speed range of a newsprint machine may be 600 to 1200 ft. per min.; a kraft machine, 200 to 800 ft; a book machine, 100 to 600 ft.; a specialty Fourdrinier Machine, perhaps 100 to 800 ft.: While a cylinder machine sometimes has a speed range as great as 35 to 350 ft.; although a more common range for this type of machine is 50 to 200 ft. of paper per min.

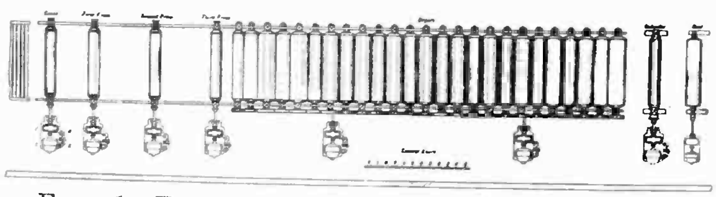


FIG. 1—TYPICAL SECTIONAL PAPER-MACHINE DRIVE

A typical high-speed Fourdrinier Machine (Fig. 1) usually consists of eight sections; a "wire" or couch section, three press sections, two dryer sections, one calender section and a reel section. Fig. 2 shows schematically a side elevation of such a machine.

The first section of the Fourdrinier Machine, known as the "Fourdrinier," "wire" or "couch" section, has a revolving wire screen of fine mesh. This Fourdrinier wire, in the form of a wide belt the width of the machine, operates around two rolls, the one at the extreme end of the machine called the breast roll and the one at the other end of the "wire," the "couch" roll. This is the driven member of the section, the breast roll being rotated as a pulley by the wire. The wire may be from

1. Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

*To be presented at the Regional Meeting of District No. 1 to be held at Cleveland, Ohio, March 18-19, 1926.*

50 ft. to more than 100 ft. long, depending upon the size and speed of the machine; and the span of the wire is kept from sagging by a large number of small "table" rolls located close together under the top pass of the wire, which carries the stock.

The press sections consist of pairs of heavy rolls, weighted with compounding levers, and between the upper and lower rolls of which the sheet, on its felt conveyor, passes. The lower roll is driven and the upper roll rotates by contact traction with the lower roll.

In the dryer sections some 15 or 20 dryer rolls or drums, four, five or six feet in diameter are nested in a group and geared together by intermeshing spur gears. There are usually two dryer sections which may be independently driven and regulated or may be geared together.

The calender stack consists usually of eight or ten chilled-steel rolls accurately ground and polished and driven by the bottom roll, all of the upper rolls being rotated by surface contact friction.

A "uniform speed" reel is commonly used, the spool and roll of paper being rotated by the traction of surface contact with the reel drum.

From the "couch" the sheet, though very wet and frail, spans a distance of a foot or more until it reaches a felt conveyor by means of which it is carried through the first press, then to the second and third presses, on independent felts and across another unsupported span to the dryer sections. Dryer felts hold the sheet in contact with the hot dryer drums as it is threaded through the nest of dryers. From the dryers, the sheet passes across a span of more than five ft. to the calender stack and thence to the reel.

Passing from the "wire" at the "couch," additional water is removed by pressure in going through the presses, and most of the remaining water is removed by heat in the steam-heated dryer sections.

The function of the paper machine is to reduce the stock mixture, evenly distributing the fibers in proper relation, fabricating them into a continuous web, removing the excess water by filtration, pressure and heat and giving the final sheet of paper the required finish, and to wind it into rolls of convenient size.

In putting the sheet on the machine, it is put over at the full normal operating speed by means of air jets, in the case of high speed machines at least, by means of which a leader strip is detached from the "wire" at the couch and blown across the gap to the felt conveyor of the first press. At each section the air jet is used to transfer the narrow leader strip to the succeeding section. As soon as the leader strip has been started the sheet is widened by tapering out at the "wire" until it is the full width of the machine.

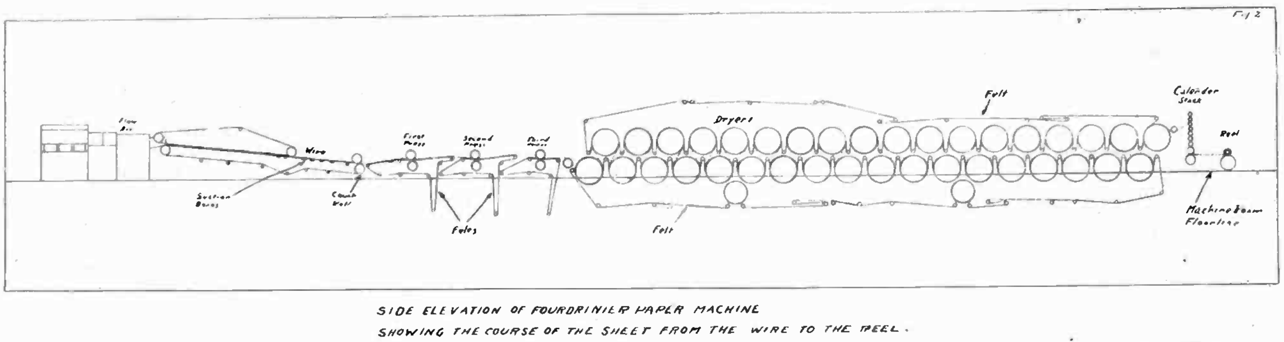



Fig. 2—Side Elevation of Fourdrinier Paper Machine Showing the Course of the Sheet from the Wire to the Reel

A very large percentage of the paper of today is made from wood pulp, the individual fibers having been reduced or separated by mechanical or chemical processes and mixed in a suitable proportion of water.

In the manufacture of paper, the raw material passes through several processes and refinements before it goes to the paper-making machine in a fluid mass consisting of approximately ½ of 1 per cent stock and 99½ per cent water.

The Fourdrinier section of the machine receives the stock from a flow box, located above the breast roll, from which it flows by gravity onto the revolving fine wire screen from a thin submerged orifice extending the width of the machine and located just above the "wire."

When the stock flows onto the "wire," much of the water immediately passes through by gravity, and further along its travel a considerable part of the remaining water is drawn through the wire from the stock film on its surface by a number of flat suction boxes located below it in which 10 to 15 inches of vacuum is maintained.

In cylinder machines, the design and functioning of the various parts is much the same as that of the Fourdrinier machine, except that the forming of the sheet is done on cylinder moulds instead of on a Fourdrinier wire. A machine may have several cylinder moulds consisting of skeleton drums covered with fine wire screen. These revolve slowly in vats containing paper stock and each cylinder mould contributes a thin layer of stock to the final heavy sheet. A revolving felt conveyor picks up the stock from the cylinder mould drums, carries the laminated stock film between small presses where it is pressed into a homogeneous fabric and part of the water is removed, and thence carries it through the first press from which the operation is similar to that of a Fourdrinier machine.

### Early Methods of Drive

For many years, the paper-making machines were mechanically driven by variable speed engines or motors or other variable speed means to take care of the speed range required, and the individual sections were driven from a line shaft through gears and belt or rope drive with cone pulleys, so that by shifting the belt on the cone pulleys, the required relative speed between sections could be obtained. Such systems were unusually subject to belt slippage on account of the poor belt contact on the cone pulley surfaces and on account of the vertical-belt drives which were usually necessary; they required mechanical clutches or belt slackening and tightening devices so that any section could be stopped and started independently of the rest of the machine; and they suffered from more than the usual troubles and limitations to which mechanical drives are subject.

As early as 1905 to 1910 several installations of electrical sectional paper machine drives, but without automatic speed regulation, were made in an effort to overcome the serious shortcomings of mechanical drive, but most of these early installations because of poor speed regulation were unsuccessful—only two of these early sectional drives remaining in service. It was only through infinite care in the design and in field adjusting of the equipment that operation was made possible, and that only by frequent hand adjustments of rheostats by the operators.

The search for a more satisfactory type of drive was a difficult one. For obvious reasons, synchronous motors could not meet the various requirements of paper-machine drives and the best inherent characteristics of d-c. motors did not provide speed regulation of sufficient precision over the speed range required, and were furthermore subject to the effects of changes in resistance due to temperature changes resulting in variations in speed. An automatic speed regulator was, therefore, sought to control the speed of the d-c. driving motors for each of the sections. It was immediately apparent that none of the usual types of speed governors or regulators would suffice, inasmuch as speed control within limits of the order of $^1/_{10}$ of 1 per cent or closer was necessary for satisfactory performance. The differential principle was, therefore, finally made use of as this offered possibilities of practically infinite precision of speed control of integrated values. To correct for a tendency of the motor to change in speed, a small change in angular displacement of the motor armature with respect to a time cycle is necessary, but the motor can be made to operate for an indefinite period without gaining or losing in rev. per min.

Paper machines sectionally driven by d-c. motors and controlled by regulators of the electrical differential type have now been in operation in this country and Canada for some six years. The details of the mechanism by means of which differential speed regulation with field control is obtained, has gone through a process of evolution whereby the apparatus required has been greatly reduced and simplified and improved in quickness of response.

### First Automatically Regulated Electrical Sectional Drive

In the first electrical sectionally-driven paper machine in this country to be automatically controlled by the electrical differential regulator principle, a master unit was provided to which the speed of the sections was referred (Fig. 3). The master consisted of a motor-driven a-c. generator, and from each section of the paper machine there was also driven, through a control speed changer, a small a-c. generator. Connected electrically between the master generator and the section generator was a wound rotor induction motor, the stator being connected to the master generator and the rotor to the section a-c. generator. When connected in the proper phase relation so that the magnetic field in the rotor would rotate in the same direction as the magnetic field in the stator and at the same speed, no rotational

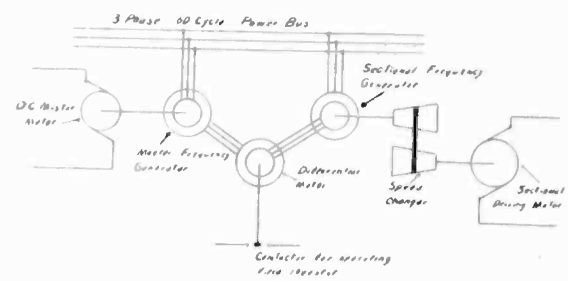



Fig. 3—Schematic Diagram of First Electrical Differential Speed Control System

movement of the rotor would take place. If, however, the d-c. section driving motor for any reason should slow down or speed up, this would, of course, cause a corresponding change in the frequency of the generator driven from the section motor, from that of the master, and the rotor of the induction motor would then rotate in the one direction or the other, depending upon the higher frequency and at a rate of speed corresponding to the difference in frequency of the two generators between which it was connected. This constituted an electrical differential.

A motor-operated field rheostat was provided in the shunt-field circuit of each of the section driving motors (Fig. 4) and through movement of the differential element, the wound rotor induction motor, contact means were provided so that a rotational movement of a very small fraction of a revolution in either direction would serve to make a contact thereby operating the rheostat in one direction or the other as required to correct the speed of the section-driving motor. This relay method of operating the field rheostat was used instead of coupling the rheostat directly to the shaft of the differential motor so as to relieve the differential control system of the necessity of developing sufficient torque to turn the rheostat which would detract from its sensitivity; and also to obtain characteristics whereby the travel of the rheostat arm was not a direct function of the movement of the rotor of the differentially connected induction motor. Reaction magnets were provided to prevent overtravel of the rheostat and hunting.

This system was quite effective but had its limitations particularly in range of control, speed of regulation and tendency to oscillate on account of the definite step characteristic of the rheostat which obviously could not be made to meet the exact requirements of the speed necessary for the section motor.

The master and section a-c. generators used were of the induction frequency changer type which appeared to be the most desirable for this service. Standard wound rotor induction motors were used and were driven at a

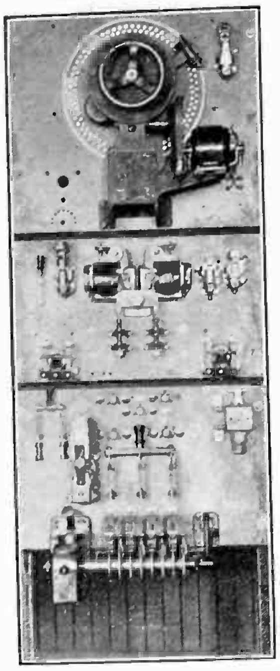


FIG. 4—DIFFERENTIAL RELAY AND MOTOR-OPERATED FIELD RHEOSTAT OF FIRST ELECTRICAL DIFFERENTIAL SPEED CONTROL SYSTEM OF SECTIONAL DRIVE

speed usually about 50 per cent below synchronous speed so that when excited from a 60-cycle source, the output frequency of these frequency changer generators would be about 30 cycles at the maximum paper speed and this frequency would increase as the paper speed decreased. The use of this type of generator avoided the necessity of d-c. excitation and provided all of the characteristics required and any variations in the frequency of the exciting source would have no affect upon the regulation as they would take place equally on both sides of the differential.

With this arrangement it will be seen that when the speed of the section motor is correct, the secondary frequency of the master and section frequency changer or generator is the same and no rotation of the induction motor connected between the two frequency changers takes place. If, however, a change in angular displacement of the section frequency changer takes place with respect to the master, a similar movement takes place in the rotor of the wound rotor motor and through the rheostat indirectly actuated by this movement, resistance is cut in or out of the shunt-field circuit of the section driving motor, thereby tending to maintain its speed at the required value.

Following shortly after the installation in 1919 of the first control system of the type described, two other systems of sectional paper-machine drive and control also came into use; one known as a "synchronous motor tie-in" system, and the other as an "interlock" system.

### SYNCHRONOUS MOTOR TIE-IN SYSTEM

The "synchronous motor tie-in" system (Fig. 5), instead of automatically regulating the d-c. section motor field strength to maintain the proper speed relation between sections, employed a synchronous motor for each paper-machine section, of about one-fifth the capacity of the main d-c. section driving motor. The synchronous motors were driven from the main d-c. section driving motors through a spur-gear reduction and a pair of cone pulleys with belt drive. The synchronous motors were d-c. excited and had their three-phase armature circuits connected to a common or "dead" bus, as it was called. This "dead" bus was not connected to any other source of power.

The object of the synchronous motors was to hold the speeds of the d-c. section driving motors at their proper speed relation, as determined by the position of the belts on the cone pulleys.

In the event of a tendency of the d-c. section driving motor to change in speed, due to a load change or temperature change, the synchronous motor was called upon to carry the increase or decrease in the load of the section, or the load thrown off or taken on by the d-c. section motor due to a temperature change and corresponding change in field resistance. This was necessary in order that the synchronous motor might remain in synchronism with the "dead" bus and the other synchronous motors.

It will be observed that with this arrangement, any load taken by the section synchronous motor as a motor must be furnished by the other synchronous motors connected to the "dead" bus, as generators; and any load furnished by the section synchronous motor in question, as a generator, must be absorbed by the other synchronous motors. Since any change in load, or tendency to change in speed, on the part of a d-c. section driving motor creates a call indirectly upon each of the other section motors to carry or absorb the change in the section in question, the entire paper machine would tend to change in speed, to a degree depending upon the droop of the load speed characteristic curves of the d-c. section driving motors and in an amount, compared to the section tending to change, approximately inversely proportional to the number of sections.

It will, also, be observed that the d-c. section driving motor in question could only change in speed with respect to the frequency of the "dead" bus, or the equivalent approximate mean paper speed, an amount permitted by the change in belt stretch, creep and slip on the cone pulleys, resulting from the change in load being transmitted, with the exception of the transient speed change coincident with the angular displacement and change in phase position of the synchronous motor accompanying its change in load. The changes in load being transmitted by the belt drive on the cone pulleys being subject to any amount within the capacity of the synchronous machine and possibly passing transmission of power from the synchronous motors was eliminated and the synchronous motor rotor was geared direct to the d-c. section driving motor and the synchronous motor stator was made to rotate at a slow speed by a small variable speed d-c. motor which was geared to the stator member of the synchronous motor. Additional bearings and slip rings were provided to permit of the rotation of the stator.

In order to adjust "draw" of the sheet, or the relative speeds of the d-c. section driving motors, it was now only necessary to adjust the speed of the small d-c. motor driving the stator of the synchronous motor, by means of a hand rheostat in its field circuit; and then to

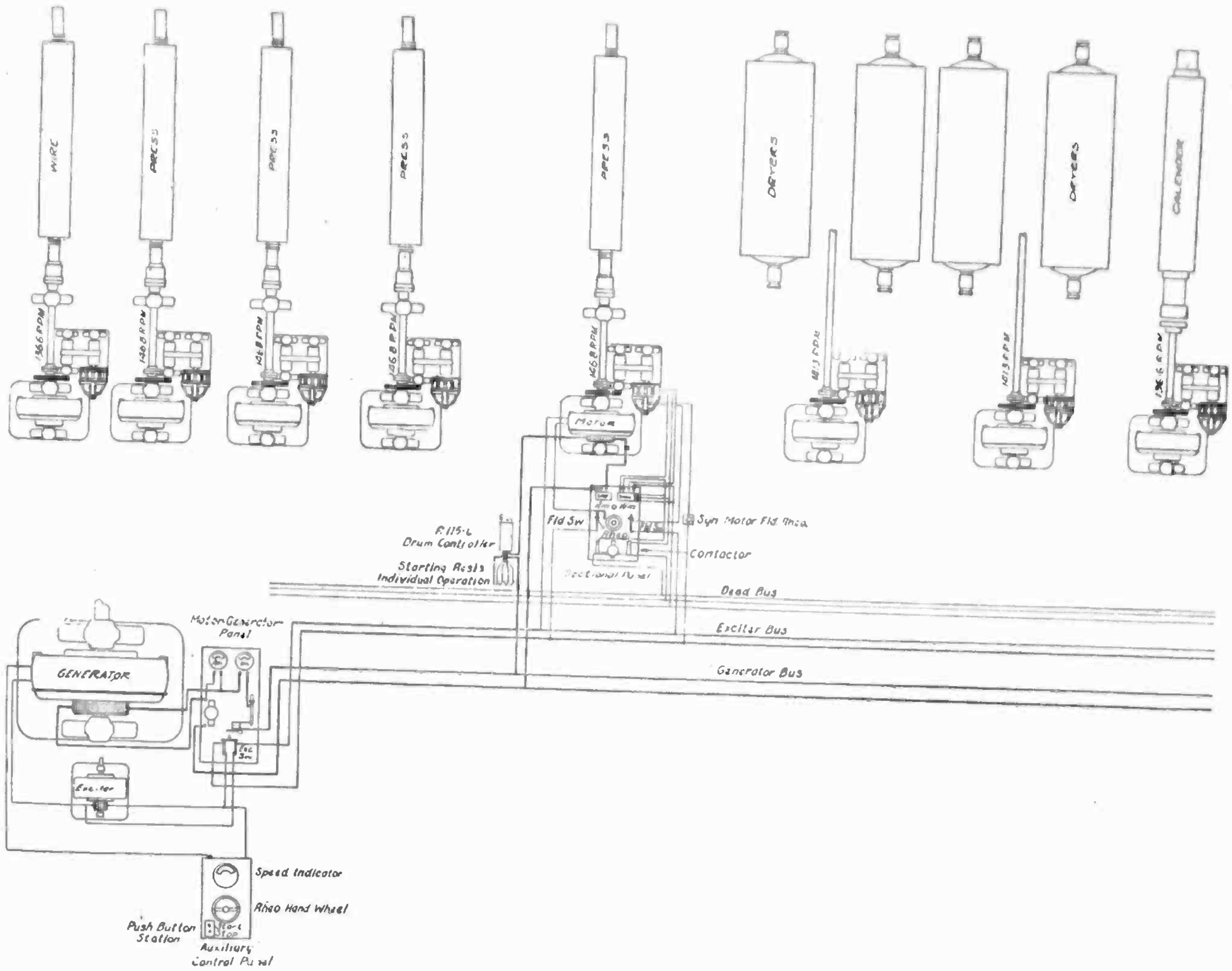



FIG. 5—SCHEMATIC DIAGRAM OF SYNCHRONOUS MOTOR TIE-IN SYSTEM OF SECTIONAL DRIVE WITH BELTS AND CONE PULLEYS

through zero torque on the synchronous machine in going from motor to generator or generator to motor (Fig. 6).

In order to maintain the synchronous motor at approximately no load, so as to be in a position to compensate for any change in either direction, it was, of course, necessary to readjust the shunt-field strength of the d-c. section driving motors at intervals, by suitable hand rheostats; a double indicating instrument being provided for each synchronous motor to indicate the approximate load as motor or generator.

This system of speed control was soon superseded by a modification wherein the belt and cone pulleys for the balance the load by adjusting the rheostat in the field of the d-c. section driving motors.

This arrangement eliminated the belt slippage factor incident to the cone-pulley belt drive, and except for variations in speed of the small d-c. motors, which were under no automatic control, the major possibilities of speed variation of the d-c. section driving motors had been eliminated. In this connection it will be seen that, while the small d-c. motors driving the stators of the synchronous motors were subject to load changes from zero to maximum and possibly even from motor to generator, if the worm gear efficiencies were high enough, considering the ratios used, the effect of the resulting speed variations of these small motors on the speed of the d-c. section driving motors was only approximately inversely proportional to the ratio of the worm gear used in driving the stators of the synchronous motors.

### "Interlock" System

The other or "interlock" system of electrical sectional paper-machine drive referred to, employed a

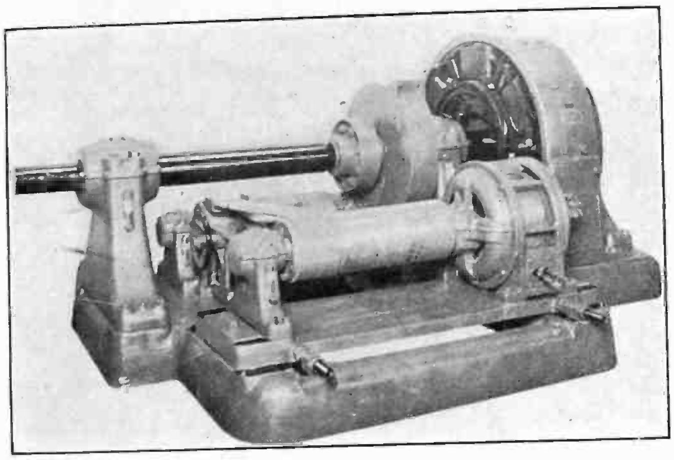


Fig. 6—Sectional Drive of Synchronous Motor Tie-In System

mechanical differential gear system for the operation of face-plate rheostats in the shunt-field circuits of the several d-c. section driving motors (Fig. 7).

A master shaft ran the entire length of the paper machine and adjacent to each of the paper machine sections, a shaft at right angles was taken off from the master shaft by means of a bevel gear. One end of the right angle shaft engaged with one member of a differential gear and the other end member of the differential gear engaged with a shaft driven by the d-c. section driving motor, through a small speed changer,

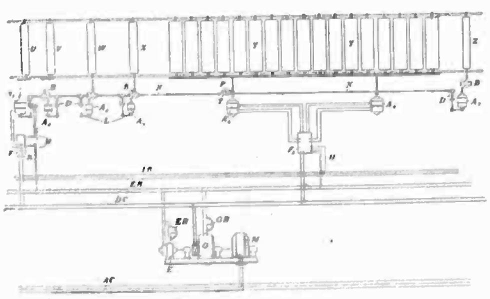


Fig. 7—"Interlock" Speed Control System of Sectional Drive

consisting of belt and cone pulleys or expanding V pulleys. The middle element of the differential gear was geared to the face-plate rheostat in the shunt-field circuit of the d-c. section driving motor. The master shaft was driven by the dryer section of the paper machine, which, therefore, became the master speed reference, and was not under regulator control.

Speed regulation of the individual d-c. section motors by this system is a function of the speed of the differential gear members, the ratio of the middle member to the rheostat arm shaft, the total resistance in the rheostat and the number of resistance steps; as well as the inherent regulation of the motors themselves and the electrical and mechanical inertia of the system. The regulation is also adversely affected by any back-lash or lost motion in the bevel, differential and rheostat gears and by the torsional elasticity of the master shaft; in fact, by any deformation or departure from synchronism or exact phase position of one part of the speed regulating system to another.

To overcome the disadvantages of the speed regulating rheostat with a rather limited number of resistance steps and of fairly high total resistance, no individual step of which is likely to give exactly the right speed, an arrangement was employed wherein the rheostat contact shoe overlaps one resistance step or button so that a very small movement of the rheostat arm will serve to transfer contact to any one of three resistance steps of the rheostat. To maintain a correct mean resistance value, it is necessary that the rheostat arm oscillate back and forth from one contact point to another, remaining in contact with either at each oscillation such a percentage of time that the mean resistance is of the required value to maintain the d-c. section driving motor at the correct average speed. Ostensibly, the only force available to cause oscillation of the rheostat arm is the d-c. section driving motor which must oscillate at the same frequency as the rheostat arm. The frequency of the oscillation is, of course, determined by the reactance of the electrical system involved, the motor field flux changes, the corresponding changes in motor torque, the inertia of the mechanical parts involved and the lost motion and torsional deformation of the gear train and shafts in the control system.

In each of the systems of electrical sectional paper-machine drive and control described, the usual method of obtaining desired changes in paper speed is by adjustment of the voltage of the d-c. generator supplying current to the armatures of each of the d-c. section driving motors.

### Electrical Differential Regulator

The second step in the development of the electrical differential type of field control speed regulator system was the elimination of the a-c. system entirely and the substitution of master and section rotary contactors. These consisted of commutators or ring segments, the master and section rotary contactor being in series and serving to periodically short-circuit resistors in the shunt-field circuit of the section motor under control as illustrated schematically in Fig. 8. Both master and section rotary contactor drums or commutators operate normally at the same speed and the angular displacement of the one to the other determines the percentage of time the resistance is cut in or out of the field circuit.

The operation as will be seen, is somewhat similar to that of a Tirrill regulator, but does not have vibrating contacts.

Differing from the Tirrill regulator, there are a multiple of resistors in series which instead of being short-circuited at the same time, are short-circuited alternately in such a way as to tend to produce the least change in voltage periodically across the motor field. To handle four resistors in series, six rings on the section rotary contactor and four rings on the master rotary contactor are required.

With this arrangement, when the section rotary contactor is exactly in phase with the master rotary contactor and running at the same speed, the regulating resistance in the shunt field circuit of the d-c. section motor is short-circuited and, therefore, cut out 100 per cent of the time. When the section rotary contactor is 180 deg. out of phase, lagging behind the master, then the regulating resistance is all cut in all of the time.

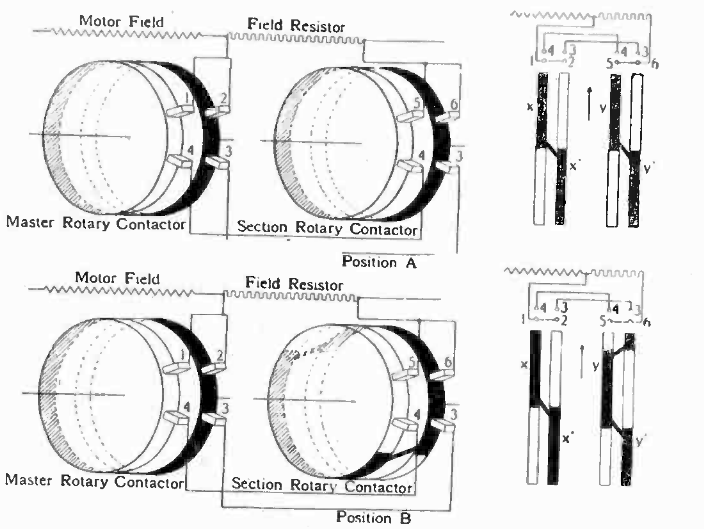



FIG. 8—SCHEMATIC DIAGRAM AND DEVELOPMENT OF MASTER AND SECTION ROTARY CONTACTORS OF ELECTRICAL DIFFERENTIAL SYSTEM

If the section rotary contactor is lagging 90 deg. behind the master, then the resistance of each resistor step is being cut in and cut out just 50 per cent of the time of each revolution of the rotary contactor drum. For any phase position of the section rotary contactor with respect to the master rotary contactor, the mean effective regulating resistance in the shunt-field circuit of the d-c. section driving motor is a direct function of the angular displacement of the section rotary contactor with respect to the master. With more than four resistance steps and a corresponding increase in the number of commutator rings, the wiring becomes very complex and difficult to trace and offers various objections for this reason.

## LATEST TYPE ROTARY CONTACTOR ELECTRICAL DIFFERENTIAL SPEED REGULATOR

The third and latest development in improving and simplifying the electrical type of differential speed regulator by field control is a change in the rotary contactor design whereby it becomes in effect a continuous rheostat automatically controlled. The rotary contactor drum consists of an annular ring segment tapered at one end, forming a conducting segment and a complementary insulating segment, the two constituting the entire surface of the drum or cylinder, (see Fig. 9).

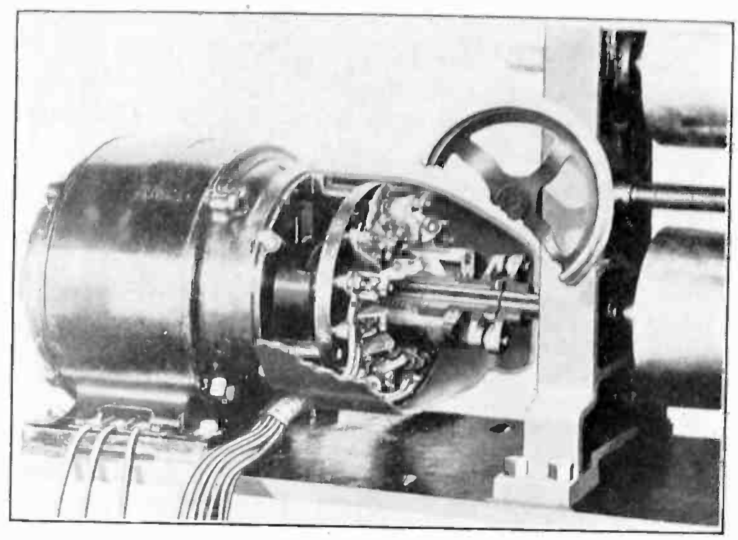


FIG. 9—LATEST SECTION ROTARY CONTACTOR UNIT OF ELECTRICAL TYPE DIFFERENTIAL SPEED REGULATOR SYSTEMS

Twelve brushes disposed radially around the periphery of the drum form a single spiral helix. Resistance units are connected between the brushes from one end of the spiral to the other in series with the shunt-field circuit of the motor. The conducting segment of the drum serves to short-circuit as many steps of resistance as there are brushes in engagement with the conducting segment at any time.

The drum is assembled on a sleeve which is mounted on the shaft of the section master synchronous motor, and is movable longitudinally on the sleeve but prevented from rotating thereon by a spline key, and the sleeve on which the drum is assembled is pinned to the shaft. The brushes are stationary and the full length

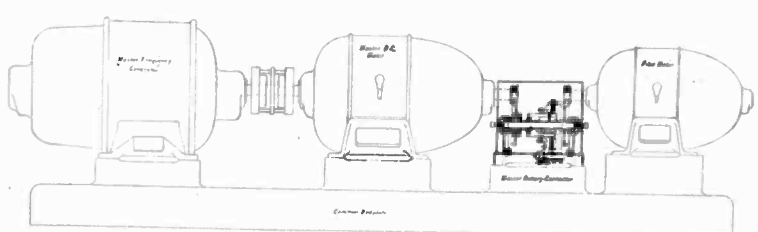


FIG. 10—MASTER SET OF LATEST ELECTRICAL TYPE DIFFERENTIAL SPEED REGULATOR SYSTEM

of the taper of the conducting segment of the drum is equal to the "pitch" from one brush to the next in a direction parallel to the axis of the drum, plus a small overlapping allowance.

The speed reference in this arrangement is a master set (Fig. 10) consisting of a master frequency generator driven by a d-c. master motor and controlled with great precision in speed by a d-c. pilot motor and master rotary contactor. It is from this master frequency generator that each of the section master synchronous motors of the section rotary contactor units operate. Both the d-c. master motor and the pilot motor of the master set operate in parallel with the d-c. section driving motors and the master rotary contactor resistors are in the shunt field circuit of the d-c. master motor. The pilot motor is the final speed reference and as it operates with substantially no-load changes and is usually located where there is little temperature change, its speed is very constant for any desired paper speed; voltage regulators being used to maintain the exciter voltage uniform and the main d-c. generator voltage constant at any desired voltage within the speed range of the paper machine.

A control speed changer, consisting of a pair of cone pulleys and belt, is provided for each section of the machine, one cone pulley being driven from the d-c. section motor to be controlled, by a chain drive; and the other cone pulley shaft coupled to the screw member of the section rotary contactor; a nut member being fixed in the outer end of the rotary contactor drum with which the screw engages. This screw member is assembled on the same sleeve with the drum to assure perfect alinement and is rotatable thereon but is restrained from moving endwise by a shoulder in the sleeve at one end of the screw and a collar at the other end on the end of the master synchronous-motor shaft. From this definite longitudinal location of the screw on the sleeve of the section rotary contactor; the spline key in the sleeve and drum, preventing rotational movement of the drum on the sleeve; and considering the engagement of the screw within the nut member of the drum; it is apparent that any difference in speed between the screw and the nut will cause a longitudinal movement of the drum beneath the brushes.

In normal operation, the screw member driven by the d-c. section driving motor through the control speed changer operates at the same speed as the nut member, drum and master; and certain resistance steps are continuously short-circuited corresponding to the brushes engaging with the continuous portion of the conducting segment of the drum. One step is being cut out periodically once every revolution, the percentage of time it is cut out corresponding with the percentage of time the brush of this step is in engagement with the tapered portion of the conducting segment which depends upon the longitudinal position of the drum beneath the brushes. The remaining resistance steps are cut in continuously, as the brushes are only in engagement with the non-conducting segment of the drum. As a result, the motor operates at a speed resulting from the mean effective resistance valve of the rotary contactor resistor—an automatic rheostat—with an infinite number of steps of infinitely small increments of effective resistance.

The extreme sensitivity of this regulating system will be appreciated by the fact that any change in angular position or phase relation of the lower cone pulley shaft of the control speed changer with respect to the master section synchronous motor, through the screw action, causes a longitudinal movement of the drum beneath the brushes and a longitudinal movement of only a few thousandths of an inch is sufficient to correct for most of the tendencies on the part of the d-c. section driving motor to change in speed. A travel of the drum of approximately three-fourths of an inch suffices to cover the range from resistance all-out to resistance all-in; and sufficient resistance is frequently used to produce a speed increase of as much as 50 per cent or more when all cut in to the shunt field circuit of the motor.

Another very important characteristic of such a differential type of regulator is the fact that any variation in speed, no matter how small, produces a positive corrective effect; and the corrective effect is cumulative and continually increases in value until the correct speed has been restored. A change in angular or phase

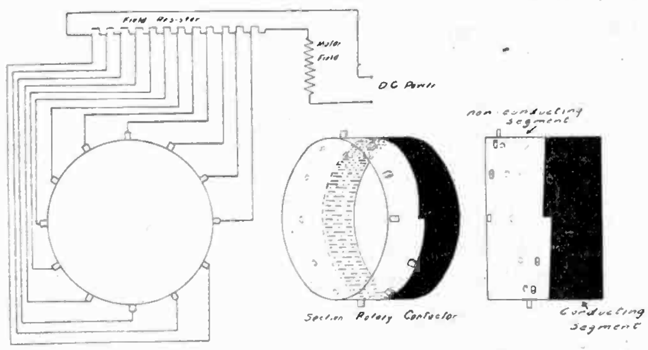



Fig. 11—Schematic Diagram and Development of Sectional Rotary Contactor Drum, Brushes and Wiring Connections of Latest Type Electrical Differential Speed Regulator Systems

position only, of the section with respect to the master serves to cut-in or cut-out sufficient resistance in the shunt field circuit of the d-c. section driving motor to maintain its speed at the same rate as before although the load may have changed.

In this respect it is interesting to observe that the d-c. motor is made to function much like a synchronous motor in so far as maintenance of speed is concerned. With the synchronous motor when a load is thrown on, the rotor falls back in phase position with respect to the generator or the frequency source and the new load is carried without more than a transient change in speed and at the same rev. per min. as before; sufficient torque having been developed in the phase displacement to carry its load. In the case of the d-c. motor with electrical speed differential field control, when a load is thrown on, the rotor falls back in phase position with respect to the master and the new load is carried without more than a transient change in speed, at the same rev. per min. as before; sufficient torque having been developed in the phase displacement and corresponding longitudinal movement of the rotary contactor drum beneath the brushes, thereby changing the motor field resistance, so as to carry the new load without change in rev. per min. When the load is thrown off, the rotor will move forward again in a manner similar to that of the synchronous motor. The number of mechanical degrees through which the d-c. motor must fall back in phase displacement in order to carry a load of given value, at the same speed as before, depends upon the droop of the load speed characteristic curve of the motor, the resistance in the rotary contactor regulating circuit, and the ratio of longitudinal drum movement to the differential angular displacement of the rotor of the motor.

This electrical speed differential field regulator in its simplest form is not fundamentally an especially high speed regulator, nor is it especially adapted to correct with exceptional quickness for extremely heavy load changes and corresponding tendencies to speed change, although with suitable auxiliary reaction features, not necessary in paper machine drive, such conditions can be taken care of. The upper limit of speed of regulation of this system without auxiliary reaction features, is determined by the reactance of the electrical system and the inertia of the mechanical system; in other words, the speed with which the motor torque can be changed to meet the requirements of constant relative speeds, the maintenance of stability of speed and the capacity to pull into synchronism with the master promptly on starting up.

In sectional paper-machine drive all of the requirements are well within the capacity of this type of electrical speed differential regulator system and the relative speeds of the section driving motors are held constant with such precision that no variation in the "draws" of the sheet can be observed even though the paper may be traveling through the machine at the rate of 1000 ft. per min. or more which speeds are now common in modern high speed paper-making machines.

The purpose of the control speed changer between the d-c. section driving motor and the screw member of the section rotary contactor is to make possible adjustments of the speed of the d-c. section driving motors and at the same time maintaining the speed of the screw member of the rotary contactor at the same speed as the section master synchronous motor. Coincident with any shifting of the belt on the control speed changer an angular displacement of the screw with respect to the nut takes place, moving the drum longitudinally, changing the regulating resistance so as to give the d-c. section motor its new speed corresponding with the new belt position on the cone pulleys.

The coning of the pulleys of the speed changer is so small that even though a change in section "draw," or relative speeds of 25 per cent to 30 per cent can be obtained, good belt contact is always secured; and as no load is transmitted by the belt no slippage or creep that can in any way be detected takes place.

Of much value in sectional paper-machine drive and fundamental in this electrical speed differential field regulator system, is the fact that the section motors do not have to oscillate in speed to maintain the proper mean regulating resistance values; nor does any other part of this control system oscillate. The motors operate at a constant uniform speed and the exact mean effective regulating resistance values required for uniform motor speeds at any desired value are obtained by the constantly rotating tapered conducting segment of the drum of the section rotary contactor.

With the twelve steps of regulating resistance normally employed in the design of the rotary contactor, resistance values sufficiently high to meet every requirement of electrical sectional paper-machine drive can be used with practically no visible sparking at the brushes and with negligible wear of brushes or drum. The mechanical movement between the screw and nut of the rotary contactor is so small that there is practically no wear of those parts.

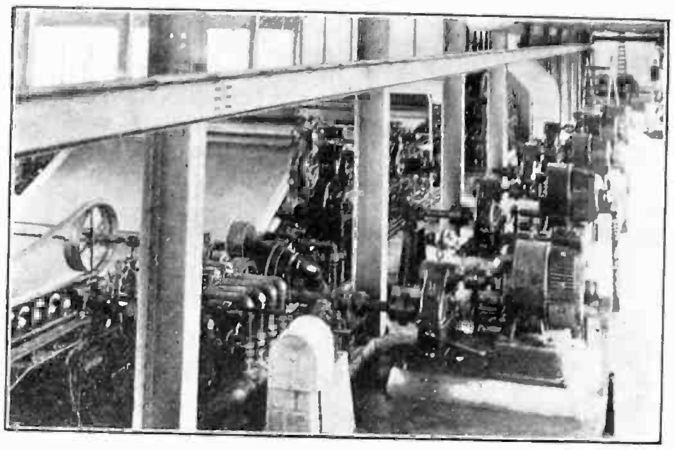


FIG. 12—SECTIONAL PAPER MACHINE DRIVE INSTALLATION OF ELECTRICAL DIFFERENTIAL TYPE, FIELD CONTROL, SPEED REGULATOR SYSTEMS

In order that the screw member may readily reengage with the nut member of the section rotary contactor, should it run out of engagement in shutting down or starting up, small helical springs are so disposed within the drum that they come into engagement and begin to compress just before the screw leaves the nut so that there is a sufficient force to cause the reengagement of the screw and nut as soon as the speeds of the respective members are such as to permit.

Full automatic push-button control of starting and stopping operation, "inching" and changing of "draw," as well as the adjustments of the speed of the machine as a whole for any paper speed within its range, adds greatly to the flexibility and makes the equipment practically fool-proof.

Rumors have been heard of the development in Europe of an a-c. type of electrical sectional paper machine drive wherein commutator-type variable speed a-c. motors are understood to be used for driving the paper-machine sections; with a differential mechanism for automatically shifting the motor brushes to control the relative speeds of the section driving motors; and by changing the master speed to effect speed adjustment over the entire range of the paper machine. Information is not at hand to confirm the successful installation and performance of this type of drive and control.

The use of electrical sectional paper machine drive has made possible the operation of paper-making machines economically at higher speeds than was possible with existing mechanical systems of drive. This was largely due to the rather limited amount of power that can be transmitted by means of cone pulleys and belt drive. With electrical sectional paper-machine drive a very considerable saving in power is accomplished and maintenance is reduced to a minimum as compared to mechanical drive. On account of the elimination of belt slippage and sectional speed variations incident thereto, breaks in the paper are greatly reduced and the operating efficiency materially increased. More exact speed regulation throughout is made possible and many other distinct advantages in specific cases and kinds of paper machines and types of product have added greatly to the general efficiency, flexibility and operating technique in the modern paper-making machines.

The object of this paper has been to chronicle the advance in the art of electrical sectional paper-machine drive and control, to indicate the several more or less distinct lines of development; to outline the outstanding characteristics of each of the several types and to point out novel and rather unique methods, so far as the author knew, for obtaining speed regulation of great precision and for the making of d-c. motors to operate at synchronous relative speeds.

The author wishes to express his appreciation of the privilege of using in this paper illustrations kindly furnished by the following: Vocational & Educational Committee of the Paper Industry and McGraw-Hill Book Company, Publishers of "Manufacture of Pulp and Paper." The Paper Mill and Wood Pulp News. The General Electric Company. Westinghouse Electric & Manufacturing Company.

# Discussion at New York Section Meeting

## HYDROGEN AS A COOLING MEDIUM FOR ELECTRICAL MACHINERY[1]

(Knowlton, Rice & Freiburghouse)

New York, N. Y., October 23, 1925.

**G. E. Luke:** In determining the probable temperature rise of any electric machine, we may first start with the calculation of the volume of fluid necessary to be circulated through the machine in a given time.

Thus, comparing air and hydrogen as possible fluids, the volume of hydrogen required will be only 2 or 3 per cent more for hydrogen than for air, on the basis of the same temperature rise of the gas due to the same loss absorbed. This temperature rise in the gas used should not be over one-half of the maximum temperature rise of the ventilating surfaces.

The ventilating-surface temperature can be calculated, when the surface-heat-transfer coefficient ($K$) is known. Considerable data regarding this constant ($K$) are available for air[2]. However, little experimental data are published for hydrogen. Some experimental tests by Rice[3] on a small cylinder (axial flow) gave a heat transfer for hydrogen 137 per cent of that for air at an average velocity of 5000 ft. per min. On the other hand Rice[4] gives for large plane surfaces this heat transfer ($K$) as proportional to $\frac{\rho\, k}{\mu}$, where $\rho$, $k$, and $\mu$ are the density, thermal conductivity, and viscosity of the gas, respectively. On this basis, the unit heat transfer from the surface will be about the same for hydrogen as for air.

Pohl[5] has calculated from Nusselt's[6] work this coefficient ($K$) to be about 50 per cent greater for hydrogen than for air. The equation given by Nusselt can be reduced to the form[7] of

$$K \,\alpha\, k^{n-1} \quad (\rho\, C_p\, V)^n$$

where

$K$ = unit surface heat transfer
$k$ = thermal conductivity of the gas
$\rho$ = density of gas
$C_p$ = specific heat of gas
$V$ = velocity of gas.

This equation is also practically the same as that given by Pohl. Thus, the ratio of the heat transfer with hydrogen to that obtained with air will depend upon the exponent ($n$) of the velocity factor. Thus, with ($n$) = 1, the ratio is about 98 per cent and with $n$ = 0.786 as given by Nusselt the ratio becomes about 150 per cent. The writer has found that for turbulent gas flow where the gas path is straight and uniform, the heat loss varies as $V^{0.85}$ to $V^{0.95}$; and where the air path is irregular the unit heat loss varies as $V^{0.75}$ to $V^{0.85}$. Hence, it is estimated that in an average generator the unit heat dissipated with hydrogen will be about 25 per cent greater than with air, which is not far from the figure given in the paper.

The paper states that the rate of heat transfer in the coolers should be about three times greater for hydrogen than for air. This figure seems too high; it might be correct for the tubular surface but is probably too high for the fin surface, and this later surface is usually several times greater than the tubular surface. The writer estimates the heat transfer in the usual type of cooler to be 50 to 100 per cent greater for hydrogen than for air. This, of course, is a big factor since the cost and size of the present cooler can be reduced.

The majority of the iron and copper losses in the core have to flow an appreciable distance through the iron to the ventilating surface. This necessarily requires a temperature drop. Where radial ventilation is used, the heat flow is mainly across the lami-

1. A. I. E. E. Journal, July, 1925, p. 724.

2. See *Cooling of Electric Machines*, by G. E. Luke, Trans. A. I. E. E., 1923, p. 635-636.

3. See *Free and Forced Convection of Heat in Gases and Liquids*, Trans. A. I. E. E., 1923, p. 653.

4. Forced Convection of Heat in Gases and Liquids, Eng. & Ind. Chem., May, 1924.

5. "Fundamentals of Heating Calc.," by R. Pohl, *Arch. f. Electro*, June 30, 1923.

6. "Heat Transmission in Conduits," by W. Nusselt, Z. V. d. I., October 23, 1909.

7. This was done on the basis of ($K$) being independent of the temperature of the gas and surface, which is practically true of the range in which we are interested.

nations, in which direction the heat flow has a high-resistance path due to the varnish and gas film between the laminations.

With one-watt flow across a 1-sq. in. section of the usual 0.017-in. varnished iron laminations, the temperature drops are approximately:

Deg. cent. drop through

| Iron | Varnish | Gas | | Total |
|---|---|---|---|---|
| 1.0 | 11.0 | (Air) | 21.0 | 33 deg. cent. |
| 1.0 | 11.0 | (Hydrogen) | 3.0 | 15 deg. cent. |

Hence the rate of heat flow across the laminations should be at least doubled by using hydrogen as the cooling medium.

One of the most important portions of the heat-flow path is from the copper through the insulation. This part has more influence in limiting the rating than any other since the thermal conductivity of insulating materials is so low. The thermal resistance through ordinary insulation in air is about 3000 times greater than that through copper. All insulation in the built-up wrapper will necessarily contain some small gas spaces; hence these gas spaces, if they are air, will offer considerable resistance to the heat flow, since the thermal resistance of air is about ten times that of the insulation itself.

To check the above, the Westinghouse Research Laboratory has made tests on the thermal conductivity of the insulation on turbo armature coils. The results show that the thermal conductivity of these mica insulations as used is from 150 per cent to 250 per cent as great with the coils in hydrogen as obtained on the same coils in air. The particular ratio depends upon the compactness of the insulation; that is, the percentage gas space in the wrapper. This increase in heat flow with the hydrogen cooling system will result in a considerable reduction of the conventional "hot spot."

The temperature of the rotor copper is usually the limiting temperature, with air as the cooling fluid. It will also tend to be the limiting factor when hydrogen is used, due to space limitations and to appreciable temperature drops through the solid iron core which will be unaffected by the gas used for cooling.

In the tests given by the writers, the apparatus simulated conditions found in a solid rotor, where there would be a considerable temperature drop through the iron. However, in a ventilated rotor, even better results could be expected, since this drop through the iron would be reduced.

Comparative Corona Effects Under 15,000 Volts for 19 Days.

As to the insulation, the writer also agrees with the authors, that its life would be materially increased in a hydrogen atmosphere. Oxygen in the air is the main factor which causes mechanical deterioration. Dr. C. F. Hill made tests regarding the corona action upon insulation in air and in hydrogen. The results were even better than those quoted in the paper in favor of hydrogen. Two kinds of insulation were tested; one varnished cambric, the other a mica wrapper. Both were wound on a glass tube and 15,000 volts a-c., 60 cycles, was applied for 19 days. Most of the stress was through the glass tube but a heavy corona could be seen covering the insulation. At the end of the test, the sample in hydrogen was unchanged, while the one in air was radically altered. The varnished cambric was bleached and was very brittle, the paper in the mica wrapper was completely destroyed. The hydrogen prevented the chemical action found on the sample in air.

As to the possibility of explosive mixtures with hydrogen, the average of nine investigations[8] gives the explosion limits as 7.9 to 69.4 per cent hydrogen in a hydrogen and air mixture.

An indicating or recording instrument for giving the purity of the mixture can be easily obtained by using the conductivity-cell bridge method[9]. This is exceedingly accurate and is well suited for such purposes.

Gases other than hydrogen can be used for a cooling medium. Thus helium, (if made available in the future) is an inert gas with a density about 1/7 of that of air. Its specific thermal capacity is about 73 per cent of that of air and its thermal conductivity is almost as high as that of hydrogen. Such a gas would be preferable to the operating men.

**L. B. Bonnett:** From the user's point of view, there are some very striking things in this Table II, showing the results of the tests on the small 3000-kv-a. machine. If we can expect to get a one-third increase in capacity out of the same material, presumably at approximately the same price, we are getting something that is very interesting indeed. At that increased rating the total loss is practically the same, in fact, it has slightly decreased.

Looking at it from a little different point of view, many of us use stand-by machines that are in operation ready to take load and the no-load losses are a very important factor. If the use of hydrogen can reduce those losses by say 50 per cent, that indeed is a very great advantage for this particular duty.

This light-load loss too, has another rather interesting application. Turbo-generators are commonly equipped with closed ventilation and air coolers and very frequently condensate is used for cooling. Since the light-load losses are usually more than half the full-load losses, the condensate at light loads has to be recirculated in a more or less complicated fashion or some other means of cooling supplied. This very great reduction in the fixed losses would mean that the losses would decrease more nearly in proportion to the load and the condensate itself might be perfectly adequate for cooling the machine all the way down.

With all the advantages mentioned in this paper,—a real astonishing catalog of advantages,—it behooves us, the users, not to be too sure that the one disadvantage, the possibility of an explosion, is an insurmountable defect. I believe our serious consideration is well worth while.

**W. B. Kirke:** It is hoped that further investigation on the life of insulating material when operated in hydrogen as compared to operation in air can be made. It might be found quite practical to operate at higher temperature limits in hydrogen than have been standardized for operation in air. It is also to be hoped that this paper will be supplemented by others which will indicate the installation cost of such a ventilating system, and some idea of the equipment necessary for its operation.

**C. J. Fechheimer:** A few years ago the only media for cooling considered were air, oil and water. The use of oil or water has never met with favor in this country, even though certain important advantages could be secured by their adoption. It seems that electrical engineers were not aware until a few years ago that the gains to be obtained by means of some other gas were sufficient to warrant employing it instead of air. Even after the suggestion of the use of a lighter gas was offered to the designing engineers, they did not immediately consider its adoption. The gas proposed in the Schüler patent is hydrogen, and the first thought that entered the mind of the engineer was the danger of explosion. It was not until he learned that

8. See article by C. J. Rodman, *Elec. World*, 6-24-22.

9. Thermal Conductivity for Analysis of Gases. Technical Paper, Bureau of Standards, No. 249.

detonation will not occur if hydrogen constitutes more than about 70 per cent of a mixture with air, that he felt that possible gains were great enough to warrant investigation. We now have records in this paper of the studies and researches given by three engineers of one of the leading electrical manufacturing companies on this subject. It is the first public presentation to a group of engineers of a systematic study of this advance which it is believed will considerably modify the design and construction of large electrical machines in the future.

Of the various gains to be obtained by means of hydrogen, there are two of prime importance. The first is the enormous reduction in windage loss due to the low density; and the other is the decrease in thermal drop through the insulation. In the large high-speed steam turbo alternator the windage is the greatest loss and may be as high as 50 per cent of the total. By substituting hydrogen for air this loss becomes almost negligible. In addition to the gain in efficiency, the temperature rise due to the windage becomes insignificant, whereas in the present day machine it is from 5 to 10 deg. cent.

It has been recognized for a number of years that the tiny voids in insulation reduce the net thermal conductivity of the wrapper to about 50 to 75 per cent of that which would obtain if the wrapper were solid throughout. Now we find that, because hydrogen diffuses so readily, hydrogen will supplant the air and the resistance to heat flow in the voids will be decreased to about one-seventh, and the net conductivity will be greatly improved. The authors find 30 to 58 per cent improvement in net conductivity for the field core, and they estimate about 42 per cent gain for the armature coil. Also, because the thermal conductivity is high, the transverse drop through a package of laminations is reduced and the drop from the surface is decreased. So the authors find that as a result of all the gains, a certain turbo-alternator can be rated about 30 per cent higher by substituting hydrogen for air. But that is not the final word; to take full advantage of the properties of hydrogen, the machine should be proportioned differently. For example, the velocities of the gas in the vent ducts can be increased, and the lamination-package thickness can be enlarged. Owing to the reduction in total losses, the volume per unit time of the gas may be lowered.

Also, as the authors state, there is a likelihood of reducing thickness of insulation wall in the stators, when mechanical considerations do not enter. At present it is difficult to state how much the weight, cost and size of the generator may be decreased, if full advantage of all gains is taken in the design. But certainly the cost will be reduced considerably.

There are a few points which are not covered in the paper. Two will be mentioned. In very large machines as designed at present, it is not feasible to evacuate in order to replace the air by hydrogen or vice versa, as the stresses arising from atmospheric pressure are prohibitive. While it is possible so to proportion those parts as to prevent collapse while evacuating, it is believed that an alternative plan which will maintain all parts at or near atmospheric pressure should be entirely satisfactory. The plan is to replace the air by an inert gas, such as nitrogen, and then to replace this inert gas by hydrogen. Tests are now being conducted for determining how satisfactorily this can be done.

Another feature is that to minimize leakage, suitable stuffing boxes should be provided where the shaft passes through the openings in the end bells. It seems at present that this is the most difficult part of the problem. Experimental work is now under way on a water-gland seal; and with this device it is believed that the leakage will be negligible. Ample precautions are being taken to avoid the escapement of water into the generator.

The authors have used the thermal-conductivity method for determining the extent to which the hydrogen is contaminated. Another method consists of a small fan driven at constant speed, the inlet and outlet of which join into the system. The pressure which the fan generates is directly proportional to the density of the gas, and the pressure difference between the inlet and outlet can readily be indicated on an ordinary manometer. The relation between the percentage of hydrogen and the reading on the manometer is linear, assuming that air is the contaminating gas. The authors state that with the thermal conductivity method, 1 per cent impurity will change the potential drop from 11.5 to 12.5 volts or 8.7 per cent. With the density method, the same change in constituency will alter the manometer reading 13.3 per cent. Thus, there is greater sensitivity, and it is believed that the device is more direct and simpler than the thermal method. The density method can be used to operate a signal, or possibly to operate switches automatically.

While further experimental work must be done prior to the building of machines for service, the outlook is very bright, and it is believed that the time is not far distant when machines using hydrogen will be in operation.

**J. Rosen** (communicated after adjournment): The authors' investigations into the difficulties of ventilation of electrical machinery will be welcome as being of theoretical interest, more particularly as they have some bearing upon the conditions for generating at higher voltages than have been customary in the past. I do not think, however, that the use of hydrogen can be considered practicable at the present moment. It has the drawback of increased cost and complication in design. Further, I do not think that the danger of forming an explosive mixture can be altogether avoided. The closed-circuit system of ventilation has now been generally adopted for large alternators. The advantage with the use of hydrogen in avoiding the danger of fire also applies to the closed-circuit system using air, as, with the limited amount of air in the latter, the damage that can be done by fire is limited. I illustrate this by the following example:

The volume of air in the alternator and ducts of the closed-circuit system of a 25,000-kv-a. alternator at 3000 rev. per min. is approximately 2000 cu. ft. containing 40 lb. of oxygen. This quantity of oxygen could consume 15 lb. of carbon or 40 lb. of wood, but as the principal product of combustion is carbonic acid gas, and a flame is extinguished when only 4 per cent of carbonic-acid gas is present, the amount of wood consumed would only be about 2 lb. The total weight of combustible material in the alternator, including wood packing and insulation exceeds 1000 lb. It is obvious therefore that the fraction of material that would be damaged, or consumed by fire would be negligible.

To reduce the losses in the fans attached to the rotor body, I prefer to use separately driven fans, and to adopt a suitable system of ventilation to reduce the pressure drop through the alternator to a minimum. By this means, an improvement in efficiency of one per cent can be obtained. In the ventilation scheme described in the paper[10] "Some Problems in High-Speed Alternators and their Solution," the air-pressure drop through the alternator is reduced to approximately 3-in. water gage.

**Robert Pohl:** The valuable research which Messrs. Knowlton, Rice and Freiburghouse publish on this subject might, with advantage be extended to the use of methane. In a paper published in 1923 (*Archiv. F. Elect.*, June 30, 1923, p. 361) I defined what one might term the cooling constant of various gases and showed that this constant is even higher for methane than for hydrogen. Since methane is also cheaply obtained as a by-product, its use may well be considered. Although the risk of explosion is not serious in any case the much smaller area of "exploibility" would be a practical advantage.

**E. H. Freiburghouse:** From the discussions it is evident that other engineers have also been giving active consideration to the subject and almost all of them seem very optimistic for the future use of hydrogen as a cooling medium for electrical machinery.

Opinions and data which have geen given seem, in the main, to agree quite well with those given in the paper. Although the

10. *Journal I. E. E.*, Vol. 61, No. 317, p. 447-8.

points raised by Mr. Fechheimer were not covered in the paper they have been carried out or considered during the investigation by the authors.

Mr. Fechheimer mentions the use of an inert gas, such as nitrogen, for replacing the air and hydrogen in the generator before and after the installation of the hydrogen. Nitrogen was used for this purpose during the heat tests which were made upon the 3380-kv-a. generator.

It was realized from the beginning that to prevent the leakage of hydrogen between the rotating and stationary parts of the generator was the most difficult and expensive problem to solve. Two different types of seals have been developed each of which reduces the leakage to a negligible value. In the liquid seal it is thought that oil is preferable to water.

A small fan driven at constant speed was used in some of our earlier investigations to determine the density of the gas mixture and, as Mr. Fechheimer states, it has several attractive features.

If hydrogen is used as a cooling medium, the authors believe that Mr. Rosen will agree that fans upon the rotor of the generator are preferable to separately driven fans. We believe that the pressure drop of the air through the generator should greatly exceed the 3 in. of water which Mr. Rosen mentions, if the necessary velocity of the air is obtained for a high value of unit-surface heat transfer.

## THREE-PHASE, 60,000-KV-A. TURBO ALTERNATORS FOR GENNEVILLIERS

(Edouard Roth)

New York, N. Y., October 23, 1925.

**W. F. Dawson:** The author is to be particularly congratulated on the production of a very fine machine. It has shown low heating, many novel and ingenious ideas, good mechanical engineering, and, I should say, very good efficiency. But there is one feature of the design that is quite startling to us in the United States. I know I speak for myself and for my immediate colleagues although I do not know that I speak for other manufacturers in this country.

Mr. Roth has laid particular stress on the fact that, by means of his leakage slot, he has achieved very low short-circuit current, current as a result of sudden short circuit. He has also pointed out that he has done this in preference to using very high armature reaction and a correspondingly low flux. Nevertheless, his armature reactions are proportionately higher than we would feel safe in using.

If we go back to the *Electrical Review* of London, April, 1923, we find there the saturation and impedance curves (page 646, issue of April 27th, 1923). The "saturation," 6000 volts is, expressed in field amperes, about 136 amperes. The short-circuit impedance at 4200 amperes is approximately 270 amperes. We feel that in designing alternators, particularly those to carry inductive load, the excitation required for normal ampere short-circuit impedance should not be much in excess of the excitation required at normal open-circuit voltage.

I understand that it is the practise of many European designers to allow a high short-circuit impedance, making a machine in which the full-load field excitation is three times the open-circuit excitation.

I also understand that somehow in general they are successful with it, probably because the increment of the load is small compared with the total load and perhaps, too, because of the more general use of automatic voltage regulators. I have had at least two or three glaring cases in my own practise, in which, before I realized the importance of designing for "voltage stability," the voltage would break down at or about full load. One case was in a cotton mill where one turbo alternator was carrying the entire load of the mill and, according to the calculations which I learned later how to make, the machine should have had a voltage breakdown at about 2300 kw.; it was rated at 2500 kw. I furnished a new armature which had lower armature reaction and, of course, higher flux, and the trouble disappeared.

I have had other cases into which it is not necessary to go; we have also noticed it particularly in the case of ship propulsion machines where one turbo alternator is to take care of the induction-motor load. That machine, or a group of machines, will be running along satisfactorily, but rough sea will increase the load on the motors and the voltage falls faster than the amperes increase, hence the kv-a. is reduced and the motors break down.

I should like the author to tell whether he has had any such experience?

**Philip Torchio:** Mr. Roth's paper gives an excellent illustration of the progress in large turbo alternator design. Some of the special features of his machines will undoubtedly be commented upon by expert designing engineers. From an operator's standpoint, I wish to express my sincere appreciation of the remarkably low temperature rises of the copper in the stator and the rotor. The long narrow slots with an abundance of radiating area, the winding bars of the armature, with their careful assembling to eliminate eddy-current losses and a combination of axial and radial ventilation, have been used to secure results which are superior to any with which I am acquainted. In making this statement I wish to add that I have not had the time to analyze closely how much the results are influenced by the differences in number of poles and the relative capacities of the machines compared. Mr. Roth has already mentioned how the difference in number of poles for machines of same capacities affects the total weights of such machines. Undoubtedly to some extent the number of poles imposes limitations upon the temperature rises. The employment of leakage slots may, however, be of a decided advantage in giving remarkably low temperature rises.

As to the advantage of reducing the short-circuit current, I shall be very much interested to learn of the comments of designing engineers. In our practise we have, for more than 13 years, considered it essential to the safe operation of a large system to install reactors between generators and buses so as to protect the main bus against sort-circuit failures in generator windings. In such installations, therefore, the reduction of short-circuit current on sound generators is limited by the external reactors, and designers may not find it necessary or desirable to employ leakage slots. This is a problem that should receive consideration in the discussion.

**C. M. Laffoon:** These generators are unique, in that certain design features are carried to rather extreme limits. The author states that the 45,000-kv-a. turbo generators, which were installed in the Gennevilliers station in 1922, were the largest four-pole turbo generators built, up to that time. This statement is somewhat liable to misinterpretation because these are 50-cycle machines and the design and construction of a given size, four-pole generator, operating at 1500 rev. per min. are not so difficult as the design and construction of a four-pole, 60-cycle generator which operates at 1800 rev. per min. At the time these Gennevilliers generators were installed, they were rated at 40,000 kv-a. At the same time the Westinghouse Company was installing the first of the Hellgate generators, which were rated at 43,750 kv-a., but were six-pole, 1200-rev. per min. The Westinghouse Company has since built generators of this same kv-a. rating but of four poles, 1800-rev. per min. Recent tests on these generators show that they will carry 50,000 kv-a. at 80 per cent power factor and do not exceed the standard guarantee of 60 deg. cent. temperature rise on the armature winding and 90 deg. on the field winding. The Westinghouse Company has also built 62,500-kv-a. generators for the Brooklyn Edison Company, but these were of six poles and 1200-rev. per min. At the present time a four-pole, 1800-rev. per min. 62,500-kv-a. 80 per cent power factor turbo generator is being developed by the Westinghouse Company and 1800-rev. per min. generators with ratings as high as 75,000 kw. and 90 per cent power factor appear feasible to build and operate.

It is to be noted that this generator is being wound for 6000 volts, which is a relatively low voltage for 60,000-kv-a. rating. In the United States the majority of central stations generate at voltages varying from 11,000 to 13,800 and with some companies there is a decided tendency to specify a final insulation test voltage of three times normal plus 1000 instead of the standard insulation test of twice normal plus 1000. However, some utility companies are considering the advisability of having generators wound for lower voltages and solidly connecting the generators to step-up transformers without any intermediate circuit breakers. In this case the final insulation test voltage would be on the order of four times normal plus 1000. On the other hand, other companies in the far west are considering 16,500-volt generators. At the present time there does not appear to be sufficient data available to determine the maximum voltage stresses due to switching, short circuits, and lightning to which the generator windings may be subjected during actual service conditions. Until these data are available, it will be difficult to determine the voltage and insulation strength which will give the greatest protection against over-voltages and still not seriously affect the cost and the reliability of operation from the standpoint of temperature.

In going over this paper the following outstanding features are of paramount importance.

1. Small physical dimensions.
2. Low short-circuit ratio, i.e., a low ratio of no-load field ampere-turns to the field ampere-turns which are required to maintain full-load sustained armature current.
3. High leakage reactance.

In comparing the physical dimensions of this 50-cycle generator with those of a four-pole, 60-cycle, 1800-rev. per. min. generator of the same kv-a. rating, it is noted that the overall length of the active iron including the ventilating ducts is considerably less than that required for the 60-cycle generator. This is partly due to the fact, as previously indicated, that, for a given rotor diameter the design and construction of a 50-cycle generator are less difficult than they are for a 60-cycle generator of the same rating and number of poles. Since the mechanical stresses in the rotor body and retaining rings are proportional to the square of the peripheral speed, approximately 20 per cent more ampere-wires per inch of wound periphery can be obtained for a given rotor diameter for the 50-cycle generator than for the 60-cycle generator on the basis of the same number of poles. In either case for a given short-circuit ratio, the kv-a. output is proportional to the product of the total flux, rotor ampere-turns, and rev. per min. Hence, the length of the active iron of the 50-cycle generator would be appreciably less than that of the 60-cycle generator and would be equal to that of the 60-cycle generator multiplied by the inverse ratio of the total flux in the machine. Since the iron loss varies approximately as the second power of the flux density and about as 1.2 power of the frequency, the relative total flux for the two cases will depend on the effectiveness of ventilation for each generator. An examination of the temperature data of Table 1 shows rather high stator-iron temperatures as compared to the temperatures on the bare copper. This indicates that the stator iron is worked at rather high magnetic induction and consequently this feature also tends toward a short machine.

From Fig. 13, the short-circuit ratio of this 60,000-kv-a. generator is approximately 0.475. This same value was obtained from the specified dimensions and design data which were given for the armature and field windings. The short-circuit ratio of a Westinghouse generator of the same rating would be on the order of 1. Similarly, the full-load field ampere-turns are approximately 3.1 times the no-load field ampere-turns, whereas, in the case of the Westinghouse generator, the ratio is about 2 to 1. This means that the armature ampere-turns are high as compared to the no-load field ampere-turns and a small change in the armature load current produces a large change in generated voltage and kw. output. Fig. 2 herewith shows the relation between armature current and voltage, armature current and kw. output, and kw. output and voltage for the 60,000-kv-a. Gennevilliers generators and for a 62,500-kv-a., 60-cycle, 1800-rev. per min. generator with the field excitation corresponding to full rated kv-a. at 80 per cent power factor. The curves for the 60,000-kv-a. Gennevilliers generators were determined from the specified design data and physical

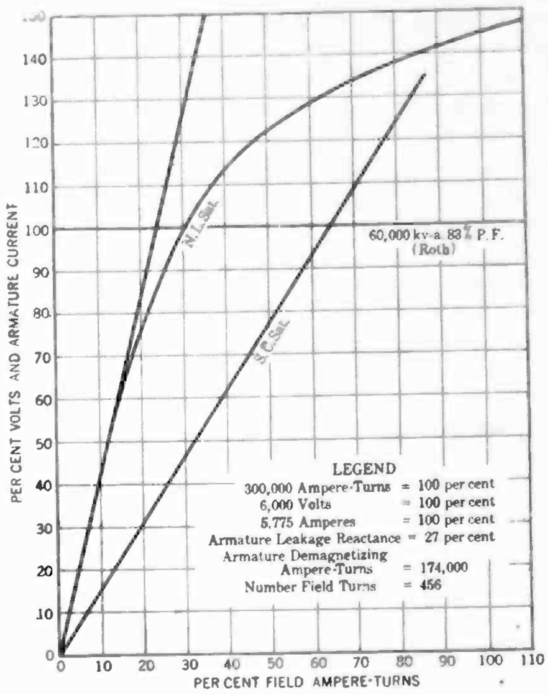



FIG. 1—NO LOAD AND SHORT CIRCUIT SATURATION CURVES 60,000-KV-A., 50,000 KW., 83 PERCENT POWER FACTOR 6000 VOLT, 50-CYCLE, 1500-REV. PER MIN., 5775-AMPERE GENNEVILLIERS GENERATORS

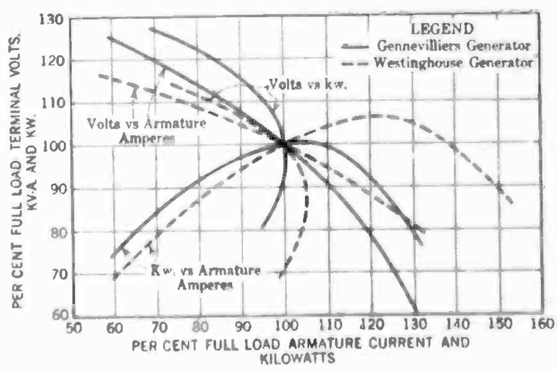



FIG. 2—LOAD CHARACTERISTICS FOR 50,000-KW. TURBO GENERATORS 80 PERCENT POWER FACTOR AND CONSTANT FIELD EXCITATION

dimensions of these machines, and the no-load and short-circuit saturation curves of Fig. 1 herewith. The curves in Fig. 1, are the same as given in Fig. 7 of the paper for the 45,000-kv-a. generators but modified to suit the design constants of the 60,000 kv-a. generators. An analysis of the load curves in Fig. 2 shows the following comparison of the stability characteristics of the two generators when operating at 7 per cent power factor loads, and with a field excitation corresponding to full-load 80 per cent power factor conditions:

1. The maximum kilowatt output of the Westinghouse generator is 108 per cent whereas that of the Gennevilliers generator is only 100.5 per cent.

2. The Westinghouse generator will deliver 100 per cent kilowatt output with an armature-current range of 100 to 138 per cent, whereas the Gennevilliers generators will deliver full kilowatt output over an armature-current range of 100 to 108 per cent only.

3. The rate of change of terminal voltage with respect to kilowatt output, at the point of 100 kw. output, is approximately five times as great for the Gennevilliers generator as for the Westinghouse generator.

This comparison shows that the Gennevilliers generators, which are designed with a low short-circuit ratio and much more sensitive to sudden changes in load than the Westinghouse generators which have a short-circuit ratio which is more than twice as large. Hence, when operating alone or in parallel with other generators which have the same characteristics, it would be necessary to provide voltage regulators in order to maintain reasonably constant voltage for rapidly changing loads on the system. The application of quick-acting voltage regulators to these machines is difficult because of the extremely wide range in field current required in going from no-load to full-load operating conditions.

If these generators were operated in parallel with other generators which have greater stability under changing load conditions, that is short-circuit ratios of 1 or more, it would be necessary not only to provide high-speed voltage regulators but the characteristics of the voltage regulators and of the governors on the driving turbines would have to be carefully designed to meet the particular conditions. But even then, there is always the possibility that hunting action may take place between the generators with poor and good regulating characteristics and reach such magnitudes as to cause the machines to pull out of step.

In the case of high-voltage transmission system the design of the generators should be such that the armature ampere-turns are small as compared to the no-load field ampere-turns; that is, the short-circuit ratios should be high.

A generator designed with a low short-circuit ratio has considerably smaller dimensions than one designed for a high short-circuit ratio on account of the fact that the portion of the field ampere-turns which is used to give stability in the high short-circuit ratio machine is used to give kv-a. output in the case of the generator with the low short-circuit ratio. There is no doubt but that generators with short-circuit ratios as low as 0.475 can be operated satisfactorily with hand regulation on systems which have reasonably smooth load curves, as well as with automatic voltage regulators on systems with varying loads, provided the voltage regulators and turbine governors are designed with the necessary characteristics. However, there is no doubt that such generators require careful attention and are likely to give trouble during transient disturbances or sudden load changes. The extent to which it is desirable to reduce the short-circuit ratio, and hence increase the output for given physical dimensions depends, to a large extent, on the load characteristics of the system on which the generator is to operate, the characteristics of the generators which operate in parallel, the characteristics of the voltage regulators and turbine governors, and the amount of attention the operators give to the machine. Our own experience and observation indicate that turbo generators which have short-circuit ratios of approximately unity give satisfactory operation on the average central-station system in this country. However, this value of short-circuit ratio can and must be widely departed from in the case of generators which operate on systems or central stations in which greater or less generator stability is necessary.

The leakage reactance of the armature winding of the Gennevilliers generators is unusually high for turbo generators. A large portion of this reactance is obtained by providing leakage slots immediately above the slots for the main winding. If it is necessary to limit the initial values of short-circuit current to values comparable with those delivered by slow-speed waterwheel-type generators and the reactance must be within the generator, this is an attractive method of obtaining a high reactance. The mechanical forces on the end turns are reduced and the increase in reactance due to the air slots does not materially increase the iron loss in going from no-load to full-load conditions. However, it must be remembered that the use of these slots increases the over-all diameter of the machine, the cost, and the value of the iron losses. The increase in diameter and cost are partially offset by the fact that more room is obtained for the armature copper. An increase in diameter not only adds to the weight but also the shipping difficulties. The iron loss in the stator teeth is usually about one-half of the value of the loss in the core. The additional tooth projections increases the iron loss in the stator teeth about 60 per cent and this corresponds to an increase in the total iron loss of approximately 20 per cent. In the case of particular generator, the additional 20 per cent increase in iron loss corresponds to 0.15 to 0.20 per cent reduction in the generator efficiency.

The leakage reactance of a 60-cycle, 1800-rev. per min. Westinghouse turbo generator of the same rating would be from 15 to 18 per cent, and the end turns of the armature winding are sufficiently well braced to withstand a three-phase short circuit at the generator terminals under no-load initial conditions and 110 per cent of normal rated voltage, as required by the 1925 A. I. E. E. Standards. So far as the initial values of the short-circuit currents are concerned, this condition corresponds very favorably with the actual conditions under full-load operation. In machines of this class the percentage of winding failures due to short circuits has been very small. In general we feel that the end turns can be sufficiently well braced to withstand short circuits that occur under usual operating conditions when the leakage reactance of the generator is 10 per cent and above. If still greater protection is desired it can be obtained by making further improvements in the bracing instead of increasing the leakage reactance by a method which involves an increase in cost and overall diameter, and a decrease in the generator efficiency of 0.15 to 0.12 per cent.

A comparison of the temperature rises obtained by detectors C, 10, and 12 show that when carrying 50,200 kv-a., the temperature rise on the bare copper at the midway axial position is only 37.5 deg. cent or 10 deg. higher than the temperature rise of detector placed between the conductor sections. Using this same temperature difference, the temperature rise of the bare copper near the ends of the machine would be 50 to 56 deg. cent. The iron temperatures vary over quite a wide range, being particularly high in the teeth at the ends of the machine and in the core at the middle of the machine. The temperature rises of the armature and field windings compare very favorably with corresponding temperatures obtained on Westinghouse generators which have a similar system of ventilation. This particular form of the multiple-path radial system of ventilation is exceptionally well worked out from the standpoint of utilizing the frame space behind the stator punchings, and gives excellent results in stator and rotor ventilation. The air requirements for the generator are approximately 105,000 cu. ft. per min. and the author states that approximately 26.5 per cent of the air passes through the rotor body. This is an unusually large percentage for the rotor and no doubt is responsible for the low temperature of the field winding.

In order to determine the losses of turbo generators when operating under normal load conditions, it is necessary to know the volume of cooling air and its temperature rise for any particular load condition. Various methods have been suggested and used for measuring the amount of air passing through the machine. When the air discharges to the atmosphere the air volume can be determined with a good degree of accuracy by measuring the velocity head at the discharge from a specially designed stack or nozzle. The discharge velocity can be made practically uniform over the entire discharge section by properly designing the stack and passing the air through fine-mesh screens as it leaves the generator. However, the most promising method is the one suggested by the author, in which the generator is operated as a synchronous motor under no-load conditions and the electrical input and final temperature rise of the cooling air are measured for two widely different values of voltage. If temperature detectors of the thermocouple or resistance type are properly placed in the inlet and outlet air ducts and due care exercised in making the measurements, the air volume can be determinded with a satisfactory degree of accuracy. Since most large turbo generators cannot be tested at the manufacture works under normal load conditions, it seems very essential that all such generator units should be so arranged that the steam end can be disconnected and the generator operated as a synchronous motor. The operating companies should have sufficient interest in the performance of the machines to be willing to cooperate with the manufacturers in making the tests.

Briefly summarizing, the 60,000-kv-a. turbo generators as described by Mr. Roth are exceedingly interesting on account of:

(1) The small physical dimensions which result from the following:

a. The generators are designed for 50 cycles at 1500 rev. per min., and consequently the stator iron can be worked at a higher magnetic induction than in a 60-cycle generator;

b. The short-circuit ratio is unusually low; that is, the portion of the field ampere-turns which is used to give stability in the case of a Westinghouse generator is used to give kv-a. output in the Gennevilliers generators; and

c. The ventilating system provides excellent cooling for both stator and rotor.

(2) Low short-circuit ratio, which results in a machine that is sensitive to load changes and is likely to be very unstable when operated on a system with rapidly changing load. The application of voltage regulators is more difficult on account of the wide range of exciting current which is required for a given load change.

(3) The high armature leakage reactance, which is obtained from the additional slots, provides short-circuit protection and the additional reactance which is secured does not materially increase the core loss under stable load conditions. However, this method of obtaining high reactance involves an increase in cost and overall diameter, and 0.15 to 0.20 per cent reduction in generator efficiency.

**C. J. Fechheimer:** A few points of interest in this paper will be pointed out in this discussion.

1. The scheme of stator ventilation is unique, as the circumferential system is combined with the axial system. The air which flows circumferentially does not pass through the stator teeth and into the air gap, but the air that flows axially first flows radially inward and then axially through the leakage slots.

Referring to Fig. 2 you will notice that at the back of the core through which the air passes first axially to get into the radial slots, there are eight openings distributed about. The air passes down, radially, in the vent ducts and then, in the same vent ducts, some passes around circumferentially and goes out. Some of the air goes farther radially between the coils and gets into the leakage slots and then moves axially. You see that on one side are shown one kind of guide for the air and on the other side of the line, the guides are arranged differently. Now on the right side of the line, the guides are for the air coming in, and to the left they are for the air going out; that is, the air moves axially and then out, radially, in the next vent duct; and that is the one at 45 deg. to the left of the division line. It moves axially through the leakage slot.

It would seem that the objections which were raised to the circumferential system of ventilation are believed not to apply to Mr. Roth's machine.[1] In the tests on the model for circumferential flow described in my A. I. E. E. paper in 1924, the air flowed radially through the vents and then circumferentially through the air gap. Although an analytical study of Mr. Roth's system of ventilation has not been made, the low temperatures obtained and the comparatively small dimensions, indicate that the system is excellent. It would seem that the supply of air to the leakage slots is sufficient to maintain comparatively low temperatures in the tooth belt where the material is worked the hardest.

2. The method which Mr. Roth uses for measuring the losses and air volumes at full load is novel. Mr. Roth assures us that he can obtain accuracy by calibrating the system, operating idle as a synchronous motor with known total losses at two different voltages. In the equation on page 10, what is the order of magnitude of $\Delta t_2 - \Delta t^1$? I presume it is about 10 deg. cent. and to obtain accuracy these temperature rises must be measured with extreme care.

The measurement of the temperature rises of the air by means of resistance coils connected in a Wheatstone-bridge network is one that is frequently used, and if proper precautions are taken, it should lead to accurate measurements. With small temperature rises, it is necessary to measure resistances with extreme accuracy, as a one degree change in temperature corresponds approximately to only 0.4 per cent change in resistance; or, if the temperature rise is 10 deg., it is necessary to read to 0.04 per cent if the error is to be not over 1 per cent. In some of our work, temperature rises of the order of only two degree are obtained, and then it is necessary to read to 0.008 per cent. While, with extreme care, such measurements of resistance can be made, there are possible sources of error, such as those due to contact resistance or those which might arise from the stretching of some of the wires, and this introduction of considerable errors.

In the early work on air-volume measurements by the thermal method at the Westinghouse Company, resistance measurements were made, but they were abandoned partly because of the necessity for great precision in measurement and partly because a few of the wires stretched and the resistance was consequently changed. We have since been using large numbers of thermocouples connected in series, and, for the most part, have been able to secure very reliable results. We can read our volumes within about 1 per cent. Of course, if only a few thermocouples are used, this method is not recommended, as a reliable average is not then obtainable.

3. The volume of air through the rotor seems to be very high. In conversation Mr. Roth explained to me the method which he used for measuring it. I think that the method is of sufficient interest to warrant him telling the members of the Institute what it is.

4. The device shown in Fig. 14, for measuring the pressure of the cooling air, is a model of part of the machine in which the flows are imitated as accurately as possible. I should inquire of Mr. Roth how close the agreement was between the pressure measured in the model and the pressure measured in the machine. I am a great believer in imitating in a model, conditions in the actual structure; but in this, care must be exercised, as sometimes the conditions are extremely difficult to imitate with sufficient accuracy.

5. Mr. Roth states that with a salient-pole alternator, the self-excitation is synchronous. It may be of interest to those who have not noted it before that it is possible to increase the

1. *An Experimental Study of Ventilation of Turbo Alternators.* TRANS A. I. E. E., 1924, pp. 486-488.

load on a salient-pole alternator gradually when it is being excited by condensive reactance until, at a certain load, the alternator pulls out of step and runs at a speed slightly above the frequency of the line. In other words, in a salient-pole machine just as in a turbo alternator it is possible to have self-excitation and operate as an asynchronous generator. One of the oscillograms in the discussion referred to by Mr. Roth shows this very clearly.[2]

**E. H. Freiburghouse:** I agree in general with what Mr. Laffoon has said as to the principles governing the limit of electrical stability of alternators and I too question whether these generators which have been described by Mr. Roth possess the necessary margin of stability.

Nevertheless, Mr. Roth has informed me that generators having these characteristics do operate successfully and that the power-station people do not find it necessary to employ voltage regulators. He states that voltage regulators have been installed but their use has not been found necessary.

Some years ago, the General Electric Company rebuilt a large foreign-made, turbine-alternator in which they even increased the originally high synchronous impedance. There have always been doubts about the stability of that generator; however, it has now been operating satisfactorily for seven years although the excitation for synchronous impedance is 2.04 times that for normal voltage at no load. The above is an abnormal ratio which we do not advocate. Instead, we usually make the ratio less than unity.

The deep, partially closed, leakage slots which Mr. Roth has employed to increase the reactance, also inherently make it necessary to assemble the stator bars axially from the end of the core. Obviously, the fit of the coil cannot be so close in the slot as if it were inserted radially under pressure from the air gap or open end of a slot. However, his machine is much shorter than we are building for that output.

We do not believe that 27 per cent reactance is necessary to insure the safety of the turbine-type alternator which has its stator winding laced at the ends to supporting rings. This machine as built in America is apparently flexible and strong enough to withstand many thousand dead short circuits without permanent distortion of the end structure. I recently witnessed a number of dead short circuits upon generators rated 35,300 kv-a. upon which there was no permanent distortion whatsoever.

Referring to the heating of these generators as given by Mr. Roth in Table I, we find that the temperatures obtained during the open-circuit run No. III were fairly uniform throughout the core; however, this was not the case during the sort circuit test No. I. On tooth G, Fig. 15, the rise was 70 deg. cent.; on tooth F, 27 deg.; and on tooth E, 26 deg. G was in the second package of iron from the end of the core whereas the others were in the middle of the core. I venture to say that the extra heating of tooth G was caused by flux from the magnetomotive-forces of the stator winding outside of the core. We are interested to know what temperatures were obtained at the other end of the core by couples 1, 2 and 3.

**W. B. Kirke:** This paper brings out new methods of incorporating characteristics of high reactance without obtaining excessive armature reaction. At the same time the use of leakage slots provides an effective method to keep the temperature rise within low limits.

The first characteristic of high reactance is provided for in a great many systems in this country by the use of external reactors in the circuit connecting the generator to the bus. Such reactors not only aid in keeping the voltage near normal with a generator short circuit but they also reduce the interrupting duty on the generator circuit breakers. On the other hand, if the reactance is built into the machine by the use of leakage slots or other means, a generator short circuit means dropping the voltage of the bus section fed by that unit.

Increasing the stability of the machine is a very desirable feature. As systems are more extended and more power plants interconnected, one wonders if ever a condition will exist when the extreme ends of an interconnected system will start rocking, due to lack of stability of the interconnected system. Any measure tending to increase the stability of a single unit will aid in stabilizing a large system consisting of many such units.

The use of leakage slots would seem to indicate a considerable advantage in ventilating the unit. With the maximum size of turbo generators steadily increasing as the size of systems and interconnection facilities develop, capacities of 100,000 kv-a. will soon be required. Any method which indicates an improved means of ventilation should be given thorough analysis by designing engineers.

**Robert Pohl:** "The most interesting part of Mr. Roth's paper is his advocacy of leakage slots below the main stator slots. This design is for obvious reasons superior to the deep slot bridges advocated by Miles Walker many years ago, but somewhat similar in principle to the practise of some makers to use much deeper open slots than necessary for the winding. The author has convincingly demonstrated the advantages of his design. I should like to say, however, that the properties of such leakage slots do not appear to me generally advantageous but only in special cases. In the first place why employ so high a reactance as 27 per cent? If Mr. Roth's 60,000-kv-a. alternator had been made without leakage slots its reactance of 18 per cent would have been fully high enough for all ordinary requirements and perhaps already too high for stations with feeder reactances and a poor power factor. In Europe we have often to deal with station power factors much below 0.8 down to 0.6. In such cases the increase of reactance makes itself seriously felt in the size and to some extent in the efficiency of the alternator.

As to the author's comparison of the two methods of obtaining high reactance, leakage slots or increased electric loading, one misses the third alternative, i.e., a separate reactor. It is obvious that an alternator with separate reactor will as regards stability, auto-excitation and stresses on end connections, behave exactly as a corresponding alternator with leakage slots and equal total reactance. A short circuit on the alternator terminals need hardly be feared. It seems to me that the leakage-slot design with its appreciable increase in the stator dimensions is the more expensive way of creating the desired additional reactance. If so, it can only be justified by the remaining advantage, i.e., the improvement in ventilation. This seems to me the decisive point. Here one has to distinguish between bipolar and multipolar designs. In bipolar turbo alternators the output is mostly limited by the temperature rise of the rotor. The stator winding is generally cool enough when placed in the ordinary way in close proximity to the rotor. Hence there appears to be no cause for changing this practise. The same applies to smaller four-pole machines with solid rotors. In the larger four-pole and even more so in the six-pole designs with built-up rotors the ventilation of the latter is more effective and the limiting temperature may be found in the stator winding. Here it may well be advantageous to employ an otherwise unnecessary depth of slot or leakage slots after Mr. Roth's proposal if there is no other way of improving the ventilation.

Another way of improving the cooling of altenators is the use of hydrogen or other gases superior to air as cooling media.

**Franklin Punga:** I congratulate Mr. Roth on his contributions to developments in the design and construction of large turbo generators, and in particular on the means by which he was able to increase to 60.000 kv-a. the rating of the 45,000-kv-a. generator, without altering the external dimensions.

2. Trans. A. I. E. E., 1920, Vol. XXXIX, p. 1637.

[illegible]garding certain features I should like to make the following o[illegible]vations:

[illegible]thoroughly endorse the employment of a stator slot pro-vi[illegible]l with a large open portion at the end opposite the air gap. Th[illegible] is very useful for ventilation purposes. In the design w[illegible]h I some time ago proposed to the Thyssen firm, and co[illegible]rary to the design of Mr. Roth, the lower third of the slot wa[illegible] widened as shown in the accompanying illustration of the sl[illegible] Fig 3. The principal reason for this relates to winding con-st[illegible]tion technicalities. In the normal partly or entirely closed sl[illegible] the conductor has to be inserted axially. This makes it ne[illegible]ssary to make a relatively great allowance for clearance be[illegible]een the side of the slot and the insulated conductor, other-w[illegible] the insulation on the conductor is liable to be harmed in the pr[illegible]ess of being inserted into place in the slot. Should any re[illegible]ir of the winding ever be necessary it is exceedingly difficult to [illegible]emove such a conductor from the slot. In designs in which th[illegible] conductor is inserted radially into an open slot, it is prac-ti[illegible]ble to allow less clearance between the insulated conductor an[illegible] the sides of the slot. This is desirable for several reasons, su[illegible] as (1) obtaining a better space factor, and (2) decreasing th[illegible] liability to corona phenomena. When employing my de-si[illegible] of slot the insulated conductor is first introduced axially in[illegible] the space in the lower third and is then pressed radially

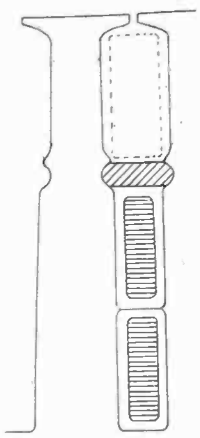


Fig. 3

[illegible]ward into place, the space available in the ventilating ducts b[illegible]ng convenient for the application of the necessary radial p[illegible]essure.

But this design of slot fulfils a second important purpose. [illegible] is well known that if the tooth saturation is too great, the [illegible]x passing parallel to the sides of the slot occasions a consider-[illegible]le copper loss. For this reason it is customary to employ [illegible] relatively low no-load tooth saturation (some 16,000 lines [illegible]r sq. cm.), so that at full load the value of 20,000 lines per [illegible]. cm. shall not be exceeded. Now the difference between the [illegible]oth saturation at full load and that at no load is chiefly de-[illegible]ndent upon the distorting ampere-turns. The decreased [illegible]oth section in the lower third of the slot consequently serves [illegible] insurance against too great saturation in the portions where [illegible]e copper is located and will be found especially valuable in [illegible]rbo generators with a cos near $\phi$ unity.

Furthermore the slot leakage is of course also decidedly [illegible]creased, although not so much as in the case of the turbo [illegible]nerator designed by Mr. Roth. The advantages which Mr. [illegible]oth mentions, relating to relatively great slot leakage are [illegible]l of them correct, but a disadvantage of the great slot leakage [illegible]ught not to be overlooked, namely, the radial saturation of [illegible]eth at particular parts of the circumference on the occur-[illegible]nce of sudden short circuits. For instance if we represent [illegible]e leakage of one slot by a vector, this will be of uniform magni-[illegible]de and direction until we come to a place on the circumference where one phase winding is completed and the next phase winding begins. In a four-pole machine with two conductors per slot, and 100 per cent winding pitch, there are on the circumference twelve such places. The slot leakage vector moves through 60 electrical degrees and the consequence is that at these points a flux represented by a vector of equal magnitude passes through the tooth and into the laminations behind the slots. Conse-quently in such a machine at short circuit there would be com-plete saturation of twelve teeth equally distributed around the circumference. This would decrease the effectiveness of the great slot leakage. In this respect the use of fractional-pitch windings is of advantage since the number of these teeth is then increased from twelve to twenty-four so that the flux set up in each tooth is appreciably smaller.

Mr. Roth's observations about self-excitation have interested me very much. In German power houses it is now required that large polyphase generators shall be able to carry as leading load 80 per cent of their rating. This requirement has a close relation to the problem of self-excitation discussed by Mr. Roth. This problem will be of even more importance in the future if the lengths and voltages of transmission lines are increased.

In conclusion I should like to briefly mention that the prin-cipal progress which has been made in the development of large turbo-generators has been due to the avoidance of stray losses. These stray losses were due to (1) current distortion in the slot copper; (2) flux passing parallel to the slot sides and of too high tooth saturation; (3) flux passing from the field into the open slot; (4) variations in flux density around the circumference of the field, due to the slot openings; (5) the leakage flux from the end windings, (a) in the copper of the end windings, (b) in the end clamping parts (6) iron short circuits due to bad workmanship in slotting and assembling the cores.

From this paper of Mr. Roth's and from his previous publica-tions it is very evident that the author has dedicated much study and research to the problem of decreasing the stray losses and of their exact measurement.

**J. Rosen** (communicated after adjourment): I would refer only to one section of Mr. Roth's paper in which he deals with the difficulty of alternator instability. It is sometimes for-gotten that many of the difficulties lie in the excitation circuit. Some ten years' ago, instability was experienced on an 18,000 kv-a. alternator, operating at unity power factor and sometimes with a leading power factor. The alternator air-gap was in-creased, with entirely satisfactory results.

Later experience and tests on other plants showed that atten-tion should also have been directed to the design of the exciter. One of the improvements adopted was the addition of a few series turns to the exciters, which overcame entirely the alter-nator instability difficulties which had up to that time, been experienced. The tests have proved that sudden changes in load, faulty synchronising, and faults in the transmission line are reflected in the alternator rotor by momentary increases in the value of the rotor current. I would refer to the papers, and the discussions upon them, on "Exciter Instability" by R. E. Doherty[3] and "Some Problems In High-Speed Alterna-tors and their Solution"[4] by the writer, in which the whole problem is discussed in full.

Calculated figures are given by Mr. Roth of the total inherent reactance of the plant. It would be of interest to learn if they are confirmed by actual sudden-short-circuit tests at the normal operating voltage.

**E. Roth:** The most important observation presented in this discussion has been expressed by Messrs. W. F. Dawson, Philip Torchio, C. M. Laffoon, E. H. Freiburghouse and W. B. Kirke

3. Journal A. I. E. E., Vol. XLI, No. 10, p. 731.
4. *Journal* I. E. E., Vol. 61, No. 317, p. 452-3.

and regards the armature reaction to which American practise gives lower values than that which exists in our alternators.

Mr. Laffoon has given a very complete statement of this point and I am in general in agreement with him. His comments apply more particularly to the conditions of stability.

These machines were designed to run first at $41^2/_3$ cycles in parallel with the distributing system of Paris, and later at 50 cycles. In fact the machines have never been operated at $41\,^2/_3$ cycles. Moreover the customer wanted a very low value of instantaneous short-circuit current, of about four times the normal current, which condition had never been required before from large turbo alternators. It was therefore necessary to design a machine in accordance with these requirements without neglecting, of course, the condition of stability.

Four years' experience have shown that these machines have been giving entire satisfaction to the users. Had difficulties arisen with regard to stability, it would have been easy to enlarge the air-gap of these machines sufficiently, without exceeding the standard American temperature rise of 90 deg. cent., which up to the present has never been attained in our machines.

These machines have been designed for 35,000 kw. at 80 per cent power-factor, that is 43,750 kv-a.; in fact, they are operated at 40,000 kw. and 50,000 to 55,000 kv-a.

Based upon this experience the 60,000-kv-a. machines have been built on the same principles but the flux has been increased slightly and the air-gap enlarged to maintain the same conditions of stability. Considering the operating conditions we are confident that they will run as satisfactorily as the former, and should difficulties arise these could be easily remedied.

As pointed out by Messrs. Torchio, Kirke and Pohl, the low value of the instantaneous short-circuit current could have been obtained by reactance coils. This solution was examined very seriously but had to be rejected. Indeed, these reactance coils are very cumbersome and the price of the alternator together with reactance coils, has been found higher than that of the alternator with leakage slots alone. The efficiency using reactance coils is less than with the solution adopted; first it is not possible to build reactance coils with a loss smaller than 0.15 to 0.20 per cent and further when external reactance coils are used the alternator has to be operated at a higher terminal voltage, which creates core losses which do not exist in the case of leakage slots.

With regard to operation the use of reactance coils or of leakage slots leads exactly to the same result. Whenever it is desired that the voltage drop at the busses on short-circuit be not too high, individual reactance coils should be installed on every feeder.

I wish to emphasize what I have already stated in my paper, that using leakage slots in a given machine does not practically alter the conditions of stability; thus should a customer require from American manufacturers as small an instantaneous short-circuit current as in the Gennevillier's machines, they could obtain it, without changing any of the properties of their machines, by simply adding leakage slots.

I greatly appreciate the technical progress which the American manufacturers have obtained by designing their 62,500-kv-a. turbo-alternator for 1800 r. p. m. I know very well the difficulties which they may have encountered and I think that this is still a more marked progress than that which the Socéité Alsacienne has made when they built their 45,000-kv-a. alternators for 1500 rev. per min., which capacity was at that time only realised at 1200 and 1000 rev. per min. I have learned with great interest that Mr. Laffoon sees the possibility of constructing 75,000-kw. machines at 90 per cent power-factor and 1800 rev. per min. In Europe we think that it is possible to build 50-cycle turbo alternators for over 100,000 kv-a. at 1500 rev. per min. and for 40,000 kv-a. at 3000 rev. per min.

# ILLUMINATION ITEMS

By the Lighting and Illumination Committee

## NEW CORRUGATED BULB AIDS IN THE PREVENTION OF AUTOMOBILE HEADLIGHT GLARE

The introduction of the corrugated automobile headlight bulb is an important step in the more exact and complete control of the beams from headlights toward which various refinements in the manufacture of the several elements of the equipment are contributing.

Glaring headlights which so greatly detract from both the pleasure and safety of night driving, result for the most part, first, from failure to properly focus and aim the headlamps, and second, from the limitations of a fixed-beam system on any except smooth, level roads. Considerable effort is being put forth to bring about better headlight adjustment and depressible-beam equipment, using the new two-filament headlight lamp, overcomes the limitations which are inherent in a fixed-beam system.

There is a third though lesser source of glare which

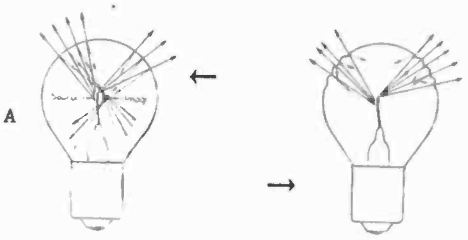
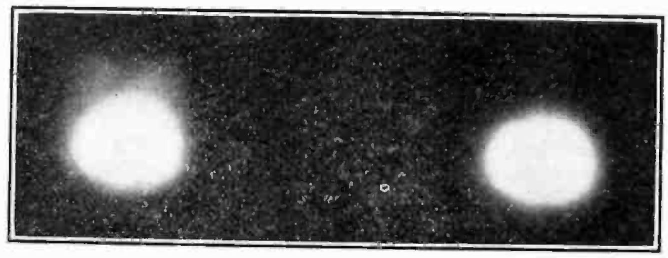



FIG. 1—(A) LIGHT REFLECTED FROM THE INNER SURFACE OF THE SPHERICAL PART OF A BULB WITH A LIGHT SOURCE NEAR ITS CENTER, FORMS AN IMAGE REMOVED FROM THE FILAMENT BY AN AMOUNT VARYING WITH THE DISPLACEMENT OF THE LIGHT SOURCE FROM THE CENTER

(B) THE CORRUGATION ON THE SPHERICAL PART OF THE BULB DISPERSE THE LIGHT AND PREVENT FORMATION OF IMAGES



A B

FIG. 2—(A) CROSS SECTION OF A BEAM OF LIGHT FROM A PARABOLIC REFLECTOR WITH A LAMP HAVING A SMOOTH BULB FROM WHICH AN IMAGE OR SECONDARY LIGHT SOURCE IS FORMED AS IN FIG. 1 A.

(B) CROSS SECTION OF THE BEAM OF LIGHT WHEN THE IMAGE OR SECONDARY LIGHT IS ELIMINATED

is found even with properly focused and aimed good equipment. It is the secondary source or filament image which is formed in a headlight by the rays reflected from the inner surface of the spherical part of the bulb. The filament is at the center of this hemisphere and hence, when it is exactly placed, the image is superimposed on the filament. Actually, there is frequently a slight displacement from this exact position, in which case the image is off-set as illustrated in Fig. 1A. The brightness of this image, or secondary source, may be as much as five per cent of that of the filament. The equipment, adjusted for the main source, will then direct the secondary beam from the image at a different angle, as indicated in Fig. 2A, and often this will be toward the approaching driver's eyes, causing him annoyance. When the spherical surface is broken up with corrugations, the reflected rays are dispersed sufficiently to avoid the formation of a definite image, as in Fig. 1B, and the resulting secondary beam.

The corrugations on headlight bulbs were not placed there to add a novelty feature, but represent the result of a long and successful search for the best means of avoiding glare from source images in the bulb.

## COST AND STANDARD OF LIGHTING

Assuming no decrease in the purchasing power of money, as much light can be purchased today for one or two cents as could be bought a century ago for one dollar. But unfortunately our dollar has had many shrinking moods during this period, and this must be taken into account in any comparison of lighting standards with those of a century ago. For the sake of comparison let it be assumed that the purchasing power of gold is only one-third as great today as it was one hundred years ago. If the use of light were keeping pace with the efficiency of light production, the workman would be supplied with three hundred times more light than he then had. But the standard of working conditions has also greatly altered. If it be assumed that this has increased about five times, the workman today should be supplied with about fifteen hundred times more light than he had a hundred years ago.

If the workman in that age of candles had an intensity of illumination of two-thirds of a foot-candle, he should have a thousand foot-candles today, if the use of light is to keep its proper pace. Of course, light is more generally distributed now in a well-lighted factory than was the case in those earlier years. The workman benefits by this better condition, but the fact remains that the actual artificial illumination under which he works is only a few times that enjoyed by his predecessor of a century ago. It is known that the best intensity of illumination for general work is of the order of magnitude of a thousand foot-candles, and on the basis of the foregoing assumptions the workman is entitled to it. If not satisfied with the assumptions, anybody may reduce them as he sees fit. Even the most radical scaling down would leave us with a hundred foot-candles or more. Then why is the workman not supplied with this amount at least? Here is a question that the reader may find it interesting to attempt to answer.—*Electrical World.*

## THE SOLUTION OF A RESIDENCE STREET LIGHTING PROBLEM

Engineering, perhaps more than any other profession, has many precepts and fundamental principles upon which there can be no differences in opinion among the members of the profession. Nevertheless, there are certain phases of this field of science in which the opinions and specifications sponsored by different engineers, may be as widely diversified as the diagnoses of a particular medical case by several physicians. It is only natural to expect that such a condition may frequently be encountered in any line of endeavor inasmuch as the realm of man's absolute knowledge is limited, consequently a thorough interchange of ideas on any problem upon which there is likely to be a diversity of opinion is nearly always advantageous to those concerned with its solution. As elsewhere, this is quite true in illuminating engineering as has been shown by the advances which have been made in this field during recent years.

Among the commercial applications of artificial lighting there have been few upon which there has been such a diversity of opinions as on the requirements and specifications of proper street lighting. In view of this fact the Illuminating Engineering Society has, at some of its past meetings, chosen the symposium* form of discussion for this subject. Sometime in advance of the actual meeting a typical street lighting problem was selected and a blueprint layout and photograph of a definite residential street were sent, together with a questionaire, to a number of illuminating engineers who were more or less concerned with the design of street lighting installations. A summary of the solutions for lighting this section of a residence street, obtained from these engineers is given in the accompanying table in a manner which shows very readily the similarities and differences in the different designs.

The consensus of opinion seems to favor a series, underground distribution system, operating at 6.6 amperes with a staggered arrangement of units, for a residential street in a city of 100,000 such as the one under discussion in this particular case. There is, of course, a variance in the recommended costs per mile for the different solutions but even such differences in cost estimates are not as great as they probably would have been ten years ago, because engineers are now more fully agreed as to what constitutes reasonably adequate street lighting. With one exception, the recommended mounting heights are included in the comparatively small range of 11 to 16 ft. and an ornamental unit is specified.

At present, there seems to be no thoroughly satisfactory method of comparing illumination values on city streets. However, by measuring these values in terms of lumens per foot there is at least some indication as to the total amount of light which is available. Using this method of measurement we find that these different solutions vary from 13 to 50 lumens per foot in their recommendations.

This general method of treating the street lighting problem seems likely to crystallize our ideas regarding practise and so not only advance the art but also tend toward the establishment of definite styles. The great value comes from the opportunity of summing up and comparing the ideas of various engineers.

*Discussion before the Annual Convention of the A. I. E. E. at Detroit, September, 1925.

THE SOLUTION OF A RESIDENCE STREET LIGHTING PROBLEM

| Solution No. | Cost per Mile per cent of Average | Illumination values | Size of Incandescent Lamps Lumens | Amp. | Arrangement of Lamps | Spacing Ft. | Fixture | Standard | Bracket | Mounting Height Ft. | Distribution System |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 158 | 30-40 Lumens per foot | 4000 | 15 | Staggered | 120 | Rippled alabaster globe and canopy. Dome refractor | Ornamental | | 11½ | Series, underground. Insulating transformers |
| 2 | 49 | 13 Lumens per foot | 2500 | 6.6 | One side | 196 | Ornamental, Post-top, refractor type | Reinforced concrete | | 11 | Series, underground. Film cut-outs |
| 3 | | 19.3 Lumens per foot | 200 watt 110 volt | | Staggered | 124 | Copper casing, porcelain reflector, diffusing globe | Ornamental | 9 ft. ornamental | 16 | Multiple underground. Clock or remote control |
| 4 | 154 | 25 Lumens per foot | 2500 | 6.6 | Staggered | 100 | Rippled alabaster globe and canopy | Ornamental iron, steel or concrete | | 12 | Series underground. Insulating transformers |
| 5 | 74 | 20-25 Lumens per foot | 3250 lumens 200 watt, 115 volt | | Staggered | 155 | Rippled alabaster globe, Dome refractor | Steel or concrete | 4½ ft. ornamental | 16 | Multiple underground, pilot wire control |
| 6 | 68 | Ft.-c Max. 0.07; Min. 0.03; Av. .05 | 2500 | 6.6 | Staggered | 150 | Ornamental lantern, asymmetric refractor | Concrete post | | 15 | Series, underground. Film cut-outs |
| 7 | 65 | 16.6 Lumens per foot Ft.-c Max. 0.292; Min. 0.026; Av. 159 | 2500 | 6.6 | Staggered | 150 | Ornamental pendant, Dome refractor | Ornamental tubular steel | 6 ft. pipe | 16 | Series, underground. Insulating transformer |
| 8 | 87 | 22 Lumens per foot 55 Lumens at street crossings | 2500 | 6.6 | Staggered | 130 | Pendant, diffusing | Ornamental iron | Gooseneck | 14 | Series, underground. Film cut-outs |
| 9 | 38 | Ft.-c Max. 0.20; Min. 0.03; Av. 10 | 4000 | 6.6 | Center span | 273 | Non-ornamental. 4-Way, 2-Way refractor | Wooden pole | Mast arm or span wire | 25 | Series, overhead. Film cut-outs |
| 10 | 97 | 20-Lumens per foot | 2500 | 6.6 | Staggered | 115 | Ornamental lantern, Dome refractor | Ornamental iron | | 11 | Series, underground. Film cut-outs |
| 11 | 222 | 50 Lumens per foot Ft.-c Max. 0.35; Min. 0.20; Av. 0.25 | 4000 | 15 | Staggered | 80 | Ornamental lantern, refractor | Reinforced concrete | | 13 | Series, underground. Film cut-outs |
| 12 | 89 | 25 Lumens per foot | 2000 | 7.5 | Staggered | 100 | Ornamental reflector without globe; frosted lamp | Ornamental concrete | | 12½ | Series, underground. Film cut-outs |

SUMMARY OF ESSENTIAL FEATURES OF ALL SOLUTIONS

# JOURNAL OF THE American Institute of Electrical Engineers

**PUBLISHED MONTHLY BY THE A. I. E. E.**
33 West 39th Street, New York
Under the Direction of the Publication Committee

M. I. PUPIN, *President*
GEORGE A. HAMILTON, *National Treasurer*
F. L. HUTCHINSON, *National Secretary*

**PUBLICATION COMMITTEE**
L. F. MOREHOUSE, *Chairman*
F. L. HUTCHINSON
DONALD MCNICOL
E. B. MEYER
J. H. MORECROFT

GEORGE R. METCALFE, *Editor*

Subscription. $10.00 per year to United States, Mexico, Cuba, Porto Rico, Hawaii and the Phillipines; $10.50 to Canada and $11.00 to all other countries. Single copies $1.00. Volumes begin with the January issue.

Changes of advertising copy should reach this office by the 15th of the month for the issue of the following month.

*The Institute is not responsible for the statements and opinions given in the papers and discussions published herein. These are the views of individuals to whom they are credited and are not binding on the membership as a whole.*


## The 1926 Midwinter Convention

### A LARGE PROGRAM OF IMPORTANT TECHNICAL PAPERS WAS DISCUSSED AT WELL-ATTENDED SESSIONS

The fourteenth Midwinter Convention of the American Institute of Electrical Engineers, held February 8-11, 1926, maintained the tradition of its predecessors in their constantly growing importance, in the increasing number of members and guests in attendance, and in the character of the papers presented and discussed. Of all the Institute meetings, the Midwinter Convention is preeminently the working convention of the year, at which entertainment is largely subordinated to the consideration of the most technical professional problems, and the attendance this year of over 1500 members attests the worth of these conventions to the electrical profession. The entertainment features, consisting of a Smoker Tuesday evening, a Dinner-Dance Wednesday evening and two instructive popular lectures Thursday evening were well patronized and greatly enjoyed. The heaviest snowfall in several years occurred at the time of the convention and for several days almost paralyzed vehicular traffic, but despite this handicap the visits of inspection to numerous engineering establishments in and about the city of New York with few exceptions were carried out according to schedule. Monday morning was devoted to registrations of members and guests and to several committee meetings. At such intervals as occurred between the technical sessions, other committee meetings were held from time to time during the convention week.

#### MONDAY AFTERNOON

*Technical Session*

The opening session of the convention convened at 2.30 p. m. in the Engineering Auditorium and was called to order by President Pupin, who extended heartiest greetings to the members assembled. He then introduced Percy H. Thomas, Chairman of the Transmission Committee, who conducted the Transmission Session which followed.

The general subject of the first session was Stability on Transmission Lines and for the benefit of those who were not entirely familiar with the subject of stability on transmission lines, Mr. Thomas gave a brief general explanation of the subject.

The first four papers of this session were presented and discussed together as their subject matter was closely related. The first paper, *Investigation of Transmission-System Power Limits*, by C. L. Nickle and F. L. Lawton was presented by Mr. Nickle. Chairman Thomas then called for the second paper, *Calculation of Steady-State Stability in Transmission Lines*, by Edith Clarke, Miss. Clarke abstracted her paper. The third paper entitled, *Practical Aspects of System Stability*, by Roy Wilkins was abstracted by Mr. Wilkins and the fourth paper, *Further Studies of Transmission Stability*, by R. D. Evans and C. F. Wagner was abstracted by Mr. Evans.

In the extended discussion which followed on this group of papers, remarks were made by R. D. Evans, H. W. Smith, H. H. Dewey, H. H. Spencer, H. K. Sels, R. E. Doherty, C. L. Fortescue, H. B. Dwight, J. W. Legg, Svend Barfoed and Mr. F. L. Lawton read a written communication by L. F. Woodruff. The discussion was closed by C. A. Nickle, Edith Clarke, Roy Wilkins and C. F. Wagner.

Chairman Thomas next called for the presentation of the last paper *Transmission Stability with Over-Compounded Voltages*, by H. B. Dwight, this was abstracted by the author. The paper was then discussed by C. B. Christie and a written discussion from L. F. Woodruff was read.

#### MONDAY EVENING

*Technical Session*

The next session of the convention convened at 8.15 p. m. and was called to order by E. B. Meyer, Chairman of the Meetings and Papers Committee. Mr. Meyer announced the subject of the evening was dielectrics and insulation. Three papers were scheduled for this session under the auspices of the Committee on Electrophysics and J. H. Morecroft, Chairman of that committee presided at the meeting.

Chairman Morecroft announced that each author would be allowed fifteen minutes to abstract his paper and that the three papers would be read in succession and then discussed together. The first author called upon by Chairman Morecroft was J. B. Whitehead, who abstracted his paper on *Dielectric Absorption and Theories of Dielectric Behavior*. The next paper, *The Theory of Absorption in Solid Dielectrics*, by V. Karapetoff was also summarized by the author. The next paper of the evening by C. L. Dawes was *Ionization Standards in Paper-Insulated Cables*. This too was abstracted by the author.

Extended discussion participated in by A. E. Kennelly, H. B. Smith, E. W. Davis, W. A. Del Mar, R. E. Marbury, R. W. Atkinson, E. S. Lee, E. W. Roper, W. B. Kouwenhoven, J. Slepian, W. F. Davison, George B. Shanklin, S. L. Gokhale and C. A. Adams followed the presentation of these three papers. Closures were made by Messrs. Whitehead, Dawes and Hoover.

#### TUESDAY MORNING

*Technical Session*

The Tuesday morning session on Protection, Control and Bus Construction was under the auspices of the Committee on Protective Devices with F. L. Hunt presiding. The following papers were presented in abstract by their authors: *Operating Performance of a Petersen Earth Coil*, by J. M. Oliver and W. W. Eberhardt, (presented by Mr. Oliver); *Theory of Auto-Valve Lightning Arresters*, by Joseph Slepian; *Current Limiting Reactors with Fire-Proof Insulation on the Conductor*, by F. H. Kierstead; *Temperature Rise and Losses in Structural-Steel Members Exposed to the Fields from A-C Conductors*, by O. R. Schurig and H. P. Kuehni, presented by Mr. Schurig; *Carrying Capacity of Sixty-Cycle Busses for Heavy Currents*, by Titus G. Le Clair and *Supervisory Systems for Electrical Power Apparatus*, by Chester Lichtenberg.

The following members took part in the discussion: K. B. McEachron, H. B. Dwight, V. M. Montsinger, S. I. Oesterreicher, C. E. Stewart, C. F. Wagner, R. G. Weiser, H. C. Forbes, A. E. Kennelly, L. P. Ferris, H. L. Wallau, W. W. Eberhardt and Joseph Slepian.

### Tuesday Afternoon

*Technical Sessions*

Parallel sessions were held on Tuesday afternoon; Session A, on Electrical Machinery, convened in the Engineering Auditorium and Session B, on Communication and Sound Reproduction, in the fifth floor assembly room.

Session A was under the auspices of the Electrical Machinery Committee and was called to order by E. B. Meyer, who requested H. M. Hobart, Chairman of the Electrical Machinery Committee, to take charge of the meeting. Chairman Hobart called on the authors of the following papers to abstract their articles, which were subsequently discussed. The papers presented were: *Experimental Determination of Losses in Alternators*, by Edouard Roth (presented by E. H. Freiburghouse); *No-Load Copper Eddy-Current Losses*, by Thomas Spooner; *Mechanical Forces Between Electric Circuits*, by R. E. Doherty and R. H. Park; *Ventilation of Turbo-Alternators*, by C. J. Fechheimer and G. W. Penney.

The discussion which followed was by Messrs. W. F. Dawson, B. L. Barns, S. L. Henderson, Joseph Slepian, W. J. Foster, C. J. Fechheimer, E. H. Freiburghouse, with closures by R. E. Doherty and E. H. Freiburghouse.

Session B was called to order by H. P. Charlesworth, Chairman of the Committee on Communication, under whose auspices the session was held. Chairman Charlesworth announced that as the program of papers was diversified in character, the session would take up each subject, followed directly by its discussion.

The first paper on the program was *The Development and Application of Loading for Telephone Circuits*, by Thomas Shaw and William Fondiller and was presented by Mr. Shaw. The paper was discussed by F. B. Jewett, W. L. Smith, M. I. Pupin, with closure by William Fondiller.

The next paper on the program called for by the Chairman was entitled *Cipher Printing Telegraph Systems*, by G. S. Vernam, and was discussed by L. F. Morehouse and Paul W. Evans. This paper was followed by one on, *Refraction of Short Radio Waves in the Upper Atmosphere*, by W. G. Baker and C. W. Rice, presentation being made by Mr. Rice. The discussion which followed was by A. E. Kennelly and W. B. Kouwenhoven with closure by W. G. Baker.

The final paper in the session was presented by its author, J. B. Maxfield and was entitled *High-Quality Recording and Reproducing of Music and Speech*. At the close of the presentation a demonstration of the audiophone was given and a comparison between this and the older style of phonograph was shown. The paper was discussed by C. R. Hanna, H. B. Marvin, E. W. Kellogg, A. E. Kennelly and closure was by J. P. Maxfield.

### Tuesday Evening

*Smoker*

Tuesday evening was devoted to a Smoker at the Hotel Astor at which about one thousand men were present, filling the Belvedere Room to capacity. The entertainment which was furnished by the New York Section consisted of moving pictures, an excellent male quartet, an interesting slight of hand performance, including an explanation of some tricks frequently employed at spiritualistic seances, together with popular music by an excellent band. A buffet supper was served toward the close of the evening and the informal but thoroughly enjoyable performance was fully appreciated by all who were present.

### Wednesday Morning

*Technical Session*

The session on Wednesday morning was under the auspices of the Electrical Machinery Committee and Mr. H. M. Hobart, Chairman of that Committee presided.

The first paper was presented by Professor Karapetoff on the subject of *Parameters of Heating Curves of Electrical Machinery*. This paper was discussed by G. E. Luke, F. H. Kierstead, W. F. Dawson, C. J. Fechheimer and the discussion was closed by Professor Karapetoff.

The next paper was on the *Rating of Electrical Machinery as Affected by Altitude*, by C. J. Fechheimer and was abstracted by the author. This was discussed by R. E. Doherty, P. L. Alger, Earl B. Paxton, E. B. Dawson and W. F. Dawson, with closing remarks by Mr. Fechheimer.

The next paper, on the subject of *Motor Band Losses*, by Thomas Spooner, was presented in abstract by the author. It was discussed by G. E. Luke and J. F. Lincoln.

The final paper of the session, *Starting Characteristics of Polyphase Squirrel-Cage Induction Motors and Their Control*, was presented by its author, H. M. Norman, and was discussed by Professor B. B. Bailey, with closure by Mr. Norman.

### Wednesday Afternoon

*Inspection Trips*

Wednesday afternoon was set aside for numerous inspection trips to the prominent engineering works in New York and vicinity, all being generously thrown open to the inspection of members of this Convention. The bus service, which had been provided to carry many of the visitors to the points of inspection, was necessarily cancelled on account of the snowbound condition of the streets, but many parties were organized, making the trips by either public or private conveyances.

### Wednesday Evening

*Dinner-Dance*

The annual Dinner-Dance at the Hotel Astor which has become an invariable feature of the Midwinter Convention was held on Wednesday Evening, and as usual proved to be a most pleasing and enjoyable function. The dinner was attended by between six and seven hundred people and the music during the dinner and for the dancing was furnished by Paul Whiteman's Picadilly Players.

The evening was a thoroughly enjoyable one and the dancing continued until an early hour.

### Thursday Morning

*Technical Session*

The session on Thursday morning was devoted to subjects of Electromagnetism and Physics and was held under the auspices of the Electrophysics Committee, J. H. Morecroft, Chairman, presiding.

The first paper announced by the chairman was *Calculation of Magnetic Attraction*, by Th. Lehmann. This paper, which had been translated by C. O. Mailloux was also abstracted by him. The next paper presented was by Hans Lippelt on the subject of *The Magnetic Hysteresis Curve* and was presented by the author. The third paper of the session by Carl Hering, entitled, *Properties of the Single Conductor* was next presented by Dr. Hering. The final paper, *Heaviside's Proof of His Expansion Theorem* was then presented by its author, M. S. Vallarta.

At the close of the presentations Chairman Morecroft called for the discussion of the papers in their regular order. The discussion which followed was by Joseph Slepian, S. L. Gokhale, S. L. Quimby, M. F. Skinker, R. H. Park and J. J. Smith. Closures were made by Dr. Mailloux, Mr. Lippelt and Dr. Hering.

THURSDAY AFTERNOON

*Technical Session*

The final technical session of the Convention was held Thursday afternoon under the auspices of the Committee on Instruments and Measurements, with William A. Del Mar presiding.

Five papers were presented at this session, the first three presented and discussed being as follows:

*A New Wave-Shape Factor and Meter*, by L. A. Doggett, J. W. Heim and M. W. White; presented by Mr. White. *Practical Application of Vibration Instruments to Rotating Electrical Machines*, by J. Ormondroyd and *A High-Frequency Voltage Test for Insulation of Rotating Electrical Machinery*, by J. L. Rylander.

After these papers had been presented in abstract, a discussion followed by Messrs. J. J. Smith, C. T. Weller, V. M. Montsinger, C. E. Lee, W. B. Craigmile, F. K. Brainard, C. W. Bates, and G. E. Luke, followed by closures by Messrs. Doggett, Ormondroyd and Rylander.

The second group of papers at this session was presented as follows:

*The Cross-Field Theory of Alternating-Current Machines*, by H. R. West and *Rating of Heating Elements for Electric Furnaces*, by A. D. Keene and G. E. Luke. These were discussed by P. L. Alger, K. L. Hansen, and Joseph Slepian. The closures were by Mr. West and Mr. Luke.

This completed the technical program of the Convention.

THURSDAY EVENING

*Illustrated Lectures*

The Convention convened Thursday Evening at 8.15 p. m. in the Engineering Auditorium to hear two illustrated lectures by Dr. Alexis Carrel, and Major Allen Carpe.

Dr. Carrel, who is a member of the Rockefeller Institute for Medical Research, gave a lecture illustrated with motion pictures showing the life of tissues outside of organisms. The pictures showed the actual growth of living cells under artificial conditions, some strains of which in Dr. Carrel's laboratory have been living and growing since 1912.

Major Allen Carpe, a Fellow of the Royal Geographical Society, described and showed motion pictures of the Ascent of Mount Logan, the highest peak in Canada which is 19,850 feet in height. Some remarkable motion pictures were shown, covering the actual climb, hand sledding over the lower glaciers, the higher levels of the mountains and pictures of the party on the summit.

Both of these lectures were highly entertaining as well as instructive and were received with hearty applause.

ACKNOWLEDGMENTS

Credit for this most successful Convention is due to the excellent work of the committees in charge of the various features of the meetings. The Meetings and Papers Committee is to be congratulated upon providing the valuable program of technical papers. The entertainment features which were provided by the New York Section were of very high class and most appropriate. The excellent general arrangements and conduct of the entire Convention was due to the efficient work of the various Convention Committees, the personnel of which was as follows:

General Committee: H. A. Kidder, Chairman: H. H. Barnes, G. L. Knight, E. B. Meyer and L. F. Morehouse.

Entertainment Committee: H. H. Barnes, Chairman: G. W. Alder, J. B. Bassett, H. Y. Hall and H. S. Sheppard.

Dinner-Dance Committee: J. B. Bassett, Chairman: A. F. Dixon, E. E. Dorting, C. R. Jones, J. F. Kelly, F. A. Muschenheim and R. A. Paine, Jr.

Smoker Committee: G. W. Alder, Chairman: H. B. Coxhead, R. R. Kime, E. C. Soares, S. B. Williams, Jr. and C. V. Woolsey.

Inspection Trips Committee: H. Y. Hall, Chairman: C. M. Gilt, I. W. Green, G. C. Hall, R. R. Kime, J. T. Lawson and G. H. Stickney.

Special Meeting Committee: H. S. Sheppard, Chairman: L. W. W. Morrow and J. W. Walters.

Finance Committee: G. L. Knight, Chairman.

## Regional Meeting at Cleveland March 18-19

The Cleveland Regional Meeting arranged by the Middle Eastern District of the Institute will be held on March 18 and 19 with headquarters at the Hotel Cleveland. An attractive program will be presented including papers on sectionalized electrical drive, domestic refrigeration, engineering and humanity, and lighting. On Thursday, March 18, a dinner will be given at which the Honorable Newton D. Baker will make an address. Another feature will be a visit to Nela Park. Details of the program are given below.

SECTIONAL ELECTRIC DRIVE

Thursday morning and afternoon will be devoted to papers and discussion on sectional electric drive. Engineers in a number of industries will be interested in this subject, for although this synchronized group type of drive was developed primarily for application to paper machines, it may now be applied to any driven apparatus where the conditions require a fixed angular relation between the different sections of the machine and where the advantages to be gained warrant the investment. It may well be considered in such applications as are found in the steel mill, the baking plant, the textile finishing plant, or in the rubber mill.

The regional dinner will be held Thursday evening and Friday evening will be spent at Nela Park of the National Lamp Works of the General Electric Company. An unusual program has been arranged, during which the magic of light will be portrayed by striking demonstrations.

Opportunity will be afforded also to make inspection trips to other Cleveland industries at the pleasure of the members.

A luncheon meeting for Counselors of Student Branches of the District has been scheduled for Friday noon.

A very enthusiastic group of committee members has made arrangements for this meeting; lack of space prohibits the publishing names other than the various chairmen who are as follows: A. G. Pierce, Vice-President of Middle Eastern District; A. M. MacCutcheon, General Chairman; G. A. Kositzky, Finance; H. B. Dates, Program; L. D. Bale, Transportation; I. H. Van Horn, Trips; A. M. Lloyd, Registration; C. N. Rakestraw, Dinner; H. L. Grant, Publicity; C. L. Dows, Reception, and E. H. Martindale, Attendance.

**PROGRAM OF CLEVELAND MEETING**

THURSDAY MORNING

Registration

9:45 A. M. Welcome, A. G. Pierce, Vice-President, A. I. E. E.

10:00 A. M. Technical Session: A. M. MacCutcheon, Chairman

*Electrification of Paper-Making Machines*, S. A. Staege, Westinghouse Electric & Mfg. Co.

This paper outlines the several trends of development in a historical sketch. It devotes special attention to a unique system of direct-current drive in which the section driving motors through a differential electrical field-control means, are caused to operate in synchronous relation at any desired relative speed values, which speed relations are at the same time adjustable at the will of the operator.

*The Development of the Sectional Paper-Machine Drive*, H. W. Rogers, General Electric Company.

In this paper the author deals with the history and development of the sectional drive as furnished by the company with which he is connected, and the relative merits of each particular type. The operation of sectional drives is explained.

Thursday Afternoon

2:00 P. M. Technical Session: A. M. MacCutcheon, Chairman.

*Sectional Paper-Machine Drive*, R. N. Norris, Harland Engineering Co.

This paper describes the type of control for sectionalized electric drive which has most generally been used in Europe and in Canada, and which has recently been successfully introduced into the United States. It tells of results secured particularly on very high-speed paper machines. The speed of each section motor is referred to a master control speed through a simple mechanical differential.

Thursday Evening

7:00 P. M. Regional Dinner, Hotel Cleveland

Address by Honorable Newton D. Baker.

Friday Morning

9:45 A. M. Technical Session: Chester L. Dows, Chairman.

*Some Scientific Phases of Refrigeration*, Charles F. Kettering, President, General Motors Research Corporation.

(1) A comparison of the problems of the household and small commercial refrigeration with those of the large commercial type; (2) a description of the various types of refrigerating mechanisms; (3) the analyzing of many possible refrigerants; (4) an explanation of the reason for the development of special electric motors for this small refrigeration work; (5) the unusual requirements of producing, selling and servicing large quantities of these smaller refrigerators.

Friday Noon

12:30 P. M. Luncheon Meeting of Branch Counselors.

Friday Afternoon

2:00 P. M.—Technical Session, Chester L. Dows, Chairman.

*Domestic Refrigeration from the Central-Station Point of View*, George E. Miller, Cleveland Electric Illuminating Co.

Possibilities of this device as a load builder and its effect on the earnings of central-station companies. The return per kilowatt of demand, load factor, power factor. Illustrated.

*Engineering and Humanity*, Farley Osgood, Consulting Engineer, Past-President, A. I. E. E.

Friday Evening

Meeting at Nela Park

8:00 P. M.—Lighting Session, at Nela Park.

*Nela Park, Its Organization and Objectives*, R. W. Shenton, National Lamp Works, General Electric Company.

*Recent Developments in Lighting*, Ward Harrison, National Lamp Works, General Electric Company, Past-President, Illuminating Engineering Society.

Inspection Trips: Through Lighting-Research Laboratories, Historical Rooms; War-Trophy Exhibit, Industrial, Automobile and other Demonstrations.

Saturday Morning

Inspection Trips: Inspection trips will be arranged to places of interest at the wishes of those attending the meeting.

## Regional Meeting at Madison May 6-7

A two-day Regional Meeting will be held by the Great Lakes District of the Institute in Madison, Wis., on May 6 and 7. Some very timely topics are on the program for discussion including rural electrification, transmission and distribution, cooperation in research between colleges and industries and radio interference. A number of foremost authorities will give papers or addresses on these subjects.

The committee in charge of the meeting consists of: Chairman, Edward Bennett, Vice-President of Great Lakes District; J. B. Bailey, A. G. Dewars, H. R. Huntley, L. E. A. Kelso, Carl Lee and R. G. Walter.

Papers and Addresses for Madison Regional Meeting

*Rural Electrification*, by Grover C. Neff, Wisconsin River Power Co.

*Important Features of a Successful Plan for Rural Electrification*, by George H. Post, Milwaukee Electric Railway and Light Co.

*The Quality Rating of High-Tension Cable*, by D. W. Roper, Commonwealth Edison Co.

*Tests on High-Tension Cable*, by F. M. Farmer, Electrical Testing Laboratories.

*The Effect of Internal Forces on Cable Operation*, by W. A. Del Mar, Habirshaw Electric Cable Co.

*Some Interconnected-System Operating Problems*, by Frank G. Boyce, Consumers Power Co.

*Cooperation Between the Colleges and the Industries in Research*, Papers or addresses by

Wm. E. Wickenden, Society for the Promotion of Engineering Education

Dean A. A. Potter, Purdue University

Benjamin F. Bailey, University of Michigan

Edward Bennett, University of Wisconsin

*Behavior of Radio Receiving Systems to Signals and to Interference*, by L. J. Peters, University of Wisconsin.

## Regional Meeting at Niagara May 26-29

A three-day Regional Meeting will be held in Niagara Falls, N. Y., on May 26-28, by the Northeastern District of the Institute. Many interesting papers are scheduled for the meeting and the recreational activities are being carefully arranged.

The technical subjects to be discussed include dielectric power-factor measurement, insulation, transmission, power-plant tests, machinery, rectifiers, speed measurements, and others.

The entertainment features have been planned as follows: On Thursday afternoon, May 26, there will be a trip down the Niagara Gorge with stops at various points of interest and inspections of the power plants on both sides of the river. On Thursday evening will be the convention dinner and a number of Institute officers will make short addresses after which will follow a lecture of general interest to ladies and men. Late in the evening if it can be arranged the Falls will be specially illuminated. On Friday evening there will be a lecture or entertainment or possibly a motion picture.

Details of the program will be published in later issues of the Journal.

## Future Section Meetings

### Baltimore

*Mechanical Power and Trend of Civilization*, by C. E. Skinner, Westinghouse Electric & Mfg. Co. Engineers' Club. March 19, 8:15 P. M.

Talk by a Member of the Local Section. Engineers' Club. April 16, 8:15 P. M.

### Connecticut

*Power Production*. Hartford. March 9.

*Illumination*. Norwich. March 19.

*Bay of Fundy*. New Haven. April 9.

### Lehigh Valley

*Automatic Control of Centrifugal Pumps*, by Otto Haentjens, Barrett Haentjens & Co., and

*Wallenpaupack Hydro-Electric Development*, by N. G. Reinicker, Pennsylvania Power & Light Co. Wilkes-Barre. March 26.

*Oil Switches*, by George A. Burnham, Condit Electric Mfg. Co., and

*Horsepower*, by John J. Johnson, Westinghouse Electric & Mfg. Co. Hazleton. April 23.

**Pittsfield**

Round-Table Discussion. March 9.

**St. Louis**

*Development of Electric Power Generation and Distribution*, by Col. Peter Junkersfeld, President, McClellan & Junkersfeld. March 17.

*Automatic Stations*, by C. A. Butcher, Westinghouse Electric & Mfg. Co. April 21.

---

## Coming Plenary Meeting of International Electrotechnical Commission

Preparations are now well advanced for the meeting of the International Electrotechnical Commission to be held in New York in April. This Commission, which is an international standardizing body in the electrical industry, was organized in 1906 following suggestions made at the Electrical Congress held in St. Louis in 1904. Despite its many years of activity it has never held a meeting in this country, the reason for this being the intervention of the war. The meeting in New York will be the first one which has been held with full representation of all the countries which were active in the Commission prior to the war.

Plans for the meeting, in so far as they have been formulated, are as follows:

European delegates will arrive on *S. S. Andania*, due in New York on April 11th. Hotel arrangements are being made through the U. S. National Committee; the hotel headquarters will be the Hotel Astor. The meetings will be held in the Engineering Societies Building, 29 West 39th Street, New York, N. Y. The greater part of the activities of the Commission will center about the meetings of the various Advisory Committees of the Commission, which Advisory Committees are organized to formulate the work in particular fields and to report their results to the Plenary Meeting of the Commission. The preliminary schedule of the meetings is given in the following table:

Particular attention should be directed to the general meeting which is to be held in the Engineering Auditorium on the evening of April 13th. It is proposed that this meeting shall be conducted under the auspices of the engineering and technical societies which support the work of the U. S. National Committee and that the membership of these Societies shall be invited to attend this meeting. The meeting will be addressed by notable engineers from foreign lands and the work and purpose of the International Electrotechnical Commission will be set forth by them. The preliminary list of delegates indicates that amongst those present will be Sir Richard Glazebrook, K. B. E., Chairman, British National Committee, Sir Archibald Denny, Bart., Chairman, British Engineering Standards Association, Prof. C. Feldmann, President, Dutch Electrotechnical Committee, Professor P. Strecker, President, German Electrotechnical Committee, Mr. E. Huber-Stockar, President, Swiss Electrotechnical Committee, together with Signor Guido Semenza, President of the International Electrotechnical Commission. The preliminary list gives the names of 55 delegates from Europe; Norwegian, Russian, Polish, Spanish, French, Belgium, German, British, and Swiss, the German, British and Swiss delegations being particularly strong numerically. It is expected that later accessions will bring the list up to about 100.

In connection with the meetings in New York, there will be a number of entertainment features offered to the visiting delegates and at the close of this meeting, a tour will be offered which will include Philadelphia, Washington, Pittsburgh, Chicago, Detroit, Niagara Falls, Ottawa, Montreal, Boston, Schenectady and New York. The Canadian National Committee, which is cooperating in this enterprise will welcome the delegates at Niagara Falls and will conduct them to Montreal, where it is expected that a public meeting will be held in their honor.

The delegates will be received in various cities by local committees who will attend to making their stay at these places both profitable and enjoyable.

It may be noted that the first President of the I. E. C. was Lord Kelvin, and that Professor Elihu Thomson was President in 1911 at the time of the meeting in Turin. Dr. C. O. Mailloux is Junior Past-President and the Honorary President of the Commission. The President of the U. S. National Committee is Dr. C. H. Sharp and the Secretary is Mr. F. V. Magalhaes. The Chairman of the Reception Committee for the foreign visit is Mr. John W. Lieb, who is associating with himself a number of those most distinguished in the electrical industry.

Arrangements for the entertainment in New York are in the hands of Mr. F. W. Smith, of the United Electric Light & Power Company, and arrangements for the tour are being perfected by Mr. C. E. Skinner of the Westinghouse Electric & Manufacturing Company.

PRELIMINARY PROGRAM
PLENARY MEETING AND ADVISORY COMMITTEES OF I. E. C.

| Time | Tuesday, 13th. | Wednesday, 14th. | Thursday, 15th. | Friday, 16th. | Saturday, 17th. | Sunday, 18th. | Monday, 19th. | Tuesday, 20th. | Wednesday 21st. | Thursday, 22nd. |
|---|---|---|---|---|---|---|---|---|---|---|
| *Morning* 9.30 to 12.30 | Opening Meeting | Prime Movers (Hydraulic Turbines)<br>Rating (Electrical Machinery) | Prime Movers (Hydraulic Turbines)<br>Rating (Electrical Machinery) | Prime Movers (Hydraulic Turbines)<br>Transformer Oils | | | Rating (Electrical Machinery)<br>Transformer Oils | Prime Movers (Steam Turbines)<br>Traction Motors | Committee of Action | Prime Movers (Steam Turbines)<br>Terminal Markings |
| *Afternoon* 2.30 to 6.30 | Experts' Papers on Rating | Prime Movers (Hydraulic Turbines)<br>Rating (Electrical Machinery) | Prime Movers (Hydraulic Turbines)<br>Rating (Electrical Machinery) | Prime Movers (Hydraulic Turbines)<br>Transformer Oils | | | Prime Movers (Steam Turbines)<br>Transformer Oils | Prime Movers (Steam Turbines) | Plenary Meeting | Prime Movers (Steam Turbines)<br>Terminal Markings |
| *Evening* | General meeting arranged by American Committee | Rules and Regulations | Symbols<br>Standard Pressures | Vocabulary<br>High Pressure Tests | | | High Pressure Tests | Lamp Holders and Caps | | |

## A. I. E. E. Director's Meeting

The regular meeting of the Board of Directors of the American Institute of Electrical Engineers was held at Institute headquarters, New York, on Tuesday, February 9, 1926.

There were present: President M. I. Pupin, New York; Past President Farley Osgood, New York; Vice-Presidents Harold B. Smith, Worcester, Mass.; Edward Bennett, Madison, Wis.; L. F. Morehouse, New York; A. G. Pierce, Cleveland, O.; and W. P. Dobson, Toronto, Ont.; Managers H. P. Charlesworth, New York; H. M. Hobart, Schenectady, N. Y.; Earnest Lunn, Chicago, Ill.; G. L. Knight, Brooklyn, N. Y.; W. K. Vanderpoel, New York; John B. Whitehead, Baltimore, Md.; J. M. Bryant, Austin, Tex.; E. B. Merriam, Schenectady, N. Y.; M. M. Fowler, Chicago, Ill.; and H. A. Kidder, New York; National Treasurer George A. Hamilton, Elizabeth, N. J.; National Secretary F. L. Hutchinson, New York.

The minutes of the Directors' meeting held December 11, 1925, were approved as previously circulated.

Reports were presented of meetings of the Board of Examiners held January 11 and 25 and February 5, 1926, and the actions taken at those meetings were approved. Upon the recommendation of the Board of Examiners, the following actions were taken: 268 Students were ordered enrolled; 392 applicants were elected to the grade of Associate; 15 applicants were elected to the grade of Member; 1 applicant was elected to the grade of Fellow; 14 applicants were transferred to the grade of Member; 5 applicants were transferred to the grade of Fellow.

In accordance with a request from Vice-President Morehouse, the Board authorized the holding of a Regional Meeting of Geographical District No. 3, in New York City, in November 1926.

Complying with a request of the Lehigh Valley Section, the Board granted authority for the extension of territory of that Section to include the following additional counties in Pennsylvania: Berks, Wyoming, Wayne, Columbia, Northumberland, and Montour.

A request from the Portland, Seattle, and Spokane Sections for certain readjustments in their boundaries to take in additional territory was referred to the chairmen of the Sections and Finance Committees with power.

Upon the recommendation of the Committee on Student Branches, authority was granted for the organization of a Student Branch of the Institute at Ohio University, Athens, Ohio.

Consideration was given to the report of the Special Committee on Institute Prizes which had been appointed in August 1925 to consider and recommend to the Board of Directors policies and procedure regarding Institute prizes. The recommendations of the committee relating to the establishment and award of National and Regional Prizes were adopted as applicable to all papers presented commencing January 1, 1926. Reference to the policy and procedure regarding Institute prizes thus adopted may be found elsewhere in this issue.

A report was presented from the General Convention Committee of the 41st Annual Convention of the Institute, held at Saratoga Springs, N. Y., June 22-26, 1925, which included a summary of receipts and expenditures in connection with the convention. The report was received with an expression of appreciation and ordered filed for future reference.

With reference to the various actions that have been taken by the Board of Directors defining the Institute's policy regarding standardization matters, and in order to summarize and confirm the general policy of the Institute in such matters, the following resolution was adopted:

Whereas this Board has by various actions taken in recent yea s adopted a definite policy regarding the relation of the Institute to standardization activities, and

Whereas it appears desirable to restate this policy from time to time, therefore be it

Resolved that the following brief statement of this policy be and hereby is adopted for publication and for transmission to the members of the Standards Committee and to representatives of the Institute upon any other committees, or upon joint bodies, dealing with the formulation of standards:

POLICY OF A. I. E. E. REGARDING THE FORMULATION OF STANDARDS

1. To continue to develop, publish and maintain in the name of the Institute electrical standards as it has done for the past 25 years.
2. That in doing this work the Institute will continue as it has in the past to avail itself to the fullest degree of the assistance of others—both individuals and organizations—with a view to serving the interests of all who may be properly concerned in this work.
3. That standards after having been developed by the Institute in accordance with 1 and 2 and adopted by the Board of Directors as Institute Standards will be, when in the opinion of the Institute such a step is proper, presented to the American Engineering Standards Committee for approval by them as American Standards.
4. That such presentation to the American Engineering Standards Committee for their consideration for approval as American Standard will be done in full conformity with the Constitution, By-Laws and Rules of Procedure of the American Engineering Standards Committee which Committee the Institute was instrumental in initiating and has continued to and does now endorse and support.
5. That when and if standards of the A. I. E. E. have been further advanced to the stage or being designated as "Approved as American Standard by the American Engineering Standards Committee," they shall continue to be printed as standards of the A. I. E. E. with a statement of approval by the American Engineering Standards Committee added to the title page or each particular standard.

The 1925 report of the President of the United States National Committee of the International Commission on Illumination, was presented and received, and copies ordered sent to each member of the Board.

In compliance with a request from the United Engineering Society, the President was authorized to nominate three members of the Institute to serve on a committee of twelve to be appointed by the Trustees of the United Engineering Society to make continuing endeavors to increase the funds of Engineering Foundation and Engineering Societies Library.

An invitation to be represented at the Pan American Congress to be held in Panama, June 18-25, 1926, was referred to the President with power to appoint a delegate.

The President was also authorized to appoint a representative to attend the National Conference on Street and Highway Safety to be held in Washington, March 23-25, in accordance with an invitation from Secretary Hoover of the Department of Commerce.

Other matters of importance were discussed, reference to which may be found in this and future issues of the Journal.

## Institute Prizes

At the meeting of the Board of Directors of the Institute held February 9, a report was presented by a special committee appointed several months ago to consider Institute prizes and to make recommendations regarding prizes which should be awarded in the future; also, to formulate the necessary regulations for the award of these prizes. The committee which prepared this report consisted of Messrs. L. W. W. Morrow, Chairman; H. P. Charlesworth; H. A. Kidder; C. E. Magnusson; M. E. Skinner; and A. C. Stevens. The Board adopted the committee's recommendations with an expression of appreciation for the valuable services rendered. The substance of the report is embodied in the following statement relating to the prizes to be awarded for papers presented at National, Regional, Section and Branch meetings during the calendar year 1926 (prizes for 1925 papers will be awarded under the previous rules).

NATIONAL PRIZES

The following National Prizes may be awarded each year.

1. Best Paper Prize.
2. First Paper Prize.
3. Best Regional Paper Prize.
4. Best Branch Paper Prize.

a. The *Best Paper Prize* shall be awarded the author or authors of the best original paper presented at any meeting of the Institute.

b. The *First Paper Prize* shall be awarded the author or authors of the most worthy paper presented at any Institute meeting, provided the author or authors have never previously presented a paper before the Institute.

c. The *Best Regional Paper Prize* shall be awarded the author or authors of the best paper presented at any Regional or Section Meeting of the Institute.

d. The *Best Branch Paper Prize* shall be awarded the enrolled student author or authors of the best paper presented at a Branch meeting.

e. All prizes shall be presented at the Annual Convention of the Institute in June.

f. Prizes will be awarded for papers presented during the calendar year preceding the year during which the Annual Convention is held.

g. A cash prize of $100 and a suitable certificate of award shall be given the author or authors of each paper receiving a prize. At the discretion of the Committee on Award of Institute Prizes, any prize award may be omitted in any year in which at least three papers are not submitted in competition for each prize. Also, at the discretion of this committee, a single paper may be awarded more than one of the prizes available, and honorable mention may be made of papers which did not receive prize awards.

h. All National prizes shall be awarded by the Committee on Award of Institute Prizes. This committee consists of the chairmen of the Meetings and Papers, Publication, and Transmission Committees, and such others as the Board of Directors may designate.

i. To be considered in the competition, all "first" papers and all papers not presented at national conventions, must be presented with a written communication to the National Secretary of the Institute on or before February 15th of the year following the calendar year in which they were presented. Papers presented at any national convention are all eligible for consideration, but "first" papers and those presented at other than national meetings, must be submitted formally. This may be done by the author or authors, by an officer of the Institute, or by the executive committees of the Institute in the Geographical District. As a normal procedure, papers presented for prize awards which were presented at Regional, Section or Branch meetings, shall be presented through the executive committees of the Geographical Districts.

j. Papers, other than those presented at national conventions, must be submitted in triplicate, to the National Secretary of the Institute.

k. Papers awarded prizes shall be published in full or in abstract, in the JOURNAL, in the TRANSACTIONS, or in pamphlet form.

l. All papers submitted for prizes (excepting for the Branch Paper Prize) must be written by members of the Institute, and when papers are written jointly at least one of the authors must be a member of the Institute, and the cash value of the prize shall be divided.

m. The fundamental consideration in the award of the National prizes, is the quality of the contribution made for the advancement of electrical engineering.

REGIONAL PRIZES

The following Regional Prizes may be awarded each year. in each Geographical District of the Institute.

1. Best Paper Prize.
2. First Paper Prize.
3. Best Branch Paper Prize.

a. The *Best Paper Prize* shall be awarded the author or authors of the best paper presented at Regional, Section or Branch Institute meeting in the District.

b. The *First Paper Prize* shall be awarded the author or authors of the best paper presented at an Institute meeting in the District, provided the author or authors have never before presented a paper before the Institute at any National, Regional or Section meeting.

c. The *Best Branch Paper Prize* shall be awarded the author or authors of the best paper presented at a Branch or Regional meeting of the Institute in the District. The authors must be enrolled Students of the Institute.

d. *Regional Prize Awards* shall be made by the District executive committees or by another committee appointed by the District executive committee.

e. Each prize shall consist of $25 from the national treasury, and a suitable certificate of award issued by the officers of the Geographical District concerned.

f. Papers must be submitted in duplicate to the District Committee on Awards, on or before January 10th of the year following the calendar year in which the papers have been presented.

g. All Regional papers submitted in competition for National prizes, which have been presented at other than national meetings, should be submitted to the National Secretary of the Institute through the District executive committee or by the authorized District Committee on Prize Awards. If in any District this procedure is inadvisable, papers may be submitted directly to the National Secretary by an officer of the Institute in the District.

## Scientific Congress

**BRUSSELS, BELGIUM—JUNE 1926**

During June next, the Association of Engineers of Brussels will celebrate the fiftieth anniversary of its foundation.

A scientific congress will be held upon this occasion, comprising two sections, one on civil engineering and the other on mechanics, electricity, chemistry and various industries.

The Institute has been invited to be represented at this congress, and American members who contemplate being in Belgium in June are requested to advise the National Secretary promptly, at Institute Headquarters, New York, so that any additional information which may be received, including the exact dates of the congress may be sent to them.

## John Fritz Medal Award

The date for the presentation of the John Fritz Medal to Edward Dean Adams has been fixed for the evening of Tuesday, March 30th, at 8:15 p. m. in the Engineering Auditorium. The Board of Award, representing the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers, the American Society of Mechanical Engineers and the American Institute of Electrical Engineers, extends a cordial invitation to all interested friends. The award will be made by Fred J. Miller, Chairman of the Board, and the speakers of the evening will be the Honorable James Montgomery Beck, formerly Solicitor-General of the United States and Arthur Edwin Kennelly, D. Sc., Professor of Electrical Engineering, Harvard University and Massachusetts Institute of Technology.

## Electrical Heating Conference at Purdue

Electric heat treating of metals in industry, including the use of electric furnaces and similar equipment, will be the subject for a state-wide conference of manufacturers and electric power producers to be held at Purdue University, Lafayette, Ind., March 16, 17 and 18. The conference which will be largely in the nature of a school with demonstrations of every description, relating to the use of electric heat treating equipment, was decided on at a recent meeting of Prof. C. F. Harding of the School of Electrical Engineering, and Prof. W. A. Knapp, in charge of the engineering extension department, with state utility men.

Among the features already arranged included a visit to the Ross Gear and Tool Works at Lafayette which has in operation two electric furnaces and plans to install more during the coming months.

## Nomination of Officers of New York Section for Year 1926-27

On February 15, 1926 The Executive Committee of the New York Section of the A. I. E. E. appointed a Nominating Committee as follows: L. F. Morehouse, Chairman; H. H. Barnes, C. E. Stephens, J. C. Parker, E. E. Dorting. The committee is particularly desirous of receiving suggestions from members of the Section for officers for 1926-27. A Chairman, secretary-treasurer, and two members of the Executive Committee are to be nominated. Petitions signed by not less than ten members of the Section may be made and should be received prior to March 8, 1926. Send your suggestions or petitions to L. F. Morehouse, Chairman Nominating Committee New York Section, 33 West 39th St., New York, N. Y.

## Columbia University Offers Scholarship in Electrical Engineering

The governing bodies of Columbia University have placed at the disposal of the American Institute of Electrical Engineers each year a scholarship in Electrical Engineering in the Schools of Mines, Engineering and Chemistry of Columbia University. The scholarship pays $350 toward the annual tuition fees which vary from $340 to $360, according to the details of the course selected. Reappointment of the student to the scholarship for the completion of his course is conditioned upon the maintenance of a good standing in his work.

To be eligible for the scholarship, the candidate recommended will have to meet the regular admission requirements, in regard to which full information will be sent without charge upon application to the Secretary of the University or to the National Secretary of the Institute.

In a letter addressed to the National Secretary of the Institute, an applicant for this scholarship should set forth his qualifications (age, place of birth, education, reference to any other activities, such as athletics or working way through college, references and photograph). A committee composed of Messrs. W. I. Slichter, Francis Blossom and H. C. Carpenter will consider the applications and will notify the authorities of Columbia University of their selection of a candidate. The last day for filing of applications for the year 1926-27 will be June 1, 1926.

The course at the Columbia School of Mines, Engineering and Chemistry, is three years in length and is on a graduate basis. A candidate for admission must have had something of a general education, including considerable work in mathematics, physics and chemistry. Three years of preparatory work in a good college or scientific school should be sufficient, if special attention has been given to the three preparatory subjects mentioned. A college graduate, with a Bachelor of Science degree in engineering can generally qualify to advantage. The candidate is admitted on the basis of his previous collegiate record, and without undergoing special examinations.

The purpose of this advanced course is to produce a high type of engineer, trained in the humanities as well as in the fundamentals of his profession. It is hoped that enrolled students and others qualified will show a keen interest in this scholarship.

## Electrical Exhibition Held By Yale Branch

On December 11-12, 1925, an electrical exhibition at which many interesting displays were made, was held by the Yale University Branch of the Institute in the Dunham Laboratory, and attended by two thousand people.

Among the exhibits were a miniature power plant, a miniature electric train and railway substation, motors and control, high-voltage equipment, household refrigerators and other appliances, an automatic telephone exchange, radio and telegraph demonstrations, and numerous interesting trick displays.

## University of Illinois Offers Research Assistantships

To assist in the conduct of engineering research and to extend and strengthen the field of its graduate work in engineering, the University of Illinois maintains fourteen Research Graduate Assistantships in the Engineering Experiment Station. Two other such assistantships have been established under the patronage of the Illinois Gas Association. These assistantships, for each of which there is an annual stipend of $600 and freedom from all fees except the matriculation and diploma fees, are open to graduates of approved American and foreign universities and technical schools who are prepared to undertake graduate study in engineering, physics, or applied chemistry.

An appointment to the position of Research Graduate Assistant is made and must be accepted for two consecutive collegiate years of ten months each, at the expiration of which period, if all requirements have been met, the degree of Master of Science will be conferred. Half of the time of a Research Graduate Assistant (approximately 900 clock hours for each ten-month period) is required in connection with the work of the department to which he is assigned, the remainder being available for graduate study.

Nominations to these positions, accompanied by assignments to special departments of the Engineering Experiment Station, are made from applications received by the Director of the Station each year not later than the first day of April. The nominations are made by the Executive Staff of the Station, subject to the approval of the President of the University. Nominations are based upon the character, scholastic attainments, and promise of success in the principal line of study or research to which the candidate proposes to devote himself. Preference is given those applicants who have had some practical engineering experience following the completion of their undergraduate work. Appointments are made in the spring, and they become effective the first day of the following September. Vacancies may be filled by similar nominations and appointments at other times.

Research work and graduate study may be undertaken in architecture, architectural engineering, ceramic engineering, chemistry, civil engineering, electrical engineering, mechanical engineering, mining engineering, municipal and sanitary engineering, physics, railway engineering, and theoretical and applied mechanics.

Additional information may be obtained by addressing The Director, Engineering Experiment Station, University of Illinois, Urbana, Illinois.

## Research Fellowships in Lehigh University

On or before June 1, 1926, the Institute of Research of Lehigh University will appoint three research fellows, as follows:

1. One New Jersey Zinc Company Research Fellow in Science and Technology, with endowment provided by the New Jersey Zinc Company. Appointment to this Fellowship will be for the period of two academic years beginning September 1, 1926, annual stipend $600, payable in ten monthly installments, and freedom from University fees, except the matriculation fee of $5.00 and the graduation fee of $10.00. Half of the time of the holder must be devoted to research work in the field

of science or technology to which he is assigned; the other half to graduate study leading to the degree of Master of Science at the end of the two year appointment, providing all University requirements for this degree have been satisfied.

2. Two Henry Marison Byllesby Memorial Research Fellows in Engineering, with endowment provided by widow of Col. Henry M. Byllesby, (M. E., Lehigh, 1875), President of the Byllesby Engineering and Management Corporation. Appointment to either of these Fellowships will be for the period of two academic years, beginning September 1, 1926, with an annual stipend of \$750, payable in ten monthly installments, and freedom from University fees, except the matriculation fee of \$5.00 and the graduation fee of \$10.00. Half of the time of the holders must be devoted to research work on some problem in electrical, mechanical or hydraulic engineering proposed by the President of the Byllesby Engineering and Management Corporation and approved by the Institute of Research; the other half to graduate study leading to the degree of Master of Science at the end of the two year appointment, providing that all University requirements for this degree have been satisfied.

Applications for appointment may be submitted by graduates in engineering or science of colleges, universities or technical schools whose requirements for graduation are substantially the equivalent of those at Lehigh University. Applications must be submitted before May 1, 1926, and they must be accompanied by a catalog of the institution from which the applicant graduated, a certificate of his college work, a list of three or more references, a recent photograph of himself, together with a statement concerning his practical experience and any other evidence of his qualifications for the position which he may choose to submit. The applicant must also indicate the line of graduate study he desires to undertake and his special qualifications for such work.

As previously indicated, appointment to these Fellowships is for the period of two years of ten months each. The holder of each of these Fellowships is required to devote approximately ninety hours per month to research work, under the direction of the Head of the department to which he is attached, without allowances for holidays or vacations during the academic year. Each appointee must pledge himself to remain through the full term of his appointment and to refrain from accepting any kind of employment during either ten month period included therein.

Applications or requests for additional information should be addressed to: Charles Russ Richards, President, Lehigh University, Bethlehem, Pa.

## National Museum of Engineering and Industry

In accordance with an invitation extended by the National Museum of Engineering and Industry to several Societies many of whose members had joined it individually to nominate representatives to its Board of Trustees, the National Societies of Civil, Mining, Mechanical and Electrical Engineers, the American Association for the Advancement of Science, the American Chemical Society and the Society for the Promotion of Engineering Education have responded favorably and are now represented on its Board constituted as follows:

SAMUEL INSULL
Chairman

| | |
|---|---|
| L. P. ALFORD[3] | FREDERICK A. HALSEY |
| B. C. BATCHELLER | DUGALD C. JACKSON[7] |
| NICHOLAS F. BRADY | LUIS JACKSON |
| F. H. COLVIN | F. B. JEWETT[4] |
| NORMAN DODGE | JOHN W. LIEB |
| GANO DUNN[4] | FRED R. LOW[3] |
| A. S. DWIGHT[2] | W. W. MACON |
| THOMAS EWING | L. C. MARBURG |
| JOHN R. FREEMAN[1] | H. P. MERRIAM |
| MICHAEL FRIEDSAM | M. I. PUPIN[5] |
| H. A. GILLIS | W. L. SAUNDERS[2] |
| HENRY GOLDMARK | J. WALDO SMITH[1] |

ELMER A. SPERRY[6]

1 Nominated by American Society of Civil Engineers.
2 " American Institute of Mining and Metallurgical Engineers
3 " American Society of Mechanical Engineers.
4 " American Institute of Electrical Engineers.
5 " American Association for the Advancement of Science.
6 " American Chemical Society.
7 " Society for the Promotion of Engineering Education.

Many of its members have donated original historical documents, old patent records, books, drawings, prints, models, photographs and descriptions of important work, etc., to the National Museum and correspondence regarding these things is solicited.

The Secretary would like to hear by letter from any one recounting items of historical value or interest or, if they should happen to be in the neighborhood, he would welcome a call during which experiences may be dictated to his amanuensis. all of these accounts will be carefully catalogued and placed in the research file for the reference of any one who can make proper use of them. They will eventually go for permanent preservation to the National Museum which is to be part of the Smithsonian Institution at Washington.

The Secretary may be addressed as follows: H. F. J. Porter, Secretary, National Museum of Engineering and Industry, 29 West 39th Street, New York City.

## Ocean Magnetic and Electric Observation Carnegie Institution

A fifth volume of "Researches of the Department of Terrestrial Magnetism" has appeared from the press of the Carnegie Institution, Washington, D. C. This volume contains articles on Magnetic Results by J. P. Ault, Atmospheric-Electric Results by Messrs. J. P. Ault and S. J. Manchly, and also further data on Ocean magnetic and electric observation and studies in atmospheric electricity based on observations made aboard the *Carnegie* during its cruises during the years 1915-21.

## Midwest Power Conference Held in Chicago

To consider how the available power resources of the country, especially of the middlewest section, might best be developed for the benefit of the people and the industries, a meeting known as the Midwest Power Conference was held in Chicago in the Furniture Club of America, January 26 to 29. This conference was sponsored by the local divisions of the A. I. E. E., A. S. M. E., A. I. M. E., N. E. L. A., Western Society of Engineers and the National Safety Council.

The conference opened with an address by Samuel Insull on "Power Developments in the Mississippi Valley," followed by the presentation of seventeen papers dealing with the advantages of full development, distribution and use of power resources, fuel, boilers, turbines, diesel engines, power generation, industrial power, superpower, rural service and safety first aid. G. E. Pfisterer, 37 W. Van Buren St., Chicago, was Secretary of the General Arrangement Committee.

## Library Service

As few members of the American Institute of Electrical Engineers appreciate the very convenient and practicable service offered by the Engineering Societies Library and as I have personally found it most useful, I should like to point out to readers of the Journal some of the opportunities it offers through its expert staff.

The library will furnish, at short notice, photoprint copies of pages of any available book or periodical, including illustrations, at 25 cents a page. This will permit, for example, obtaining a permanent copy of any article or extract, for which only a reference is available.

In case of long articles which would be expensive to photoprint, complete, the library will sometimes make the prints and loan them at a reasonable per diem charge with the option of subsequent purchase.

The library will translate any available article in a foreign language at about $6.00 a thousand words, so that references to foreign articles can be very readily investigated.

The library will make searches of the periodicals or technical books and list all articles bearing on any particular subject matter that may be prescribed. Where such a search is to be for general information, or to find what has been written about some particular matter or what has been done to solve a special problem, the time required is short and the charge small. In the case of patent searches or exhaustive studies, the time and charges will be such as may be appropriate.

This is an extremely convenient and valuable service when one gets in the habit of using it, especially for an engineer who has new designs to make or new problems arising from time to time.

The library will lend books where duplicates are available for a 5 cents per diem charge, delivering them by mail, and such books are available on many subjects. They may usually be subsequently purchased.

The library has a sort of clipping bureau to the extent that it will follow the technical periodical press and regularly send notices or articles or books appearing on any particular subject, an appropriate charge being made.

In general the library is ready in any practicable manner to use the books and periodicals and the services of the staff to help members of the founder societies or any other persons who may wish to take advantage of the facilities, to get any information that may be wanted, quickly, and conveniently, and without visiting the library, if desired. Engineers should make use of this service as often as possible, first because as they come to realize the convenience of it they will obtain great benefit and second because it strengthens the library and enables better service to be given.

PERCY H. THOMAS

## ENGINEERING FOUNDATION

### ELECTION OF OFFICERS

At the annual meeting of Engineering Foundation February 11, the following officers were elected for the ensuing year: Chairman, Lewis B. Stillwell (member, American Institute of Electrical Engineers, American Society of Civil Engineers); Vice-Chairman, Elmer A. Sperry (member, American Institute of Electrical Engineers, American Society of Mechanical Engineers). George A. Orrok (member, American Society of Mechanical Engineers, Am. Inst. of Mining and Metallurgical Engineers, American Society of Civil Engineers). Additional members of Executive Committee, J. Vipond Davies, (member Am. Inst. of Mining & Metallurgical Engineers, Am. Society of Civil Engineers). Arthur M. Greene, Jr., (member, American Society of Mechanical Engineers). Director and Secretary, Alfred D. Flinn; Treasurer, Jacob S. Langthorn; Assistant Treasurer, Henry A. Lardner.

## United Engineering Society

### EXTRACTS FROM PRESIDENT'S REPORT FOR YEAR 1925

Throughout 1925, as in the preceding year, the energies of the Trustees were devoted largely to improving the investment of trust funds. Especial attention was given to the Engineering Foundation endowment. A new active bank account was authorized to be established January 1, 1926 at the Fifth Avenue branch of The Farmers' Loan and Trust Company.

In June, the $50,000 legacy establishing the Henry R. Towne Engineering Fund was received in cash. It has been invested.

Assessment of Engineering Societies Building for taxation in 1925 was reduced by the Department of Taxes and Assessments, after a hearing, from $1,450,000 to $195,000, applying only to space occupied by taxable organizations.

A medallion of General Pershing was placed in the Entrance Hall as a companion to the medallion of Marshal Foch received in 1921. In December, the flags of the 24th Regiment of Engineers (Mechanical) were received and placed in the cabinet with the flags of the 27th Engineers received in 1924.

President Ralph Budd, of the Great Northern Railway, presented to United Engineering Society a bronze replica of the statue of John F. Stevens, Hon. M. Am. Soc. C. E., set up last July in Marias Pass through the Rocky Mountains, which he discovered. The statuette was placed in the Library.

A name for the Auditorium in Engineering Societies Building was adopted in December. It is "Engineering Auditorium."

By direction of the Board of Trustees, the Secretary has prepared a History of United Engineering Society and the Fifth Revision of the Charter and By-Laws.

Engineering Societies Building is in excellent condition and fully occupied, with a waiting list. Erection of new buildings and remodeling of old ones in the vicinity have improved the external fire hazard. In November, a contract was made with the New York Steam Corporation for heating service from its new main in 39th Street and at the end of the year the necessary piping was being installed.

Memberships of the Founder Societies at the end of 1925 totaled 55,695 and of the Associate Societies 52,204, an aggregate of 107,899 engineers having headquarters in our building.

All departments of United Engineering Society closed the year without deficits. The assets for which the Society is responsible (real estate at cost, trust funds at book value, and Library as appraised) total $3,145,395.44.

BALANCE SHEET

ASSETS

| | | |
|---|---|---|
| Real Estate: | | |
| Land | $ 540,000.00 | |
| Building | 1,369,398.28 | |
| Equipment | 33,171.16 | |
| Founders' Preliminary Expenses | 24,000.00 | $1,966,569.44 |
| Investments and Cash Uninvested: | | |
| Depreciation and Renewal Fund | | $ 192,623.70 |
| Engineering Foundation Fund | | 479,542.97 |
| Library Endowment Fund | | 97,506.37 |
| General Reserve Fund | | 10,000.00 |
| Reserve for Depreciation of Library Capital | | 4,000.00 |
| Henry R. Towne Engineering Fund | | 49,953.13 |
| Operating Cash and Petty Cash | | 8,310.38 |
| Accounts Receivable | | 4,389.45 |
| | | $2,812,895.44 |

LIABILITIES

| | |
|---|---|
| Founders' Equity in Property | $1,966,569.44 |
| Depreciation and Renewal Fund | 192,623.70 |
| Engineering Foundation Fund | 479,542.97 |
| Library Endowment Fund | 97,506.37 |
| General Reserve Fund | 10,000.00 |
| Reserve for Depreciation of Library Capital | 4,000.00 |
| Henry R. Towne Engineering Fund | 49,953.13 |
| Deposits on Account Hall Rentals | 35.00 |
| Credit Balance in Accounts Receivable | 101.68 |
| Deferred Credit—Miscellaneous Contributions to Library | 3,065.87 |
| Credit Balance in Activity Accounts | 9,479.28 |
| | $2,812,895.44 |

### MEETING OF THE BOARD OF TRUSTEES

At the annual meeting of the Board of Trustees of United Engineering Society held January 28, the following officers were elected for the ensuing year: President, W. L. Saunders; 1st Vice-President, Bancroft Gherardi; 2nd Vice-President, Lewis D. Rights; Secretary, Alfred D. Flinn; Treasurer, Jacob S. Langthorn and Assistant Treasurer Henry A. Lardner.

## PERSONAL MENTION

H. W. Young, President of the Delta-Star Electric Co., Chicago, sailed March 6th on the Berengaria for a six weeks business trip to England, France and Italy. He is accompanied by Mrs. Young.

B. Lazich has resigned his position in the Equipment Engineering Department of the Bell Telephone Company at Pittsburgh, to accept a position in the engineering department of the Union Switch and Signal Co. at Swissvale, Pa.

Hazael Colatine Prado, of Santander, Cauca, Columbia, S. A., an Associate of the Institute, has been laying out a new town of over 62 plazas, at the hacienda of La Libertad, Municiple de San Joaquin, Caldas. These blocks consist of sixteen lots 15 x 30 meters, given away by the owner.

Walter P. Holcombe, member of the Institute and John C. Parker, Fellow, were appointed vice-presidents of the Brooklyn Edison Company at a meeting of the board of directors yesterday. Mr. Holcombe has been purchasing agent for the company for several years, and Mr. Parker has been chief electrical engineer for the Company.

A. W. Berresford, Fellow of the Institute and its President during the year 1920-21, has just been appointed executive vice-president of the Nizer Corporation, Detroit, manufacturers of the Nizer Electric Ice Cream cabinets and automatic refrigerating units. Mr. Berresford, for some twenty years, has been vice-president and general manager of the Cutler-Hammer Manufacturing Company. He was also recently elected vice-president of the American Engineering Council.

Miss Edith Clarke, Associate of the Institute and for the past six years, engineer of the General Electric Company at Schenectady, N. Y., is the first woman member to present a paper before the American Institute of Electrical Engineers, when her paper, *Steady-State Stability in Transmission Lines*, was delivered at the Midwinter Convention of last month. Miss Clarke is a Vassar graduate, she took her engineering degree at Massachusetts Institute of Technology and upon April 13, 1923, became one of five women members of the A. I. E. E.

Farley Osgood, Past-President of the Institute, has opened offices in the National Bank of Commerce Building, New York, for consulting engineering in the design, construction, operation and interconnection of public utilities.

After receiving his education at Massachusetts Institute of Technology, Dr. Osgood went in 1894 with the American Bell Telephone Company, Boston. In 1897-98, he affiliated himself with the New England Telephone and Telegraph Company, and finally became Division Manager of the New York and New Jersey Telephone Company. In 1904 he was appointed Chief Engineer and General Manager of the New Milford Power Company, and in 1908 he was made General Superintendent of the Public Service Electric Company of New Jersey, advancing later to the position of Vice-President and General Manager of that Company.

He has always been an active worker in the A. I. E. E., the N. E. L. A. and other representative organizations. In 1911-14, he was a Director of the Institute, Vice-President in 1914-15-16 and President in 1924-25. From 1921 to 1922 he was Chairman of the Institute's New York Section, and he has served the Institute also on the following committees: Executive, Finance, Edison Medal, Standards, Safety Codes and others.

L. C. Brooks, who has been identified with marine electrical applications since the inception of the art on the *U. S. S. Kearsarge* and *Kentucky*, twenty-five years ago, and for the last eight years electrical engineer of the Bethlehem Shipbuilding Corporation, has resigned. Mr. Brooks has been chairman of the A. I. E. E. Committee on Applications to Marine Work for two years. He expects to take a much needed vacation, after which his plans may lead him into an entirely new field of activity.

## Obituary

**Edmund Hugh Pryce** died at his home, 568 West 149th Street, New York City, on February 12th. Born at Llanidloes, Wales, in 1872, Mr. Pryce's early education was through the English Grammar School at the Oswestry Grammar School, South Kensington course at Oswestry. For five years he was apprenticed in technical shops and offices of the Cambrian Railway Company. This was followed by two years' training in mechanical and electrical engineering with the Central Marine Engine Company. He was also with the British India Steam Navigation Company for seven years in varying capacities and held the Chief Engineers Certificate granted by the Board of Examiners, Trinity House, London. Coming to the United States, Mr. Pryce was first engaged with the National Automatic Fire Alarm Company as constructing Electrical Engineer, but left them very shortly to enter the Wool Exchange. Mr. Pryce joined the Institute in 1904 but continued as an Associate until the time of his death.

**Charles C. Clancy Grandy,** Radiologist of the Lutheran Hospital, Fort Wayne, Indiana, an Associate of the Institute since 1920, and past-chairman of the Fort Wayne Section of the A. I. E. E., (1923-1924) died the morning of February 12th, 1926. Doctor Grandy was born at Wall Lake, Iowa. After finishing High School at Warsaw, Indiana, he entered the Indiana University from which he obtained his A. B. in 1908 and A. M. in 1909. He next attended the Rush Medical College, Chicago, Illinois, from which he graduated with his M. D. degree in 1911. Since then he has been doing the X-ray work at the Fort Wayne Lutheran Hospital, having charge of the laboratory there. Doctor Grandy will be much missed by his medical colleagues as well as by the members of the Institute's Fort Wayne Section. Due to his death, the meeting scheduled for February 12th was cancelled.

**Robert Alexander Paine, Jr.,** after an illness of a month's period, died at the Methodist Episcopal Hospital, Brooklyn, February 7th. His death is keenly felt by his business associates in the Brooklyn Edison Company, for whom he has been plant engineer for some time past. He was born in Richmond, Va., August 30, 1887 and his early schooling was obtained in the Ashland Grammar School, Ashland, Va. September 1904 he entered the Randolph-Macon College, at Ashland, obtaining his A. B. degree there in 1905. He next attended the Virginia Polytechnic Institute, Blacksburg, Va., whence he graduated June 1908 with a B. S. degree in Electrical Engineering and in June 1909 with a degree in Mechanical Engineering. June 1910 he entered the Testing Department of the General Electric Company, Schenectady, but left the following year to become assistant to the Chief Engineer of the Coney Island and Brooklyn Railroad Company, Brooklyn, N. Y. Here he was promptly appointed acting electrical engineer in charge of electric operation, remaining with them until in 1914 he became general foreman, Development Research Bureau of the Edison Electric Illuminating Company of Brooklyn. Mr. Paine was elected to the grade of Associate in the Institute in 1913.

## Addresses Wanted

A list of names of members whose mail has been returned by the Postal Authorities is given below, together with the addresses as they now appear on the Institute records. Any member knowing the present address of any of these members is requested to communicate with the Secretary at 33 West 39th St., New York, N. Y.

All members are urged to notify the Institute Headquarters promptly of any change in mailing or business address, thus relieving the member of needless annoyance and also assuring the prompt delivery of Institute mail, the accuracy of our mailing records, and the elimination of unnecessary expense for postage and clerical work.

1.—William E. Ames, Detroit Edison Co., Research Div., Detroit, Mich.
2.—H. R. Bailey, Room 923, Electric Bldg., Portland, Ore.
3.—J. E. Contesti, 350 W. 58th St., New York, N. Y.
4.—Ralph Elsman, 120 Broadway, New York, N. Y.
5.—L. W. Ferguson, Box 331, Barbourville, Ky.
6.—Chas. A. Foust, 10505 93rd St., Woodhaven, N. Y.
7.—George Frasher, 1209 So. 4th Ave., Louisville, Ky.
8.—S. Alden Griffin, 19 Elliott St., Springfield, Mass.
9.—Harold G. Haines, 7416 Sylvester, Detroit, Mich.
10.—Wm. J. Hay, 320 Second St., Aspinwall, Pa.
11.—Wendell E. Haywood, 823 Boatmens Bank, St. Louis, Mo.
12.—Elmer D. Johnson, 1481 Harvard St., Washington, D. C.
13.—Harry W. Kohler, 200 14th St., Milwaukee, Wis.
14.—Charles L. Leaf, 175 Dodd St., East Orange, N. J.
15.—John E. Lewis, 376 Meyran Ave., Oakland Station, Pittsburgh, Pa.
16.—Chas. W. Magee, c/o Pelser, 210 West 102nd St., New York, N. Y.
17.—J. A. McDermott, Y. M. C. A. Lima, Ohio.
18.—Raymond W. Noddins, 230 East Ohio St., Chicago, Ill.
19.—Lieut. A. G. Scott, 68 West 107th St., Apt. 2D, New York, N. Y.
20.—A. B. Smedley, c/o Cooper Hewitt Elec. Co., 1406 First Nat'l Bank, Cincinnati, Ohio.
21.—C. D. Smith, 857 St. Charles St., New Orleans, La.
22.—Will M. Strickler, 301 Detroit Life Bldg., Detroit, Mich.
23.—A. R. Williamson, 561 Delaware Ave., Norwood, Pa.

## Book Review

Annual Proceedings of the A. S. T. M. Prices: $6.00 in paper, $6.50 in cloth and $8.00 in half-leather binding.

Part I (962 pp.) contains the annual reports of 35 of the standing committees of the Society, with the discussion thereon at the annual meeting. These include reports of Committees on Ferrous Metals, Non-Ferrous Metals, Cement, Ceramics, Concrete, Gypsum, Lime, Preservative Coatings, Petroleum Products, Road Materials, Coal and Coke, Water-proofing Materials, Electrical Insulating Materials, Rubber Products, Textile Materials, Thermometers, Metallography, including a report on Metal Radiography and *X*-ray Crystallography. Methods of Testing and Nomenclature and Definitions: 83 tentative standards which have either been revised or are published for the first time; annual address of the President and the annual Report of the Executive Committee.

Part II (454 pp.) contains 26 technical papers with discussion, giving valuable information regarding results of investigations by experts in the field of engineering materials including the fatigue of metals, the effect of temperature on the properties of metals and investigations on the corrosion of metals. Mention should also be made of the many papers on cement and concrete and on the stability of bituminous mixtures as well as on such subjects as bituminous materials, paint, gypsum, brick, textiles, etc.

# Engineering Societies Library

*The library is a cooperative activity of the American Institute of Electrical Engineers, the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers and the American Society of Mechanical Engineers. It is administered for these Founder Societies by the United Engineering Society, as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West Thirty-ninth St., New York.*

*In order to place the resources of the Library at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies or translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.*

*The Library maintains a collection of modern technical books which may be rented by members residing in North America. A rental of five cents a day, plus transportation, is charged.*

*The Director of the Library will gladly give information concerning charges for the various kinds of service to those interested. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.*

*The library is open from 9 a. m. to 10 p. m. on all week days except holidays throughout the year except during July and August when the hours are 9 a. m. to 5 p. m.*

### BOOK NOTICES (JAN. 1-31 1926)

Unless otherwise specified, books in this list have been presented by the publishers. The Society does not assume responsibility for any statement made; these are taken from the preface or the text of the book.

All books listed may be consulted in the Engineering Societies Library.

Administration of Industrial Enterprises.

By Edward D. Jones. New edition. N. Y., Longmans, Green & Co., 1925. 618 pp., illus., tables, 9 x 6 in., cloth. $4.75.

The purpose of this book is to present in compact outline a survey of the art of business management as it exists in the United States at this time. The treatment aims to present practise with reasonable fullness of detail but, wherever possible, to deduce and formulate the general principles, or the philosophy, controlling action.

The chief outstanding characteristic is the inclusion, for the first time in such a treatise, of a full discussion of the underlying general principles of administration which govern all efficient joint enterprises, whether of a business nature or otherwise.

This edition has been thoroughly revised, the new material exceeding the subject matter of the first edition. The numerous bibliographies have been brought up to date.

Aeronautical Meteorology.

By Willis Ray Gregg. N. Y., Ronald Press Co., 1925. (Ronald Aeronautic Library). 144 pp., illus., diagrs., tables, 9 x 6 in., cloth. $2.50.

Intended to give concisely the essential facts concerning the upper air and to point out their relation to the development and safety of aeronautics. The book is intended for pilots, aeronautical engineers and others requiring an intimate knowledge of the characteristics of the atmosphere.

Architectural Iron Design and Detailing, as Required by the Laws of New York.

By Daniel M. Driscoll. N. Y., D. Van Nostrand Co., 1926. 349 pp., illus., plates, tables, 8 x 11 in., cloth. $4.00.

The subjects covered are the designing and detailing of stairs, elevator drip pans, door bucks, door saddles, doors, gratings, sidewalk gratings and other miscellaneous metal work, and fire-escapes; and the fabricating and setting of light structural steel. Appendices give useful tables, cuts of stock ornamental moulding and shapes, the Building Code of New York City, the Tenement House Law and Labor Law of New York State, the Code of Ordinances and the Rules of the Board of Standards and Appeals of New York City, and a glossary. The book is intended for draftsmen, not beginners. It should be particularly useful because of its careful attention to the laws governing the design of these articles.

Bureau of Standards.

By Gustavus A. Weber. Balt., Johns Hopkins Press, 1925. (Institute for Government Research. Service monographs, no. 35). 299 pp., illus., 9 x 6 in., cloth. $2.00.

The history, activities and organization of the Bureau of Standards are presented in detail in this volume, which gives a complete account of its purpose, its achievements and their cost. The laws governing it, the character of its plant, its functions and its personnel are described, and a full bibliography of the sources of information bearing on it is given.

Condensed Collection of Thermodynamic Formulas.

By P. W. Bridgman. Cambridge, Harvard University Press, 1925. 34 pp., 9 x 6 in., cloth. Price not quoted.

This collection of formulas is intended both for students of thermodynamics and for use in practice. The formulas given apply to systems for which temperature and pressure are a possible set of independent variables; and to systems for which pressure is a function of temperature, and temperature and volume are a possible set of independent variables. The latter table applies to two-phase systems such as water and steam in contact.

Illustrative examples show how the tables are used. The author also shows how to extend the tables, in a number of cases, to systems subjected to other external forces than a hydrostatic pressure.

The Dynamo . . . v. 3, Alternators.

By C. C. Hawkins. 6th edition. N. Y., Isaac Pitman & Sons, 1925. 572 pp., illus., diagrs., 9 x 6 in., cloth. $8.50.

The first two volumes of this edition appeared a few years ago. They are now supplemented by a third volume devoted to alternators. It discusses armature winding, the loop e.m. f. of the heteropolar and the toothed armature, armature reactions, the construction of armatures and field magnets, the design of the salient-pole alternator, the turbo-alternator with cylindrical rotor and the parallel working of alternators. The treatment is brief enough for the student, but is intended to provide a basis for further consideration of the various phenomena discussd, with reference to sources of more detailed information.

Electrical Power and National Progress.

By Hugh Quigley. Lond., George Allen & Unwin, 1925. 160 pp., graphs, 9 x 6 in., cloth. 8-6.

The volume, which is based on articles that have appeared in various British newspapers, examines the probable effects of a reorganization of power generation and distribution on the industrial life of Great Britain, and the economic consequences of the national development of electrical power.

History of Engineering.

By A. P. M. Fleming & H. J. Brocklehurst. Lond., A. & C. Black; [N. Y., Macmillan Co.], 1925. 312 pp., illus., 9 x 6 in., cloth. 12/6.

The title is misleading, for with the exception of a chapter on ancient engineering, the account is limited to the development of engineering in Great Britain. For that country, the authors give a concise, readable account of progress in the refinement of measurement; the construction of docks, harbors, canals, roads and bridges; the invention of the steam engine; the development of railroad, gas, oil and electric engineering; and of the influence of progress in iron making on engineering.

Hutte, Des Ingenieurs Taschenbuch, v. 1.

By Akademischen Verein Hütte. Berlin, Wilhelm Ernst & Sohn, 1925. 1080 pp., diagrs., table. 8 x 5 in., cloth. 12,20 mk.

When twenty-five editions of a book have been called for in sixty-eight years, its popularity is evident. In spite of its frequent revision, the new edition shows still further important changes and novelties. An attempt has been made to collect the theoretical principles of all engineering in volume one, and this has necessitated some rearrangement. A new section, "Technical physics," has been added, and new chapters provided on nomography and the kinetics of gearing. All sections have been carefully revised and new standards have been adopted.

Induction Motor in Theory, Design and Practice.

By Herbert Vickers. N. Y., Isaac Pitman & Sons, 1925. 322 pp., diagrs., plates, tables, 9 x 6 in., cloth. $6.00.

Primarily intended to introduce the student electrical engineer to the theory and design of these motors, this is a well-balanced text-book, in which an endeavor is made to place design on a firm scientific basis. The latest developments in speed control and power-factor control are dealt with.

The Industrial Museum.

By Charles R. Richards. N. Y., Macmillan C., 1925. 117 pp., illus., 10 x 6 in., cloth. $3.00.

During the year 1923-24, the author made a survey of foreign museums of industrial art for the American Association of Museums. The present book forms part of the report submitted and deals with industrial museums.

The museums described include the Conservatoire des Arts et Métiers, the Science Museum, the Deutsches Museum, and the Technisches Museum für Industrie und Gewerbe in Wien. There are also a chapter on industrial museums in this country and appendices on various foreign museums devoted to particular subjects, such as traffic, the marine and agriculture. The illustrations include photographs of many of the more interesting exhibits.

Lockwood's Directory of the Paper and Allied Trades. 1926.

N. Y., Lockwood Trade Journal Co., 1925. 942 pp., 9 x 6 in., cloth. $7.50.

This directory lists the paper mills of North and South America, showing their locations, officers, equipment and capacity. It also contains a directory of mill officials and classified lists of the mills making different papers, of makers of paper specialties, of paper merchants, of dealers in raw materials, of paper box manufacturers, of stationers of brands and of trade associations. The book covers every brand of the industry and has long been the authority in its field.

Mercury-Arc Rectifiers and Mercury-Vapour Lamps.

By J. A. Fleming. Lond. & N. Y., Isaac Pitman & Sons, 1925. 100 pp., illus., diagrs., 7 x 5 in., cloth. $1.75.

Now that this rectifier has become available for electrical work on a large scale and has reached a durability and efficiency comparable with that of dynamos, its working and use are of interest to all electrical engineers. The mercury-vapor lamp has also important commercial and therapeutic uses. The present little book has been written to supply a small treatise on the mode of operation and the uses of these devices.

Statement and Engineering Report Submitted to the International Joint Commission Respecting the Proposal to Develop the St. Lawrence River. 1921.

By Hydro-Electric Power Commission of Ontario. Toronto, 1925. 119 pp., plans, maps, tables, 10 x 7 in., cloth. $7.50.

When the International Joint Commission was empowered, in 1920, by the governments of Canada and the United States to make a special investigation respecting the improvement of the St. Lawrence River, the Hydro-Electric Power Commission of Ontario arranged that the information which it already possessed should be supplemented with the information obtained by additional research and the whole reduced to a report intended to help the International Joint Commission in its investigation.

This was done, but as the report has never appeared in print, the Hydro-Electric Power Commission has now published it. The report is directed to plans for power development, but the improvements are planned, it is stated, to safeguard navigation.

Talks About Radio . . .

By Sir Oliver Lodge. N. Y., George H. Doran Co., 1925. 267 pp., 8 x 6 in., cloth. $2.50.

Sir Oliver Lodge writes informally and interestingly of various topics connected with radio, addressing his book to the large army of amateurs. Among the subjects touched upon are broadcasting, the work of the pioneers, the discovery of the waves and the development of radiotelegraphy. The vast range of ether vibrations, the transmission of wireless waves, their peculiarities and the general theory of ether waves are discussed. The second part is concerned with some details that make for efficiency, and the third part gives advice and simple rules for various calculations that the amateur constructor needs.

Telephone Communication Systems.

By Royce Gerald Kloeffler. N. Y., Macmillan Co., 1925. (Engineering science series). 284 pp., illus., diagrs., 9 x 6 in., cloth. $4.50.

This book is intended to give the general information needed for a short college course in telephony and also to supply to the worker in telephony a knowledge of matters outside his own particular work. The text is confined to typical present day apparatus and systems.

TRANSFORMERS FOR SINGLE AND MULTIPHASE CURRENTS.

By Gisbert Kapp. 3rd edition revised by Reginald O. Kapp. N. Y., Isaac Pitman & Sons, 1925. 391 pp., illus., diagrs., plates, 9 x 6 in., cloth. $4.50.

In the last edition of this book, issued in 1908, the late Gisbert Kapp spoke of a 3500 kv-a. transformer as "one of the largest made." Today, 60,000 kv-a. transformers are in service. During the interval there has also been great development in construction, insulation and accessories, and many special types for special purposes have been introduced.

In order to keep the book of reasonable size, the reviser has had to confine himself to selected aspects of the subject. In his selection he has kept in mind the needs of students of electrical engineering and of electrical engineers in general rather than those of specialists in transformer design and those interested in the mathematics of the transformer.

The new edition omits some material on the general theory of electricity and on matters no longer of chief importance. More space has been devoted to construction, installation and maintenance. The chapters on design have been revised and new chapters on structural details and on potential and current transformers have been added.

PRINCIPLES OF SOUND SIGNALLING.

By Morris D. Hart and W. Whately Smith. Lond., Constable & Co., 1925. 139 pp., 9 x 6 in., cloth. 12/6. New York, D. Van Nostrand Company.

This book is mainly concerned with the examination of the conditions under which any required acoustical effect may be produced with the minimum expenditure of power. The treatment is theoretical, the object being to identify the factors that affect the efficiency of an acoustical system and to determine the sense in which each operates, so that it will be possible to formulate conditions for an efficient system. The authors discuss in detail the processes of sound production, transmission and reception, and the selection of the most satisfactory combination of these elements.

# Past Section and Branch Meetings

## SECTION MEETINGS

### Akron

*Philo Generating Station of the Ohio Power Company*, by J. A. Bergin, Superintendent of Operation. Illustrated with slides. January 16. Attendance 90.

### Boston

*Latest Design and Practise in Power Plants*, by V. E. Alden, Consolidated Gas, Elec. Lt. & Power Co. Joint meeting with A. S. M. E. January 14. Attendance 180.

### Cincinnati

*Progress in Design of Steam Turbines*, by D. S. Brown, Union Gas and Electric Co., and

*The New York-Chicago Telephone Cable*, by J. J. Pilloid, American Telephone and Telegraph Co. Illustrated with slides and motion pictures. A demonstration showed effects which occur in the cable. January 14. Attendance 234.

### Cleveland

*The Engineer in Business*, by S. M. Vauclain, Baldwin Locomotive Works. Joint meeting with Association of Iron and Steel Electrical Engineers, A. S. C. E., A. S. M. E., A. I. M. E. and Society of Industrial Engineers. January 21. Attendance 450.

### Connecticut

*Maintenance of Industrial Equipment*, by F. D. Hallock, Westinghouse Elec. & Mfg. Co. January 19. Attendance 85.

*The Quest of the Unknown*, by Professor H. B. Smith. Illustrated with slides. January 29. Attendance 60.

### Denver

*Superpower*, by T. R. Cuykendall;

*The Photo-Electric Cell as a Photometer*, by Stuart Ellis, and

*Low-Intensity Photometry*, by Dr. Reuben Nyswander, University of Denver. January 15. Attendance 36.

### Erie

*Mechanical Power and the Trend of Civilization*, by C. E. Skinner, Westinghouse Elec. & Mfg. Co. January 19. Attendance 65.

### Indianapolis-Lafayette

*The Design, Manufacture and Test of Extra High Voltage Bushings*, by Prof. C. Francis Harding, Purdue University. December 11. Attendance 33.

*Recent Interesting Features in the Industrial Heating Field*, by W. S. Scott, Westinghouse Elec. & Mfg. Co. February 5. Attendance 39.

### Kansas City

*The Application of Electricity to the Medical and Surgical Profession*, by E. A. Monroe, Rosenthal X-Ray Co., and

*The Indictment Against the Electrical Engineer*, by B. J. George, Kansas City Power & Light Co. December 7. Attendance 19.

*Application of Switching Equipment from Economical Standpoint*, by J. H. Starr, Condit Electrical Mfg. Co. Illustrated with slides. January 18. Attendance 34.

### Lehigh Valley

*Research of Today, the Engineering of Tomorrow*, by E. B. Craft, Bell Telephone Laboratories, Inc. January 20. Attendance 118.

### Los Angeles

*The Local Telephone Problem*, by N. R. Powley, Southern California Telephone Co., and

*Development and Research by Bell Telephone Laboratories*, by M. B. Long, Bell Telephone Laboratories, Inc. Illustrated with stereoptican. A dinner preceded the meeting. February 2. Attendance 133.

### Lynn

Inspection trip to the *Boston Globe*. December 12. Attendance 110.

Inspection trip to the South Boston Dry Dock. January 16. Attendance 250.

*The Latest Design and Practises in Power Plants*, by V. E. Alden, Consolidated Gas, Elec. Lt. & Power Co. Illustrated with slides. January 13. Attendance 68.

*Bullets*, by Dr. P. P. Quayle, U. S. Bureau of Standards. Illustrated with slides. January 26. Attendance 68.

### Madison

*Water Power Development with Special Reference to Automatic Generating Stations*, by C. V. Seastone, Consulting Engineer. Joint with University of Wisconsin Branch. January 13. Attendance 50.

### Mexico

*Railroad Electrification*, by E. Cox, General Electric Co. January 7. Attendance 31.

*Meters*, by Scott Lynn, Sangamo Meter Co., and G. Solis Payan. February 4. Attendance 25.

### Minnesota

Dinner Dance. Joint with Engineers Society of St. Paul, Engineers Club of Minneapolis and the A. S. M. E. November 21. Attendance 300.

*New High Bridge Station, St. Paul*, by J. A. Colvin, Northern States Power Co. After the meeting an inspection trip was made through the plant. February 1. Attendance 100.

### Philadelphia

*Automatic Control Equipment*, by Engineers of the Cutler Hammer Mfg. Co., General Electric Co. and Westinghouse Electric & Mfg. Co. Illustrated. January 11. Attendance 165.

### Pittsburgh

*The Invisible Service of Science*, by Dr. M. I. Pupin, National President, A. I. E. E., and

*Giant Power*, by Dr. Farley Osgood, Past President, A. I. E. E. A dinner preceded the meeting. January 8. Attendance 368.

### Pittsfield

*The Electron Theory*, by Dr. Saul Dushman. January 12. Attendance 80.

*Analogies in Mechanics and Electricity*, by Professor W. S. Franklin, Mass. Inst. of Tech. In the afternoon preceding this meeting Professor Franklin spoke to 600 ladies who were guests of the Pittsfield Section. January 19. Attendance 300.

*Electric Welding*, by R. E. Wagner, General Electric Co. The lecture was illustrated by actual welding, samples of various welding processes and by slides. January 26. Attendance 250.

*The Pallotrope, Pallophotophone and the Panatrope*, by C. A. Hoxie, General Electric Co. February 2. Attendance 520.

**Portland**

*The Transmission of Photographs over Telephone Wires*, by M. B. Long, Bell Telephone Laboratories. January 20. Attendance 150.

**Rochester**

*Superpower*, by R. M. Searle, Rochester Gas and Electric Corp. January 8. Attendance 100.

**San Francisco**

*Mechanical Appliances in Line Erection*, by J. A. Koontz, Great Western Power Co. Illustrated with moving pictures. A dinner preceded the meeting. January 15. Attendance 155.

*Electrical Relays and Their Application*, by E. H. Bancker, General Electric Co. Illustrated. January 29. Attendance 155.

**Schenectady**

*Harnessing the Tides in the State of Maine*, by Dexter Cooper. December 11. Attendance 400.

*Mercury-Arc Rectifiers*, by D. C. Prince. Illustrated with slides. January 8. Attendance 260.

**Seattle**

*The Plant of the Seattle Cedar Lumber Company*, by G. T. Thirsk. Illustrated with slides and moving pictures. November 18. Attendance 135.

*The Preliminary Report of the Skagit Engineering Commission*, by Major Joseph Jacobs, Chairman, S. B. Hill and W. C. Morse. Discussion followed. Joint meeting with A. S. C. E., A. S. M. E. and A. I. M. E. A dinner preceded the meeting. December 14. Attendance 250.

*The Problems Confronting the Port of Portland*, by J. H. Polhemus and Robert Kalim. January 20. Attendance 53.

**Sharon**

*Long-Distance Radio*, by S. M. Kintner, Westinghouse Electric & Mfg. Co. February 2. Attendance 175.

**Southern Virginia**

*Power Development in Virginia*, by J. R. Horsley, Water Power & Development Commission;

*Rural Electrification*, by Dr. C. E. Seitz;

*Flood Control*, by Dr. W. A. Nelson, and

*The State Port of Hampton Roads*, by members of State Port Commission. January 15. Attendance 71.

**Spokane**

*Electrical Transmission of Pictures*, by M. B. Long Bell Telephone Laboratories, Inc. January 13. Attendance 60.

*Cushman Hydro-Electric Plant*, by J. L. Stannard. Illustrated with slides. January 22. Attendance 56.

**Syracuse**

*The Problem of Radio Broadcasting*, by C. W. Horn, Westinghouse Electric & Mfg. Co. January 11. Attendance 135.

*Better Engineers—Do We Need Them and Can We Get Them?*, by W. E. Wickenden, Society for the Promotion of Engineering Education. January 18. Attendance 75.

**Toledo**

*Telephone Projects in Toledo*, by V. A. Diggs, Ohio Bell Telephone Co. Illustrated with slides. January 27. Attendance 48.

**Toronto**

*High Voltage Switching and Phase Isolation*, by W. R. Huttinger, Electric Power and Equipment Corp. Illustrated with slides. January 15. Attendance 90.

*Voltage Regulation of Distribution Systems*, by F. F. Ambuhl, Toronto Hydroelectric System. February 5. Attendance 65.

**Urbana**

*Voltage Surges in Transmission Systems*, by J. F. Peters, Westinghouse Electric & Mfg. Co. Illustrated. January 20. Attendance 82.

**Vancouver**

*Operation of British Columbia Electric Power System*, by J. Teasdale, British Columbia Railway Co. Illustrated with charts, maps, forms, photos, etc. February 2. Attendance 46.

**Washington**

*The Effects of Gases as Used in the Chemical Warfare Service*, by Major-General A. A. Fries. Noon-day luncheon meeting. November 24. Attendance 48.

*The French Debt Problem*, by Dr. H. G. Moulton, Institute of Economics. Joint with A. S. M. E. A dinner preceded the meeting. January 13. Attendance 90.

Ladies Night. February 9. Attendance 102.

**Worcester**

*Application of Electric Heat to the Metal-Working Industry*, by W. S. Scott, Westinghouse Electric & Mfg. Co. A dinner preceded the meeting. January 28. Attendance 75.

## BRANCH MEETINGS

**Alabama Polytechnic Institute**

Talk by R. L. Shepherd, *Electrical World*. The following officers were elected: Chairman, C. W. McMullan; Vice-Chairman, J. M. Edwards; Secretary-Treasurer, J. B. Davis; Reporter, W. H. H. Putnam. January 20. Attendance 31.

**University of Arizona**

Motion picture, entitled "Electric Travelogue," was shown. January 9. Attendance 15.

*The Arc Transmitter*, by T. L. Carnes. Motion picture, entitled "Something about the Telephone," was shown. January 16. Attendance 18.

**Brooklyn Polytechnic Institute**

*Characteristics of Electromagnetic Clutches*, by M. M. Landesberg, student. Illustrated with slides; and

*The Organization of the Brooklyn Edison Company*, by R. V. Richard. Illustrated with slides. January 14. Attendance 45.

**California Institute of Technology**

*Design and Performance of Auto Start Motors*, by E. S. Mendenhall, U. S. Motors Corp. Illustrated with charts. January 8. Attendance 34.

Motion pictures, entitled "An Electric Travelogue," "The Story of an Electric Locomotive," and "Rolling Steel by Electricity," were shown. January 29. Attendance 195.

**University of California**

Talks by Robert Sibley and Jos. Le Conte. Joint meeting with A. S. M. E. January 20. Attendance 29.

**Case School of Applied Science**

*Lightning Arresters*, by K. B. McEachron, General Electric Co. January 12. Attendance 62.

**Catholic University of America**

*Power-Plant Conditions in Florida*, by M. J. Idail, Frank Weller Construction Co. January 14. Attendance 30.

**University of Cincinnati**

*Inductive Interference*, by Boris Volgovskoy, student. December 17. Attendance 35.

*Measurement of Transients for Lightning-Arrester Design*, by K. B. McEachron, General Electric Co. January 14. Attendance 65.

**Colorado State Agricultural College**

Business Meeting. February 8. Attendance 12.

**University of Colorado**

*The Student Training Course of the General Electric Company*, by A. S. Anderson. January 6. Attendance 80.

*The Work of the Telephone and Associated Companies*, by R. B. Bonney, Mountain States Telephone and Telegraph Co. January 23. Attendance 40.

**Cooper Union**

*The Quest of the Unknown*, by Professor H. B. Smith, Worcester Polytechnic Institute. February 6. Attendance 120.

**Clarkson College of Technology**

Talk by Professor Van Housen of the Potsdam Normal School. February 2. Attendance 22.

**University of Denver**

*The Photo-Electric Cell as a Photometer*, by Stuart Ellis and Earl Reed, and

*Low-Intensity Photometry*, by Dr. Reuben Nyswander. Illustrated with slides. January 15. Attendance 48.

**Drexel Institute**

*Correct Amplification for Radio and Public-Address Systems*, by G. B. Egge, Bell Telephone Co. Illustrated and demonstrated. January 15. Attendance 64.

**University of Florida**

*Testing the Heat Insulation of "Insulath,"* by R. D. Ross. January 11. Attendance 8.

Motion picture, entitled "Coal is King," was shown. February 1. Attendance 17.

**University of Idaho**

*Public-Service Commissions*, by Marshall Blair; and

*Electrical Applications Aboard Ship*, by Donald Coons. January 5. Attendance 12.

**State University of Iowa**

*Bakelite*, by Frank Wiggins, and

*Use of Engineering Library*, by Percy Williams. January 13. Attendance 41.

**Heaviside**

*Up-and-Down Movement of the Layer*, by S. J. Lambert;

*Student Course at General Electric Company*, by J. M. Nelson, and

*The Instant Heavisidion*, by C. E. Woolridge. January 20. Attendance 49.

Business Meeting. The following officers were elected: President, Leon Dimond; Vice-President, L. A. Ware; Secretary-Treasurer, A. C. Boeke. February 3. Attendance 49.

*Opportunities for Engineers at Westinghouse*, by Fred Homer, and

*The Long Span Across the Narrows at Tacoma*, by H. G. Cox. February 10. Attendance 43.

**University of Kansas**

*The Radio Conference in Washington*, by Professor H. W. Anderson. The following officers were elected: Chairman, K. R. Krehbiel; Vice-Chairman, W. R. Becker; Secretary, K. B. Clark; Treasurer, E. Kietzman. January 7. Attendance 51.

*A Trip through the General Electric Company*, by C. C. Adams and Ross Parker, General Electric Co. February 4. Attendance 100.

**Lafayette College**

*Oil Circuit Breakers*, by R. M. Spurck, General Electric Co. January 14. Attendance 20.

*Research and Engineering*, by E. B. Craft, Bell Systems Laboratories, Inc. Joint meeting with Engineers Club of the Lehigh Valley and Lehigh Valley Section, A. I. E. E. January 20. Attendance 225.

**Massachusetts Institute of Technology**

*Richmond Station of the Philadelphia Electric Company*, by Constantine Bary, student. Illustrated with slides. January 20. Attendance 15.

**Michigan State College**

*Characteristics of Electric Motors*, by E. L. Bailey, Cleveland Electric Motor Co. Motion picture, entitled "Mans Conquest of Time," was shown. January 12. Attendance 53.

**University of Michigan**

*Lightning Arresters*, by K. B. McEachron, General Electric Co. January 18. Attendance 60.

**Engineering School of Milwaukee**

A motion picture, entitled "Queen of the Waves," was shown. January 22. Attendance 82.

**Missouri School of Mines and Metallurgy**

*Switchboard Equipment of a Power Station.* A motion picture entitled "The Story of the Storage Battery," was also shown. January 14. Attendance 17.

**Montana State College**

*The General Electric Post-Graduate Course in Electrical Engineering*, by M. M. Boring, General Electric Co. January 18. Attendance 170.

*Opportunities Offered by the Western Electric Company*, by C. W. Brotherton, Western Electric Co.; and

*Opportunities in the American Telephone and Telegraph Company*, by R. B. Bonney, Mountain States Telephone and Telegraph Co. January 25. Attendance 159.

**University of Nevada**

*The Bell Telephone Laboratories, Inc.*, by M. B. Long. January 26. Attendance 50.

**University of North Carolina**

*Laying a High-Tension Cable*, by J. L. Cantwell, Tidewater Power Co. January 18.

*The Moncure Steam Plant*, by R. F. Stainback. January 28. Attendance 18.

**University of Notre Dame**

*Theory of Rates and System of Metering*, by R. H. Anders, Indiana-Michigan Co. January 18. Attendance 30.

**Ohio Northern University**

*Fundamentals*, by Professor Berger. January 14. Attendance 17.

Business Meeting. February 4. Attendance 26.

**Ohio State University**

*Various Phases of Engineering*, by Professor F. C. Caldwell. January 15. Attendance 110.

**University of Oklahoma**

*Problems Confronting an Engineering Graduate*, by W. A. Kitchen, Oklahoma Gas and Electric Co. January 21. Attendance 27.

**Oregon Agricultural College**

Business Meeting. January 18. Attendance 41.

Business Meeting. February 2. Attendance 35.

**Pennsylvania State College**

*Super-Power*, by D. E. Trucksess, J. H. Garbrick, M. S. Longenecker, A. P. Jackel and H. M. Patrick. January 13. Attendance 50.

*The Processes of Insulating Copper Wire*, by Professor D. L. Markle. A motion picture, entitled "Voice Highways in the Making," was shown. January 27. Attendance 70.

*Spectacular Illumination for the Sesquicentennial*, by Professor E. B. Staveley. Illustrated with slides; and

*Rate Making*, by E. Axman. February 10. Attendance 35.

**University of Pennsylvania**

Fall Dance. November 13. Attendance 100.

Business Meeting. December 18. Attendance 44.

Business Meeting. January 29. Attendance 40.

Business Meeting. February 9. Attendance 45.

**University of Pittsburgh**

*Boiler Tests at Colfax*, by R. R. Thorne, student. January 8. Attendance 26

*Recent Developments in Boiler Design*, by J. H. Crane. January 15. Attendance 30.

*The Opportunities Afforded by the Westinghouse Electric & Mfg. Company*, by D. S. Templeton. January 22. Attendance 35.

**Purdue University**

*The Lighting Business*, by F. H. Talbott, student, and

*History of the Incandescent Lamp*, by Professor A. N. Topping. Illustrated. February 9. Attendance 70.

**Rose Polytechnic Institute**

*Lightning Arresters* and *The Study of High-Speed Transients*, by K. B. McEachron, General Electric Co. January 13. Attendance 47.

Motion picture on Arc Welding was shown. February 11. Attendance 35.

**South Dakota State School of Mines**

*The Development of Electrical Engineering Course*, by E. E. Clark;

*Valuable Statistics for the Electrical Engineer*, by H. M. Johnson; and

*Feild for the Electrical Engineers of the Future*, by Professor J. O. Kammerman. January 19. Attendance 51.

**Stanford University**

*The Different Grades of Brass and Bronze*, by G. T. Piersol, American Brass Co. A motion picture, entitled "Brass—From Mine to Consumer," was shown. January 14. Attendance 60.

Smoker. Joint meeting with A. S. M. E. Mr. C. V. Moroney, West Coast Sugar Refining Co., gave a talk on Organization and Management. Short talks on Engineering were also given by Professor H. J. Ryan and Professor G. H. Marx. February 3. Attendance 100.

**Swarthmore College**

*Steam Generation and Superheat*, by W. H. Berry. February 11. Attendance 35.

**Syracuse University**

*The Inverter*, by F. A. Lewis. January 6. Attendance 17.

**University of Utah**

*Accepting Engineering Responsibilities*, by Lafayette Hanchet, Utah Light and Power Co. Joint meeting with Engineering Society of the University of Utah, A. S. M. E. and A. S. C. E. February 2. Attendance 523.

**Virginia Military Institute**

*Electricity and Its Relation to Communication*, by L. S. Griffith, and

*Progress in the Aeronautical Industry*, by L. H. von Shilling. February 3. Attendance 47.

**Virginia Polytechnic Institute**

*Insulations*, by J. S. Lapp, Lapp Insulator Co. January 15. Attendance 66.

Motion pictures, entitled respectively "The Life of Thomas Edison" and "The Revelations of the X-Ray," were shown. January 25. Attendance 300.

*Advantages of the Electric over the Steam Road*, by F. S. Oliver, student; *The Value of Individual Thought*, by L. B. Proctor, student; *The Duofold Oscillograph*, by H. J. Harris, student, and *Short Wave Transmission*, by E. D. Gray, student. January 27. Attendance 45.

**University of Virginia**

A motion picture, entitled "A Romance of Rails and Power," was shown. February 1. Attendance 20.

**University of Wisconsin**

*Water-Power Development and Automatic Stations*, by Mr. Seastone, Consulting Engineer. Illustrated with slides. January 13. Attendance 45.

**Worcester Polytechnic Institute**

*Hydroelectric Plants of the New England Power System*, by W. R. Bell, New England Power Co. Illustrated with slides. January 20. Attendance 42.

**University of Wyoming**

*Evolution of the Telephone*, by I. W. Bond, Mountain States Telephone and Telegraph Exchange. January 28. Attendance 16.

# Engineering Societies Employment Service

*Under joint management of the national societies of Civil, Mining, Mechanical and Electrical Engineers cooperating with the Western Society of Engineers. The service is available only to their membership, and is maintained as a cooperative bureau by contributions from the societies and their individual members who are directly benefited.*

*Offices:—33 West 39th St., New York, N. Y.,—W. V. Brown, Manager.*
*53 West Jackson Blv'de., Room 1736, Chicago, Ill., A. K. Krauser, Manager.*

*MEN AVAILABLE.—Brief announcements will be published without charge but will not be repeated except upon requests received after an interval of one month. Names and records will remain in the active files of the bureau for a period of three months and are renewable upon request. Notices for this Department should be addressed to* ***EMPLOYMENT SERVICE, 33 West 39th Street, New York City,*** *and should be received prior to the 15th of the month.*

*OPPORTUNITIES.—A Bulletin of engineering positions available is published weekly and is available to members of the Societies concerned at a subscription rate of $3 per quarter, or $10 per annum, payable in advance. Positions not filled promptly as a result of publication in the Bulletin may be announced herein, as formerly.*

*VOLUNTARY CONTRIBUTIONS.—Members obtaining positions through the medium of this service are invited to cooperate with the Societies in the financing of the work by nominal contributions made within thirty days after placement, on the basis of $10 for all positions paying a salary of $2000 or less per annum; $10 plus one per cent of all amounts in excess of $2000 per annum; temporary positions (of one month or less) three per cent of total salary received. The income contributed by the members, together with the finances appropriated by the four societies named above, will it is hoped, be sufficient not only to maintain, but to increase and extend the service.*

*REPLIES TO ANNOUNCEMENTS.—Replies to announcements published herein or in the Bulletin, should be addressed to the key number indicated in each case, with a two cent stamp attached for reforwarding, and forwarded to the Employment Service as above. Replies received by the bureau after the positions to which they refer have been filled will not be forwarded.*

**POSITIONS OPEN**

ELECTRICAL ENGINEER, particularly interested and experienced in relay and breaker applications and protection problems on larger power systems. Location, Pennsylvania. R-8506.

ENGINEER, with experience in design and installation of power station switching equipment. Must be able to supervise and make schematic diagrams of station layout drawings. Not a drafting job, but requires design ability. Permanent. Opportunity. Apply by letter. Location, Pennsylvania. R-8530-C.

ENGINEER, technically trained for investigation of raw materials. Young man who possesses native interest in work of this nature preferred. Ability to thoroughly analyze problems pertaining to raw materials is essential. Apply by letter, stating qualifications, age, education and salary expected. Location, Illinois. R-8535-C.

ENGINEER, technically trained, with some knowledge of accounting, must write good English and be qualified for analytical work in cost and rate department. Apply by letter and enclose photograph. Location, New York. R-8722.

ENGINEER, over 35, the executive and financial experience, for general management in electrical contracting firm. Must be capable financier. May take financial interest. Salary nominal but with participation in profits. Location, New York. R-7874.

**MEN AVAILABLE**

GRADUATE M. E. and E. E., age 36, wide range of engineering experience, and especially well qualified in public utility electrical engineering. power plants, substations and lines. Highly trained technically, but prefers a position requiring a combination of technical and executive ability. Now employed. B-5842.

ELECTRICAL ENGINEER, Canadian, married, age 46. Graduate McGill University. Long experience electrical and mechanical sales, also operation and construction. Desires position management or sales but consider operation or construction. Absolutely reliable, active, capable handling men. Best references. C-837.

ELECTRICAL ENGINEERING TEACHER desires research position in New York City. Salary required $4000 per annum. Graduate 1917, master's degree 1923. Four years' teaching of electrical engineering subjects, two years with public utility. Lieutenant Signal Corps U. S. B-82.

ENGINEERING EXECUTIVE, age 35, married, graduate electrical engineer. At present assistant to chief executive well known electric utility, desires executive position, department head or local manager with holding company. Present duties consist of handling budget, construction orders, scheduling, expediting and following major construction, as well as miscellaneous management, personnel problems. Capable design engineer with consulting experience. B-754.

ELECTRICAL TECHNICAL GRADUATE, age 36, married, eighteen years' experience electrical design, construction, operation ofc entral stations, substations and transmission lines. Responsible experience specifications and purchase negotiations. Capable of handling the electrical phase of central stations from inception to commercial operation. Design, construction or operation acceptable. Location immaterial but minimum travel desirable. B-2511.

YOUNG MAN, age 27, E. E. and A. M. with several years' teaching and some radio laboratory experience, would like teaching or laboratory position. Work in physics or electricity desired. Available on short notice. B-3411.

ELECTRICAL ENGINEER, age 39, sixteen years' supervision design, installation, maintenance, operation various kinds electrical work large railroad; lighting, motors, distribution, transmission (including submarine cables), substations, power plant electrical apparatus, meter surveys, etc. Desires connection with industrial in charge electrical activities, utility, or electrical sales work. Central or South location. Salary $4200 up, depending on conditions and location. B-9772.

ELECTRICAL ENGINEER, age 38, married, eight years' experience in design and drafting, checking of electrical stations and substations. two years of squad leader assistant, four years installation and operation of storage batteries, rotary converters, transformers, generators, etc. Speaks' Spanish and French. Available on two weeks' notice. C-403.

ELECTRICAL ENGINEER, age 37, desires position as power or plant engineer with large industrial concern. Fifteen years' experience industrial plant layout, installation, maintenance. Thorough knowledge all plant problems including power application, industrial lighting, heating, ventilation and air conditioning. Available immediately. Preferable location, New England States, but will consider other locations. B-5326.

CHIEF-SUPERVISING OR CONSULTING ENGINEER, thirty-five years mechanical and electrical engineering, electric railways, public utilities, engineering and industrial companies, planning and execution several steam railroad electrifications. rehabilitation steam plants, chemical process development, public utility valuations and economic reports, electrolysis research, power transmission. Railway or industrial engineering preferred. Available soon. Employed. B-3246.

ELECTRICAL GRADUATE, of Purdue University, age 28, single, one year General Electric Company test and one year industrial control engineering with General Electric Company. Two years' control experience with large light and power company. Finished Alexander Hamilton Institute Modern Business Course. Desires position in control engineering or sales. Salary $225 a month. C-890.

ELECTRICAL CONSTRUCTION ENGINEER, age 38, wide experience electrical construction. operation. Ten years construction, eight years general superintendent of railways, power plants, substations, general utility work. At present on contract for electrical construction, foreign service. Prefers connection large electrical concern as representative in Latin countries. Technical training. Speaks Spanish, English. Available after six months. C-886.

ELECTRICAL ENGINEER, graduate of Purdue University, age 31, three years General Electric test and engineering departments, three years in substation design with large public utility company. Desires position with consulting engineer, public utility or manufacturing company. Salary $2500. Available on reasonable notice. C-920.

ELECTRICAL ENGINEERING GRADUATE, five years out of college, having had experience in testing, switchboard engineering, indoor and outdoor substation layouts, transmission and distribution. Desires position in engineering work. B-8622.

ELECTRICAL ENGINEER, age 28, technical graduate, desires position with public utility, preferably in the Middlewest. One and one-half years G. E. test, four years' distribution engineering experience with public utility in East. Available on two weeks' notice. B-9040.

INDUSTRIAL ELECTRICAL ENGINEER, wide experience design, installation maintenance of electrification as applied to industrial plants, including power houses, substations, high and low voltage distribution and general motor and control applications. Desires position with large industrial concern as electrical engineer, or power superintendent. University graduate, 36, married. Available on reasonable notice to present employer. B-9113.

WANTED. Position as general superintendent, or district manager of public utility by graduate electrical engineer with ten years' varied experience; construction, maintenance, operation; power plants, substations, transmission and distribution systems, commercial and rate work. B-9480.

ENGINEERING EXECUTIVE, age 39, varied experience, technical graduate. Was machinist, inspector, foreman, engineer, superintendent in charge of 700 men. With present concern sixteen years. Had charge production, shop equipment. Designed, installed numerous labor saving devices, machine tools. Expert on application electric motors, other electric devices for special machinery. Desires sales engineering or executive position. B-8153.

ELECTRICAL ENGINEER, age 28, single, wishes position as executive or assistant electrical engineer. Good character, pleasing personality. German. English, French. Familiar theory and practice electrical and scientific measurements, electrical instruments meters, relays. Transmission. distribution, protection. dielectric circuits. Three years research laboratory, two years designing. Location, preferably New York. Minimum salary $3500. Available on month's notice. C-930.

GRADUATE ELECTRICAL ENGINEER, 30, single, experience operation, maintenance power plants, substation design, construction work. Calculation of generators motors, transformers for special purposes. Chief of testing department. Specialties: rectifiers, mercury vapour (Brown Boveri Company) for high power, thermionic rectifiers for high voltages. Desires permanent connection public utility, or electrical consulting organization. Available on month's notice. C-924.

EXECUTIVE OR MANAGER, age 43, married, eighteen years' electrical experience; successful in organizing and directing international engineering service. Qualified for and desires position requiring greater responsibility. Salary $10,000. Any location, although slight preference South or Middlewest. B-122.

GRADUATE ELECTRICAL AND MECHANICAL ENGINEER with ten years' experience in electrical testing, drafting and designing, also two years' shop experience as department head. Desires permanent position along above lines or similar at reasonable starting salary with good future. Age 37, married. Location preferred, Ohio. C-374.

EDITOR, age 31, married, university journalistic education, and twelve years' practical experience as associate editor, co-publisher-editor, and managing editor of radio and technical publications, including trade paper. Editor and author of numerous technical papers, magazine articles and books. Available within three weeks. Location, New York. C-829.

ENGINEER, age 37, married, over fifteen years' experience industrial and power plant organization, design and operation, transmission, group substations, layout, equipment, valuation, costs. Has some financial backing to interest in a conservative utility. Full time salary $7500. Location in or about New York, and the East. B-8863.

ASSISTANT ENGINEER, age 24, single, B. S. degree in electrical engineering, two years as assistant engineer with valuation department of California State Railroad Commission. Desires work with consulting engineer, or manufacturer in power, or industrial electrical field. Location, Pacific Coast. Available immediately. C869 1-A-42.

VALUATION ENGINEER specializing in reports, inventories and appraisals of public utilities and industrial plants. Formerly with New York State Public Service Commission. Good working knowledge of Spanish. Available on two weeks' notice. Salary $300 per month and expenses. B-9636.

# MEMBERSHIP — Applications, Elections, Transfers, Etc.

**ASSOCIATES ELECETD FEBRUARY 9, 1926**

ABE, TOKUSABURO, Manager. Elec. Dept., Japanese Government Railways, Metropolitan Bldg., 1 Madison Ave., New York, N. Y.

ADAM, ARMAND OTTO, Jr., Telephone Engineer. Bell Telephone Laboratories, Inc., 463 West St., New York, N. Y.; res., Newark, N. J.

*ADKINS. ALONZO HOWARD, Railway Salesman. Electric Storage Battery Co., 1823 L St., N. W., Washington, D. C.

*AHRLING, GEORGE ALBERT, Appraisal Engineer, Murrie & Co., Inc., 45 E. 17th St., New York, N. Y.; res., Palisade, N. J.

*AIKINS, NELSON BROWN, Transmission Tester, New England Tel. & Tel. Co., Portland; res., South Windham, Maine

ALEXANDER, GEORGE HUGH WEBB, Plant Engineer, Bell Telephone Laboratories, Inc., 463 West St., New York, N. Y.

ALEXANDER, ROBERT, Jr., Inspector, Murrie & Co., 45 E. 17th St., New York, N. Y.

*ALLEN, JOHN PAYTON, Transmission Engineer, New York Telephone Co., 309 Washington St., Newark; res., Peapack, N. J.

ALLISON, DONALD CAMERON, Asst. Manager, General Electric, S. A., Mexico, D. F., Mex.

*ANDEM, KENNETH SHERWOOD, Engineering Assistant. Public Service Production Co., 86 Park Place, Newark, N. J.

*ANDERSON, ALBERT SIGFRID, Distribution Engineer, New Orleans Public Service' Inc., 823 Union St., New Orleans, La.

*ANDERSON, ELMER WEBSTER NATHANALL, Asst. Engineer, Virginia Northern Power Co., Warrenton. Va.

*ARNOLD, OTTO BERNARD, Proposal Engineer, Switchboard Dept., General Electric Co., Schenectady, N. Y.

ASCHMAN, GEOFFREY DONALD, Elec. Engg. Cadet, Public Works Dept., Shannon, N. Z.

ASPLUND, CLIFFORD D., Electrician, Construction Dept., Consumers Power Co., Battle Creek; for mail, Ironwood, Mich.

AUER, GEORGE, Telephone Engineer, Automatic Electric, Inc., 1033 W. Van Buren St., Chicago, Ill.

*BAER, HERBERT JACOB, Distribution Engineer, Metropolitan Edison Co., 141 S. 7th St., Reading, Pa.

BAILY, FRANCIS ARTHUR ALBERT, Test Engineer, Canadian Marconi Co., 173 William St., Montreal, P. Q., Can.

*BARBER, HIRAM W., Jr., Student Engineer, General Electric Co., Lynn; res., West Lynn, Mass.

BARLEY, THOMAS TRUSSELL, Meter Dept., Public Service Electric & Gas Co., 375 Lakeside Ave., Orange; res., East Orange, N. J.

BARRINGER, FRANKLIN D., Pratt Institute, Brooklyn, N. Y.

BARTHELD, LESLIE PETER, Telephone Engineer, Bell Telephone Laboratories, Inc., 463 West St., New York, N. Y.
BARTHOLOMEW, HERMAN GERARD, New York Telephone Co., 366 E. 150th St., New York, N. Y.
*BATT, LEWIS THEODORE, Cadet Engineer, Public Service Electric & Gas Co., 80 Park Place, Newark; res., South Orange, N. J.
*BAUMGARTEN, ADOLPHE JOHN, Graduate Student, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.; res., Washington, D. C.
*BAXANDALL, FRANK MATTHEW, Engineer, Commonwealth Power Corp. of Michigan, 244 Michigan Ave., W., Jackson, Mich.
*BAXTER, LAWRENCE HENRY, Meter Engineer, Hydro Electric Power Commission of Ontario, 190 University Ave., Toronto, Ont., Can.
*BAYERS, CHARLES, Station Tester, Brooklyn Edison Co., Inc., 14 Rockwell Place, Brooklyn; res., Winfield, N. Y.
BEDI, HARKISHAM, SINGH, Substation Operator, Public Service Co. of No. Illinois, 72 W. Adams St., Chicago, Ill.
*BELLER, C. J., Operator, Cleveland Electric Illuminating Co., 313 Illuminating Bldg., Cleveland, Ohio.
BERGEN, PHILIP VOLZ, Electrical Inspector, Bronx Gas Electric Co., 43 Westchester Sq., Bronx, New York, N. Y.
BITTERLI, JOHN ALFRED, Draftsman, Inside Plant Engg. Dept., Commonwealth Edison Co., Chicago, Ill.
BIXBY, OSCAR MERRILL, Asst. Engineer, New York Central Railroad, 466 Lexington Ave., New York, N. Y.
BLOCKLIN, H. G., Telephone Engineer, Bell Telephone Laboratories, Inc., 463 West St., New York, N. Y.
BLUMSTEIN, GUSTAVE, Electrician, Pullman Car Co., Sunnyside Yard, Long Island City; res., New York, N. Y.
BOLSTAD, ARCHIE LEONARD, Sub-Foreman, Installation Dept., Western Electric Co., 523 White Bldg., Seattle, Wash.
BORGE, WILLIAM PETTERSEN, Illinois Power & Light Corp., 231 S. La Salle St., Chicago, Ill.
BOURCHIER, LEONARD HAROLD JORDAN Supt., Radio Telegraphs, The Wireless Station, Belize, British Honduras
BRACKEN, HARRY PARKER, General Foreman, Hydro-Electrica Station, Sao Paulo Electric Co., Sorocaba Falls, Brazil, S. America.
*BRANDT, G. HERMAN, Engineer, Chas. B. Hawley & Co., 1132 Munsey Bldg., Washington, D. C.
BRAZIER, WILLIAM, Draftsman, The Canadian Crocker-Wheeler Co., Ltd., St. Catharines, Ont., Can.
*BROWN, HAROLD HOLT, Traveling Electrician, Iowa Electric Co., Cedar Rapids, Ia.
*BROWN, LELAND PRESTON, Engineer, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
*BROWN, NORRIS HERBERT, Sales Engineer, Consolidated Steam Specialty Co., Milwaukee, Wis.
*BRUCE, EDMOND, Radio Research Engineer, Bell Telephone Laboratories, Inc., Cliffwood; res., Red Bank, N. J.
BRUHN, HARRY D., Equipment Engineer, Bell Telephone Laboratories, Inc., 463 West St., New York, N. Y.
*BUCKNER, LAURENCE OLIPHANT, Sales Engineer, American Trona Corp., 233 Broadway, New York, N. Y.
BUGGE, ANDREAS FREDRIK CHRISTIE, Tester, Westinghouse Elec. & Mfg. Co., Sharon, Pa.
BUMP, RICHARD L., Engineer, General Electric Co., Boston & Bond Sts., Bridgeport, Conn.
*BURKHART, WILLIAM G., Operator, Commonwealth Edison Co., 72 W. Adams St., Chicago, Ill.
*BURNETT, NEWTON OSBORN, Engineering Assistant, New York & Queens Electric Light & Power Co., Lawrence & Grove Sts., Flushing, N. Y; for mail, Morristown, N. J.
*BURNS, ARTHUR F., Member, Technical Staff, Bell Telephone Laboratories, Inc., 463 West St., New York, N. Y.
BUSTEED, JOHN ROBERT, Technical Employee, American Tel. & Tel. Co., 195 Broadway, New York; res., Hartsdale, N. Y.
*BYRNE, JOHN ALOYSIOUS, Elec. Engineer, Troy Gas Co., 19-21 Second St., Troy; res., North Troy, N. Y.
*CALLOW, CHARLES ARNDT, Operating Engineer, Utah Power & Light Co., Grace, Idaho.
CAMP, G. B., Supt., Elec. Dept., Artic Dairy, Products Co., 3301 Grand River Ave., Detroit, Mich.
*CAMPBELL, ARTHUR B., Madras Hotel, 443½ Washington St., Portland, Ore.
*CARADONNA, VICTOR, Tester, New York Edison Co., 92 Vandam St., New York, N. Y.; for mail, Worcester, Mass.
*CARLSON, EDWARD, Jr., Electrical Squad, Drafting Dept., Stone & Webster, Inc., 147 Milk St., Boston; res., East Lexington, Mass.
*CAYWOOD, RUSSELL ERIC, Switchboard Engineer, Westinghouse Elec. & Mfg. Co., East Pittsburgh; res., Wilkinsburg, Pa.
CHAPIN, RAYMOND IRVING, Electrical Engineer, Crocker McElwain Co., Chemical Paper Mfg. Co., 642 Main St., Holyoke, Mass.
*CHURCHILL, THOMAS CHARLES DEANE, Toll Transmission Engineer, Bell Telephone Co. of Canada, Toronto, Ont., Can.
*CLARK, HOWARD HOY, Asst. Distribution Engineer, Ohio Public Service Co., 562 Broadway Lorain, Ohio.
*CLARK, RAYMOND FRANCIS, Maintenance Inspector, Edison Electric Illuminating Co. of Boston, 1165 Mass. Ave., Boston, Mass.
CLARKE, HOWARD ALBERT, Supt., Meter Dept., City of Norwich, Norwich, Conn.
CLARKE, PALMER, Toll Assignment Clerk, Southern New England Telephone Co., 157 Church St., New Haven, Conn.
*CLIFORD, CHARLES J., Junior Mathematician, Div. of Geodesy, U. S. Coast & Geodetic Survey, Washington, D. C.
*COLE, CLAUDE CLIFFORD, Automatic Control Man, Duquesne Light Co., Duquesne Bldg., Pittsburgh, Pa.
COMBS, CLINTON R., Estimator & Engineer Omar-Schaefer Electric Co., 6336 Charlevoix Ave., Detroit, Mich.
*CONTINO, NICHOLAS, Test Engineer, Public Service Electric & Gas Co., Irvington, N. J.; for mail, New York, N. Y.
CONWAY, JOHN THOMAS, Inspector, Murrie & Co., 45 E. 17th St., New York, N. Y.; res., Hoboken, N. J.
COOK, HORACE SAYWARD, Acting Manager, Cia. Cubana de Electricidad, Inc., Sancti-Spiritus, Cuba.
COOK, JOHN WESLEY, Equipment Engineer, Telegraph Dept., A. T. & S. F. R. R. Co., Topeka, Kansas.
CORBY, ERNEST, Foreman, General Electric Co., Bridgeport, Conn.
*COULTRIP, RAYMOND LAVERNE, Service Engineer, Fansteel Products Co., Inc., Chicago, Ill.
CRABTREE, THEODORE HUDSON, Telephone Engineer, Bell Telephone Laboratories, Inc., 463 West St., New York, N. Y.
CROSBY, R. A., Special Meter Man, Los Angeles Gas & Electric Corp., 725 Channing St., Los Angeles, Calif.
CROSSE, EDWARD ALEXANDER, Testing Dept., Standard Underground Cable Co., Perth Amboy, N. Y.
DAHL, HARRY A., Electrical Engineer, Bell Tel. Laboratories, 463 West St., New York; res., N. Tarrytown, N. Y.
DAHL, JACK FREDERICK, Telephone Engineer, Bell Telephone Laboratories, Inc., 463 West St., New York, N. Y.
DALEY, JOHN JOSEPH, Asst. Valuation Engineer, Murrie & Co., 45 E. 17th St., New York; res., Woodside, N. Y.
*DAVIS, CALEB FORBES, Jr., Testing Dept., General Electric Co., Schenectady, N. Y.
DAVIS, JOSEPH ANTHONY, Research & Development Dept., Automatic Electric Co., Morgan & Van Buren Sts., Chicago, Ill.
DAY, JOSEPH FRANK, Electrical Testing, Westinghouse Elec. & Mfg. Co., Sharon, Pa.
DAYMUDE, EARL LUDLOW, Chief Draftsman, Puget Sound Pr. & Lt. Co., 470 Pittock Block, Portland, Ore.
DEAN, HARVEY CLINTON, Asst. Engineer, Distribution Dept., Brooklyn Edison Co., Inc., 360 Pearl St., Brooklyn, N. Y.
DEONER, LE ROY ALLEN, Electrical Engineer, Industrial Controller Co., 306 Hanover St., Milwaukee, Wis.
De GRAW, HALSEY, Industrial Elec. Engineer, Louis Kalischer, Inc., 288 Livingston St., Brooklyn, N. Y.
DENSMORE, URIAH HARRY, Consulting & Estimating Engineer, Wadeford Electric Co., 163 W. Washington St., Chicago, Ill.
de SAVOYE, LOUIS ADOLPHE, Laboratory Assistant, Research Bureau, Brooklyn Edison Co., Pearl & Johnson Sts., Brooklyn, N. Y.
*DEWEY, GLEN H., Engineer, Industrial Engg. Dept., General Electric Co., Schenectady, N. Y.
*DICKINSON, ALBERT GODFREY, Asst. Chief Electrician, Consolidated Mining & Smelting Co., Trail, B. C., Can.
DIETZ, HAROLD WILLIAM, Industrial Foreman, Auto Specialties Co., Inc., 216 W. Tyler Ave., Elkhart, Ind.
DITTWE, GEORGE ROBERT, Inspector, Pacific Gas & Electric Co., 245 Market St., San Francisco, Calif.; for mail, Schenectady, N. Y.
*DOWLING, ROY C., Plant Engg. Dept., Wisconsin Telephone Co., 1401 Clybourn St., Milwaukee, Wis.
*DOWNING, WILLIAM CHAPPELL, Jr., Instructor, Elec. Engg. Dept., Yale University, 10 Hillhouse Ave., New Haven, Conn.
*DREYER, WILLIAM CONKLIN, Engineer, General Engg. Dept., Westinghouse Elec. & Mfg. Co., East Pittsburgh; res., Wilkinsburg, Pa.
DUGGER, PERCY KYLE, Chief Engineer, Farmville, Va.
*DUNN, BRIAN JOSEPH, Service Manager, Victor X-Ray Corp. of Texas, 2503 Commerce St., Dallas, Texas.
EBERT, HARRY, Meter, Transformer & Street Lighting Specialist, Canadian General Electric Co., 212 King St. W., Toronto, Ont., Can.
*EHRKE, LOUIS FREDERICK, Asst. Research Engineer, Westinghouse Lamp Co., Bloomfield, N. J.
*ELLIS, FRANKLIN ALEXANDER, Demonstrator, Elec. Engg. Dept., University of Toronto, 917 Palmerston Ave., Toronto 4, Ont., Can.
*ENSOR, JOHN STOKES, General Engineer, Westinghouse Elec. & Mfg. Co., East Pittsburgh; res., Wilkinsburg, Pa.
ERWIN, EDSON LOCKWOOD, Member, Technical Staff, Bell Telephone Laboratories, Inc., 463 West St., New York, N. Y.
ESSIG, CHARLES H., Draftsman, Pacific Gas & Electric Co., 245 Market St., San Francisco; res., Oakland, Calif.
EVERETT, W. J., Engineer, Cia. Cubana de Electricidad, Inc., Cienfuegos, Cuba.
FARNHAM, CHARLES, Salesman, Schweitzer & Conrad, Inc., 300 Ferguson Bldg., Los Angeles, Calif.

FIDLER, ISAAC, Electrical & Consulting Engineer, Stehli Silks Corp., 104 East 25th St., New York; res., Forest Hills, N. Y.

*FINKELSTEIN, LOUIS MARSHALL, Elec. Engineer, International Harvester Co., McCormick Works, 26th St. & Blud Island Ave., Chicago, Ill.

FINKENSTEIN, ALBERT, Construction Foreman, General Electric Co., 129 Church St., New Haven, Conn.

FITZ-GERALD, MAURICE CHARLES, Transmission Tester, Pacific Tel. & Tel. Co., 333 Grant Ave., San Francisco, Calif.

*FITZGERALD, WILLIAM FRANCIS, Engineer, Chicago Surface Lines, 3901 West End Ave., Chicago, Ill.

FLYNN, JOSEPH A., Construction Inspector, Interborough Rapid Transit Co., 148th St. & 7th Ave., New York, N. Y.

*FORBES, LESTER N., Engineer, Underground Construction, Northern Indiana Gas & Electric Co., Hammond, Ind.

FORD, WILLIAM FRANCIS, Foreman, Switchboard & Control Wiring, Union Gas & Electric Co., 1107 Plum St., Cincinnati, Ohio.

FREEDMAN, ERWING A., Engg. Draftsman, New York Central Railroad, 466 Lexington Ave., New York, N. Y.

FRENCH, BENEDICT VAN KLEECK, Radio Engineer, American Bosch Magneto Corp., N. Main St., Springfield, Mass.

FRUCHTMAN, MORRIS, Switchboard & Panelboard Designer, Metropolitan Electric Co., East Ave. & 14th St., Long Island City; res., New York, N. Y.

*GALLUP, WILLIAM GORDON, Foreman, Meter Dept., Bay Village Dist., Lake Shore Electric Railway Co., Dover Bay Substation, Bay Village; res., Bellevue, Ohio.

GAMBOA, OCTAVIO FRANCISCO, Division Engineer, Cia. Cubana de Electricidad, Inc., Station Clara, Cuba.

*GANNON, JOSEPH THOMAS, Inspector, Brooklyn Edison Co., Pearl & Johnson Sts., Brooklyn, N. Y.

*GERARD, HAROLD, Distribution Engineer, Public Service Co. of No. Illinois, 198 N. Schuyler Ave., Kankakee, Ill.

*GERHART, PAUL LEROY, Inspector, Electrical Testing Laboratories, 80th St. & East End Ave., New York; for mail, Brooklyn, N. Y.

*GEYMER, HOMER H., Student, Armour Institute of Technology, Chicago, Ill.

*GIERSCH, OTTO LUMLEY, Carrier Current Field Engg., General Electric Co., Schenectady, N. Y.

*GILCHRIST, JOHN MASON, Construction Dept., Empire Gas & Electric Co., Auburn, N. Y.

GILLEN, GUY, Electrician, Pennsylvania Power & Light Co., Hauto; res., Lansford, Pa.

GIRAULT, MANUEL, Engineer, General Electric S. A., Mexico D. F., Mex.

GODDARD, ERNEST JOSEPH, Electrical Wireman, Pennsylvania Railroad, 4th & Front Sts., Long Island City; res., Brooklyn, N. Y.

GOLDSWORTHY, THOMAS HENRY, Substation Operator, Portland Electric Power Co., Portland, Ore.

GOODWIN, SCHUYLER, Technical Estimator, Brooklyn Edison Co., Pearl & Johnson Sts., Brooklyn, N. Y.

*GRAHAM, ALEXANDER, Asst. Research Engineer, Postal Tel. & Commercial Cable Co., 6 Murray St., New York; res., Richmond Hill, N. Y.

*GRAHAM, ROLAND CREELMAN, Assistant, Bartholomew & Montgomery, 614 Standard Bank Bldg., Vancouver, B. C., Can.

GRAY, EDGAR VINCENT, Student, Pratt Institute, Ryerson St., Brooklyn, N. Y.

GRAY, FRANCIS R., Transmission & Distribution Dept., Murrie Engineering Co., 45 E. 17th St., New York; res., Farmingdale, N. Y.

GRAY, ROBERT H., Foreman Electrician, City of Los Angeles, 2228 W. 6th St., Los Angeles, Calif.

GREENE, OLIVER WATSON, JR., Elec. Engg. Dept., General Electric Co., Pittsfield, Mass.

GREENWALD, ROBERT CLARK, Appraisal Engineer, Murrie & Co., Inc., E. 17th St., New York; res., Brooklyn, N. Y.

GREER, LANIER, Student Engineer, General Electric Co., 24 Baker St., Lynn, Mass.

*GRIFFIN, GEORGE ALLEN, Asst. Engineer, Union Gas & Electric Co., 1107 Plum St., Cincinnati, Ohio.

GUSSETT, NORWICH BERNARD, Asst. Engineer, San Antonio Public Service Co., San Antonio, Texas.

GUSTAFSON, HERMAN MILTON, Elec. Engineer, General Electric Co., 811 First Ave. Seattle, Wash.

*HADLEY, PAUL THOMAS, General Electric Co., Schenectady, N. Y.

*HALLORAN, DELAVAN, Engineering Assistant, New York & Queens Electric Light & Power Co., Flushing; res., Richmond, N. Y.

*HALPIN, LEWIS C., Maintenance Foreman, A. P. & L. Corp., 23 Ridge St., Glens Falls, N. Y.

*HAMILTON, WILLIAM R., Asst. System Operator, West Penn Power Co., 14 Wood St., Pittsburgh, Pa.

HAMKE, JULIUS C., Asst. Elec. Supt., Aluminum Co. of America, Lower Canal Basin, Niagara Falls, N. Y.

HARRIS, HERMANN R., Foreman Electrician, Detroit Edison Co., Connors Creek Plant, Detroit, Mich.

HARRISON, CHARLES ALLISON, Asst. to General Supt., Public Service Co. of Colorado, 900 15th St., Denver, Colo.

HART, WILLIAM JENNINGS, Draftsman, Westinghouse Elec. & Mfg. Co., Sharon, Pa.

HATCH, PRENTICE M., Asst. General Manager, The Connecticut Power Co., New London, Conn.

*HAUSMAN, SIDNEY, Engineer, I. R. Nelson Co., Bond St., Newark, N. J.; res., New York, N. Y.

HAW, CURTIS HOMER, Asst. Switchboard Operator, Waterside No. 1, New York Edison Co., 666 First Ave., New York, N. Y.; res., Weehawken, N. J.

*HAZLETT, HERBERT MILTON, Electrical Assistant, U. S. Bureau of Reclamation, Rupert, Idaho.

*HEARDING, WILLIAM SANGER, Cadet Engineer, Brooklyn Edison Co., 360 Pearl St., Brooklyn, N. Y.

HENDRICKSON, OSCAR FREDERICK, Student, Pratt Institute, Brooklyn; res., Cedarhurst, N. Y.

HERSHEY, PERRY J., Western Electric Co., 395 Hudson St., New York, N. Y.

*HERSKIND, CARL CURTIS, Test Dept., General Electric Co., Radio Test Bldg. 77, Schenectady, N. Y.

*HIBBELER, ALVIN F., Deputy Starting Engineer, Commonwealth Edison Co., 72 W. Adams St., Chicago, Ill.

*HICKS, FRED T., Patent Examiner, U. S. Patent Office, Washington, D. C.

*HILL, AUSTIN S., Erection Dept., Allis-Chalmers Mfg. Co., Milwaukee; res., Wauwatosa, Wis.

HIRSCH, CHARLES J., Electrical Engineer, 452 Riverside Drive, New York, N. Y.

*HOFFMAN, NORBERT W., Asst. Service Engineer, The Milwaukee Electric Railway & Light Co., 217 Sycamore St., Milwaukee, Wis.

HOLBORN, FREDERICK, Research Engineer, Hazeltine Corp. Laboratories; Stevens Institute, Hoboken, N. J.

HOOKS, JAMES H., Electrical Engineer, E. L. Phillips & Co., 50 Church St., New York; res., Flushing, N. Y.

HOTCHKISS, FRED H., Division Supervisor, Western Electric Co., 208 W. 36th St., New York, N. Y.

HUBBELL, FRANK JOSEPH, Engineer, Western Electric Co., Inc., 395 Hudson St., New York, N. Y.

*HUGGINS, L. GALE, Engineer, Transmission Engg. Dept., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

*HUSEBY, GISLE EDWIN, Equipment Engineer, Western Electric Co., Inc., 212 W. Washington St., Chicago, Ill.

*HUSSEY, EDWARD ORVILLE, Dist. Engineer, Alabama Power Co., Tuscaloosa, Ala.

INMAN, EDWARD JAMES, Transformer Tester, Westinghouse Elec. & Mfg. Co., Sharon, Pa.

*JACOCKS, THOMAS BAKER, Testing Dept., General Electric Co., Schenectady, N. Y.

JARVIE, JAMES, Traveling Lineman, The Kansas City Southern Railway Co., Meavener, Okla.

*JATLOW, JACOB LAWRENCE, Research Engineer, Conner Crouse Corp., Grand Central Terminal Bldg., New York, N. Y.; res., Elizabeth, N. J.

JEFFERY, ALBION GEORGE, Telephone Engineer, Bell Telephone Laboratories, Inc., 463 West St., New York, N. Y.

*JEWETT, ULMER MANNING, Electrician, Cons. Dept., Eastern Connecticut Power Co., 362 Main St., Norwich, Conn.

JOCKERS, FRANK EDWARD, President, Greenpoint Electric Equipment Co., 136 Greenpoint Ave., Brooklyn, N. Y.

*JOHANNESSEN, VAUGHN L., Student Engineer, Western Electric Co., Hawthorne Sta., Chicago; res., La Grange, Ill.

*JOHNSON, ROYCE E., Asst. Engineer, Railroad Commission of Wisconsin, Madison, Wis.

*JOHNSON, VERNON LESLIE, Member, Technical Staff, Bell Telephone Laboratories, Inc., 463 West St., New York, N. Y.

*JOHNSTON, DONALD FRANCIS, Testing Engineer, Bell Telephone Laboratories, Inc., 463 West St., New York, N. Y.

JOSLIN, GEORGE BYRON, Telephone Engineer, Bell Telephone Laboratories, Inc., 463 West St., New York, N. Y.

*KAHN, JOSEPH, Draftsman, Otis Elevator Co., 1 Woolworth Ave., Yonkers; res., Brooklyn, N. Y.

*KAPLAN, SAMUEL, Insulation Research Laboratory, General Electric Co., Pittsfield, Mass.

*KARSTEN, EDGAR JOHN, Electrical Draftsman, United Light & Power Co., 125 W. 3rd St., Davenport, Iowa.

*KEETON, THADDEUS ELTON, Supt. of Distribution, Cia, Cubana de Electricidad, Inc., Cienfuegos, Cuba.

KEMP, MAURICE VIRGIL, Electrical Engineer, Westinghouse Elec. & Mfg. Co., Sharon, Pa.

KEOUGHAN, LAURENCE M., Asst. Designing Engineer, Duquesne Light Co., Pittsburgh, Pa.

*KEPP, KARL, Meter Tester, Puget Sound Power & Light Co., Elec. Bldg., 7th & Olive, Seattle, Wash.

KERN, WILLIAM M. A., Chief Electrician, Fuller-Lehigh Co., 326 Church St., Catasauqua, Pa.

KERSHNER, VIRGIL HUGH, Distribution Engineer, Oklahoma Gas & Electric Co., Eastern Div., Muskogee, Okla.

*KIETZMANN, EDWARD HERMAN, Distribution Engineer, Beloit Water, Gas & Electric Co., Beloit, Wis.

KING, CLIFFORD W., Asst. Engineer, Union Gas & Electric Co., 1107 Plum St., Cincinnati, Ohio.

KINNEY, ALFRED ADOLPHUS, Electrical Engineer, Murrie & Co., 45 E. 17th St., New York, N. Y.

KIRCHNER, BARNEY J., Supervising Methods Engineer, Western Electric Co., Inc., 268 W. 36th St., New York; res., Glenwood Landing, N. Y.
*KIRK, DOUGLAS, Inspector, Ware Radio Corp., 529 W. 42nd St., New York; res., Jamaica, N. Y.
*KISSEL, ALFRED LAWRENCE, Student, School of Engineering of Milwaukee, Milwaukee, Wis.
KOCH, EARL L., Engineer, Vacuum Tube Depts., Kellogg Switchboard & Supply Co., 1066 W. Adams St., Chicago, Ill.
KOOISTRA, LAMMERT F., Draughtsman, Babcock & Wilcox Co., 3rd St., Bayonne; res., Jersey City, N. J.
*KRISTAN, PETER, Jr., Electrical Tester, Brooklyn Manhattan Transit Co., 500 Kent Ave., Brooklyn; res., East Islip, N. Y.
*KRUPY, ALEXANDER JOSEPH, Elec. Engineer, Street Dept., Commonwealth Edison Co., 72 W. Adams St., Chicago, Ill.
*KUELLING, VINCENT ARNOLD, Asst. Production Manager, Marko Storage Battery Co., 1402 Atlantic Ave., Brooklyn, N. Y.
KUNEF, CYRIL T., Elec. Instructor & Maintenance Man, Engineer School Detachment, Fort Humphreys, Va.
KURTZ, E. K., Power Engineer, Edison Electric Co., Griest Bldg., Lancaster, Pa.
LaFORGE, CHARLES, Distribution Dept., Murrie Engineering Co., 45 E. 17th St., New York, N. Y.
*LAMB, JOHN FRAZER, General Engineer, General Engineering Dept., Westinghouse Elec. & Mfg. Co., East Pittsburgh; res., Newcastle, Pa.
*LANDAU, MAURICE, Draftsman, Bureau of Power & Light, City of Los Angeles, Los Angeles, Calif.
LANGMAN, JAMES DONALD, Manager, Langman Electric & Mach. Co., Portland, Ore.
*LANGWORTHY, REUBEN S., Foreman, Meter & Test Dept., United Electric Light & Power Co., 21 Audubon Ave., New York, N. Y.
*LARNER, RAY A., Field Engineer, Texas Power & Light Co., Dallas, Texas.
LAWTHERS, STANLEY MACK, Engineer, Union Switch & Signal Co., Swissvale, Pa.; res., New Haven, Conn.
*LEY, HARRY S., Local Test Engineer, East Penn Electric Co., Fishbach Substation, Pottsville; res., Cressona, Pa.
LINDVALL, IVAR, Elec. Designer, Adirondack Power & Light Corp., Clinton St., Schenectady, N. Y.
LITCHFIELD, HAROLD S., Engg. Dept., Blackstone Valley Gas & Electric Co., 231 Main St., Pawtucket; for mail, Providence, R. I.
*LITTLE, FRED GEORGE, Engineer, Home Tel. & Tel. Co. of Pasadena, 9 W. Colorado St., Pasadena; res., Los Angeles, Calif.
*LOCHER, LEO L., Operator, WHO Broadcasting Station, Des Moines, Iowa.
*LONG, GERRY ALLISON, Jr., Student Engineer, Illuminating Engg. Lab., General Electric Co., 1 River Road, Schenectady, N. Y.
*LUDLOW, MARION OMER, Electrician, Pacific Gas & Electric Co., Antioch, Calif.
LUNDIUS, E. RICHARD, Supervisor, Bell Telephone Laboratories, Inc., 463 West St., New York; res., Richmond Hill, N. Y.
MacLAREN, RAYMOND P., Telephone Engineer, Bell Telephone Laboratories, Inc., 463 West St., New York, N. Y.; res., West Orange, N. J.
*MALLETT, MONTVILLE B., Electrical Engineer, General Electric Co., Pittsfield, Mass.
*MALONEY, JAMES IRVING, Draftsman, Engg. Dept., Bell Telephone Co. of Pa., 261 N. Broad St., Philadelphia, Pa.
*MALTBY, CLIFFORD WILLIAM, Maintenance Dept., So. California Tel. Co., Los Angeles, Calif.
MARGIOTTS, GAETANO, Elec. Draftsman, Engg. Dept., New York Edison Co., 44 E. 23rd St., New York; res., Astoria, N. Y.
MAROUSEK, GEORGE, House Electrician, W. A. Wieboldt, & Co., Ashland & Monroe Sts., Chicago, Ill.
MARSANO, RONALD W. S., Radio Operator Experimenter Engineer, Music Master Co., 10th & Cherry Sts., Philadelphia,; res., West Philadelphia, Pa.
*MARTIN, JOHN I., Foreman, Repair Dept., Wagner Electric Corp., 1725 So. Michigan, Chicago, Ill.
*MARTIN, WILLIAM HAROLD, Test Man, General Electric Co., Schenectady, N. Y.; for mail, St. Louis, Mo.
MASON, MARION A., Meter Tester, Los Angeles Gas & Electric Corp., 725 Channing St., Los Angeles, Calif.
MATHISEN, KARSTEN VICTOR, Tester, Westinghouse Elec. & Mfg. Co., 273 N. Oakland Ave., Sharon, Pa.
*MATSON, THEODORE MALVIN, Research Assistant, F. G. Baum, Crystal Lake Laboratory, Cassel via Redding, Calif.
MATUNAGA, YOSINOBU, Research Engineer, Research Laboratory, Shibaura Engineering Works, Kanasugi, Shiba, Tokyo, Japan.
MAUS, THOMAS JOSEPH, Substation Operator, Commonwealth Edison Co., 72 W. Adams St., Chicago, Ill.
*MAXWELL, MARVIN V., Design Engineer, Power Engg. Dept., Westinghouse Elec. & Mfg. Co., E. Pittsburgh; res., Wilkinsburg, Pa.
MAZAK, JOHN JR., Planning Engineer, Western Electric Co., Inc., 1505 Race St., Philadelphia, Pa.
*McCAULEY, CHARLES, Jr., 32 Wool St., San Francisco, Calif.
McCLELLAN, BURT ARLO, Student Engineer, Hudson Motor Car Co., Maintenance Dept., Detroit, Mich.; res., Windsor, Ontario, Can.
*McDANIEL, OTTO S., Transmission Engineer, Southwestern Bell Tel. Co., 361 Boatmen's Bank Bldg., St. Louis, Mo.
McDOUGALL, JOHN B., System Operator, Interborough Rapid Transit Co., 600 W. 59th St., New York, N. Y.
McINTIRE, MANNING MAYFIELD, Asst. Elec. Engineer, Merced Irrigation Dist., Exchequer; res., Turlock, Calif.
McKECHNIE, JOHN DOUGLAS, Engg. Dept., Charles H. Tenney & Co., 200 Devonshire St., Boston, Mass.
*McNALLY, JAMES OSBORNE, Research Laboratories, Bell Telephone Laboratories, Inc., 463 West St., New York, N. Y.
McNICOL, FORREST CHARLES, Electrical Engineer, Industrial Controller Co., 316 Hanover St., Milwaukee, Wis.
*MEADOWS, JOHN JOSEPH, Designer & Detailer, New York Central Railroad Co., 466 Lexington Ave., New oYrk, N. Y.
*MEEKS, JOHN RUSSELL, Service Engineer, Westinghouse Elec. & Mfg. Co., 467 10th Ave., New York; res., Jamaica, N. Y.
*MEIERS, WALTER WILLARD, Engg. Draftsman, New York Central Railroad Co., 466 Lexington Ave., New York; res., Auburndale, N. Y.
*MESERVE, WILBUR ERNEST, Instructor, Elec. Engg. Dept., University of Maine, Orono, Maine.
*METHFESSEL, C. W., Elec. Engg. Dept., Commonwealth Power Corp., Jackson, Mich.
METZNER, HENRY A., Electrical Inspector, Interborough Rapid Transit Co., 165 Broadway, New York, N. Y.
MICHELSEN, J. H., Pacific Tel. & Tel. Co., 1414 Kay St., Sacramento, Calif.
MILLER, ARCHIBALD TEARSE, Engineer, Bureau of Tests, International Paper Co., Glens Falls, N. Y.
*MILLER, GEORGE WILLIAM, Student Engineer, Rochester Telephone Corp., 95 North Fitzhugh St., Rochester, N. Y.
MINNICH, J. WALTER, Supervisor, System Operation, Pennsylvania Power & Light Co., 117 E. Broad St., Hazleton, Pa.
MOELLENDICK, KARL FREDERICK, Electric Garage Foreman, L. A. Automotive Works, 1010 Towne Ave., Los Angeles, Calif.
MONTEMURRO, MICHAEL MILINOCKET, Engg. Apprentice, Hydro-Electric Power Commission, 190 University Ave., Toronto, Ont., Can.
MORALES, DOLAREA, O., Student, Westinghouse Elec. & Mfg. Co., East Pittsburgh; res., Wilkinsburg, Pa.
MORRISON, JAMES JOSEPH, Supt., Elec. Cable Works, American Steel & Wire Co., 767 Millbury St., Worcester, Mass.
*MULFORD, VIRGIL ARTHUR, Asst. Engineer, American Gas & Electric Co., 30 Church St. New York, N. Y.; res. Arlington, N. J.
MUNDY, THEODORE VREELAND, Inspector, Public Service Production Co., Kearny; res., East Orange, N. J.
MYERS, FOSTER WHITLOCK, Distribution Engineer, United Power & Light Corp., 117 N. Main St., Hutchinson, Kans.
MYERS, LEON E., Local Test Engineer, Pennsylvania Power & Light Co., 117 E. Broad St., Hazleton, Pa.
NARDI, MAX, Draftsman, Engg. Dept., Commonwealth Power Corp., Jackson, Mich.
NEIFERT, JAMES O., Electrician, Pennsylvania Power & Light Co., Hauto; res., Mauch Chunk, Pa.
*NOCK, HERBERT K., Engineer, Newburyport Gas & Electric Co., Newburyport. Mass.
NORLANDER, SVON GUNNAR SIGFRID, Designer, Adirondack Pr. & Lt. Corp., Schenectady, N. Y.
*NORMAN, GEORGE HUGH CHARLES, Asst. Supt., Cottrell Plants, Consolidated Mining & Smelting Co., Trail, B. C., Canada.
*NORTH, CHARLES STEWART, Supervisor of Construction, Mrs. Martha North, 49 Kay St., Newport, R. I.
O'CONNELL, MICHAEL J., Electrician, Pennsylvania Power & Light Co., Hauto; res., Lansford, Pa.
*OLIVER, CUTHBERT JACK, Engineer, Rio de Janeiro Tramways Co., Ltd., Caixo de Correo 571, Rio de Janeiro, Brazil.
OLIVIER, CHARLES NUMA, Electrical Supt., So. New Orleans Lt. & Traction Co., Algiers, La.
*OLSEN, HAROLD ADOLPH, Engineer, Pacific Tel. & Tel. Co., 140 New Montgomery St., San Francisco, Calif.
O'NEIL, THOMAS JOHN, Equipment Engineer, Bell Telephone Laboratories, Inc., 463 West St., New York, N. Y.
PAIGE, JAMES HENRY, Estimator & Construction Supt., W. E. Langstaff, 1256 N. Fair Oaks Ave., Pasadena, Calif.
PALMER, EVERETT LOW, Commercial Dept., Pennsylvania Pr. & Lt. Co., 802 Hamilton St., Allentown, Pa.
*PARKER, CECIL NELSON, Student Engineer, Southern Sierras Power Co., Riverside, Calif.
PARNALL, WALTER STANLEY, Draftsman, The Canadian Crocker Wheeler Co., Ltd., St. Catharines, Ont., Can.
PAXTON, ROBERT, Electrical Engineer, General Electric Co., Schenectady, N. Y.
PEDERSEN, LUDWIG ERLING, Telephone Engg., Bell Telephone Laboratories, Inc., 463 West St., New York, N. Y.
PENNELL, STANLEY BLAIR, Electrical Inspector, New York Central Railroad Co., 466 Lexington Ave., New York, N. Y.
PERCY, JAMES P., General Supt., Compania Azucarera Arroyo Blanco, Maceo, Oriente; for mail, Central Maceo, Oriento, Cuba.
*PETERS, JACOB CLARENCE, Jr., Research Engineer, Leeds & Northrup Co., 4901 Stenton Ave., Philadelphia, Pa.
PETERS, JAMES RAYMOND, Asst. Distribution Engineer, City Light Dept., Seattle, Wash.

*PETERS, RALPH COMPTON, Switchboard Specialist, Westinghouse Elec. & Mfg. Co., 141-157 Milton St., Buffalo, N. Y.
PETERSON, DAVID M., Office & Outside Sales Work, Ohio Brass Co., 451 East 3rd St., Los Angeles, Calif.
PHILLIPS, CYRUS F., Instructor, Elec. Dept., Mechanics Institute, Rochester, N. Y.
*PLANT, PAUL RUSSELL, Engg. Draftsman, Elec. Dept., New York Central Railroad, 466 Lexington Ave., New York; res., Yonkers, N. Y.
PLASS, RAYMOND B., General Engineer, Westinghouse Elec. & Mfg. Co., 1st National Bank Bldg., San Francisco, Calif.
PORTS, EARL GEORGE, Research Engineer, Bell Telephone Laboratories, Inc., 463 West St., New York, N. Y.
PRANGLEY, ARTHUR G., Jr., 28 Division St., Schenectady, N. Y.
PREMO, GEORGE. Jr., Electrical Draftsman, Commonwealth Power Corp., 244 W. Michigan, Jackson, Mich.
PRIETO, ANGEL I., Student, Mech. Engg. Dept., Stevens Institute of Technology, Hoboken, N. J.; for mail, New York, N. Y.
PRIOR, WILLIS JAMES, Los Angeles Gas & Electric Co., 428 So. Hope St., Los Angeles, Calif.
PRITCHARD, ERNEST OWEN, Electrical Engineer, Bell Telephone Laboratories, Inc., 463 West St., New York, N. Y.
*RAAB, HARRY J., Industrial Engineer, Chas. Cory & Son, Inc., 11-17 Mission St., San Francisco, Calif.
RANDOLPH, LINGAN STROTHER, Engg. Draftsman, New York Central Railroad Co., 466 Lexington Ave., New York, N. Y.
REDPATH, REGINALD ANDERSON, Asst. Electrical & Erection Engineer, A. D. Riley & Co., Ltd., Wellington, N. Z.
*REESE, LEWIS, Jr., Meter Tester, Pacific Gas & Electric Co., Modesto, Calif.
*REMINGTON, ARTHUR ERNEST, Junior Elec. Draftsman, City Light Dept., City of Seattle, 204 County-City Bldg., Seattle, Wash.
RHODES, ROBERT STRONG, Engg. Draftsman, New York Central Railroad Co., 466 Lexington Ave., New York., N. Y.
*ROBERTSON, BURTIS LOWELL, Teaching Assistant, University of Michigan, Engg. Bldg., University of Michigan, Ann Arbor; res., Ypssilanti, Mich.
*ROBERTSON, EVERARD P., Asst. to Operating Engineer, Detroit Edison Co., 2000 Second Ave., Detroit; res., Highland Park, Mich.
*ROBINSON, CARL R., Test Engineer, Bell Telephone Laboratories, Inc., 463 West St., New York, N. Y.
ROBINSON, HYMAN I., Telegraph Engineer, Postal Telegraph Co., 253 Broadway, New York, N. Y.
ROJAS, JUAN G., Student Engineer, General Electric Co., 114 S. Ferry St., Schenectady, N. Y.
*ROLFE, JOHN THOMAS, Tester, Westinghouse Elec. & Mfg. Co., 337 Jefferson Ave., Sharon, Pa.
*ROUNDS, THOMAS EMERSON, Jr., Engg. Draftsman, New York Central Railroad Co., 466 Lexington Ave., New York; res., Yonkers, N. Y.
RUMRILL, HAMILTON, Ass't. Electrical Engineer, General Electric Co., West Lynn, res., Swampscott, Mass.
RUPPENTHAL, FREDERICK WILLIAM Jr., Planning Engineer, Western Electric Co., Inc., 1505 Race St., Philadelphia, Pa.
*RUSH, SAMUEL ELLIS, Asst. Engineer, Union Gas & Electric Co., 1107 Plum St., Cincinnati, Ohio.
RUSSELL, RICHARD HERR, Group Chief, Raw Material Ordering Dept., Western Electric Co., Hawthorne Works, Chicago; for mail, Berwyn, Ill.
SALIGER, HENRY FREDERICK, Draftsman, S. California Edison Co., 2nd & Boylston Sts., Los Angeles; res., Inglewood, Calif.
SAVAGE, ELMER, Chief Electrician, American Can Co., 26th & Wilson Sts., Portland, Ore.
SCHAFFER, ROLLIN M., Northern Indiana Gas & Electric Co., Hammond, Ind.
*SCHNAUTZ, WILLIAM JOHN, Outside Plant Engineer, New York Telephone Co., 63 E. Delawan Ave., Buffalo, N. Y.
SCHNURR, FRANCIS EDWIN, Asst. Valuation Engineer, Murrie & Co., 45 E. 17th St., New York; res., Stapleton, N. Y.
SCHRUM, MILO O., Telephone Engineer, Bell Telephone Laboratories, Inc., 463 West St., New York, N. Y.
SEESE, ROBERT ST. CLARE, Sales Engineer, Western Electric Co., 1947 E. Kirby Ave., Detroit, Mich.
SEIPLE, WILLIAM MacDONALD, Electrical Engineer, Pennsylvania Power & Light Co., 135 N. Washington St., Wilkes-Barre; res., Kingston, Pa.
*SHELHORSE, ALBERT WILLIAM, Student, Westinghouse Elec. & Mfg. Co., 1420 Electric Ave., East Pittsburgh, Pa.
SHEPHERD, DONALD HARRY, Inspector, Electrical Instruments & Meters, New York Telephone Co., 204 2nd Ave., New York; res., Mt. Vernon, N. Y.
*SHIROYAN, HAIG KRIKOR, Asst. Research & Test Engineer, American Brass Co., Hastings-on-Hudson, N. Y.
SIMMONS, ORIE J., Electrical Engineer, Fairbanks-Morse Elec. Mfg. Co., 21 & Northwestern, Indianapolis, Ind.
SIMON, HENRY O., Equipment Engineering Checker, Western Electric Co., Hawthorne Sta., Chicago, Ill.
SIMPSON, PHILIP H., Sales Manager, Eastern Dist., Gould Coupler Co., 250 Park Ave., New York, N. Y.
SKRODER, CARL E., Instructor, Elec. Engg. Dept., University of Illinois, Urbana, Ill.
*SLATER, FRANCIS ROBERT, Student, Elec. Engg. Dept., Oregon Agricultural College, Corvallis; res., Portland, Ore.
SODERBERG, E. W., Draftsman, Pacific Gas & Electric Co., 447 Sutter St., San Francisco; res., Berkeley, Calif.
SOGGE, RICHARD CHARLES, Administrative Div., Central Station Dept., General Electric Co., 1 River Road, Schenectady, N. Y.
*SOVITZKY, WALTER V., Efficiency & Time Study Engineer, Pawling & Harnischgeger Co., 38 E. National Ave., Milwaukee, Wis.
*SPAULDING, JOHN NORMAN, Hydrographer, Great Western Power Co., 530 Bush St., San Francisco; res., Oakland, Calif.
SPICER, FLOYD O., Radio Engineer, Radio Corp. of America, 233 Broadway, New York, N. Y.
*SPRING, ERNEST WALKER, Operating Dept., The Detroit Edison Co., 2000 2nd Ave., Detroit, Mich.
STANDISH, GERALD, Engineer of Surveys, Bronx Gas & Electric Co., 43 Westchester Sq., New York, N. Y.
*STASTNY, JOHN FRANCIS, Electrical Designer, International Harvester Co., Blue Island & Oakley Aves., Chicago, Ill.
STEWARD, HAROLD RAYMOND, Asst. Test Engineer, East Penn. Electric Co., Fishbach Substation, Pottsville; for mail, Summit Hill, Pa.
STEWART, ASA WILLIAM JOHN, Dist. Manager, Toronto Hydro-Electric System, 225 Yonge St., Toronto, Ont., Can.
*STEWART, HERBERT R., General Engineer, Westinghouse Elec. & Mfg. Co., East Pittsburgh; res., East Liberty, Pa.
STONE, EDWARD G., Foreman, Hat Creek Power Houses, Mt. Shasta Power Corp., Cassel, Calif.
SYLER, R. E., Supervisor of Long Lines, Mountain States Tel. & Tel. Co., Denver, Colo.
*TANG, KWAN YAU, Instructor, Elec. Engg. Dept., Ohio State University, Columbus, Ohio.
TATE, WILLIAM, Supt. of Electrification, Mexicana Railroad, Maltrata, Vera Cruz, Mex.
*TECKLENBURG, HERBERT C., Junior Electrical Engineer, New York & Queens Electric Light & Power Co., Lawrence & Grove Sts., Flushing; res., Bay Shore, N. Y.
TERRY, DONALD M., Telephone Engineer, Bell Telephone Laboratories, Inc., 463 West St., New York, N. Y.
*THIELMAN, JOSEPH A., Inspector, Station Elec. Constr. Dept., Philadelphia Electric Co., 1000 Chestnut St., Philadelphia, Pa.
*THOMAS, JAMES WILLIAM, Student, Johns Hopkins University, 1730 Calvert St., Baltimore, Md.
THOMAS, OSCAR J., Supervisor of Radio, Pennsylvania Power & Light Co., 117 E. Broad St., Hazleton, Pa.
THOMPSON, ALBIN JAMES, Engineer, The Pacific Tel. & Tel. Co., 140 New Montgomery St., San Francisco, Calif.
THOMPSON, ARTHUR WILLIAM, Mechanical Engineer, Engg. Dept., Drafting Div., Westinghouse Elec. & Mfg. Co., Sharon, Pa.
THORUD, ERLING, Electrical Designer, Adirondack Power & Light Corp., 248 Clinton St., Schenectady, N. Y.
*TOMLINSON, FENIS R., Transformer Dept., General Electric Co., 1133 E. 152nd St., Cleveland, Ohio.
TOUSEY, CLARENCE HINCKLEY, Substation Inspector, The Detroit Edison Co., 2000 2nd Ave., Detroit, Mich.
*TOWERS, RICHARD ANTHONY, Metro-Goldwyn-Mayer Corp., Culver City; for mail, Oakland, Calif.
*TRACY, HAROLD HUDSON, Instrument Man, Oregon Short Line Railroad Co., Pocatello, Idaho; res., Salt Lake City, Utah.
*TROY, JOHN REDMOND, Inspector, Murrie & Co., 45 E. 17th St., New York; res., Brooklyn, N. Y.
TRUE, JOHN GEORGE, Draftsman, Tampa Electric Co., Tampa, Fla.
TUCKER, REXFORD S., Electrical Engineer, American Tel. & Tel. Co., 195 Broadway, New York, N. Y.
*TUDOR, RICHARD DeBOSE, Installer, Western Electric Co., 800 14th St., Denver, Colo.
TUTTLE, CHARLES MALLARD, General Storekeeper, General Electric Co., Bridgeport, Conn.
UNDERHILL, WILLIAM LESLIE L., Engineer in Charge, Langley Substation, British Columbia Electric Railway Co., Coghlan, B. C., Can.
UTTER, RAYMOND EDWARD, Asst. Elec. Engineer, Union Gas & Electric Co., 1107 Plum St., Cincinnati, Ohio.
*VACLAVIK, FRANK JOSEPH, Engineer, Commonwealth Power Corp.; Consumers Power Co., 244 W. Michigan Ave., Jackson, Mich.
VALENTINE, CLIFFORD W., Sales Assistant, Westinghouse Elec. & Mfg. Co., 150 Broadway, New York; res., Brooklyn, N. Y.
*VAN WYK, H., Meter Tester, Puget Sound Power & Light Co., 7th & Olive, Seattle, Wash.
VELASCO, LUIS RAIMUNDO, Operator, Maltrata Substation, Mexican Railroad Co., Vera Cruz., Mex.
*VOGELSANG, LEWIS OSCAR, Engineer, San Antonio Public Service Co., 201 N. St. Marys St., San Antonio, Texas.
VOSS, HOWARD MADEIRA, Field Man, So. California Telephone Co., 433 S. Olive St., Los Angeles; res., Gardena, Calif.
WADSLEY, CHARLES RAYNOR, Telephone Engineer, Bell Telephone Laboratories, Inc., 463 West St., New York, N. Y.

*WAITE, ROGER THORNTON, Engineer, Research Dept., Aetna Life Insurance Co., Hartford, Conn.
*WALIGOSKI, ADAM ARNOLD, Equipment Engineer, Western Electric Co., Hawthorne Sta., 48th & 22nd Ave., Chicago, Ill.
WALKER, JOHN JOSEPH R., Asst. Dept., Supervisor, Western Electric Co., 268 W. 36th St., New York, N. Y.
*WALKER, SAMUEL WEYLIE, Inspector, Canadian National Railways, New Union Station, Toronto, Ont., Can.
WEBB, WALTER RAY, Electrical Engineer, Worthington Pump & Machinery Corp., Laidlaw Works, Elmwood Place, Hamilton Co., Ohio.
WEBER, CARL W., Electrical Contractor Engineer, Western Electric, 410 W. 43rd St., Kansas, Mo.
WEINER, WILLIAM, Electrical Inspector, Pennsylvania Railroad Co., Sunnyside Engine House, Long Island City, N. Y.
WESTIN, CARL HAROLD, Diagram Engineer, Westinghouse Elec. & Mfg. Co., East Pittsburgh; res., Pittsburgh, Pa.
WILLIAMS, FRANCIS A., Dept. Head, Western Electric Co., Inc., 395 Hudson St., New York, N. Y.
*WILLIAMS, STUART ROBERT, Special Representative, Westinghouse Elec. & Mfg. Co., South Bend, Ind.; for mail, Chester, Pa.
WILLS, ARTHUR LLOYD, Engineer, General Electric Co., 1301 Pierce Bldg., St. Louis, Mo.
WITHROW, CHARLES HUNTER, Telephone Engineer, Bell Telephone Laboratories, Inc., 463 West St., New York, N. Y.
WURTH, CHARLES G., Supervising Methods Engineer, Western Electric Co., Inc., 268 W. 36th St., New York, N. Y.
*YARMACK, JOHN EREMEI, Asst. Instructor Elec. Engg. Dept., Yale University, 10 Hillhouse Ave., New Haven, Conn.
ZUCCO, JOHN JOSEPH, New York EdisonCo., 327 Rider Ave., New York, N. Y.

Total 382

*Formerly enrolled students.

**ASSOCIATES REELECTED FEBRUARY 9, 1926**

CARR, CHARLES CLEMENT, Telephone Engineer, Bell Telephone Laboratories, Inc., 463 West St., New York, N. Y.
CHANDLER, MAX, Engineering Dept., Commonwealth Power Co., Jackson, Mich.
MARCHANT, LEWIS, Traffic Manager, D. P. Robinson & Co., 125 E. 46th St., New York, N. Y.; res., Wilton, Conn.
MARSTELLER, GEORGE F., Electrical Designer, Calculator, C. H. Tenney & Co., 200 Devonshire St., Boston, Mass.
PENMAN, ROY FRANKLIN, Instructor, Elec. Engg. Dept., Cornell University, Franklin Hall, Ithaca, N. Y.
SCHAEFER, JOSEPH HARVEY, Equipment Engineer, New York Telephone Co., 158 State St., Albany, N. Y.
SMITH, E. DARWIN, Jr., Secretary & Electrical Engineer, Rochester Electric Products Corp., 640 Driving Park Ave., Rochester, N. Y.
STEINMETZ, RICHARD BIRD, Sales Correspondent, Westinghouse Elec. & Mfg. Co., 150 Broadway, New York; res., Brooklyn, N. Y.
TINKEY, OTTO G., Foreman of Construction, Ideal Electric Co., Champaign; res., Urbana, Ill.

**MEMBERS ELECTED FEBRUARY 9, 1926**

BURRIER, EARL ROSCOE, Colliery Electrical Engineer, Hudson Coal Co., Scranton, Pa.
BUSHMAN, ANDREW KIDD, Engineer, General Electric Co., 230 S. Clark St., Chicago, Ill.
CORAM, ROY EVERETT, Engineer, Bell Telephone Laboratories, Inc., 463 West St., New York, N. Y.
GOLDSMITH, LESTER M., Consulting Engineer, Atlantic Refining Co., 260 S. Broad St., Philadelphia, Pa.
GRANICH, ALFRED MATHEWS, Telephone Engineer, Bell Telephone Laboratories, Inc., 463 West St., New York, N. Y.
KECKLER, CHARLES WILLIAM, Telephone Engineer, Bell Telephone Laboratories, Inc., 463 West St., New York, N. Y.
MARTING, HEBER EDWIN, Member, Technical Staff, Bell Telephone Laboratories, Inc., 463 West St., New York, N. Y.; res., Rutherford, N. J.
PAINE, LOUIS ARTHUR, Experimental Engineer, Lincoln Meter Co., 72 Stafford St., Toronto, Ont., Can.
PAINTON, EDGAR THEODORE, Chief, Electrical Sales Dept., The British Aluminum Co., Ltd., 109 Queen Victoria St., London, Eng.
PARKER, LEVI WRIGHT, Telephone Engineer, Bell Telephone Laboratories, Inc., 463 West St., New York, N. Y.; res., East Orange, N. J.
PETERSON, EUGENE, Electrical Engineer, Engg. Dept., Western Electric Co., 463 West St., New York, N. Y.
PLOTNER, LOYD D., Telephone Engineer, Bell Telephone Laboratories, Inc., 463 West St., New York; res., Brooklyn, N. Y.
REICHARD, WADE HAMPTON, Consulting Electrical Engineer, General Railway Signal Co., Rochester, N. Y.
SHILEY, SAM WELLES, Supervisor, Toll System Development, Bell Telephone Laboratories, Inc., 463 West St., New York; res., Port Washington, N. Y.
ZIMMERMAN, JOHN ALEXANDER, Chief Elec. Draftsman, charge of High Tension Trans. Design, Chas. H. Tenney & Co., 200 Devonshire St., Boston, Mass.

**FELLOW ELECTED FEBRUARY 9, 1926**

HELPBRINGER, J. NELSON, Gen. Supt., Staten Island Edison Co., Staten Island, N. Y.

**TRANSFERRED TO GRADE OF FELLOW FEBRUARY 9, 1926**

BETTIS, ALEXANDER E., Vice-President, Kansas City Power & Light Co., Kansas City, Mo.
CURTIS, HARVEY L., Senior Physicist, Bureau of Standards, Department of Commerce, Washington, D. C.
DANN, WALTER M., Electrical Engineer, Westinghouse Electric & Mfg. Co., Sharon, Pa.
HOBART, K. E., Superintendent Overhead Lines, Commonwealth Edison Co., Chicago, Ill.
PRINCE, DAVID C., Research Engineer, General Electric Co., Schenectady, N. Y.

**TRANSFERRED TO GRADE OF MEMBER FEBRUARY 9, 1926**

EWENS, W. SYDNEY, District Manager, Alfred Collyer & Co., Toronto, Ont., Can.
HAZELTINE, HAROLD L., Engineer of Insulation, Sterling Varnish Co., Pittsburgh, Pa.
JOHNSON, EDWARD J., Member of Technical Staff, Bell Telephone Laboratories, New York., N. Y.
MEYER, A. A., Assistant General Superintendent, Detroit Edison Co., Detroit, Mich.
NOSS, MARSENA A., Chief Engineer, International Telepost Co., New York.
ROBINSON, BLIGHT S., Engineer, R. W. Cramer & Co., Inc., New York.
SHEPARD, ROBERT B., Electrical Engineer, Underwriters' Laboratories, New York.
SILSBEE, FRANCIS B., Physicist, Bureau of Standards, Department of Commerce, Washington, D. C.
SINGLETON, L. D., Senior Field Electrical Engineer, Braden Copper Co., Rancagua, Chile.
SMITH, EVERETT H., Supervising Equipment Design Engineer, Bell Telephone Laboratories, New York.
SNIDER, GEORGE E., Chief Electrical Engineer, Ohio Public Service Co., Cleveland, O.
STEVENS, ALEXANDER C., Electrical Engineer, General Electric Co., Schenectady, N. Y.
WEIGHT, JOHN W., Head, Industrial Truck and Locomotive Dept., Electric Storage Battery Co., New York.
WILKINS, ROY, Assistant Engineer, Dept. of Hydro-Elec. & Transmission Engg., Pacific Gas & Electric Co., San Francisco, Calif.

**RECOMMENDED FOR TRANSFER**

The Board of Examiners, at its meeting held February 5, 1926, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the National Secretary.

**To Grade of Fellow**

FLEAGER, CLARENCE E., Chief Engineer, Pacific Telephone & Telegraph Co., San Francisco, Calif.

**To Grade of Member**

CLARK, JOHN A., Research Engineer, Weston Electrical Instrument Corp., Newark, N. J.
CUNNINGHAM, R. E., Operating Electrical Engineer, Southern California Edison Co., Los Angeles, Calif.
DAVIES, HAROLD C., Station Section, Elec. Engineering Dept., Hydro-Electric Power Commission, Toronto, Ontario.
FIELDS, ERNEST S., Asst. Electrical Engineer, Union Gas & Electric Co., Cincinnati, O.
GRAHAM, FRANK B., Telephone Engineer, Bell Telephone Laboratories, New York, N. Y.
HALE, WILLIAM K., State Electrical Engineer, Mountain States Tel. & Tel. Co., Denver, Colo.
HARRIS, IRVING C., Consulting Engineer, Cone and Harris, Los Angeles, Calif.
HEALY, EDWIN S., Transmission Engineer, Electric Bond & Share Co., New York, N. Y.
HINSON, N. B., System Planning Engineer, Southern California Edison Co., Los Angeles, Calif.
HORN, A. F. E., Manager, General Electric Co., Washington, D. C.
JOHNSON, JAMES A., Works Manager, Canadian Crocker Wheeler Co., Ltd., St. Catherines, Ont.
JONES, ARTHUR L., District Engineer, General Electric Co., Denver, Colo.
PUBLOW, CEDRIC F., Asst. Station Engineer, Hydro-Electric Power Commission, Toronto, Ont.
SIMPSON, WILLIAM L., Division Engineer, Postal Telegraph-Cable Co., Chicago, Ill.
SOULE, WILLIAM H., Electrical Superintendent, Mond Nickel Co., Coniston. Ont.
STARR, JAMES H., District Engineer, Condit Electrical Manufacturing Co., St. Louis, Mo.

**APPLICATIONS FOR ELECTION**

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated, the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before March 31, 1926.

Abbott, H. H., American Tel. & Tel. Co., New York, N. Y.
Amson, R. I., United Electric Light & Power Co., New York, N. Y.
Axon, W. R., Westinghouse Elec. & Mfg. Co., Philadelphia, Pa.

Axtell, H. B., American Tel. & Tel. Co., St. Louis, Mo.
Baker, A. W., American Electric Railway Association, New York, N. Y.
Baker, H. D., Sales Engineer, 602 Ford Bldg., Detroit, Mich.
Baker, H. W., Bell Telephone Laboratories, Inc., New York, N. Y.
Barden, W. S., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Barnard, G. H., (Member), Electro-Dynamic Co., Bayonne, N. J.
Barton, H. P. S., Jr., Postal Telegraph-Cable Co., New York, N. Y.
Beach, W. C., Bell Telephone Laboratories, Inc., New York, N. Y.
Beck, A. D., Westinghouse Elec. & Mfg. Co., Cleveland, Ohio
Bellis, A. P. S., John A. Roebling's Sons Co., Trenton, N. J.
Bingel, G. H., C. H. Stevens Co., New York, N. Y.
Bird, T. C., Line Material Co., South Milwaukee, Wis.
Black, H. M., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Blakey, L. M., Hartford Accident & Indemnity Co., Hartford, Conn.
Blois, R. K., (Member), Cons. Mining & Smelting Co. of Can., Ltd., Trail, B. C.
Bloser, W. C., Thomas E. Murray & Co., New York, N. Y.
Bonn, N. E., Leeds & Northrup Co., Philadelphia, Pa.
Bonner, W. F., Public Service Electric & Gas Co., Irvington, N. J.
Boolos, S. G., Brooklyn Edison Co., Brooklyn, N. Y.
Brake, W. J., Light & Power Dept., City of Regina, Regina, Sask., Can.
Braue, C. A., Brooklyn Edison Co., Brooklyn, N. Y.
Bressner, J., Pratt Institute, Brooklyn, N. Y.
Brice, W. A., Illinois Bell Telephone Co., Chicago, Ill.
Brown, E. C., Hartford Electric Light Co., Hartford, Conn.
Brown, E. C., E. C. Brown Co., Boston, Mass. (Applicant for re-election.)
Browne, W. H., 3rd, McCollom Geological Explorations Corp., Chevy Chase, D. C.
Burbidge, L., R. A. Lister & Co., Inc., New York, N. Y.
Burchill, G. H., Canadian General Electric Co., Peterborough, Ont., Can.
Burri, J. J., (Member), Staten Island Edison Co., Staten Island, N. Y.
Buswell, J. F., Westinghouse Elec. & Mfg. Co., Boston, Mass.
Caldwell, E., American Rolling Mill Co., Ashland, Ky.
Camilli, G., General Electric Co., Pittsfield, Mass.
Carey, F. K., Llewellyn Iron Works, Los Angeles, Calif.
Cartland, F. W., Western State Normal School, Kalamazoo, Mich.
Case, J. W., General Electric Co., Schenectady, N. Y.
Caster, J. H., (Member), Hydro-Elec. Pr. Comm. of Ontario, Toronto, Ont., Can.
Castro, L., Jr., General Electric Co., Schenectady, N. Y.
Centeno, J. G., Brooklyn Edison Co., Brooklyn, N. Y.
Charles, D. M., Reliance Elec. & Engineering Co., Cleveland, Ohio
Cheney, M. C., Rockbestos Products Corp., New Haven, Conn.
Chun, H. H., Premier Electric Co., Chicago, Ill.
Clarke, S. O., United Electric Light & Power Co., New York, N. Y.
Coffin, L., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Cox, B. C., Carter Electric Co., Atlanta, Ga.
Craig, P. H., University of Cincinnati, Cincinnati, Ohio
Cresson, G. V., Public Service Corp. of N. J., Newark, N. J.
Crist, J. A., New York Telephone Co., New York, N. Y.
Crotty, H. F., General Electric Co., West Lynn, Mass.
Cummings, A. E., New York Telephone Co., New York, N. Y.
Daniel, T. A., Western Electric Co., Chicago, Ill.
Davies, W. B., Saskatchewan Telephone System, Saskatchewan, Can.
Dawson, L. L., Erie Railroad Co., Jersey City, N. J.
de Kay, R. D., Bell Telephone Laboratories, Inc., New York, N. Y.
de la Garrigue, J. L., School of Engg. of Milwaukee, Milwaukee, Wis.
Demerec, Mary Z., New York Telephone Co., New York, N. Y.
de Polac, L. C., Westinghouse Elec. & Mfg. Co., New York, N. Y.
De Tar, D. R., General Electric Co., Schenectady, N. Y.
Dettwiller, C. J., Western Electric Co., Inc., Hawthorne Sta., Chicago, Ill.
Dickinson, R. B., Duke Price Power Co., Ltd., Isle Maligne, Lake St. John, P. Q.
Dolton, E. G., (Member), Div. of Architecture & Construction, State of New Jersey, Trenton, N. J.
Donnelly, J. F., Pennsylvania State Sanatorium, S. Mountain, Mont Alto, Pa.
Dua, M. S., Pacific Gas & Electric Co., San Francisco, Calif.
Duvander, B. F. H., Pacific Gas & Electric Co., San Francisco, Calif.
Egli, J., American Brown Boveri Electric Corp., Camden, N. J.
Ellsworth, F. P., Western Electric Co., Inc., New York, N. Y.
Fauerbach, W. F., Westinghouse Elec. & Mfg. Co., New York, N. Y.
Feldman, J. J., Westinghouse Elec. & Mfg. Co., Brooklyn, N. Y.
Forbes, A. H., Pennsylvania State College, State College, Pa.
Franz, A. S., Postal Telegraph-Cable Co., New York, N. Y.
Furbish, C. T., Warren Foundry & Pipe Co., Phillipsburg, N. J.
Garrison, J. D., W. A. Beile & Co., Chicago, Ill.
Gedge, W. J., New York Telephone Co., New York, N. Y.
Goard, L. C., (Member), The Ohio Public Service Co., Ashland, Ohio
Godfrey, J. H., Westinghouse Elec. & Mfg. Co., Springfield, Mass.
Golikoff, A., "Ural-Platinum Trust," New York, N. Y.
Goss, R. C., Ohio Brass Co., Philadelphia, Pa.
Graybrook, H. W., Westinghouse Elec. & Mfg. Co., Springfield, Mass.
Griffin, T. J., Westinghouse Elec. & Mfg. Co., Philadelphia, Pa.
Gunnarson, G. A., Electric Bond & Share Co., New York, N. Y.
Hackbush, R. A., Canadian Westinghouse Co., Ltd., Toronto, Ont., Can. (Applicant for re-election.)
Haga, J., Brooklyn Edison Co., Brooklyn, N. Y.
Hahn, W. C., General Electric Co., Chicago, Ill.
Hanstein, H. B., Brooklyn Edison Co., Brooklyn, N. Y.
Hare, J. G., East York Hydro-Electric Commission, Toronto, Ont., Can.
Harte, J. A., Dept. of Plant & Structures, New York, N. Y.
Henritze, R. J., Westinghouse Elec. & Mfg. Co., New York, N. Y. (Applicant for re-election.)
Hewlett, R. C., Pratt Institute, Brooklyn, N. Y.
Hickcox, T. W., Pratt Institute, Brooklyn, N. Y.
Hill, G. J., Western Electric Co., Inc., Washington, D. C.
Holleman, E. M., Radio Salesman, Germains, Los Angeles, Calif.
Houck, F. J., Erie Railroad Co., Jersey City, N. J.
Howlett, P. W., Sangamo Elec. Co. of Canada, Ltd., Toronto, Ont., Can.
Hughes, A. A., Radio Corp. of America, Rocky Point, L. I., N. Y.
Hunter, R. J., Brooklyn Edison Co., Brooklyn, N. Y.
Inglis, J. G., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Jaczko, J., Westinghouse Elec. & Mfg. Co., Sharon, Pa.
Jones, H. P., Philadelphia Electric Co., Philadelphia, Pa.
Jones, R. W., Consumers Power Co., Flint, Mich.
Judge, F. G., (Member), Pierce Electric Co., Tampa, Fla.
Kaneb, B. M., American Steel & Wire Co., Worcester, Mass.
Keller, E. J., Roxborough High School, Philadelphia, Pa.
Kelly, C. R., K & K Electr Co., Perth Amboy, N. J.
Kenah, R. M., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Kincklner, R. A., Philadelphia Electric Co., Philadelphia, Pa.
Kinsella, R. H. F., Brooklyn Edison Co., Brooklyn, N. Y.
Krauss, R. A., Counties Gas & Electric Co., Norristown, Pa.
Kray, J. F., Bell Telephone Co. of Pa., Philadelphia, Pa.
Krueger, R. A., Wisconsin Valley Electric Co., Wausau, Wis.
Lambert, A. W., Pacific Tel. & Tel. Co., San Francisco, Calif.
Lederhause, H. W., Bell Telephone Laboratories, Inc., New York, N. Y.
Leeson, G. E., Saskatchewan Gov't. Telephones, Yorkton, Sask., Can.
Leonard, E. M., Pittsburgh Transformer Co., Pittsburgh, Pa.
Levy, M. L., Stromberg-Carlson Tel. Co., Rochester, N. Y.
Lewis, H. G., (Member), Westinghouse Elec. & Mfg. Co., Springfield, Mass.
Lewis, J. G., Potomac Edison Co., Cumberland, Md.
Leyden, A. F., Bell Telephone Laboratories, Inc., New York, N. Y.
Lippincott, C. D., Adirondack Power & Light Corp., Schenectady, N. Y.
Lyster, M. S., The Pacific Tel. & Tel. Co., San Francisco, Calif.
Lippman, W. O., Westinghouse Elec. & Mfg. Co., Springfield, Mass.
Lorje, H., Empire Companies, Bartlesville, Okla.
Low, H. M., Andes Copper Mining Co., New York, N. Y.
Mahl, J. A., Pacific Gas & Electric Co., San Francisco, Calif.
Martingell, L. W., Cansfield Electric Works, Toronto, Ont., Can.
Mathews, E. C., U. S. Shipping Board, Los Angeles, Calif.
McCormick, H. V., C. L. Stevens Co., Boston, Mass.
McKearney, J. J., Postal Telegraph-Cable Co., New York, N. Y.
Mendenhall, H. E., California Institute of Technology, Pasadena, Calif.
Michael, J. H., Allis-Chalmers Mfg. Co., West Allis, Wis.
Miller, N. O. C., Schwall Electric Works, Stockton, Calif.
Modlin, W. G., Public Service Electric & Gas Co., Newark, N. J.
Moes, G., Simplex Wire & Cable Co., Cambridge, Mass.
Molmoe, R., Knoxville Power & Light Co., Knoxville, Tenn.
Morgan, R. A., R. A. Turner & Co., Springfield, Mass.
Moxon, A. W., Pratt Institute, Brooklyn, N. Y.
Nakamoto, H., Public Service Electric & Gas Co., Newark, N. J.
Nicholson, R. F., Catholic University of America, Brookland, D. C.

Norstrand, C. O., New Amsterdam Casualty Co., New York, N. Y.
Norwig, J., Jr., United Electric Light & Power Co., New York, N. Y.
O'Brien, E. C., J. J. O'Brien & Son, New York, N. Y.
Orcutt, H. S., United Electric Light & Power Co., New York, N. Y.
Osborn, A. L., S. New England Telephone Co., New London, Conn.
Osburn, M. P., Hydro-Elec. Pr. Commission of Ontario, Toronto, Ont., Can.
Ouellette, E. F., Ford Motor Co., Detroit, Mich.
Pagano, L. A., Brooklyn Edison Co., Inc., Brooklyn, N. Y.
Painter, C. L., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Patrick, P. D., Philadelphia Electric Co., Philadelphia, Pa.
Paul, H. F., The Electric Controller & Mfg. Co., Cleveland, Ohio
Peters, A. W., Shawinigan Water & Power Co., Montreal, Que., Can.
Peterson, J. R., Western Union Telegraph Co., San Francisco, Calif.
Pike, A. T., Western Electric Co., Inc., New York, N. Y.
Pike, W. K., Westinghouse Elec. & Mfg. Co., Springfield, Mass.
Pollard, A. H., International General Electric Co., Schenectady, N. Y.
Purucker, R. E., University of Wisconsin, Madison, Wis.
Quededo S. A., Westinghouse Elec. International Co., Havana, Cuba
Rathgeber, M. D., Potomac Electric Co., Washington, D. C.
Ricks, H. M., Weston Electrical Instrument Corp., New York, N. Y.
Riddle, W. L., Westinghouse Elec. & Mfg. Co., Springfield, Mass.
Robb, F. H., Westinghouse Elec. & Mfg. Co., Springfield, Mass.
Robinson, J. W., Leeds & Northrup Co., Philadelphia, Pa.
Rockefeller, H. C., Westinghouse Elec. & Mfg. Co., East Springfield, Mass.
Ross, R. W., Leeds & Northrup Co., Philadelphia, Pa.
Rubel, W. L., Memco Engineering & Manufacturing Co., Long Island City, N. Y.
Runcie, A. A., Lundin Electric & Machine Co., Boston, Mass.
Sampson, G. H., Nashua Manufacturing Co., Nashua, N. H.
Saurwein, V. E., Ohio Bell Telephone Co., Cleveland, Ohio
Schmeltzer, C. F., Western Electric Co., Inc., Cicero, Ill.
Schmidt, H., U. S. E. M. Co., New York, N. Y.
Scholz, C. E., (Member), Federal Telegraph Co., Palo Alto, Calif.
Schroeder, R. F., Brooklyn Edison Co., Brooklyn, N. Y.
Seaward, E. S., Gould Storage Battery Co., Depew, N. Y.
Shaw, R. H., Tampa Electric Co., Tampa, Fla.
Singer, R. H., The Union Gas & Elec. Co., Cincinnati, Ohio
Skinner, D. C., Youngstown Sheet & Tube Co., Youngstown, Ohio
Smith, A. W. S., Hydro-Electric Power Commission of Ontario, Toronto, Ont., Can.
Smith, E. C., Russell Mfg. Co., Middletown, Conn.
Spann, R. D., Capt., Coast Artillery Corps, U. S. A., New York, N. Y.
Spellmire, W. B., (Member), General Electric Co., Pittsburgh, Pa. (for re-election)
Stack, S. S., General Electric Co., Schenectady, N. Y.
Strymoe, J. E., Westinghouse Elec. & Mfg. Co., Chicago, Ill.
Strod, A. J., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Stuart, B. O., 3824 Waldo Ave., New York, N. Y.
Stufft, J. W., Westinghouse Elec. & Mfg. Co., New York, N. Y.
Suppers, H. G., John A. Roebling's Sons Co., Trenton, N. J.
Sutton, C. A., Bethelhem Steel Corp., Bethlehem, Pa.
Swazey, H. A., Philadelphia Electric Co., Philadelphia, Pa.
Taylor, S. B., Reliance Electric & Engineering Co., Cleveland, Ohio
Teker, L., Leeds & Northrup Co., Philadelphia, Pa.
Thomson, O. R., (Member), Hydro-Electric Power Commission of Ontario, Belleville, Ont., Can.
Toetz, F. W., Emsco Derrick & Equipment Co., Los Angeles, Calif.
Trachtman, H., Bronx Electric Co., Bronx, New York, N. Y.
Turner, C. M., Dept. of Public Works, State of Washington, Olympia, Wash.
Upp, J. W., Jr., (Member), Ohio Brass Co., Mansfield, Ohio
Vaden, T. H., Alabama Power Co., Anniston, Ala.
von Sneidern, A. A., General Electric Co., Schenectady, N. Y.
Wadlek, J., Westinghouse Elec. & Mfg. Co., Sharon, Pa.
Waller, J. L., Rome Wire Co., Rome, N. Y.
Webber, C. W., 410 W. 43rd St., Kansas City, Mo.
Weckworth, H. F., Northern Indiana Gas & Electric Co., Hammond, Ind.
Weiner, L., Anaconda Sales Co., New York, N. Y.
Weitzman, H. A., with Edward J. Cheney, New York, N. Y.
Welsh, W. E., Penn. Power & Light Co., Ashley, Pa.
Wendler, H. J., Public Service Production Co., Newark, N. J.
White, H. G., Mancha Storage Battery Locomotive Co., St. Louis, Mo.
Wilfley, V. B., Westinghouse Elec. & Mfg. Co., Wilkinsburg, Pa.
Wilkinson, T. A., Westinghouse Elec. & Mfg. Co., New York, N. Y.
Williams, F. R., Dixie Power Co., Cedar City, Utah
Williamson, R. B., General Railway Signal Co., Rochester, N. Y.
Wittenberg, A. J., Brooklyn Edison Co., Inc., Brooklyn, N. Y.
Wolf, A., Philadelphia Electric Co., Philadelphia, Pa.
Woodward, J. E., Standard Oil Co. of N. J., Bayway Refinery, Elizabeth, N. J.
Wurst, L. L., Public Service Co. of No. Illinois, Kankakee, Ill.
Wyatt, R. M., Western Electric Co., Inc., New York, N. Y.
Young, T. J., Bell Telephone Laboratories, Inc., New York, N. Y.
Yount, L. E., Western Radio, Inc., Los Angeles, Calif.
Zellweger, F., Schweitzer & Conrad, Inc., Chicago, Ill.
Zimmermann, A. G., The Pacific Tel. & Tel. Co., San Francisco, Calif.
Total 217

### Foreign

Beaumont, L., Shanghai Municipal Electricity Dept., Shanghai, China
Brown, F. W., Public Works Dept., Mangahao Pr. Sta., Shannon, N. Z.
Cangucu, O. G., Paulista Railway, Sao Paula, Brazil, S. A.
Coulson, W., The Electrical Installation & Repairing Co., Belfast, Ireland
Dennis, W. E., Bombay Baroda & Central India Railway, Bombay, India
Deronne, M., S. F. de M. d'e. A. Tekka, Gopeng, Perak, F. M. States
Dunham, D., Southland Electric Power Board, Invercargill, N. Zealand
Forrest, F., 14 Dale End, Birmingham, Eng.
Garnett, H. S., Messrs. Merz & McLellan, Westminster, London, Eng.
Heffelman, M. C., Chile Exploration Co., Chuquicamata, Chile, S. A.
Liebert, S. F. E., Chief Elec. Engineer's Branch, Postmaster-General's Dept., Melbourne, Aust.
Mackay, A., Ferranti, Ltd., Hollinwood, Lancashire, Eng.
Matel., M. T. H., A. B. Bergslagens Gemensamma, Kraftforvaltning, Vasteras, Sweden
McLauchlan, C. D., (Member), Telegraphs & Country Telephones, Perth, W. Australia
Pistorius, L. H., British Thomson-Houston Co., Ltd., Rugby, Eng.
Pitt, F. E., S. Wales Electrical Power Distribution Co., Cwmbran, Monmouth Co., Eng.
Ponday, G. P., Chaba, Simla Municipality Pr. Station, Simla Dist., Punjab, India
Raju, M. G., (Member), The Andhra Elec. Lighting Scheme, Guntur, S. India
Riseley, R. L., Chile Exploration Co., Chuquicamata, Chile, S. A.
Roth, A., The Ateleirs de Constructions electriques de Delle., Lyon-Villeurcanne, France
Steukvist, K. E., Allmanna Svenska Electric Co., Ludvika, Sweden
Thompson, S., Westinghouse Elec. International Co., Johannesburg, S. Africa
Tsou, T. Y., Anderson & Meyer Co., Shanghai, China
Total 23

### STUDENTS ENROLLED

Abbott, Frank R., Stanford Univ.
Adair, George P., Texas A. & M. College
Albert, William H., Jr., Cooper Union
Apsley, William J. E., Johns Hopkins Univ.
Ashby, Rulon S., Univ. of Delaware
Bail, Roderick, Worcester Poly. Inst.
Bailey, John W., Cornell Univ.
Baumgartner, Rupert P., Missouri School of Mines
Beckwith, Sterling, Stanford Univ.
Behrens, Chester C., Ohio State Univ.
Bell, Donald S., Cooper Union
Bell, Theron S., Rose Poly. Inst.
Bergmann, J. S., Northeastern Univ.
Berry, Robert U., Mass. Inst. of Tech.
Black, John B., Georgia Tech.
Blackstone, Harry W., Northeastern Univ.
Blatz, Irving H., Brooklyn Poly. Inst.
Bogert, William M., Cooper Union
Bradbury, Lauris J., Northeastern Univ.
Briggs, Rufus L., Mass. Inst. of Technology
Brittingham, Harry H., Missouri School of Mines
Brooking, James M., Virginia Poly. Inst.
Brooks, Norman M., Va. Poly. Inst.
Brown, Otis, Colorado Univ.
Byrne, John F., Ohio State Univ.
Cacciola, Joseph, Milwaukee School of Engg.
Campbell, Charles S., Univ. of Colorado
Campbell, Stuart M., Univ. of Michigan
Caris, Darl F., Univ. of Michigan
Carpenter, Donald W., Northeastern Univ.
Carroll, William J., Univ. of Delaware
Carter, Earle H., Univ. of Colorado
Childers, Joseph W., Univ. of Idaho
Clark, Howard D., Cornell Univ.
Coleman, John B., Mass. Inst. of Tech.
Constantino, Angelo J., Cooper Union
Cramer, Harold, Cooper Union
Crawford, James O., Mass. Inst. of Technology
Crumbaugh, Daniel, Mo. School of Mines
Dalzelle, Robert C., Johns Hopkins Univ.
D'Aniello, John P., Brooklyn Poly. Inst.
Davis, Darrell M., Texas A. & M. College
Davis, Enoch A., Jr., Virginia Poly. Inst.
Day, Charlie B., Clemson College
Dill, Robert C., Clemson College
Ditsch, John F., Newark Technical School
Doat, Irvin T., Ohio State Univ.
Dunn, Raymond E., Univ. of Michigan
Eckart, Kurt G., Cooper Union
Ellis, Stanley W., Northeastern Univ.
Evangelides, Christopher E., Brooklyn Poly. Inst.
Evans, Norman H., Carnegie Inst. of Tech.
Fankuchen, Isidore, Cooper Union
Fife, Samuel, Univ. of Cincinnati

Foster, Edwin L., Ohio State Univ.
Garrett, James E., Virginia Poly. Inst.
Gibson, Floyd L., Virginia Poly. Inst.
Glover, Arthur B., Univ. of Missouri
Grace, William J., Rice Institute
Graves, Edward, Univ. of Cincinnati
Green, Alfred R., Virginia Poly. Inst.
Gullion, Guy, Univ. of Colorado
Hanckel, John S., Washington & Lee Univ.
Harrelson, Ottis M., Clemson College
Helprin, Sydney, Cooper Union
Henderson, Edward H., Ohio Univ.
Herbert, Loren P., Ohio University
Hinkston, Donald R., California Inst. of Tech.
Hogan, Benjamin W., Virginia Poly. Inst.
Hollingsworth, Clarence T., Ohio University
Hoskin, Benjamin P., Iowa State College
Hovick, Robert L., Univ. of Wyoming
Hughes, John G., Virginia Poly. Inst.
Jain, Everett W., Univ. of Colorado
Jarvis, Henry O., Johns Hopkins Univ.
Johantges, Frank A., Purdue Univ.
Judson, Walter G., Cooper Union
Kalb, Robert M., Ohio State Univ.
Kelley, Edward F., Rose Poly. Inst.
Kelley, James B., Marquette Univ.
Ketay, Morris F., Cooper Union
Kimpton, Charles D., Univ. of Mich.
Knowles, Harold E., Univ. of Mich.
Koontz, Lawrence F., Virginia Poly. Inst.
Kritt, Raymond B., Univ. of Cincinnati
Kuenne, Kuno R., Milwaukee School of Engg.
Kunkel, Joseph M., Virginia Poly. Inst.
Lafore, Robert W., Swarthmore College
Lambert, Standish J., State Univ. of Iowa
LeBaron, George I., Carnegie Inst. of Technology
Levin, Morris J., Univ. of Cincinnati.
Liacos, Stavros J., Cooper Union
Light, G. Gordon, Virginia Poly. Inst.
Lindsay, Andrew W., Washington & Lee Univ.
Lo, Hsiao C., Purdue Univ.
Lord, Samuel E., Jr., Northeastern Univ.
Lorraine, Richard, Univ. of Colorado
Lubkin, Samuel, Cooper Union
Lusk, Robert R., Missouri School of Mines
Lynch, Edwin L., Marquette Univ.
Marks, George F., Brooklyn Poly. Inst.
Martin, Samuel M., Virginia Poly. Inst.
Masonick, Louis F., Lewis Inst.
Matthias, Lynn H., Univ. of Wisconsin
Metcalf, William L., Mo. School of Mines
Mikula, Charley R., Ohio Univ.
Miller, Carlyle W., Cooper Union
Miller, Frederic H., Cooper Union
Miller, Max I., Virginia Poly. Inst.
Morgan, Frank, Ohio Univ.
Morrison, Howard, Worcester Poly. Inst.
Murch, John A., Univ. of Maine
Myers, John A., Johns Hopkins Univ.
Nason, Louis T., Northeastern Univ.
Newland, John W., Milwaukee School of Engg.
O'Conor, John J., Johns Hopkins Univ.
Owen, Arthur T., Ohio State Univ.
Owens, Ralph G., Ohio State Univ.
Parsons, Richard B., Mass. Inst. of Tech.
Pellum, Jerome L., Rose Poly. Inst.
Peters, Quentin I., Cooper Union
Peterson, Douglas A., Mass. Inst. of Technology
Petzing, William N., Texas A. & M. College
Phippeny, Forrest I., Mich. State College
Pierce, George I., Worcester Poly. Inst.
Polis, Max M., Brooklyn Poly. Inst.
Pomeroy, Arthur L., Worcester Poly. Inst.
Pottinger, Alexander, Univ. of British Columbia
Pullen, Ralph W., Washington & Lee Univ.
Quick, John E., Ohio Univ.
Rawlins, Louis M., Johns Hopkins Univ.
Rayment, Walter, Cooper Union
Raymond, Ralph G., Lewis Inst.
Reeves, William, Univ. of Idaho
Reibeisen, Joseph, Cooper Union
Reinken, L. W., Cooper Union
Ressler, Ralph E., Cooper Union
Riemer, Fred W., Newark Tech. School
Roberts, Gerald A., Mo. School of Mines
Robisch, Norman G., Univ. of Wisconsin
Rojas, Leopoldo, Lewis Inst.
Roman, Walter G., Univ. of Colorado
Root, T. R., Ohio Univ.
Rosenfelder, Francis G., Newark Technical School
Rubinowitz, Isidore, Cooper Union
Sands, Frank N., Jr., Johns Hopkins Univ.
Schneider, John, Case School of Applied Science
Schrader, Arthur C., Ohio State Univ.
Schwartz, Benjamin, Penn. State College
Schwarzler, Charles, Jr., Cooper Union
Seaman, Joseph L., Ohio State Univ.
Seletzky, Anatoli C., Johns Hopkins Univ.
Sewell, Floyd E., Mo. School of Mines
Silk, Robert, Jr., Virginia Poly. Inst.
Slonczewski, Thaddeus, Cooper Union
Smith, Douglas Y., Cooper Union
Smith, Harvey W., Univ. of Southern California
Smith, Mitchell H., Ohio Univ.
Smith, Newell R., Ohio Univ.
Smithberger, Roman L., Ohio Univ.
St. Auburn, Wilford M., Cornell Univ.
Steinberg, Samuel J., Virginia Poly. Inst.
Steinmueller, Adelbert A., Ohio State Univ.
Stephens, Donald L., Virginia Poly. Inst.
Stocker, C. Paul, Ohio Univ.
Stuckert, Ernest M., Northeastern Univ.
Swanson, Marvin W., Milwaukee School of Engg.
Taylor, J. B., Jr., Leland Stanford Univ.
Turner, Kenneth D., Lewis Inst.
Urbi, John T., Lewis Institute
Valentine, Donald, Ohio State Univ.
Vivell, Allen E., Johns Hopkins Univ.
Ware, Robert L., Virginia Poly. Inst.
Waterman, Edwin S., Ohio State Univ.
Welch, John J., Cooper Union
Wells, Philip H., Case School of Applied Science
Wilhelm, Henry T., Cooper Union
Wishart, William, Univ. of Arizona
Woll, Willard M., Mass. Inst. of Tech.
Young, Willard A., Marquette Univ.
Total 179

# OFFICERS OF A. I. E. E. 1925-1926

**President**
M. I. PUPIN

**Junior Past Presidents**
FARLEY OSGOOD
HARRIS J. RYAN

**Vice-Presidents**
HAROLD B. SMITH
EDWARD BENNETT
JOHN HARISBERGER
L. F. MOREHOUSE
H. W. EALES
P. M. DOWNING
HERBERT S. SANDS
W. E. MITCHELL
ARTHUR G. PIERCE
W. P. DOBSON

**Managers**
H. M. HOBART
ERNEST LUNN
G. L. KNIGHT
WILLIAM M. McCONAHEY
W. K. VANDERPOEL
H. P. CHARLESWORTH
JOHN B. WHITEHEAD
J. M. BRYANT
E. B. MERRIAM
M. M. FOWLER
H. A. KIDDER
E. C. STONE

**National Treasurer**
GEORGE A. HAMILTON

**National Secretary**
F. L. HUTCHINSON

**Honorary Secretary**
RALPH W. POPE

### LOCAL HONORARY SECRETARIES

T. J. Fleming, Calle B. Mitre 519, Buenos Aires, Argentina, S. A.
Carroll M. Mauseau, Caixa Postal No. 571, Rio de Janiero, Brazil, S. A.
Charles le Maistre, 28 Victoria St., London, S. W. 1, England.
A. S. Garfield, 45 Bd. Beausejour, Paris 16 E, France.
H. P. Gibbs, Tata Sons Ltd., 24 Bruce Road, Bombay—1, India.
Guido Semenza, 39 Via Monte Napoleone, Milan, Italy.
Eiji Aoyagi, Kyoto Imperial University, Kyoto, Japan.
P. H. Powell, Canterbury College, Christchurch, New Zealand.
Axel F. Enstrom, 24a Grefturegatan, Stockholm, Sweden.
W. Elsdon-Dew, P. O. Box 4563, Johannesburg, Transvaal, Africa.

## A. I. E. E. COMMITTEES

(A list of the personnel of Institute committees may be found in the January issue of the JOURNAL.)

### GENERAL STANDING COMMITTEES AND CHAIRMEN

EXECUTIVE, M. I. Pupin
FINANCE, G. L. Knight
MEETINGS AND PAPERS, E. B. Meyer
PUBLICATION, L. F. Morehouse
COORDINATION OF INSTITUTE ACTIVITIES, Farley Osgood
BOARD OF EXAMINERS, Erich Hausmann
SECTIONS, Harold B. Smith
STUDENT BRANCHES, C. E. Magnusson
MEMBERSHIP, J. L. Woodress
HEADQUARTERS, H. A. Kidder
LAW, W. I. Slichter
PUBLIC POLICY, Gano Dunn
STANDARDS, H. S. Osborne
EDISON MEDAL, Gano Dunn
CODE OF PRINCIPLES OF PROFESSIONAL CONDUCT, John W. Lieb
COLUMBIA UNIVERSITY SCHOLARSHIP, W. I. Slichter
AWARD OF INSTITUTE PRIZES, E. B. Meyer
SAFETY CODES, Paul Spencer

### SPECIAL COMMITTEES

INSTITUTE PRIZES—POLICIES AND PROCEDURE, L. W. W. Morrow
LICENSING OF ENGINEERS, Francis Blossom
TECHNICAL ACTIVITIES, A. G. Pierce

### TECHNICAL COMMITTEES AND CHAIRMEN

COMMUNICATION, H. P. Charlesworth
EDUCATION, Harold Pender
ELECTRICAL MACHINERY, H. M. Hobart
ELECTROCHEMISTRY AND ELECTROMETALLURGY, George W. Vinal
ELECTROPHYSICS, J. H. Morecroft
INSTRUMENTS AND MEASUREMENTS, A. E. Knowlton
APPLICATIONS TO IRON AND STEEL PRODUCTION, F. B. Crosby
PRODUCTION AND APPLICATION OF LIGHT, Preston S. Millar
APPLICATIONS TO MARINE WORK, L. C. Brooks
APPLICATIONS TO MINING WORK, F. L. Stone
GENERAL POWER APPLICATIONS, A. M. MacCutcheon
POWER GENERATION, Vern E. Alden
POWER TRANSMISSION AND DISTRIBUTION, Percy H. Thomas
PROTECTIVE DEVICES, E. C. Stone
RESEARCH, John B. Whitehead

## A. I. E. E. REPRESENTATION

(The Institute is represented on the following bodies; the names of the representatives may be found in the January issue of the JOURNAL.)

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, COUNCIL
AMERICAN BUREAU OF WELDING
AMERICAN COMMITTEE ON ELECTROLYSIS
AMERICAN ENGINEERING COUNCIL
AMERICAN ENGINEERING STANDARDS COMMITTEE
AMERICAN MARINE STANDARDS COMMITTEE
AMERICAN YEAR BOOK, ADVISORY BOARD
APPARATUS MAKERS AND USERS COMMITTEE
BOARD OF TRUSTEES, UNITED ENGINEERING SOCIETY
CHARLES A. COFFIN FELLOWSHIP AND RESEARCH FUND COMMITTEE
COMMITTEE ON ELIMINATION OF FATIGUE, SOCIETY OF INDUSTRIAL ENGINEERS
ENGINEERING FOUNDATION BOARD
JOHN FRITZ MEDAL BOARD OF AWARD
JOINT COMMITTEE ON WELDED RAIL JOINTS
JOINT CONFERENCE COMMITTEE OF FOUR FOUNDER SOCIETIES
LIBRARY BOARD, UNITED ENGINEERING SOCIETY
NATIONAL FIRE PROTECTION ASSOCIATION, ELECTRICAL COMMITTEE
NATIONAL FIRE WASTE COUNCIL
NATIONAL MUSEUM OF ENGINEERING AND INDUSTRY, BOARD OF TRUSTEES
NATIONAL RESEARCH COUNCIL, ENGINEERING DIVISION
NATIONAL SAFETY COUNCIL, ELECTRICAL COMMITTEE OF ENGINEERING SECTION
THE NEWCOMEN SOCIETY
RADIO ADVISORY COMMITTEE, BUREAU OF STANDARDS
SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION, BOARD OF INVESTIGATION AND COORDINATION
U. S. NATIONAL COMMITTEE OF THE INTERNATIONAL ELECTROTECHNICAL COMMISSION
U. S. NATIONAL COMMITTEE OF THE INTERNATIONAL ILLUMINATION COMMISSION
WASHINGTON AWARD, COMMISSION OF

## A. I. E. E. SECTIONS AND BRANCHES

See the January issue for the latest published list. The Institute now has 51 Sections and 86 Branches.

# DIGEST OF CURRENT INDUSTRIAL NEWS

## NEW CATALOGUES AND OTHER PUBLICATIONS

*Mailed to interested readers by issuing companies*

**Electricity on Battle Ships.**—Bulletin GEA-306, 12 pp., entitled "The Electric Fleet." Describes the electrified first line battle ships and airplane carriers in the United States Navy. The General Electric Company, Schenectady, N. Y.

**Machine Vibration Isolation.**—Bulletin, 12 pp., entitled "How to Isolate Machine Vibrations." Describes Korfund treated cork plates used in foundations to absorb vibration of machinery. The Korfund Co., Inc., 11 Waverly Place, New York.

**Motors.**—Bulletin 100, 4 pp. Describes squirrel cage induction motors for general purpose applications, ½ to 50 h. p. Bulletin 101, 4 pp. describes fire pump motors, a-c. open and enclosed types, for the operation of direct connected centrifugal fire pumps. Northwestern Manufacturing Company, Milwaukee, Wis.

**Insulator Flashover Values.**—The Delta-Star Monthly Message (Vol. 2, No. 7) contains an article on standardization giving comparative flashover values on insulators, by M. M. Samuels, which should be of particular interest to designing engineers. The Delta-Star Electric Company, 2400 Block Fulton Street, Chicago, Ill.

**Switching Equipment for Alternating-Current Power Stations.**—Publication 1541-C, 112 pp. This special publication deals with the general fundamentals that should be borne in mind in laying out a switchboard, and describes in detail the various types of switching equipment. It is profusely illustrated with diagrams and halftone illustrations. Westinghouse Electric & Mfg. Company, East Pittsburgh, Pa.

## NOTES OF THE INDUSTRY

**The American Steel & Wire Company,** Chicago, announces the appointment of H. S. Durant as manager of the Cold Rolled Strip and Spring Sales Department, Chicago, vice Lewis Johnson, deceased.

**New Oscillating Fan.**—The Wagner Electric Corporation, of St. Louis, has developed and is placing on the market a new three-speed, ten inch, oscillating fan to retail at a popular price.

**New Plant for Ajax Furnaces.**—The Ajax Electrothermic Corporation, Trenton, N. J., has purchased 25 acres of land on the Reading Railroad where the erection of a new factory has been begun. The company manufactures high-frequency induction furnaces developed by Dr. E. F. Northrup.

**The Belden Manufacturing Company,** Chicago, announces the appointment of Edward A. Sipp as aviation research engineer for the development of special cables for airplane and similar work. The increased demand for special wiring harnesses or cables for airplane applications has made it necessary for the company to organize a separate department to design and manufacture such products.

**Pressed Steel Plate Field Rheostats.**—The Ward Leonard Electric Company, Mount Vernon, N. Y. is now building its vitrohm circular-plate generator and motor field rheostats with pressed-steel instead of cast-iron plates. The new design permits lighter and much stronger plate to be supplied for the same duty. Accessories furnish provision for all desirable combinations of plates with direct, concentric or sprocket drive, floor, wall or ceiling mounting, and for front or rear-of-switchboard mounting.

**New French Allis-Chalmers Organization.**—Allis-Chalmers business in continental Europe will be handled through an organization recently incorporated as Allis-Chalmers (France) with headquarters at 3 rue Taitbout, Paris. H. I. Keen, who has been manager of European sales through the company's district office in Paris, will be the managing director of the new organization. The company has maintained for many years an office in London, 728 Salisbury House, London Wall, E. C. 2.

**Large Street Lighting Contract to Westinghouse.**—The Westinghouse Electric & Manufacturing Company has secured an order for 1500 ornamental lighting units to be installed in the Davis Islands, Tampa-in-the-Bay, Florida, a new real estate development. Westinghouse Hollowspun concrete standards will be used. More than 300,000 feet of cable will be required, which will be laid at a depth of twelve inches along the curbway and put down at the same time as the pavement to facilitate construction.

**Supplementary Compensation to G. E. Employees.**—The sum of $1,367,426 07 was paid in February by the General Electric Company to employees who have been with the company for five years or more. These payments, termed supplementary compensation, represent 5 per cent of each individual's earnings for the six months ending December 31,1925. Payments were made in General Electric Employes' Securities Bonds or cash, as desired. About one-third of the total amount was distributed in the Schenectady works.

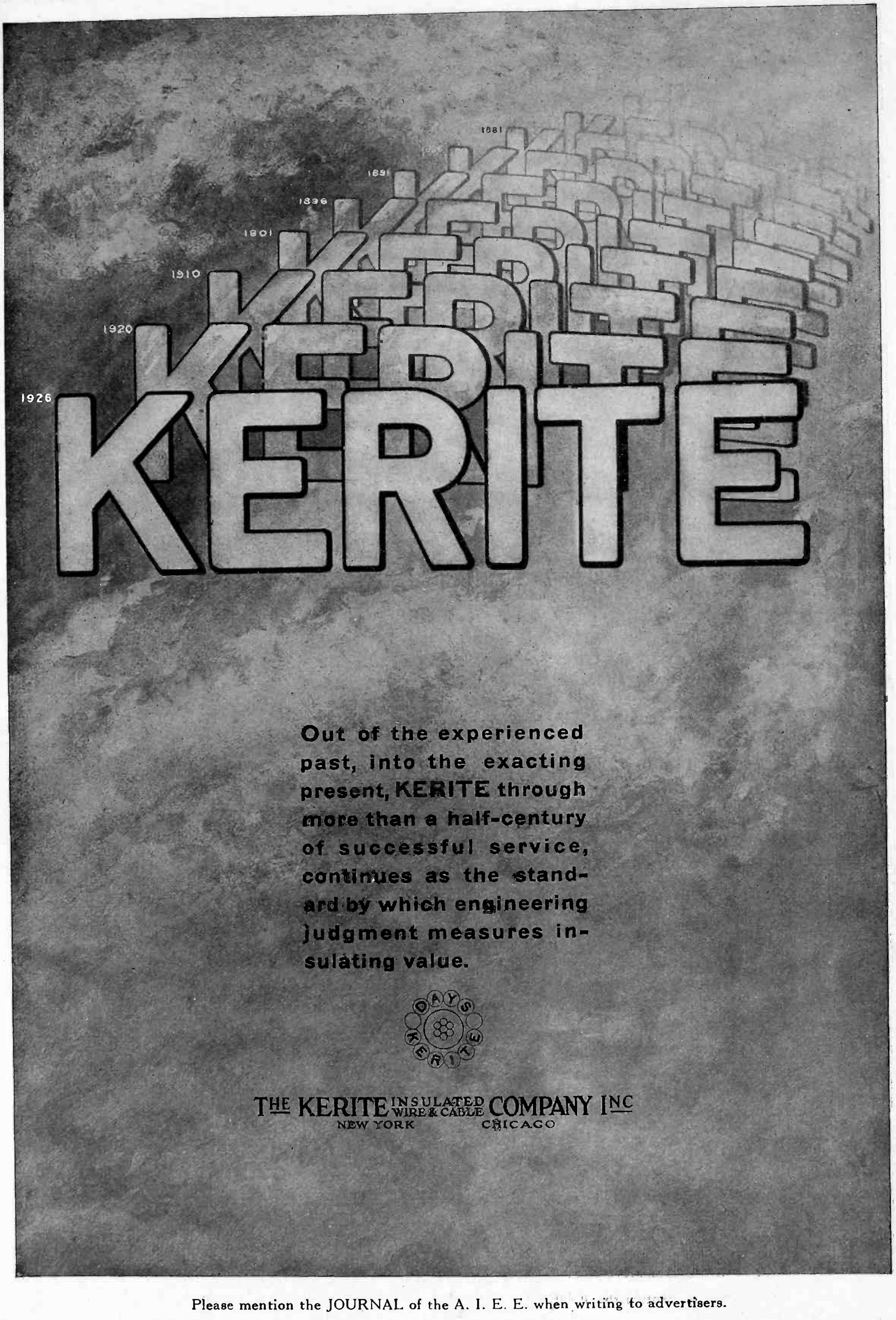
**Promotions in Hazard Mfg. Company.**—The Hazard Manufacturing Company, Wilkes-Barre, Pa., manufacturers of wire rope and electrical cables, announces the appointment of Laurence W. Bevan as general manager. Mr. Bevan entered the employ of the company thirteen years ago as metallurgical engineer. William S. Hart has been appointed special representative in charge of Hazard sales in the oils field of the United States with headquarters in Wilkes Barre. He has been in the employ of the company since 1888. Thomas A. Keefe was appointed district manager of the Chicago branch. Mr. Keefe came to the company in 1913 as a salesman.

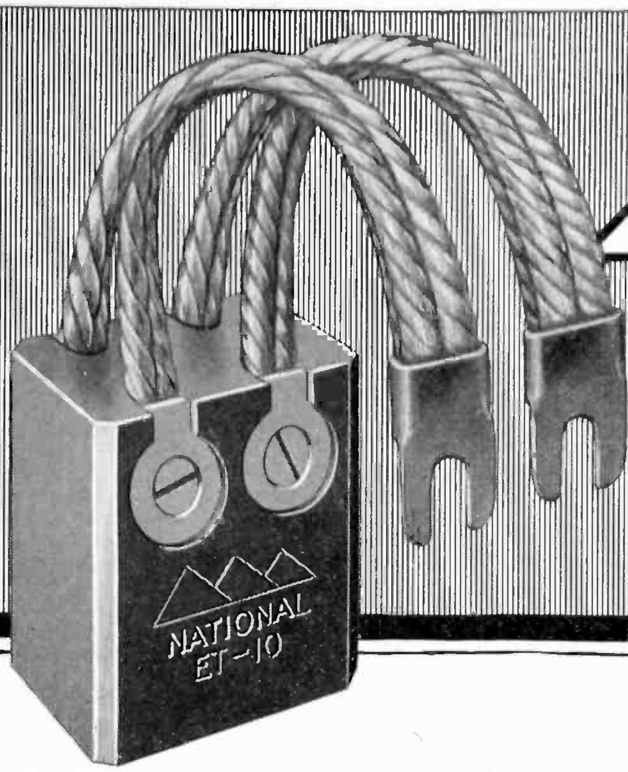
**Ohio Brass Company Develops New Iron.**—The Ohio Brass Company, Mansfield, Ohio, has developed a new metal which it calls "Flecto" iron. This is a type of malleable iron which by virtue of a heat treating process, is freed from all tendency toward embrittlement when hot-dip galvanized. While retaining all of the desirable characteristics of malleable iron, the Flecto process so improves the metal with added valuable properties that it is considered to be practically a new metal. The announcement is made only now, but it is understood that all malleable iron castings produced by this manufacturer during the past two years have been treated by this process, the company having withheld announcement until the metallurgy of this new metal had been thoroughly proved by its use in the field.

The process for making Flecto iron is patented, but is available to other manufacturers under a liberal license arrangement.

**Century Electric Expands.** The Century Electric Company, St. Louis, Mo., has purchased an eight acre factory site located on a branch of the Wabash R. R. at Spring Avenue, on which it will erect buildings for manufacturing and warehousing. The present factories will be retained. The growth of the Century Electric Company, one of the pioneers in single-phase motor development, has been remarkable. Starting in 1903 in a small building at 1011 Locust Street, the company's factories, of modern construction, now occupy more than eleven acres of floor space, giving employment to over 3,000. The founders of the company are still actively directing all phases of the business. The officers include: E. S. Pillsbury, Prest.; S. M. Jones, and E. W. Collins, Vice-Prests.; R. J. Russell, Vice-Prest. and Secy.; B. M. Whittemore, Treas. and J. L. Woodress, Sales Manager.

The Company has arranged to distribute as a bonus from 1925 earnings, $190,000.00 in the common stock of the company at $120 per share to those of its 3,000 employees who have been connected with the company during the entire year of 1925, and who are still with the company on March 15, 1926. This means that each of those who are entitled to participate will receive at least 7 per cent of his salary or earnings.


1881
1891
1896
1901
1910
1920
1926
KERITE
Out of the experienced past, into the exacting present, KERITE through more than a half-century of successful service, continues as the standard by which engineering judgment measures insulating value.
THE KERITE INSULATED WIRE & CABLE COMPANY INC
NEW YORK CHICAGO




*Where heavy starting torque or speed control is necessary, consider the advantages of commutator type motors.*

# National ET-10

## *"Made in the U. S. A."*

AFTER many months of experimental manufacturing under the Ringsdorff formulæ, the world-famous Ringsdorff ET-10 Brush for rotary converters is now produced in America, in our factory at Cleveland, Ohio. It will be known as the "National ET-10."

Hans Ringsdorff himself set the seal of approval on the National ET-10 during a recent visit to this country, and subsequently in his laboratory at Mehlem, from which he writes: "As I told you when I was over there . . . the American-made ET-10 is apparently just as good as the material made by us in Mehlem. This impression was fully confirmed by the experiments which we made on your material which I brought back with me, and I congratulate you on being able to control this relatively difficult manufacturing problem in such a short time."

# National
## Pyramid Brushes

*Manufactured and guaranteed by*

NATIONAL CARBON COMPANY, INC

*Carbon Sales Division*

Cleveland, Ohio San Francisco, Cal.

Canadian National Carbon Co., Limited, Toronto, Ontario

*Emergency Service Plants*

CHICAGO, ILL.
551 West Monroe St.
*Phone:* State 6092

PITTSBURGH, PA.
Arrott Power Bldg. No. 3
Barker Place
*Phone:* Atlantic 3570

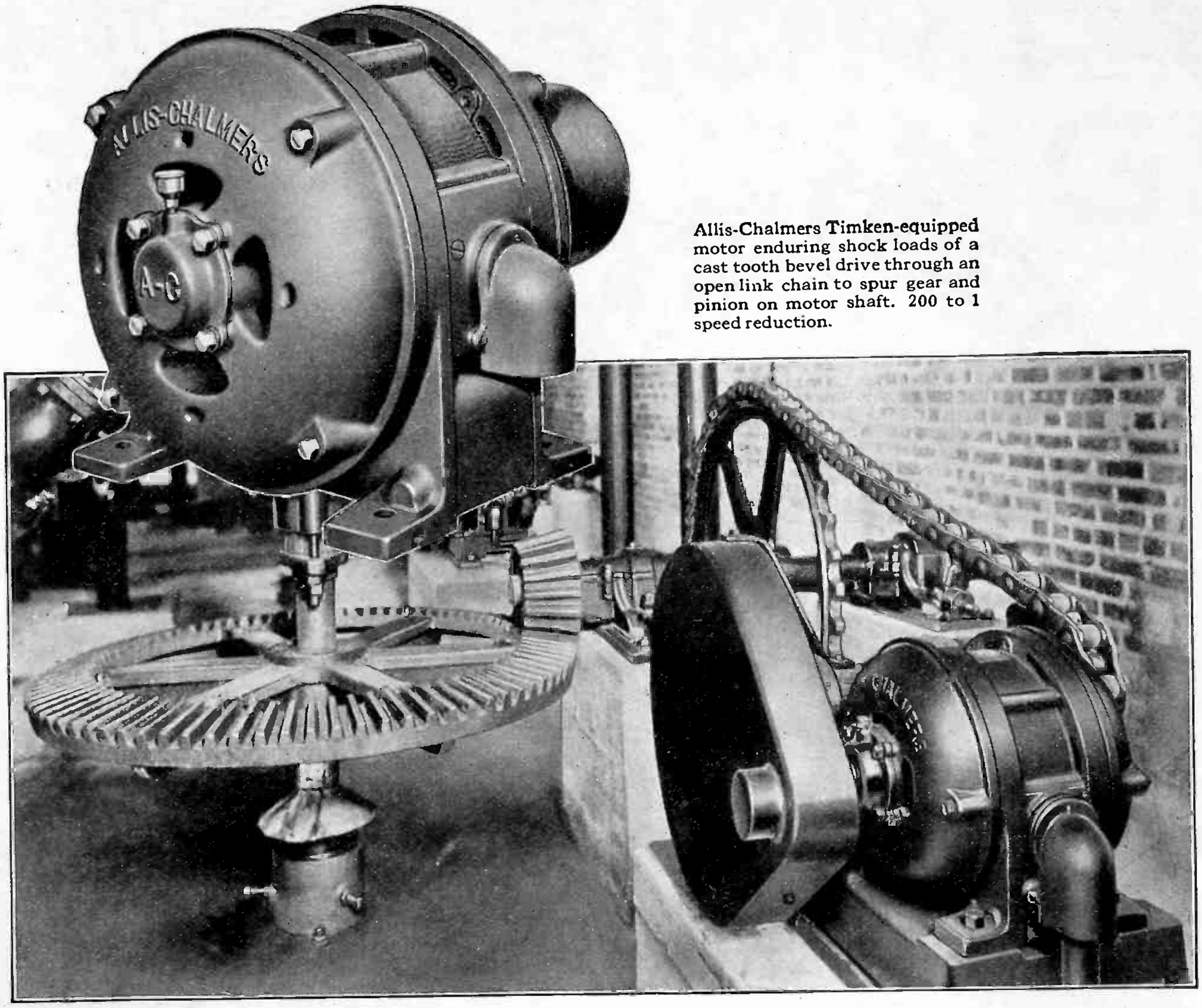
NEW YORK, N. Y.
357 West 36th St.
*Phone:* Lackawanna 8153

# Timken-Equipped by Allis-Chalmers

Timken-equipped electric motors need *never* have as much bearing clearance as ordinary motors to *start* with! And bearing clearance means that the bearing, the rotor, or both, are off-center—depending upon the age of the motor. Maintaining the gap precisely, needing lubrication only months apart at most, permitting greater compactness and rigidity, and improving starting and running conditions, Timken Bearings in Allis-Chalmers motors are one of the great betterments in applying electricity.

THE TIMKEN ROLLER BEARING CO.
CANTON, OHIO

**TIMKEN** *Tapered Roller* **BEARINGS**




Allis-Chalmers Timken-equipped motor enduring shock loads of a cast tooth bevel drive through an open link chain to spur gear and pinion on motor shaft. 200 to 1 speed reduction.

# Working for Less

In every great industry, at every brutal task, Allis-Chalmers electric motors have for years given the very best account of themselves. Unusual power, endurance and all-around economy are to be expected of the many unusual and exclusive Allis-Chalmers practices.

Allis-Chalmers frames, spiders and other parts, wherever possible, are of cast steel in preference to lesser metals. The laminated core construction is a scientific achievement. Windings are insulated and baked by special Allis-Chalmers processes unequaled for thoroughness. The uniformity of cooling is itself a tribute to Allis-Chalmers engineering. Lubrication is most highly developed.

Now Allis-Chalmers betterments also include Timken Tapered Roller Bearings on the shaft. Rigidity, compactness, endurance, economy are multiplied. Here are motors that run for months at least without added lubrication—motors that run for life without bearing deterioration.

In its line of induction motors with anti-friction bearings, as in all other types, Allis-Chalmers offers electric motors best able to pay for themselves.

ALLIS-CHALMERS MANUFACTURING CO., MILWAUKEE

*District Sales Offices in all Principal Cities*

# ALLIS-CHALMERS MOTORS

WARD LEONARD RIBOHM

# Ribohm Resistors

## make use of cast grids unnecessary

WARD LEONARD Ribohm units, designed especially for heavy currents, occupy much less space, and weigh only a fraction of equivalent cast-iron grid assemblies. Ribohm units are rustproof and practically unbreakable. Even after years of service the resistance value of a Ribohm unit is the same as when it is new.

These units are rigid and self-supporting even at a red heat. The high ratio of surface to mass gives them great heat dissipating capacity, either singly or in groups.

Ribohm Rheostats are made for a great variety of services such as battery charging, generator field control, motor control, motor starting, search-light regulation, and electro-plating.

Bring us your resistance problems.

**Ward Leonard Electric Company**

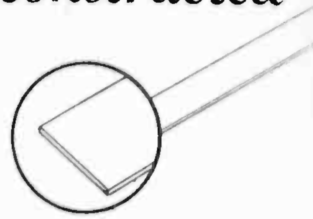
Mount Vernon, New York

37-41 South Street Mount Vernon, N. Y.

2523-2

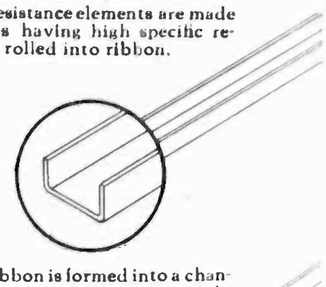
## How Ribohm Rheostats are constructed

1



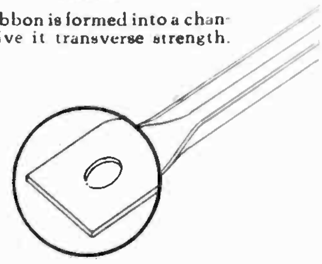
The resistance elements are made of alloys having high specific resistance rolled into ribbon.

2



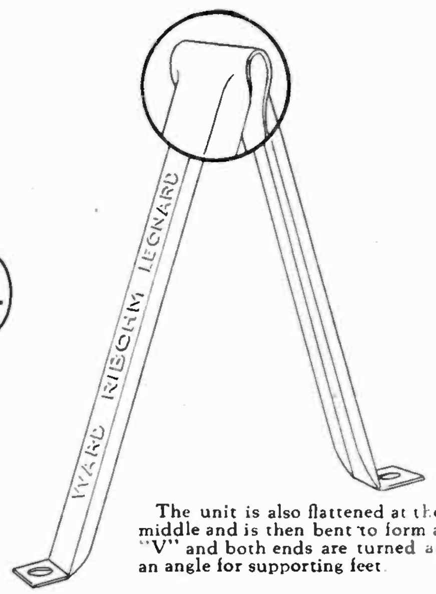
The ribbon is formed into a channel to give it transverse strength.

3



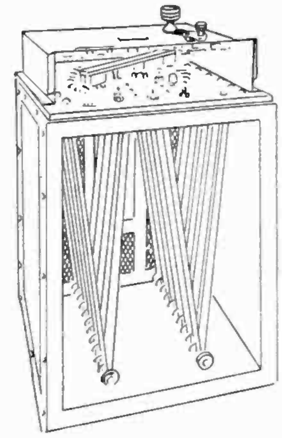
It is then flattened at both ends to provide terminals and supports, as shown.

4

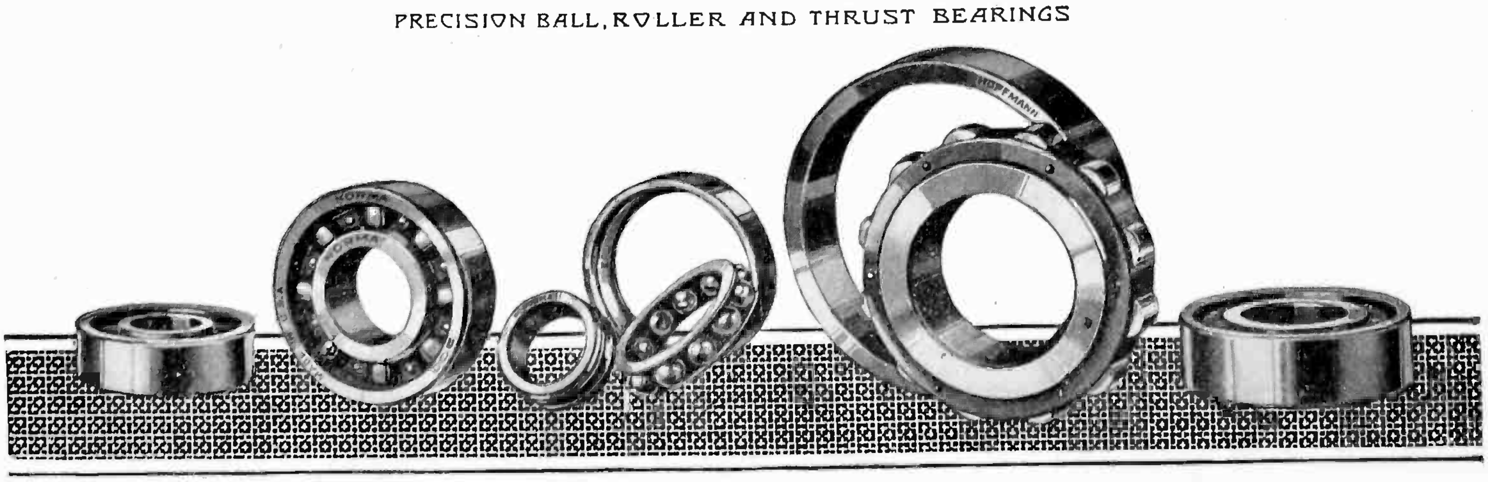



The unit is also flattened at the middle and is then bent to form a "V" and both ends are turned at an angle for supporting feet.

5



This 20-step Ribohm Field Rheostat, rated at 9000 watts continuous duty, occupying 19½ by 18½ by 26¼ inches of space and weighing only 81 pounds, attests to the fact that Ribohm Units have the largest watt capacity for a given weight and volume of any resistance element ever devised.

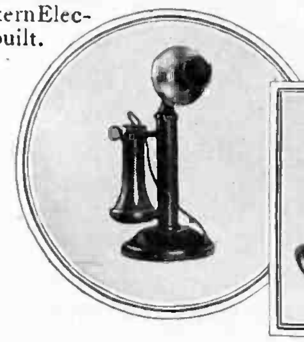


NORMA
NORMA
HOFFMANN

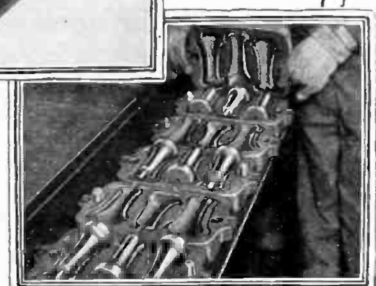
# "THE HOUSE THAT JACK BUILT"

## — *and your telephone*

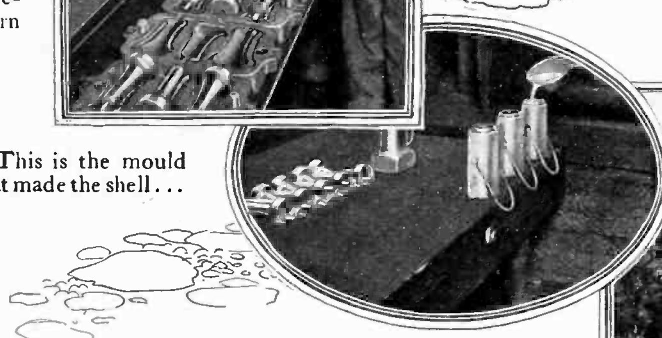
This is the telephone that Western Electric built.



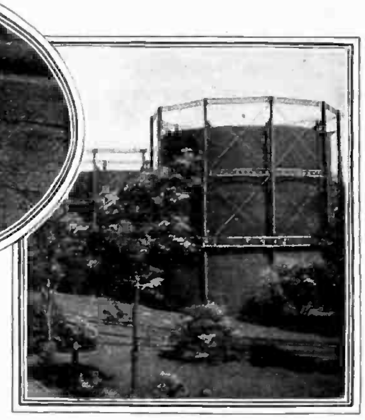
This is the shell that inclosed the receiver on the telephone that Western Electric built.



This is the mould that made the shell . . .



This is the lead that formed the mould. . . .



This is the plant that made the gas that heated the lead that formed the mould that made the shell that inclosed the receiver on the telephone that Western Electric built.

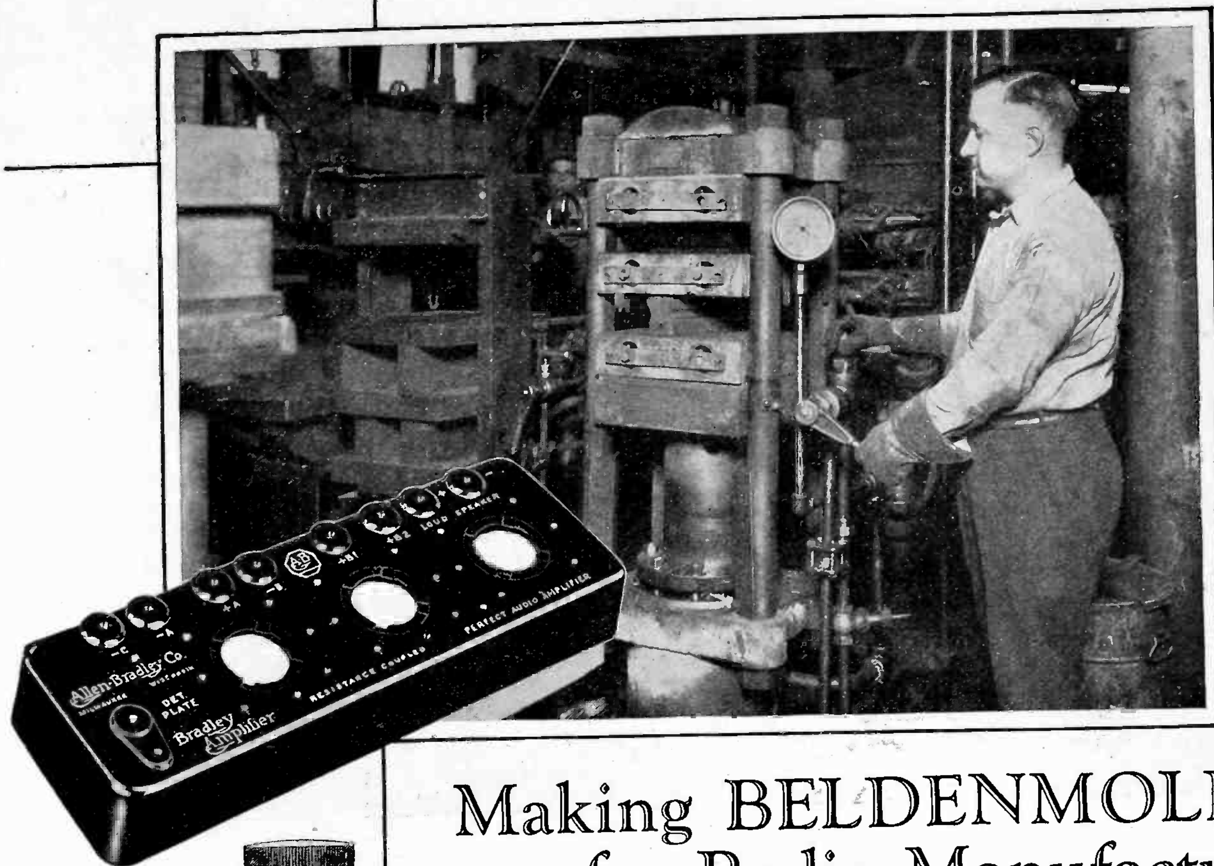
YOU recall the chain of events in the House that Jack Built—one thing leading to another? When it comes to the Telephone that Western Electric Built you find the same sort of chain.

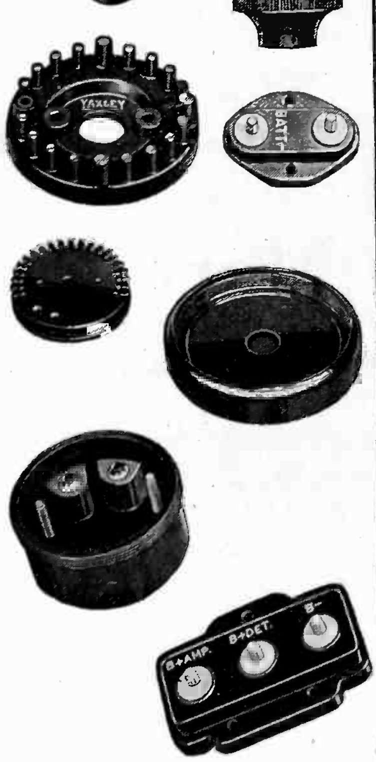
At Western Electric skilled artisans carry the work of making the Bell telephone on through all its stages. Industries within an industry have been developed here—not only a factory for producing the many types of telephone equipment, but also a tool factory, a rubber mill, a cable shop, a wire-drawing plant and many others.

For all the world it is like a fairy tale come true. But on how vast a scale—the fact greater than the fancy.

# Western Electric

SINCE 1882 MANUFACTURERS FOR THE BELL SYSTEM




# Making BELDENMOLD Pieces for Radio Manufacturers

*Prompt Belden Service is Assured on*
BAKELITE MOLDED PARTS

ARE you making a radio set, a loud speaker, a B-eliminator, or any other radio part or accessory?

If so, you probably can improve your product and save time and money in your assembling department by using Beldenmold parts wherever a molded piece is usable.

You will have less service complaints and more compliments about the better appearance of your unit if Beldenmold parts are used.

RADIO manufacturers are using more Beldenmold pieces every year, and Belden molding facilities are keeping pace with the growing demand.

Just submit your drawing or finished product to us.

We can often show you how to produce a better product and still save money with Beldenmold parts. Our suggestions will cost you nothing—and they may save you time, trouble and money.

***Send for Beldenmold Booklet***

USE THE COUPON

Specify Belden

**Belden Manufacturing Company**
**2316B So. Western Ave., Chicago**

Please send us your booklet on Beldenmold pieces and How to Design Molded Parts.

Name....................................

Address..................................

.........................................

*Furniture Mart, Chicago, Served by Kuhlman Transformers*

# Kuhlman Transformers Were Chosen for the Lighting of the American Furniture Mart

This building is said to be the largest of its kind in the world. It contains approximately 1,500,000 square feet of floor space, about 32 acres.

On the day of its opening it was 80 per cent occupied.

It is significant that Kuhlman Transformers were chosen to service the magnificent lighting effects that are found in the FURNITURE MART.

**KUHLMAN ELECTRIC COMPANY**

*Manufacturers of Power, Distribution and Street Lighting Transformers*

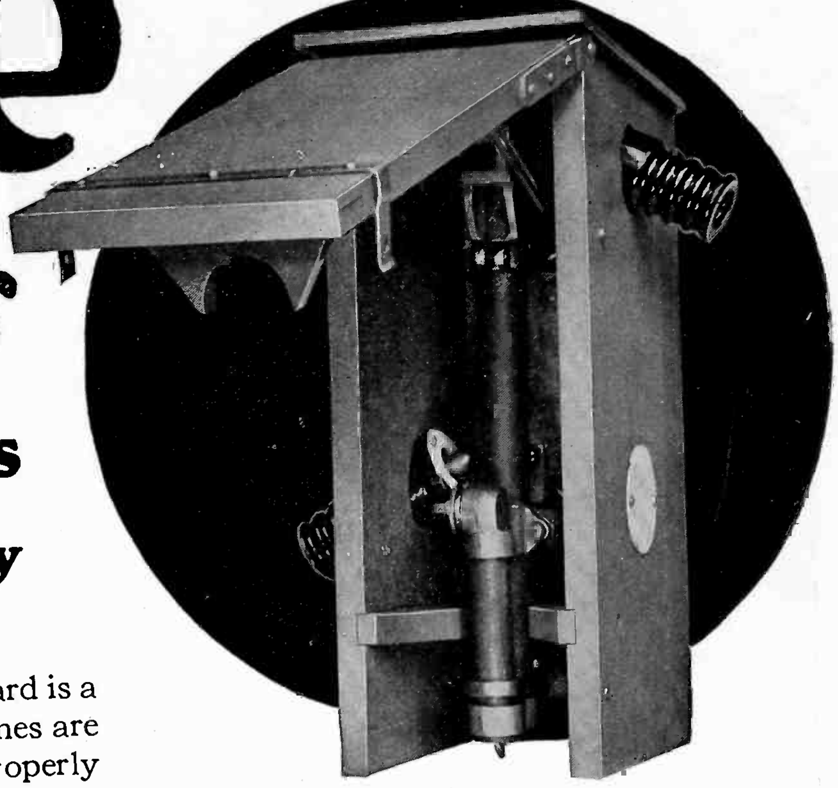
BAY CITY, MICHIGAN

# KUHLMAN TRANSFORMERS

# Safe always

## —and in all ways

### To Men...To Property



ELIMINATING the danger hazard is a big factor to you. Matthews Fuswitches are the safest fuswitches. When they are properly fused it is impossible to burn them up and their rupturing capacity is immense. They protect against "out-of-service". Safest and easiest to refuse or inspect—just lift the hinged door, and the whole contents of the box is revealed and accessible.

## Vital Facts

The records of dependable service that Matthews Fuswitches are continually hanging up are easily explained when you consider the design and the materials from which Matthews Fuswitches are made ‹ ‹ ‹ Box of Tide Water Cypress, "the wood eternal" ‹ ‹ ‹ Boiled in linseed oil and coated with high di-electric paint ‹ ‹ ‹ Wet process porcelain bushings and mountings throughout ‹ ‹ ‹ Higher flash-over value ‹ ‹ ‹ Greater rupturing capacity.

W. N. MATTHEWS CORPORATION
3706 Forest Park Blvd. ‹ ‹ St. Louis, Mo.

# MATTHEWS FUSWITCHES
## and DISCONNECTING SWITCHES

*Matthews Fuswitches can be furnished in the following ratings*

CLOSED TYPES

| | | |
|---|---|---|
| Type OK | 100 amp. or less | 7500 volts or less |
| Type HQ | 200 amp. or less | 7500 volts or less |

OPEN TYPE

100 amperes or less 15000 volts or less

*Matthews Disconnecting Switches*

CLOSED TYPES

| | | |
|---|---|---|
| Type OK | 125 amp. or less | 7500 volts or less |
| Type HQ | 250 amp. or less | 7500 volts or less |

OPEN TYPE

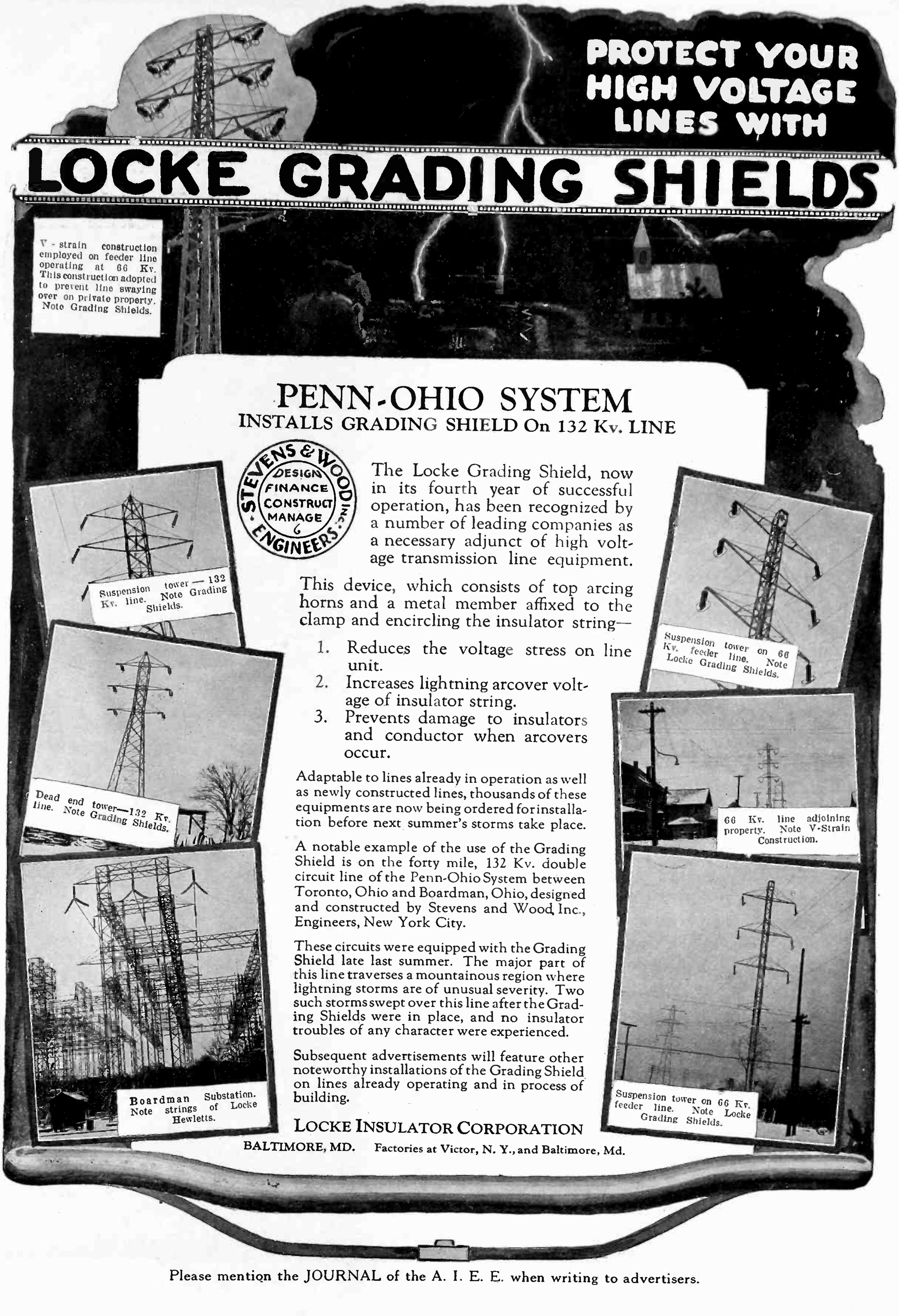
125 amperes or less 15000 volts or less

### Ask about these

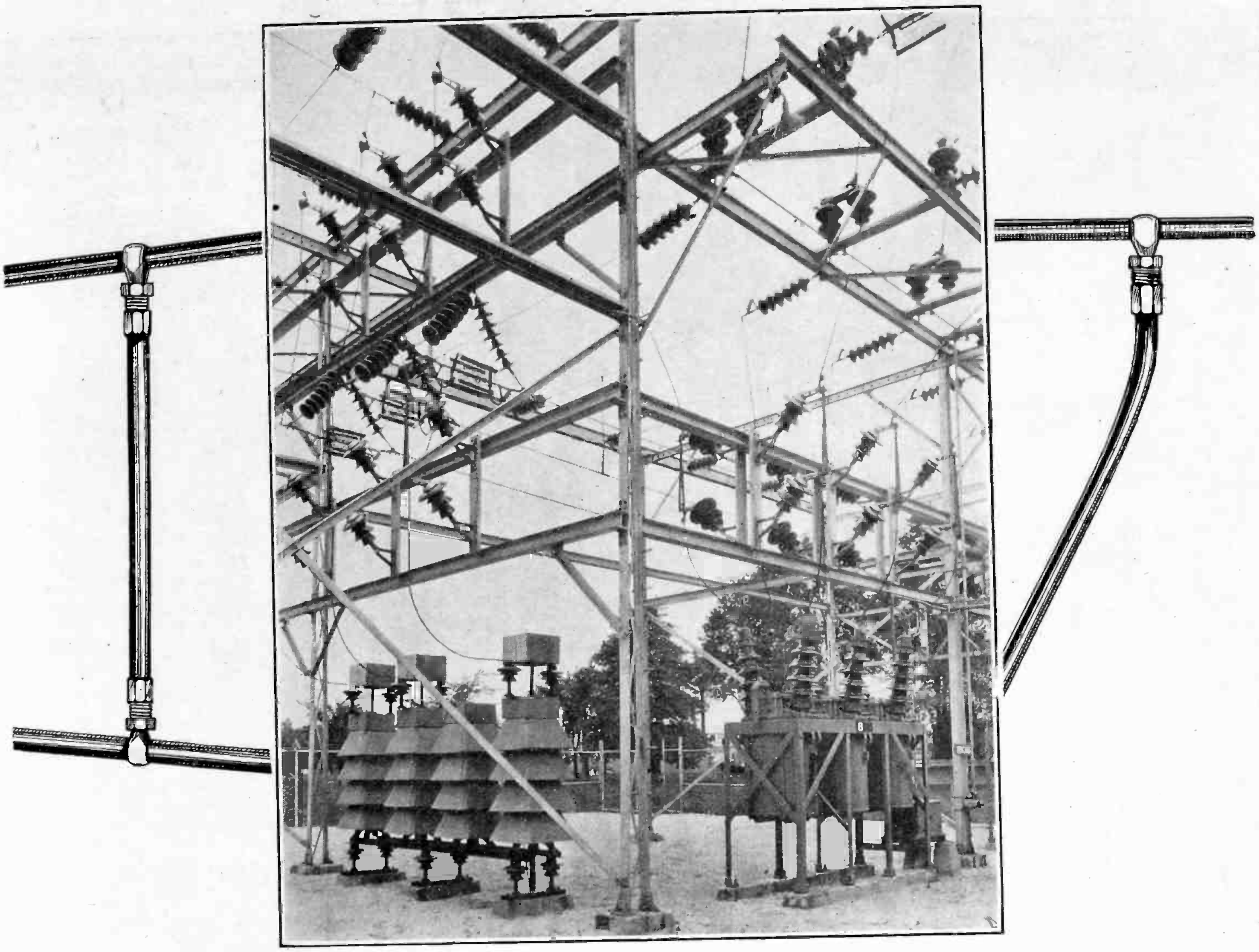
Matthews Fuswitches
Matthews Disconnecting Switches
Matthews Scrulix Anchors
Matthews Adjustable Reel
Matthews Guy Clamps
Matthews Slack Puller
Matthews Cable Clamps
Matthews Lamp Guards
Matthews Telefault
Matthews Teleheight

*Distributors in all Principal Cities*


Since 1899


PROTECT YOUR HIGH VOLTAGE LINES WITH
LOCKE GRADING SHIELDS
V-strain construction employed on feeder line operating at 66 Kv. This construction adopted to prevent line swaying over on private property. Note Grading Shields.
PENN-OHIO SYSTEM
INSTALLS GRADING SHIELD On 132 Kv. LINE
STEVENS & WOOD INC. DESIGN FINANCE CONSTRUCT MANAGE ENGINEERS
The Locke Grading Shield, now in its fourth year of successful operation, has been recognized by a number of leading companies as a necessary adjunct of high voltage transmission line equipment.
This device, which consists of top arcing horns and a metal member affixed to the clamp and encircling the insulator string—
1. Reduces the voltage stress on line unit.
2. Increases lightning arcover voltage of insulator string.
3. Prevents damage to insulators and conductor when arcovers occur.
Adaptable to lines already in operation as well as newly constructed lines, thousands of these equipments are now being ordered for installation before next summer's storms take place.
A notable example of the use of the Grading Shield is on the forty mile, 132 Kv. double circuit line of the Penn-Ohio System between Toronto, Ohio and Boardman, Ohio, designed and constructed by Stevens and Wood, Inc., Engineers, New York City.
These circuits were equipped with the Grading Shield late last summer. The major part of this line traverses a mountainous region where lightning storms are of unusual severity. Two such storms swept over this line after the Grading Shields were in place, and no insulator troubles of any character were experienced.
Subsequent advertisements will feature other noteworthy installations of the Grading Shield on lines already operating and in process of building.
Suspension tower — 132 Kv. line. Note Grading Shields.
Dead end tower—132 Kv. line. Note Grading Shields.
Boardman Substation. Note strings of Locke Hewletts.
Suspension tower on 66 Kv. feeder line. Note Locke Grading Shields.
66 Kv. line adjoining property. Note V-Strain Construction.
Suspension tower on 66 Kv. feeder line. Note Locke Grading Shields.
LOCKE INSULATOR CORPORATION
BALTIMORE, MD. Factories at Victor, N. Y., and Baltimore, Md.

# *Note the Dosserts*



## 33,000 Volt Automatic Sub-Station of the Toledo Edison Company

Dosserts are of course the standardized method of connections in the power plants and substations of central stations and electric railways.

The Toledo Edison Company uses Dosserts also on its 23,000 and 66,000 volt outdoor substations.

There are more than a thousand types, sizes and combinations shown in the Dossert 20th year book.

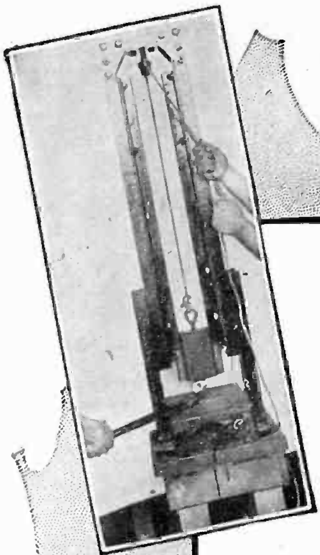
*Write for copy.*

DOSSERT & CO. H. B. Logan, Pres. 242 West 41st St., New York

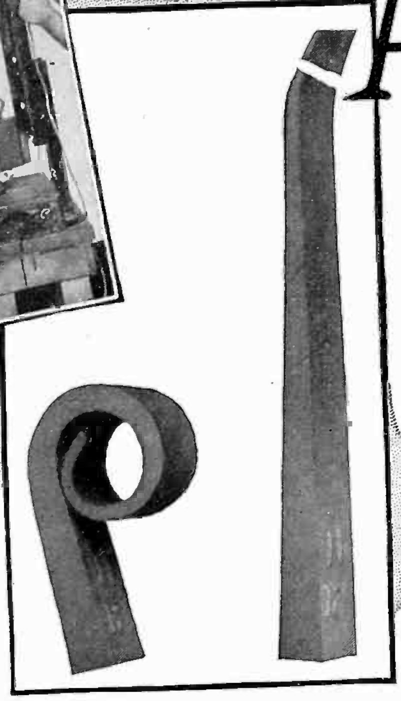
# DOSSERT

## SOLDERLESS CONNECTIONS

# A New Malleable O-B FLECTO IRON



Weight Drop Machine for Testing Malleable Iron.



## *Insurance against breakage of Hot-dip Galvanized Malleable Fittings*

HERE ARE TWO identical test pieces of Hot-dip Galvanized Malleable Cast Iron. Both were made from the same raw materials, in the same furnace, and under the same working conditions.

What is the difference?

Simply this.

The test piece on the left is galvanized O-B FLECTO IRON. It bends. It is ductile. It will not break in service. It is your insurance against broken or brittle malleable fittings.

The other is just regular good hot-dip galvanized malleable iron. Frequently it is brittle.

**O-B Flecto Iron**

is the material of which the following O-B products have been made for the past two years.

Catenary Hangers
Mine Trolley Harps
Pole Brackets
Pole Hardware, Miscellaneous
Suspension Insulator Caps
Suspension Strain Clamps
Suspension Wire Clamps
Trolley Bases
Trolley Catchers
Trolley Retrievers
Trolley Clamps
Trolley Cross-overs
Trolley Frogs
Trolley Hangers
Trolley Pull-overs
Wood Strain Insulators

Hot-dip Galvanizing of malleable iron has a tendency to cause it to become embrittled. Experience has shown that an average of 20%, or 1 out of every 5 ordinary malleable castings are brittle after galvanizing. Out of the same heat, after hot-dip galvanizing, part of the castings will be brittle—while the remainder will retain their malleable properties.

Many attempts have been made to dodge the real problem by the use of substitute methods of rust-proofing. Yet the fact remains that no commercial protective coating, yet invented, is quite as good as hot-dip galvanizing.

Through long research, the Ohio Brass Company has developed a special heat treatment that causes the iron to retain its ductility after galvanizing. It actually makes brittle iron good and good iron better. It eliminates the faulty 20%. This special process raises the shock resisting qualities to the maximum and makes this maximum permanent. The product of this new patented process has been named "Flecto Iron".

Really, O-B Flecto Iron is not new. For the past two years all O-B Malleable Castings have been made of Flecto Iron. And through the most severe test—the test of service—this iron has proved its worth. Now, with the product thoroughly proved, the process is announced.

**Ohio Brass Company, Mansfield, O.**
Dominion Insulator & Mfg. Co., Limited
Niagara Falls, Canada

9

# Ohio Brass Co.

PORCELAIN INSULATORS LINE MATERIALS RAIL BONDS CAR EQUIPMENT MINING MATERIALS VALVES

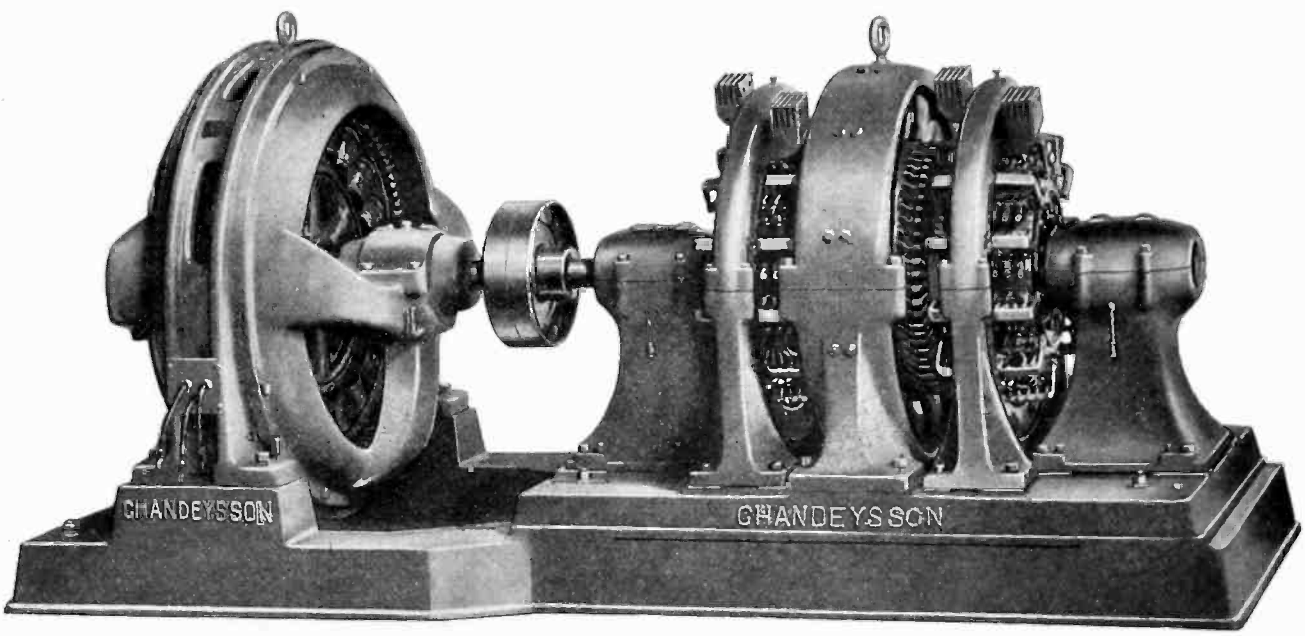
# Chandeysson

## Generators

25 to 25,000 Amperes

Direct Connected to

## Motors




G-E MOTOR 60 H. P. 3 PHASE 60 CYCLE, 440 VOLT. GENERATOR, 6000/3000 AMP. 6/12 VOLTS, 360 R. P. M.

ONE OF 4 UNITS

OPERATING AT THE BRIDGEPORT WORKS OF THE

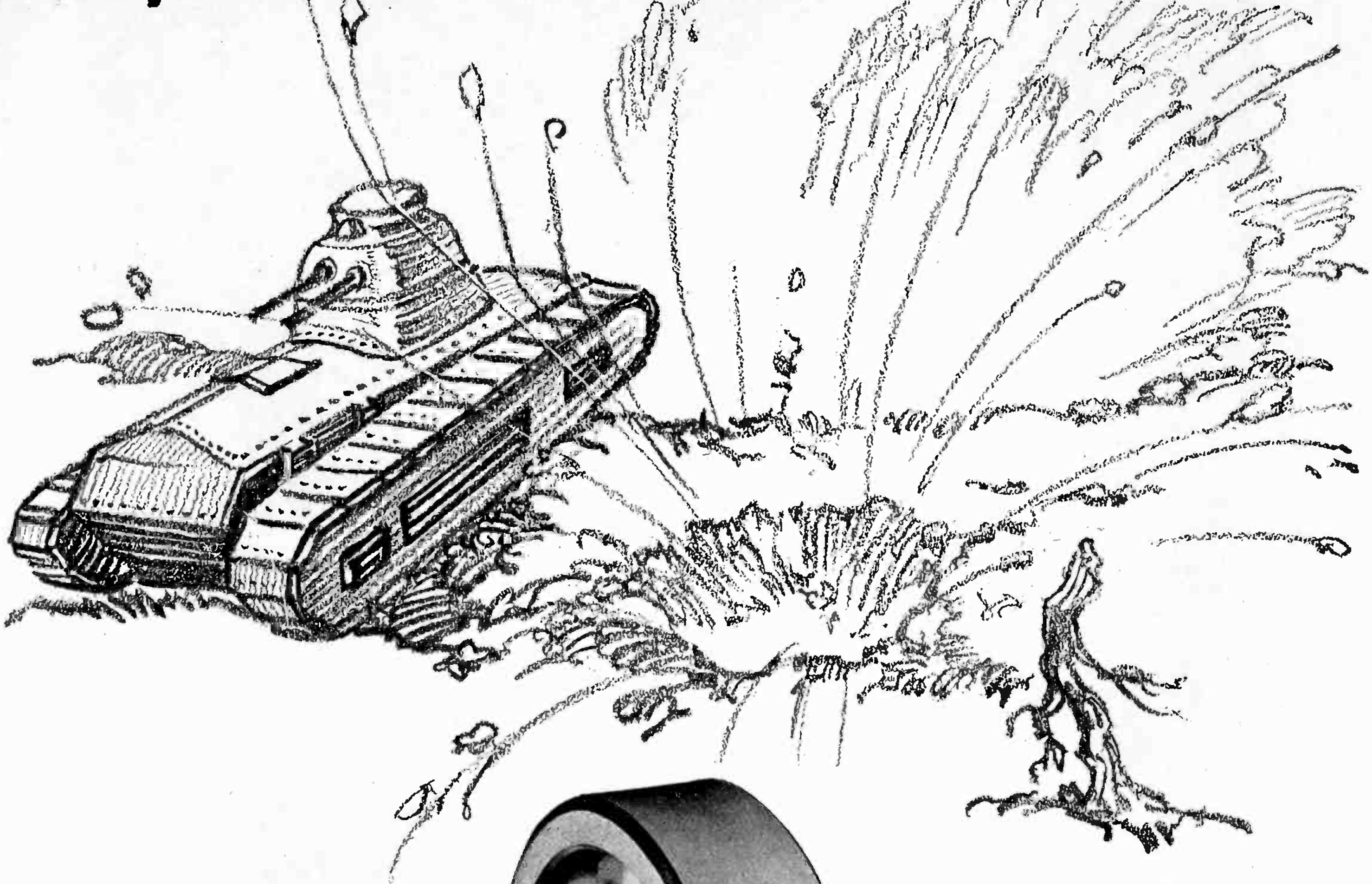
GENERAL ELECTRIC COMPANY

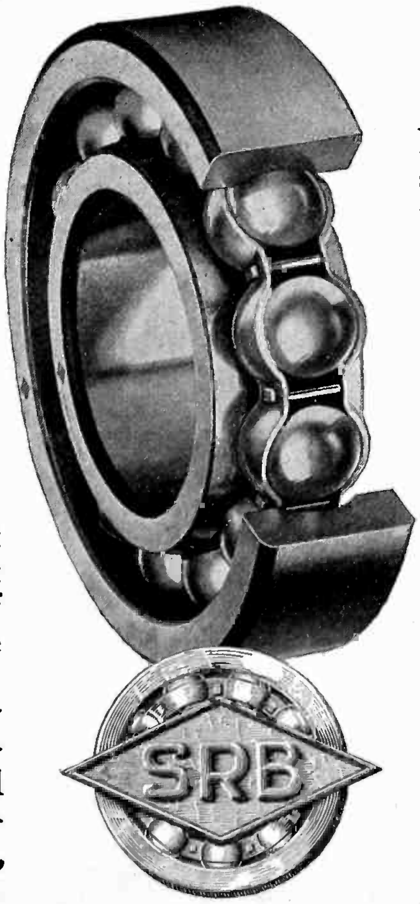
INSTALLED 1923

---

**CHANDEYSSON ELECTRIC CO.,** ST. LOUIS, U. S. A.

# Mo-lyb-den-um Steel had to stand this!






IT was a baptism of fire that gave birth to this tougher, harder steel. Something had to be found to resist the tearing bite of shrapnel—something harder than the steel then being rolled.

Out in Colorado was found an unlimited supply of the element Molybdenum which engineers had proved would increase the strength and toughness of armour plate. They set it to work in the war because it produced a tough, shock-proof steel and was available in large quantities.

SRB Bearings are constantly waging a silent war against friction. If Molybdenum Steel proved a better war-time steel—why wouldn't it make tougher, more durable ball bearings?

Five years ago, SRB engineers started laboratory and service tests which resulted last July in the announcement of the adoption of forged Molybdenum Steel Balls for SRB Bearings. This gave Industry a ball bearing which has greater toughness —greater resistance to wear—greater load carrying capacities —and greater endurance than was ever before possible with any other steel.

With Molybdenum Steel, SRB has thus won an industrial war against the stresses, shocks, and friction attacks of ball bearing service.

*Write for information and specify SRB Annular Ball Bearings equipped with forged Molybdenum Steel Balls for greater load carrying capacity and durability.*

**STANDARD STEEL AND BEARINGS INCORPORATED**

PLAINVILLE — CONNECTICUT

USE SRB BALL BEARINGS-*First!* — *they'll last*

# instruments

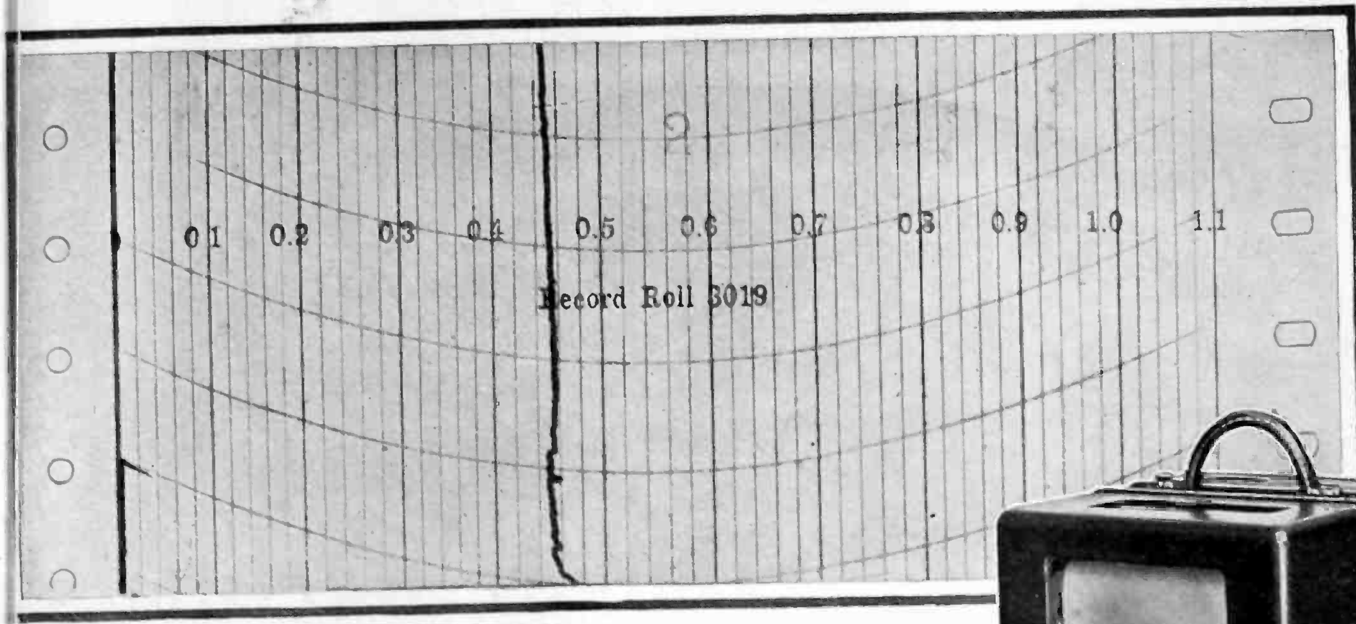



*Chart actual size*

*Type CP-4 5-amp. 110/220/550 self-contained Polyphase Wattmeter.*

# CP-4 & CP-5 Recording Instruments

*Recording instruments for alternating-current work —ammeters, voltmeters, single-phase and polyphase wattmeters, power factor meters and frequency meters.*

### *Applications*

These instruments make a record of electrical measurements —such as the power used or distributed for a certain period—to be used as a basis for improving plant machinery, methods, power conditions, etc.

### *Range*

The instruments are self-contained up to 20 amp., potentials of 110, 220, and 550 volts. Chart speeds are 1 in., 3 in., 6 in., or 12 in. per hour, and all instruments are equipped for changing from inches per hour to inches per minute, or vice versa.

### *Superior Features*

High torque.
Mercury damping unaffected by temperature and sufficient for rapidly fluctuating loads.
Very substantial construction but light in weight.
Shielded from stray fields.
Reroll of simple construction.
Triple voltage capacity.
Four chart speeds and facilities for quickly changing speed.
Low losses in both potential and current circuits.

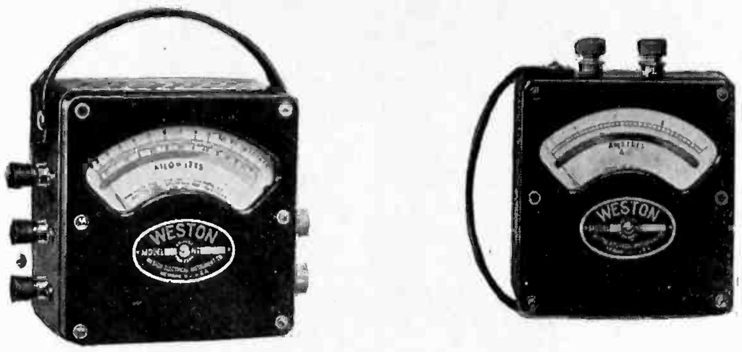
Portable curve-drawing instruments have a wide range of possible applications and can be used to advantage in the solution of many specific problems, always pointing the way to the introduction of needed economies. General Electric meter specialists can cite many of these instances to suggest how you can profit from practical testing.

35A-1

# ELECTRIC

SALES OFFICES IN ALL PRINCIPAL CITIES

# *The Work of the* WESTON *Juniors*




DISCOVERING power losses, preventing shut-downs, maintaining electrical equipment under all conditions . . . these are the functions of Weston instruments. Wherever economy is a factor, engineers can depend upon them for accurate and satisfactory service.

Weston Juniors are made as Ammeters (Single and Double Range) Voltmeters and Single Phase Wattmeters.

They are compact, light in weight, contained in strong Bakelite cases, and will render a life-time of accurate, dependable service.

*For further information address*

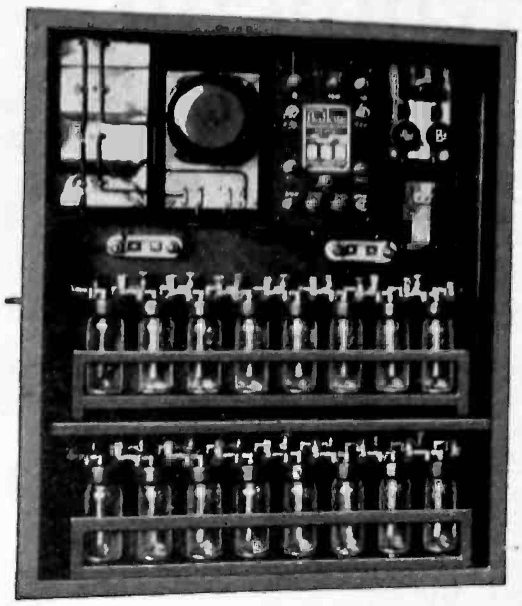
WESTON ELECTRICAL INSTRUMENT CORPORATION

48 Weston Avenue, Newark, N. J.

STANDARD THE WORLD OVER

**WESTON**

*Pioneers since 1888*



# Balkite Rectifiers for Railway Telephone Service

Telephone selectors are used in railway train dispatching and other circuits for the purpose of selecting and calling the station desired. Such selectors are usually operated by direct current at up to 400 volts and one-quarter ampere.

The Balkite telephone selector power unit pictured above supplies the required power from an alternating current source such as is commonly available. The output is filtered in order that no undesirable hum will result in the telephone circuit.

Similar units are made for other applications requiring direct currents of like magnitude. Examples are: telegraph line current, current for magnetic devices, and plate current for public address systems.

Detailed information regarding any specific application will be gladly sent.

FANSTEEL

**Balkite Rectifiers**

FANSTEEL PRODUCTS COMPANY, INC.
NORTH CHICAGO, ILL.

FANSTEEL PRODUCTS COMPANY, Inc., *North Chicago, Illinois*

Gentlemen: Please send me information on uses of the Balkite Rectifiers in the type of work checked below.

- ☐ Substation Control
- ☐ Time Recording Systems
- ☐ Burglar Alarm Systems
- ☐ Fire Alarm Systems
- ☐ Emergency Lighting
- ☐ Communication Systems
- ☐ Signaling Systems
- ☐ Power Plant Control
- ☐ Instrument Operation

Name__________

Company__________

Address__________

__________

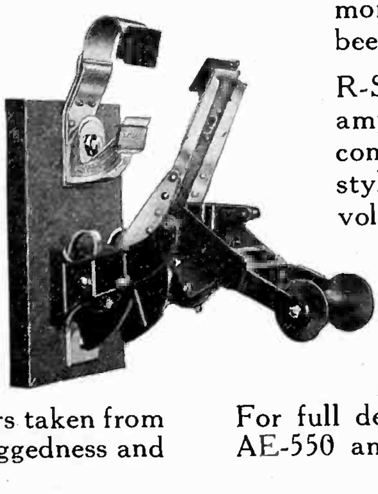
Position__________

Lighting the "Olympian" of the Chicago, Milwaukee & St. Paul Railway

# Unshakable Dependability of ROLLER-SMITH Circuit Breakers

Approximately 80% of the baggage car dynamo equipped trains of the Chicago, Milwaukee & St. Paul Railway—including the famous "Olympian"—use ROLLER-SMITH circuit breakers.

These circuit breakers are used in connection with the steam driven generator installed in the baggage car for lighting the trains. A ROLLER-SMITH circuit breaker mounted on a panel in the baggage car stands all the shaking, jarring and pounding received while the train is traveling over the mountain divisions between St. Paul and the Pacific Coast.



These R-S breakers are *not* specially built for this rough service. They are the regular Standard Type circuit breakers taken from stock. This type of service proves the ruggedness and serviceability of R-S Standard Type Breakers and repeat orders regularly testify to the favorable records these R-S breakers have made. Up to the present time more than 400 of these R-S breakers have been supplied for the C. M. & St. P. alone.

R-S circuit breakers are available up to 12,000 amperes and larger, A. C. and D. C., for all commercial voltages and can be had in all styles of trips, overload, underload, under-voltage, over-voltage, shunt trip, reverse current, etc. Also one or multi-pole and with such special features as shockproof, free handle, interlocked trip, remote control, enclosed, etc., etc.

For full details send for Bulletins AE-520, AE-530, AE-550 and AE-560.

*"Over thirty years experience is behind ROLLER-SMITH"*

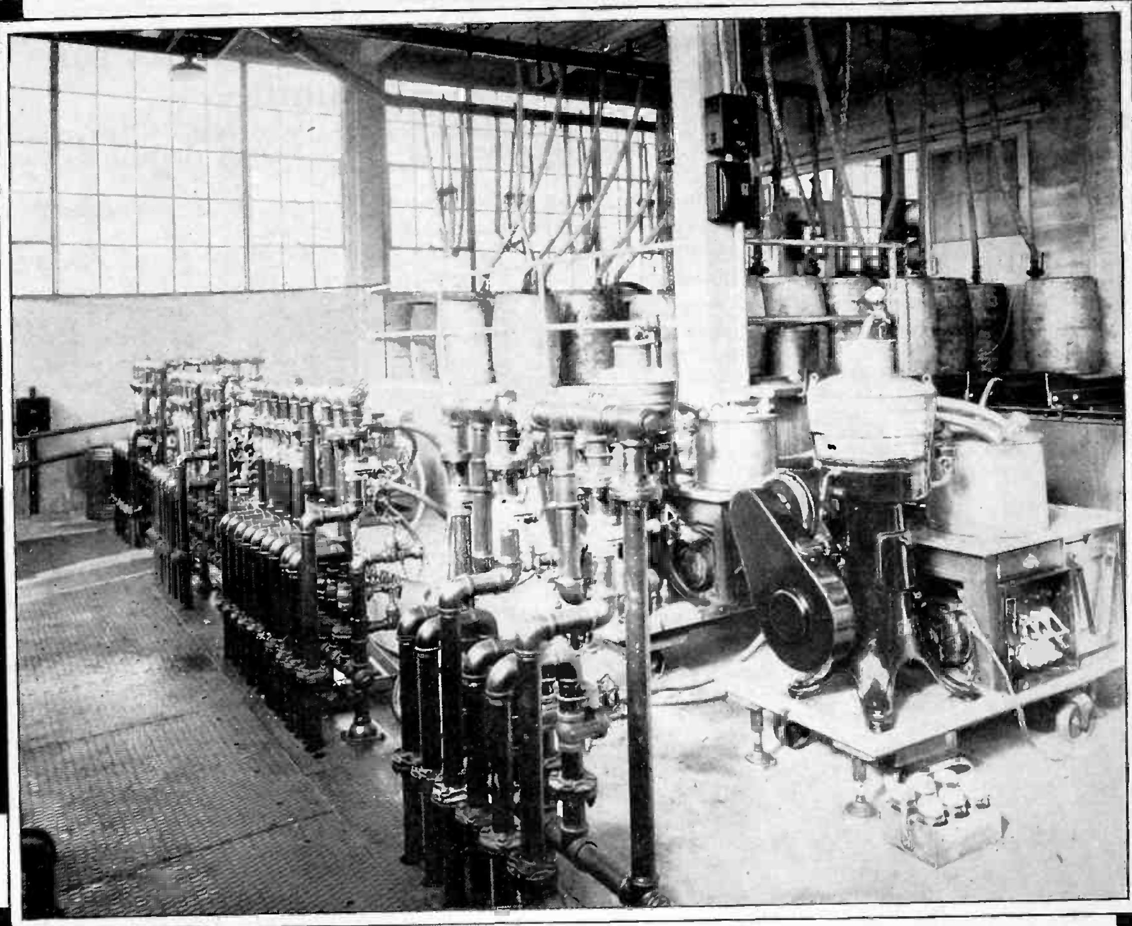
**ROLLER-SMITH COMPANY**
Electrical Measuring and Protective Apparatus

ROLLER SMITH

**MAIN OFFICE**
**12 Park Place, NEW YORK**

**WORKS**
**Bethlehem, Penna.**

*Offices in principal cities in U. S. A. and Canada, also in Havana, Cuba*



# De Laval Oil Purifiers Protect Southern California Edison Lines

THE Southern California Edison Company, operators of the world's longest high-voltage transmission line and one of America's five largest producers of electrical energy, use six De Laval Oil Purifiers. Three of these machines are in service at generating stations of the Company to keep lubricating oil free from impurities, and three others are used to maintain the dielectric strength of transformer oil and switch oil.

The illustration shows two De Laval Transformer Oil Purifiers of the portable type, in the Southern California Edison Company's new reinforced concrete oil house at Alhambra, Calif., just outside the city limits of Los Angeles. The oil house is connected with eight steel storage tanks having a total storage capacity of 365,000 gallons of circuit breaker and transformer oil which is purified by the De Laval centrifugal machines.

Repeat orders for De Laval Purifiers received from this outstanding electric power system are testimony of their extremely satisfactory operation.

Eighty per cent of the largest power systems in America now use De Laval Oil Purifiers.

**The De Laval Separator Company**

**New York** — **165 Broadway**

**Chicago** — **600 Jackson Boulevard**

**DE LAVAL PACIFIC COMPANY**
**San Francisco**

# De Laval Oil Purifiers

Please send Bulletin containing further information regarding the De Laval Oil Purifier as checked below:

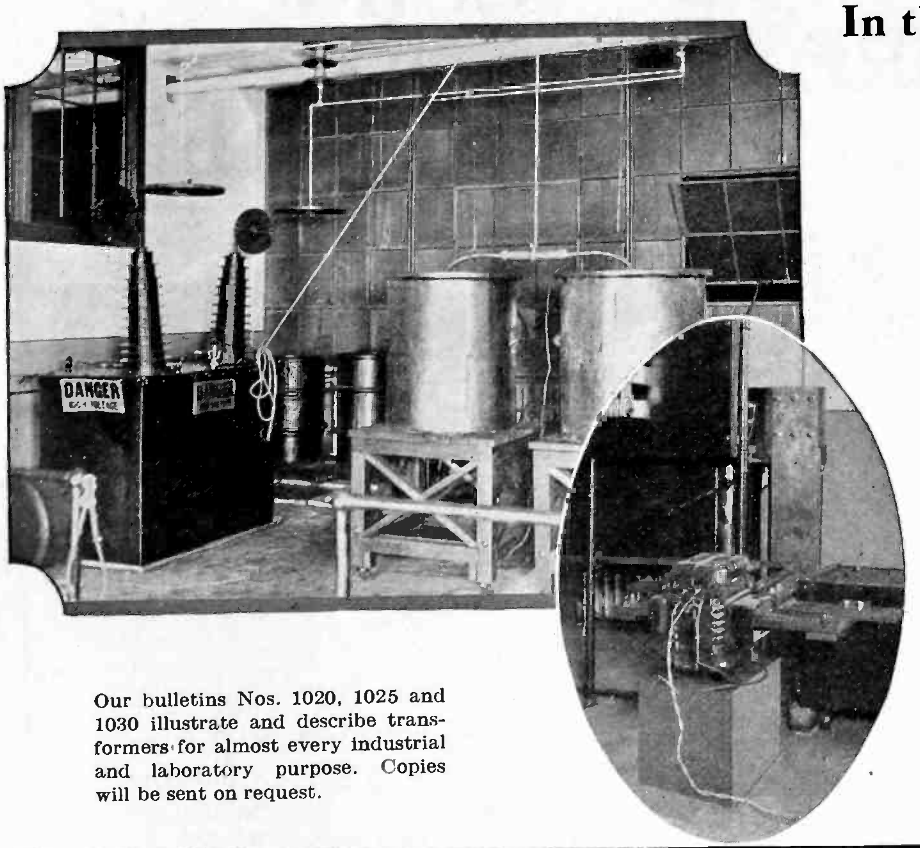
- ☐ Purification of turbine lubricating oil.
- ☐ Purification of Diesel lubricating and fuel oil.
- ☐ Dehydration of transformer oil.

Name..........

Company..........

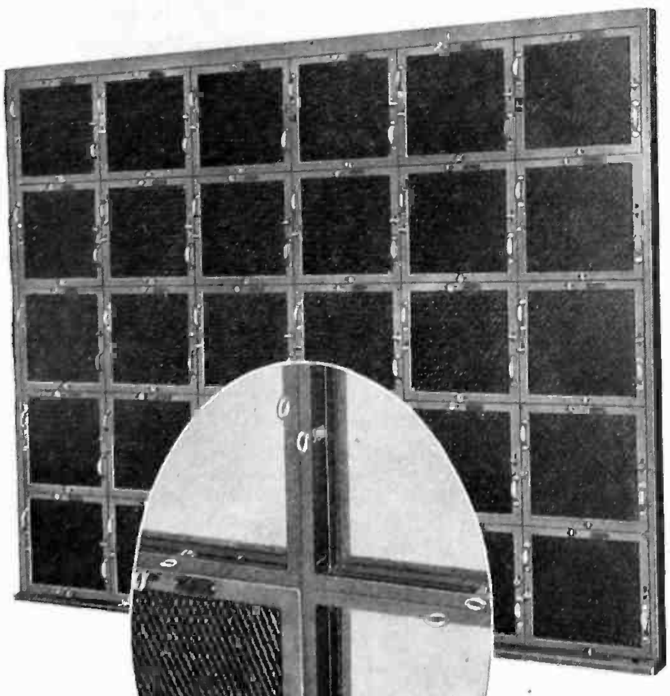
Address..........

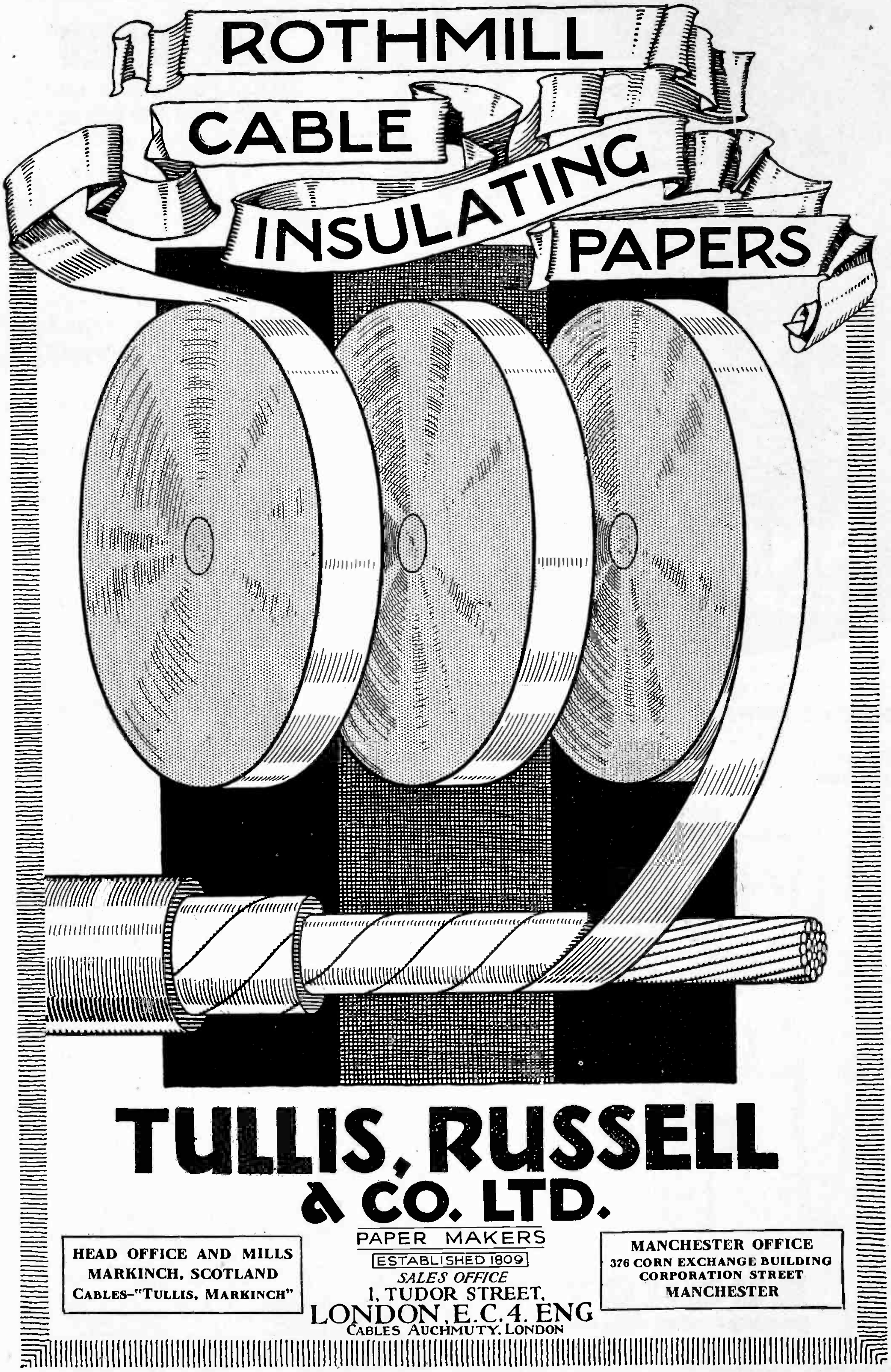
JAI-618T

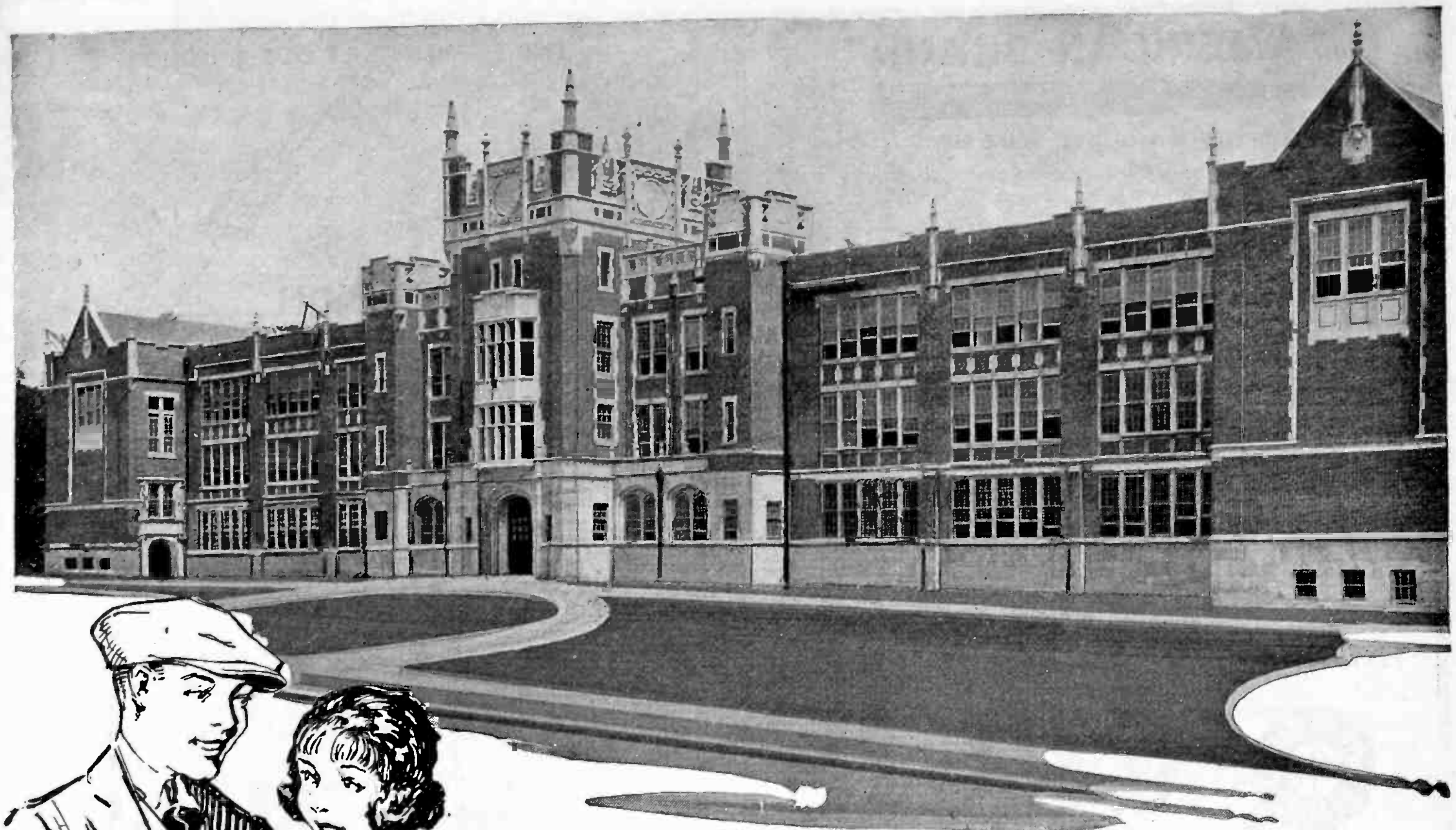

DANGER








ROTHMILL
CABLE
INSULATING
PAPERS
TULLIS, RUSSELL
& CO. LTD.
PAPER MAKERS
ESTABLISHED 1809
SALES OFFICE
1, TUDOR STREET,
LONDON, E.C.4. ENG
CABLES AUCHMUTY, LONDON
HEAD OFFICE AND MILLS
MARKINCH, SCOTLAND
CABLES—"TULLIS, MARKINCH"
MANCHESTER OFFICE
376 CORN EXCHANGE BUILDING
CORPORATION STREET
MANCHESTER



# Gwynns Falls High School, Baltimore, Uses Americore Wire

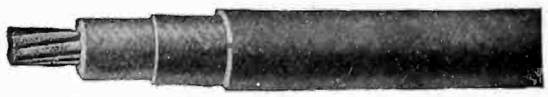
Citizens of Baltimore, Md., may be justly proud of the new Gwynns Falls High School, for the workmanship and architecture are a credit to the community and to those responsible for its construction.

In building for permanence, Americore Rubber Covered Wire—a product of the American Steel & Wire Company—was selected for the interior wiring. The amount used—105,000 feet—is, in itself, a recommendation of the highest order for the quality, performance and economy of this wire.

Americore meets all the National Electrical Code requirements and can be recommended for all service conditions in which the working pressure is 7000 volts or under.

Let us send you an indexed hand book and catalogue of Electrical Wires and Cables for ready reference. Estimates furnished promptly from any of our offices, located in all of the principal cities.

**Solid Tinned Copper Conductor**



**Stranded Tinned Copper Conductor**

**Solid or Stranded Tinned Copper Conductor**

# American Steel & Wire Company

# Americore

## Rubber-covered wire

Sales Offices

| | |
|---|---|
| Chicago | 208 So. La Salle Street |
| New York | 30 Church Street |
| Cleveland | Rockefeller Building |
| Worcester | 94 Grove Street |
| Boston | 185 Franklin Street |
| Philadelphia | Widener Building |
| Pittsburgh | Frick Building |
| Buffalo | 670 Ellicott Street |
| Detroit | Foot of First Street |
| Atlanta | Trust Company of Georgia Building |
| Cincinnati | Union Trust Building |
| Baltimore | 32 So. Charles Street |
| Wilkes Barre, Pa. | Miners Bank Building |
| St. Louis | Liberty Central Trust Company Bldg. |
| Kansas City | 417 Grand Avenue |
| St. Paul-Minneapolis | Pioneer Bldg., St. Paul |
| Oklahoma City | First National Bank Building |
| Birmingham, Ala. | Brown-Marx Building |
| Memphis, Tenn. | Union and Planters Bank Bldg. |
| Denver | 1st National Bank Building |
| Dallas | Praetorian Building |
| Salt Lake City | Walker Bank Building |

Export Representative: U. S. Steel Products, Co., New York
Pacific Coast Representative: U. S. Steel Products Company, San Francisco Los Angeles Portland Seattle

# THE ROWAN A.C. STARTING SWITCH

**PUSH BUTTON OPERATED**
**OIL IMMERSED**


FOR
STARTING AND STOPPING SMALL SQUIRREL CAGE MOTORS THAT CAN BE THROWN ACROSS THE LINE

**ROWAN CONTROL**
THE ROWAN CONTROLLER CO., BALTIMORE, MD.

# DUNCAN
*Watthour Meters*

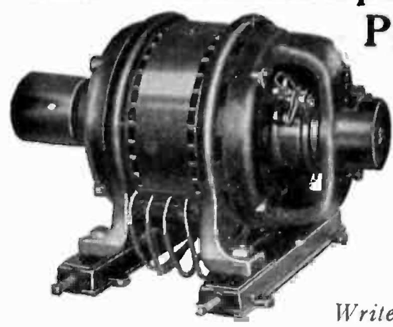
Model M2.

Accurate
and
Dependable

Write for bulletins

**DUNCAN ELECTRIC MFG. CO.**
Lafayette, Ind.

## "AK" Variable Speed Motor for Printing Machinery



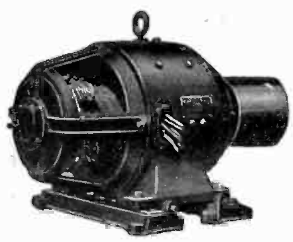
Highest efficiency under variable load. Wound for 25% overload. Push button control. For A. C. any cycles. In sizes 1/20 to 5 H. P.

Modern, safe equipment for job or cylinder press

*Write for complete information*

**NORTHWESTERN ELECTRIC COMPANY**
Also Mfrs. of the "Martin" Rotary Converter
409 So. Hoyne Avenue
CHICAGO, ILL.

## Star Ball Bearing Motors

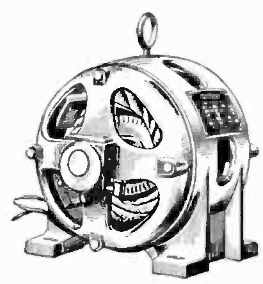


For
Hard
Usage
—
A. C.
and
D. C.

Complete line of standard motors and generators, all sizes up to 75 h.p. and 50 kw. respectively.
*Our Engineering Department at your service for all special applications*

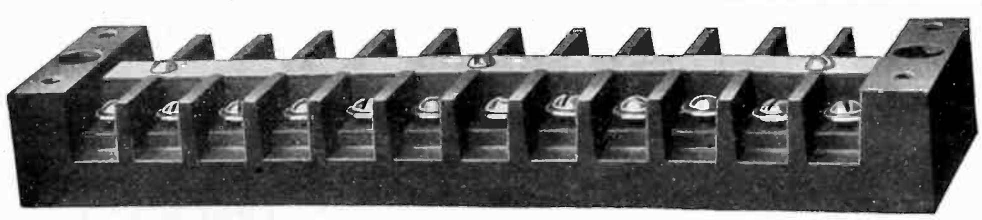
**STAR ELECTRIC MOTOR CO.**
NEWARK, NEW JERSEY

## Sturtevant Electric Motors



—A. C. and D. C.; single and polyphase—built in sizes from small fractional to 250 horse-power—designed to operate under a constant full load where uninterrupted service is demanded.

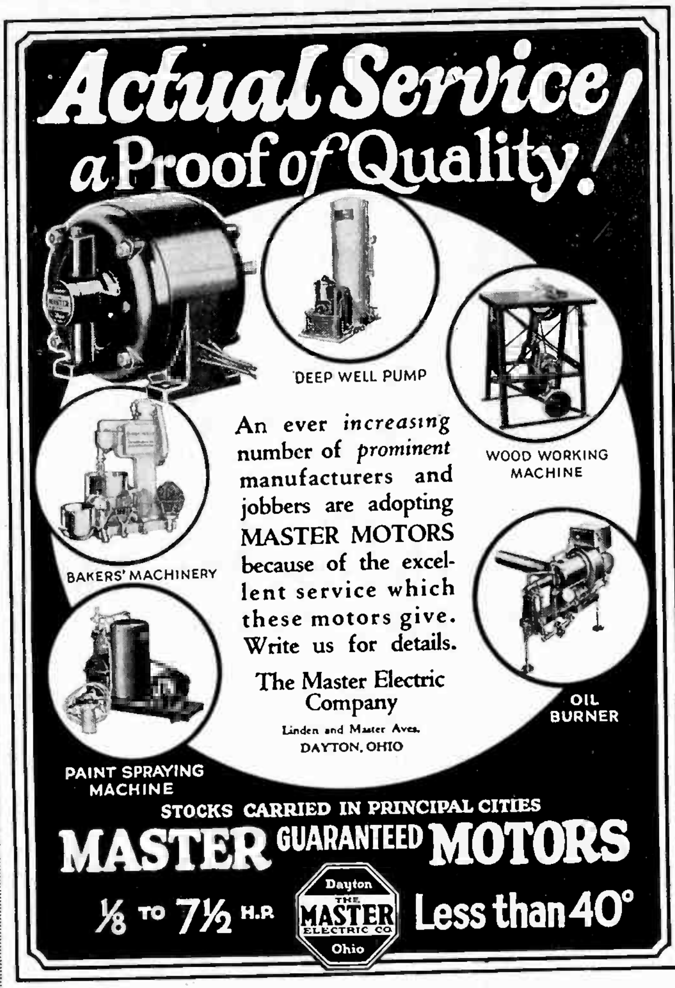
**B. F. STURTEVANT COMPANY**
HYDE PARK, BOSTON, MASS.

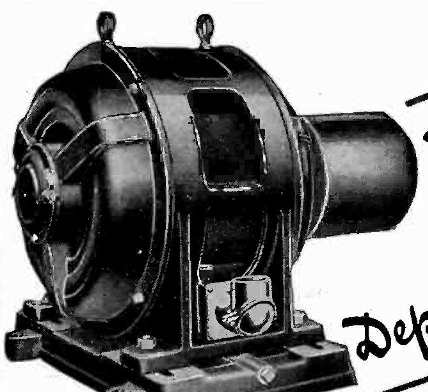


## "BURKELECT" Moulded Controlead Terminal Blocks

By the use of these Terminal Blocks simplifications in all methods of control wiring circuits are possible and offer many other advantages which are fully described in Bulletin H-2.

**BURKE ELECTRIC COMPANY**
HIGH TENSION EQUIPMENT DIVISION
ERIE, PA.



*Built for Dependability*

WHEN the **Electro Dynamic** Polyphase Induction motor was first conceived, **it was** our determination to produce a motor as dependable as human ingenuity and practical limitations would permit. A motor so well designed, electrically and mechanically, of such sturdy construction, of such expert workmanship, that it would be practically trouble-free and fool-proof.

Our engineers will be glad to explain to you the many distinctive features that mean absolute dependability and true economy.

**ELECTRO DYNAMIC COMPANY**

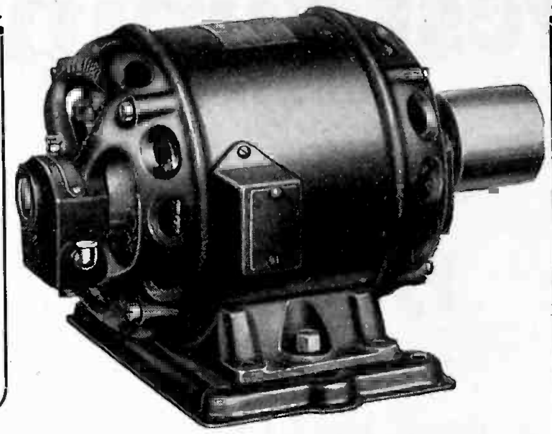
(Est. 1880)

BAYONNE, N. J.

*Manufacturers of A. C. and D. C. Motors and Generators.*

*½ to 1000 H.P.*

*"They Keep a-Running"*



*¼ Horse Power Century Repulsion-Start Induction Single-Phase Motor*

# One Year Without Reoiling

The addition of the Century Wool-yarn System of Lubrication to all fractional horse power Century Repulsion-start Induction Single-phase Motors assures more than one year's continuous 24-hour-per-day service without reoiling.

1 Only continuous unbroken strands of pure wool yarn are used.

2 Due to the capillary action of these continuous unbroken strands, a generous supply of oil is always being delivered to the bearing surfaces.

3 Because of the filtering properties of pure wool yarn, abrasive particles, compounds, dust and grit cannot reach the bearings through the oil wells.

4 There is no plug in the bottom of the oil well—leakage tendencies are eliminated and the entire oil supply conserved indefinitely.

These features, together with other desirable characteristics, are responsible for the wide use of Century Repulsion-start Induction Single-phase Motors for household refrigerating systems, ice cream cabinets, soda fountains, oil burners, house pump service, etc.

Temperature rise not more than 40 degrees Centigrade and they will at least meet all of the test specifications of the A. I. E. E. and Electric Power Club.

Built in other standard sizes from 1-8 to 40 horse power.

**Century Electric Company**

**1806 Pine Street St. Louis, Mo.**

*For More Than 22 Years at St. Louis*

⅛ to 40 H. P. Century MOTORS ⅛ to 40 H. P.

# PROFESSIONAL ENGINEERING DIRECTORY

For Consultants in the Fields of Engineering and Related Arts and Sciences



ADDITIONAL CARDS ON NEXT PAGE

# Classified Advertiser's Index for Buyers

Manufacturers and agents for machinery and supplies used in the electrical and allied industries.

Note: For reference to the Advertisements see the Alphabetical List of Advertisers on page 50.

AIR COMPRESSORS
- Allis-Chalmers Mfg. Co., Milwaukee
- General Electric Co., Schenectady
- Western Electric Co., All Principal Cities

AIR COMPRESSOR FILTERS
- Midwest Air Filters, Inc., Bradford, Pa.
- Spray Engineering Co., Boston

AIR FILTERS, COOLING
- Midwest Air Filters, Inc., Bradford, Pa.
- Spray Engineering Co., Boston

AIR WASHERS
- Spray Engineering Co., Boston
- Sturtevant Company, B. F., Boston

ALARMS, TEMPERATURE, PRESSURE
- Cory & Son, Inc., Chas., New York

AMMETER COMPENSATING COILS
- Minerallac Electric Co., Chicago

AMMETER, VOLTMETERS
- (See INSTRUMENTS, ELECTRICAL)

ANCHORS, GUY
- Matthews Corp., W. N., St. Louis

ANNUNCIATORS, AUDIO-VISIBLE
- Cory & Son, Inc., Chas., New York

BATTERY CHARGING APPARATUS
- Electric Specialty Co., Stamford, Conn.
- Fansteel Products Co., Inc., North Chicago
- General Electric Co., Schenectady
- Ward Leonard Electric Co., Mt.Vernon, N.Y.
- Western Electric Co., All Principal Cities
- Westinghouse Elec. & Mfg. Co., E. Pittsburgh

BEARINGS, BALL
- New Departure Mfg. Co., The, Bristol, Conn.
- Norma-Hoffmann Bearings Corp., Stamford, Conn.
- Standard Steel & Bearings, Inc., Plainville, Conn.

BEARINGS, ROLLER
- Timken Roller Bearing Co., The, Canton, O.

BOXES, FUSE
- General Electric Co., Schenectady
- Metropolitan Device Corp., Brooklyn, N. Y.
- Western Electric Co., All Principal Cities
- Westinghouse Elec. & Mfg. Co., Pittsburgh

BOXES, JUNCTION
- G & W Elec. Specialty Co., Chicago
- Metropolitan Device Corp., Brooklyn, N. Y.
- Standard Underground Cable Co., Pittsburgh

BRUSHES, COMMUTATOR

*Carbon*
- Morganite Brush Co., Inc., New York
- National Carbon Co., Inc., Cleveland
- Westinghouse Elec. & Mfg. Co., E. Pittsburgh

*Copper Graphite*
- Morganite Brush Co., Inc., New York
- National Carbon Co., Inc., Cleveland
- Westinghouse Elec. & Mfg. Co., E. Pittsburgh

BUS BAR FITTINGS
- Burndy Engineering Co., Inc., New York
- Delta-Star Electric Co., Chicago
- General Electric Co., Schenectady
- Westinghouse Elec. & Mfg. Co., E. Pittsburgh

CABLE ACCESSORIES
- Delta-Star Electric Co., Chicago
- Dossert & Co., New York
- G & W Electric Specialty Co., Chicago
- General Electric Co., Schenectady
- Minerallac Electric Co., Chicago
- Standard Underground Cable Co., Pittsburgh
- Western Electric Co., All Principal Cities

CABLES
- (See WIRES AND CABLES)

CABLEWAYS
- American Steel & Wire Co., Chicago
- Roebling's Sons Co., John A., Trenton, N. J.

CAMBRIC, VARNISHED
- Belden Mfg. Co., Chicago
- Irvington Varnish & Ins. Co., Irvington, N. J.

CARRIER CURRENT TELEPHONE EQUIPMENT
- Dubilier Condenser & Radio Corp., NewYork
- Western Electric Co., All Principal Cities
- Wireless Specialty Apparatus Co., Boston

CIRCUIT BREAKERS

*Air—Enclosed*
- Cutter Co., The, Philadelphia
- Roller-Smith Co., New York
- Sundh Electric Co., Newark, N. J.
- Ward Leonard Electric Co., Mt. Vernon, N. Y.
- Western Electric Co., All Principal Cities

*Oil*
- Condit Electrical Mfg. Corp., Boston
- General Electric Co., Schenectady
- Westinghouse Elec. & Mfg. Co., E. Pittsburgh

CLAMPS, GUY & CABLE
- Burndy Engineering Co., Inc., New York
- Matthews Corp., W. N., St. Louis

COILS, CHOKE
- Burke Electric Co., Erie, Pa.
- General Electric Co., Schenectady
- Westinghouse Elec. & Mfg. Co., E. Pittsburgh

COILS, MAGNET
- Acme Wire Co., New Haven, Conn.
- Belden Mfg. Co., Chicago
- Dudlo Mfg. Corp., Ft. Wayne, Ind.
- General Electric Co., Schenectady
- Westinghouse Elec. & Mfg. Co., E. Pittsburgh

CONDENSATION PRODUCTS
- Bakelite Corporation, New York

CONDENSERS, COUPLING

*For Carrier Current Telephone*
- Dubilier Condenser & Radio Corp., NewYork
- Wireless Specialty Apparatus Co., Boston

CONDENSERS, RADIO
- Dubilier Condenser & Radio Corp., NewYork
- General Radio Co., Cambridge, Mass.
- Pacent Electric Co., New York

CONDENSERS, STEAM
- Allis-Chalmers Mfg. Co., Milwaukee
- General Electric Co., Schenectady
- Westinghouse Elec. & Mfg. Co., E. Pittsburgh

CONDUIT, UNDERGROUND FIBRE
- Western Electric Co., All Principal Cities

CONNECTORS, SOLDERLESS
- Dossert & Co., New York
- Western Electric Co., All Principal Cities
- Westinghouse Elec. & Mfg. Co., E. Pittsburgh

CONNECTORS AND TERMINALS
- Belden Mfg. Co., Chicago
- Burke Electric Co., Erie, Pa.
- Burndy Engineering Co., Inc., New York
- Dossert & Co., New York
- G & W Electric Specialty Co., Chicago
- Western Electric Co., All Principal Cities
- Westinghouse Elec. & Mfg. Co., E. Pittsburgh

CONTACTS, TUNGSTEN
- Fansteel Products Co., Inc., North Chicago
- General Electric Co., Schenectady

CONTROL SYSTEMS
- Ward Leonard Electric Co., Mt. Vernon, N.Y.

CONTROLLERS
- General Electric Co., Schenectady
- Rowan Controller Co., Baltimore
- Sundh Electric Co., Newark, N. J.
- Ward Leonard Electric Co., Mt. Vernon, N.Y.
- Western Electric Co., All Principal Cities
- Westinghouse Elec. & Mfg. Co., E. Pittsburgh

CONVERTERS—SYNCHRONOUS
- Allis-Chalmers Mfg. Co., Milwaukee
- Electric Specialty Co., Stamford, Conn.
- Northwestern Electric Co., Chicago
- Wagner Electric Corp., St. Louis
- Westinghouse Elec. & Mfg. Co., E. Pittsburgh

COOLING PONDS
- Spray Engineering Co., Boston

COPPER CLAD WIRE
- Belden Mfg. Co., Chicago
- Copperweld Steel Co., Rankin, Pa.
- Standard Underground Cable Co., Pittsburgh
- Western Electric Co., All Principal Cities

CUT-OUTS
- Condit Electrical Mfg. Corp., S. Boston
- General Electric Co., Schenectady
- G & W Electric Specialty Co., Chicago
- Metropolitan Device Corp., Brooklyn, N. Y.
- Western Electric Co., All Principal Cities
- Westinghouse Elec. & Mfg. Co., E. Pittsburgh

DIMMERS, THEATRE
- Ward Leonard Electric Co., Mt. Vernon, N.Y.

DYNAMOS
- (See GENERATORS AND MOTORS)

DYNAMOTORS
- Burke Electric Co., Erie, Pa.
- Electric Specialty Co., Stamford, Conn.

ELECTRIFICATION SUPPLIES, STEAM ROAD
- General Electric Co., Schenectady
- Ohio Brass Co., Mansfield, Ohio
- Westinghouse Elec. & Mfg. Co., E. Pittsburgh

ENGINEERS, CONSULTING AND CONTRACTING
- (See PROFESSIONAL ENGINEERING DIRECTORY)

ENGINES

*Gas & Gasoline*
- Allis-Chalmers Mfg. Co., Milwaukee
- Sturtevant Company, B. F., Boston

*Oil*
- Allis-Chalmers Mfg. Co., Milwaukee
- Sturtevant Company, B. F., Boston

*Steam*
- Allis-Chalmers Mfg. Co., Milwaukee
- Sturtevant Company, B. F., Boston

FANS, MOTOR
- Century Electric Co., St. Louis
- General Electric Co., Schenectady
- Star Electric Motor Co., Newark, N. J.
- Sturtevant Company, B. F., Boston
- Western Electric Co., All Principal Cities
- Westinghouse Elec. & Mfg. Co., E. Pittsburgh

FARM LIGHTING GENERATORS
- Western Electric Co., All Principal Cities
- Westinghouse Elec. & Mfg. Co., E. Pittsburgh

FIBRE
- Belden Mfg. Co., Chicago
- National Vulcanized Fibre Co., Wilmington, Del.

FIRE PROTECTION APPARATUS
- Kidde & Co., Inc., Walter, New York

FLOW METERS
- Cory & Son, Inc., Chas., New York
- General Electric Co., Schenectady
- Spray Engineering Co., Boston

FURNACES, ELECTRIC
- General Electric Co., Schenectady
- Westinghouse Elec. & Mfg. Co., E. Pittsburgh

FUSES

*Enclosed Refillable*
- General Electric Co., Schenectady
- Western Electric Co., All Principal Cities
- Westinghouse Elec. & Mfg. Co., E. Pittsburgh

*Enclosed Non-Refillable*
- General Electric Co., Schenectady
- Western Electric Co., All Principal Cities

*Open Link*
- General Electric Co., Schenectady
- Metropolitan Device Corp., Brooklyn, N. Y.
- Western Electric Co., All Principal Cities

*High Tension*
- Delta-Star Electric Co., Chicago
- Metropolitan Device Corp., Brooklyn, N. Y.
- Western Electric Co., All Principal Cities

GEARS, FIBRE
- General Electric Co., Schenectady
- National Vulcanized Fibre Co., Wilmington, Del.

GENERATORS AND MOTORS
- Allis-Chalmers Mfg. Co., Milwaukee
- Burke Electric Co., Erie, Pa.
- Century Electric Co., St. Louis
- Chandeysson Electric Co., St. Louis
- Electric Specialty Co., Stamford, Conn.
- Electro-Dynamic Co., Bayonne, N. J.
- General Electric Co., Schenectady
- Master Electric Co., The, Dayton, O.
- Northwestern Electric Co., Chicago
- Star Electric Motor Co., Newark, N. J.
- Sturtevant Company, B. F., Boston
- Wagner Electric Corp., St. Louis
- Western Electric Co., All Principal Cities
- Westinghouse Elec. & Mfg. Co., E. Pittsburgh

GENERATING STATION EQUIPMENT
- Allis-Chalmers Mfg. Co., Milwaukee
- Burke Electric Co., Erie, Pa.
- General Electric Co., Schenectady
- Western Electric Co., All Principal Cities
- Westinghouse Elec. & Mfg. Co., E. Pittsburgh

GROUND RODS
- Copperweld Steel Co., Rankin, Pa.
- Western Electric Co., All Principal Cities

HEADLIGHTS
- Ohio Brass Co., Mansfield, O.

HEATERS, INDUSTRIAL
- General Electric Co., Schenectady
- Western Electric Co., All Principal Cities
- Westinghouse Elec. & Mfg. Co., E. Pittsburgh

INDICATORS, LOAD
- Cory & Son, Inc., Chas., New York

INDICATORS, SPEED
- Roller-Smith Co., New York

INDICATORS, WATER LEVEL
- Cory & Son, Inc., Chas., New York

INSTRUMENTS, ELECTRICAL

*Graphic*
- Bristol Co., The, Waterbury, Conn.
- Ferranti, Ltd., London, Eng.
- Ferranti Meter & Transformer Mfg. Co., Ltd., Toronto, Ont.
- General Electric Co., Schenectady
- Westinghouse Elec. & Mfg. Co., E. Pittsburgh

*Indicating*
- Ferranti, Ltd., London, Eng.
- Ferranti Meter & Transformer Mfg. Co., Ltd., Toronto, Ont.
- General Electric Co., Schenectady
- Jewell Elec. Instrument Co., Chicago
- Roller-Smith Co., New York
- Westinghouse Elec. & Mfg. Co., E. Pittsburgh
- Weston Elec. Inst. Corp., Newark, N. J.

*Integrating*
- Duncan Elec. Mfg. Co., Lafayette, Ind.
- Ferranti, Ltd., London, Eng.
- Ferranti Meter & Transformer Mfg. Co., Ltd., Toronto, Ont.
- General Electric Co., Schenectady
- Roller-Smith Co., New York
- Sangamo Elec. Co., Springfield, Ill.
- Western Electric Co., All Principal Cities
- Westinghouse Elec. & Mfg. Co., E. Pittsburgh

*Radio*
- General Radio Co., Cambridge, Mass.
- Jewell Elec. Instrument Co., Chicago

# Classified Advertiser's Index for Buyers—*Continued*

INSTRUMENTS, ELECTRICAL—*Continued*
*Repairing and Testing*
Electrical Testing Laboratories, New York
Jewell Elec. Instrument Co., Chicago
*Scientific, Laboratory, Testing*
General Electric Co., Schenectady
Jewell Elec. Instrument Co., Chicago
Metropolitan Device Corp., Brooklyn, N. Y.
Roller-Smith Co., New York
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh
Weston Elec. Inst. Corp., Newark, N. J.
*Telegraph*
Western Electric Co., All Principal Cities

INSULATING MATERIALS
*Board*
West Va. Pulp & Paper Co., New York
*Cloth*
Acme Wire Co., New Haven, Conn.
Irvington Varnish & Ins. Co., Irvington, N. J.
Minerallac Electric Co., Chicago
Westinghouse Elec. & Mfg. Co., E. Pittsburgh
*Composition*
American Lava Corp., Chattanooga
Bakelite Corporation, New York
Belden Mfg. Co., Chicago
Westinghouse Elec. & Mfg. Co., E. Pittsburgh
*Compounds*
Minerallac Electric Co., Chicago
Standard Underground Cable Co., Pittsburgh
Western Electric Co., All Principal Cities
*Fibre*
National Vulcanized Fibre Co., Wilmington, Del.
West Va. Pulp & Paper Co., New York
*Lava*
American Lava Corp., Chattanooga, Tenn.
*Mica*
New England Mica Co., Waltham, Mass.
*Paper*
Acme Wire Co., New Haven, Conn.
Irvington Varnish & Ins. Co., Irvington, N. J.
Tullis, Russell & Co., Ltd., London, Eng.
*Silk*
Acme Wire Co., New Haven, Conn.
Irvington Varnish & Ins. Co., Irvington, N. J.
*Tape*
Belden Mfg. Co., Chicago
Minerallac Electric Co., Chicago
Okonite Co., The, Passaic, N. J.
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh
*Varnishes*
Acme Wire Co., New Haven, Conn.
General Electric Co., Schenectady
Irvington Varnish & Ins. Co., Irvington, N. J.
Minerallac Electric Co., Chicago

INSULATORS, HIGH TENSION
*Composition*
General Electric Co., Schenectady
*Glass*
Hemingray Glass Co., Muncie, Ind.
*Porcelain*
General Electric Co., Schenectady
Lapp Insulator Co., Inc., LeRoy, N. Y.
Locke Insulator Corp., Baltimore
Ohio Brass Co., Mansfield, O.
Thomas & Sons Co., R., East Liverpool, O.
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh
*Post Type*
Delta-Star Electric Co., Chicago

INSULATORS, TELEPHONE & TELEGRAPH
Hemingray Glass Co., Muncie, Ind.
Western Electric Co., All Principal Cities

LAMP GUARDS
Matthews Corp., W. N., St. Louis
Western Electric Co., All Principal Cities

LAVA
American Lava Corp., Chattanooga

LIGHTING FIXTURES
Cory & Son, Inc., Chas., New York

LIGHTNING ARRESTERS
Delta-Star Electric Co., Chicago
General Electric Co., Schenectady
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

LOCOMOTIVES, ELECTRIC
General Electric Co., Schenectady
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

METERS, ELECTRICAL
(SEE INSTRUMENTS, ELECTRICAL)

MICA
New England Mica Co., Waltham, Mass.

MOLDED INSULATION
Bakelite Corporation, New York
Belden Mfg. Co., Chicago
Burke Electric Co., Erie, Pa.
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

MOLYBDENUM
Fansteel Products Co., Inc., North Chicago

MOTORS
(See GENERATORS AND MOTORS)

OHMMETERS
Cory & Son, Inc., Chas., New York
Jewell Elec. Instrument Co., Chicago
Roller-Smith Co., New York
Weston Elec. Instr. Corp., Newark, N. J.

OIL SEPARATORS & PURIFIERS
DeLaval Separator Co., The, New York
Sharples Specialty Co., The, Philadelphia
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

PANEL BOARDS
(See SWITCHBOARDS)

PATENT ATTORNEYS
(See PROFESSIONAL ENGINEERING DIRECTORY)

PLUGS
Delta-Star Electric Co., Chicago
General Electric Co., Schenectady
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

POLES, STEEL
American Bridge Co., Pittsburgh
Pacific Coast Steel Co., San Francisco
Western Electric Co., All Principal Cities

POLES—TIES, WOOD
Western Electric Co., All Principal Cities

POTHEADS
G & W Electric Specialty Co., Chicago
Standard Underground Cable Co., Pittsburgh
Western Electric Co., All Principal Cities

PROTECTIVE DEVICES
Metropolitan Device Corp., Brooklyn, N. Y.
Western Electric Co., All Principal Cities

PULLERS, SLACK
Matthews Corp., W. N., St. Louis

PULLEYS, PAPER
Rockwood Mfg. Co., The, Indianapolis

PUMPS
Allis-Chalmers Mfg. Co., Milwaukee

PUMPS, SPIRAL
Cramp & Sons Ship & Engine Bldg. Co., The Wm., Philadelphia

RADIO LABORATORY APPARATUS
General Radio Co., Cambridge, Mass.
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

RAILWAY SUPPLIES, ELECTRIC
General Electric Co., Schenectady
Ohio Brass Co., Mansfield, O.
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

REACTORS
Metropolitan Device Corp., Brooklyn, N. Y.

RECTIFIERS
Fansteel Products Co., Inc., North Chicago
General Electric Co., Schenectady
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

REGULATORS, VOLTAGE
Burke Electric Co., Erie, Pa.
General Electric Co., Schenectady
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

RELAYS
Cory & Son, Inc., Chas., New York
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

RESISTOR UNITS
General Electric Co., Schenectady
Ward Leonard Electric Co., Mt. Vernon, N.Y.

RHEOSTATS
Biddle, James G., Philadelphia
General Electric Co., Schenectady
Sundh Electric Co., Newark, N. J.
Ward Leonard Electric Co., Mt. Vernon, N.Y.
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

ROPE, WIRE
American Steel & Wire Co., Chicago
Roebling's Sons Co., John A., Trenton, N. J.

SEARCHLIGHTS
General Electric Co., Schenectady
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

SHEETS, ELECTRICAL
Trumbull Steel Co., The, Warren, O.

SOCKETS AND RECEPTACLES
General Electric Co., Schenectady
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

SOLENOIDS
Acme Wire Co., New Haven, Conn.
Belden Mfg. Co., Chicago
Dudlo Mfg. Co., Ft. Wayne, Ind.
General Electric Co., Schenectady
Sundh Electric Co., Newark, N. J.
Ward Leonard Electric Co., Mt. Vernon, N.Y.
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

STARTERS, MOTOR
Condit Electrical Mfg. Corp., Boston
General Electric Co., Schenectady
Rowan Controller Co., Baltimore, Md.
Sundh Electric Co., Newark, N. J.
Ward Leonard Electric Co., Mt. Vernon, N.Y.
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

STEEL, SHEET & STRIPS
Trumbull Steel Co., The, Warren, O.

STOKERS, MECHANICAL
Sturtevant Company, B. F., Boston
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

SUB-STATIONS
General Electric Co., Schenectady
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

SWITCHBOARDS
Allis-Chalmers Mfg. Co., Milwaukee
Condit Electrical Mfg. Corp., Boston
General Electric Co., Schenectady
Metropolitan Device Corp., Brooklyn, N. Y.
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

SWITCHES *Automatic Time*
Ferranti, Ltd., London, Eng.
Ferranti Meter & Transformer Mfg. Co., Ltd., Toronto, Ont.
General Electric Co., Schenectady
Minerallac Electric Co., Chicago
Sundh Electric Co., Newark, N. J.
Westinghouse Elec. & Mfg. Co., E. Pittsburgh
*Disconnecting*
Burke Electric Co., Erie, Pa.
Condit Electrical Mfg. Corp., Boston
Delta-Star Electric Co., Chicago
General Electric Co., Schenectady
K-P-F Electric Co., San Francisco
Matthews Corp., W. N., St. Louis
Thoner & Martens, Boston
*Fuse*
General Electric Co., Schenectady
Matthews Corp., W. N., St. Louis
Metropolitan Device Corp., Brooklyn, N. Y.
Thoner & Martens, Boston
*Knife*
Condit Electrical Mfg. Corp., Boston
General Electric Co., Schenectady
Matthews Corp., W. N., St. Louis
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh
*Magnetic*
Ward Leonard Electric Co., Mt. Vernon, N.Y.
*Oil*
Condit Electrical Mfg. Corp., Boston
General Electric Co., Schenectady
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh
*Remote Control*
Condit Electrical Mfg. Corp., Boston
General Electric Co., Schenectady
Rowan Controller Co., Baltimore
Sundh Electric Co., Newark, N. J.
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

TANTALUM
Fansteel Products Co., Inc., North Chicago

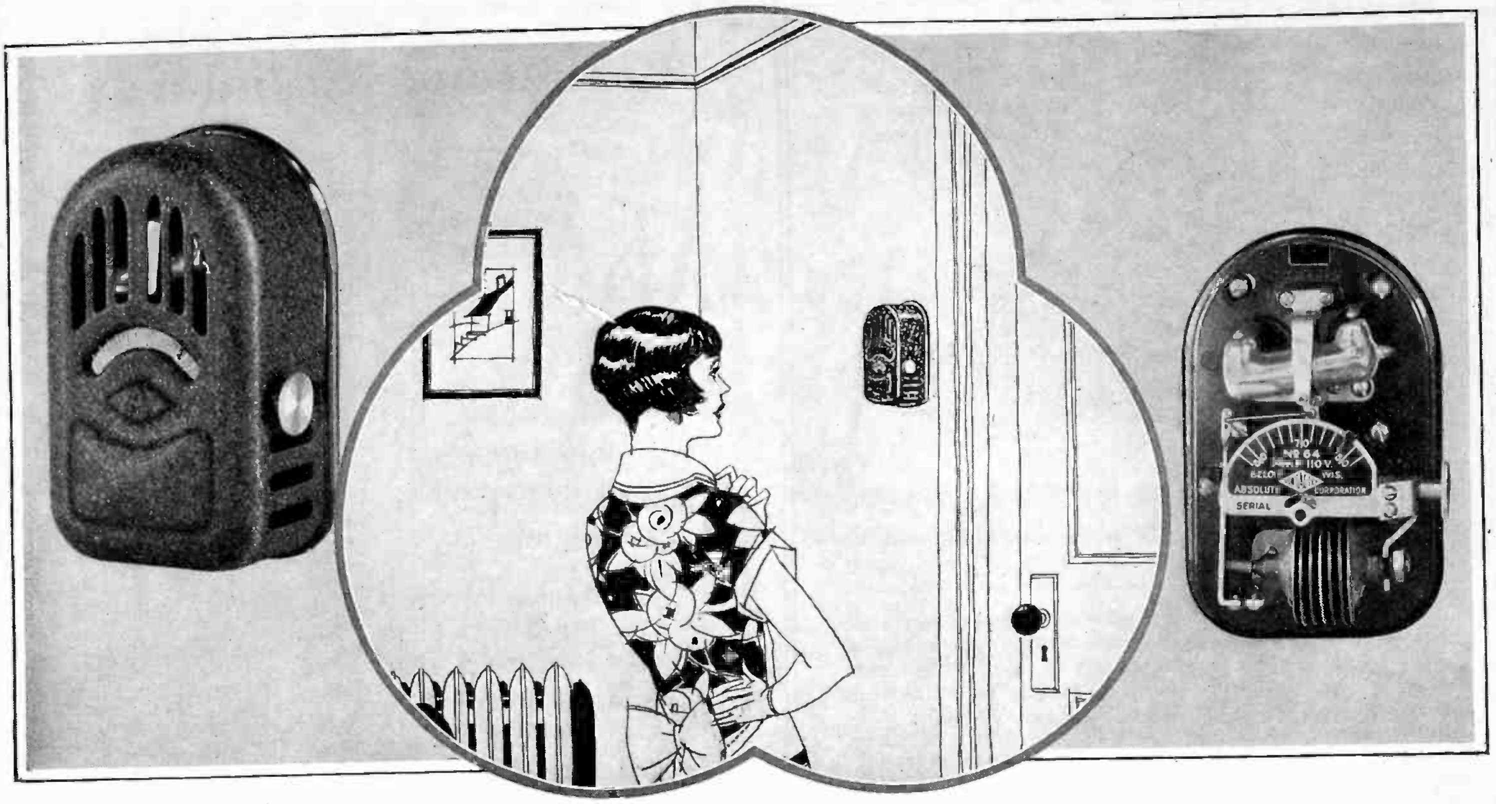
TELEGRAPH APPARATUS
Western Electric Co., All Principal Cities

TELEPHONE EQUIPMENT
Cory & Son, Inc., Chas., New York
Western Electric Co., All Principal Cities

TESTING LABORATORIES
Electrical Testing Labs., New York

TOWERS, TRANSMISSION
American Bridge Co., Pittsburgh
Pacific Coast Steel Co., San Francisco
Western Electric Co., All Principal Cities

TRANSFORMERS
Allis-Chalmers Mfg. Co., Milwaukee
American Transformer Co., Newark, N. J.
Duncan Elec. Mfg. Co., Lafayette, Ind.
Ferranti, Ltd., London, Eng.
Ferranti Meter & Transformer Mfg. Co., Ltd., Toronto, Ont.
General Electric Co., Schenectady
Kuhlman Electric Co., Bay City, Mich.
Moloney Electric Co., St. Louis
Pittsburgh Transformer Co., Pittsburgh
Wagner Electric Corp., St. Louis
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh
*Factory*
American Transformer Co., Newark, N. J.
Kuhlman Electric Co., Bay City, Mich.
Moloney Electric Co., St. Louis
Pittsburgh Transformer Co., Pittsburgh
Wagner Electric Corp., St. Louis
Western Electric Co., All Principal Cities
*Furnace*
Allis-Chalmers Mfg. Co., Milwaukee
American Transformer Co., Newark, N. J.
Moloney Electric Co., St. Louis
Pittsburgh Transformer Co., Pittsburgh
*Metering*
American Transformer Co., Newark, N. J.
Ferranti, Ltd., London, Eng.
Ferranti Meter & Transformer Mfg. Co., Ltd., Toronto, Ont.
Pittsburgh Transformer Co., Pittsburgh
*Mill Type*
Pittsburgh Transformer Co., Pittsburgh
*Radio*
American Transformer Co., Newark, N. J.
*Street Lighting*
Kuhlman Electric Co., Bay City, Mich.
Western Electric Co., All Principal Cities

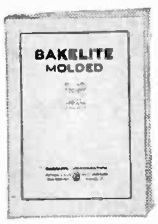


*Con-tac-tor Thermoswitch, made by Absolute Con-tac-tor Corporation, Beloit, Wis.*

# *"Design almost impossible without Bakelite"*

The panel on which this Con-tac-tor Thermoswitch is mounted is molded of Bakelite because it combines the properties of high electrical and thermal insulation, and is non-warping.

Without Bakelite, the makers say "the design would be almost impossible" and in any other material "the cost would be much higher and its operation much less satisfactory."




The number of electrical devices being improved or perfected through the use of Bakelite is constantly increasing. Perhaps reading our booklet No. 3, "Bakelite Molded," may suggest some way in which you, too, may benefit through the use of Bakelite. Ask for it and a copy will be sent by return mail.

Bakelite engineers and laboratories are ready to cooperate with you whenever you desire.

**BAKELITE CORPORATION**
247 Park Avenue, New York, N. Y.
Chicago Office: 636 West 22nd Street
BAKELITE CORP. OF CANADA, LTD.
163 Dufferin Street, Toronto, Ont., Canada

*¶ We have an industrial motion picture film called "THE STORY OF BAKELITE", which shows the various stages of the manufacture of Bakelite from the raw materials, down to the fabrication of a wide variety of finished products. It is a two-reel subject, prepared on standard width non-inflammable stock. ¶ We will be glad to send a print to any manufacturer who has the proper projection apparatus.*

# BAKELITE

REGISTERED U. S. PAT. OFF.

THE MATERIAL OF A THOUSAND USES

"The registered Trade Mark and Symbol shown above may be used only on products made from materials manufactured by Bakelite Corporation. Under the capital "B" is the numerical sign for infinity, or unlimited quantity. It symbolizes the infinite number of present and future uses of Bakelite Corporation's products."

## Classified Advertiser's Index for Buyers—*Continued*

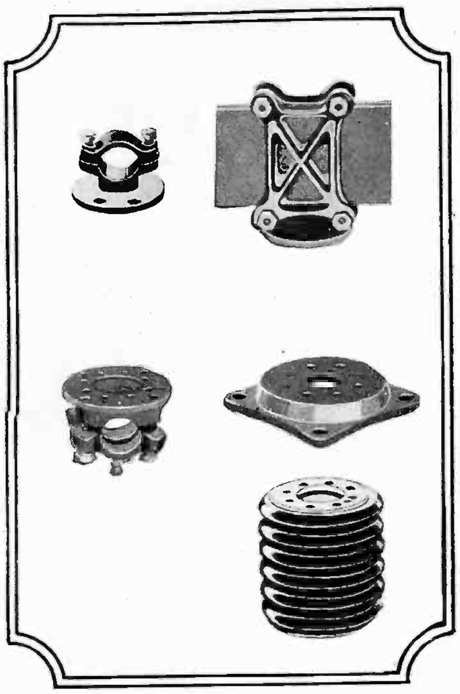
## ALPHABETICAL LIST OF ADVERTISERS



(For classified list of Advertisers see pages 44, 46 and 48.)

Please mention the JOURNAL of the A. I. E. E. when writing to advertisers.

# High Points of Champion Superiority



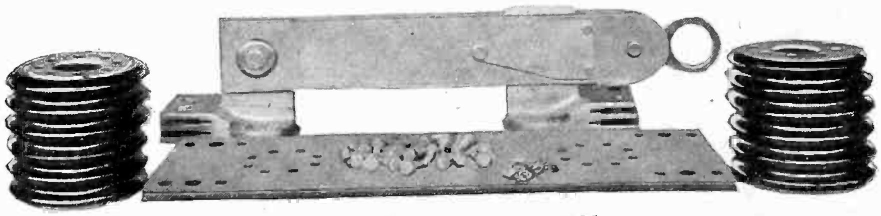
Champion Disconnecting Switch and Component Parts

Champion products are distinguished by their one-piece, porcelain insulators and one-piece, drop-forged hinge and contact clips, two outstanding advantages that assure better service and greater economy.

Engineers specify Champion disconnecting switches and bus supports because they meet their requirements to a greater degree than any other similar products. Substantial superiorities dictate this choice.

Complete interchangeability is one of the high points of these superiorities. Hardware is detachable. Insulators, if broken or damaged, can be quickly removed and easily replaced. It is only necessary to stock the interchangeable insulators, which are all of cementless construction.

Simplicity, dependability, high cantilever strength—these are some of the factors responsible for Champion's notable record for long life. They explain, in large measure, why Champion users have fewer interruptions of service—why their maintenance and operating costs are lower.

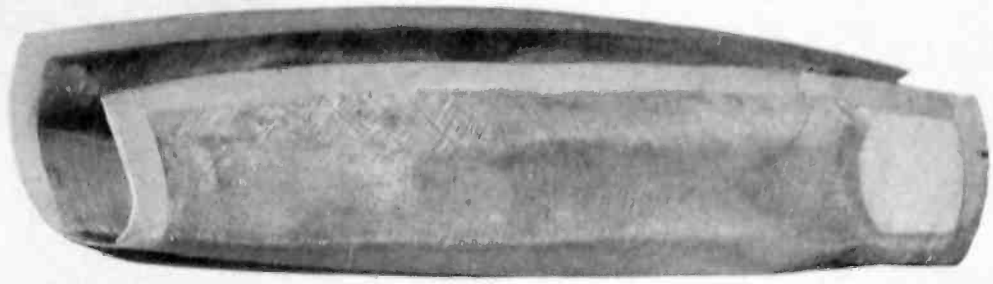


Champion Bus Support Assembly

THE CHAMPION SWITCH COMPANY
550 ABBOTT ROAD—BUFFALO, N. Y.

NEW YORK CHICAGO ATLANTA

## The CHAMPION SWITCH COMPANY



# ELECTROSTATIC SHIELDS

in

# Metropolitan

## High Tension

# CABLE JOINTS

(MURRAY PATENTS)

### HIGH TENSION TESTS

When you use this Metropolitan Cable Joint you know that tests have proven the joint to stand up under abnormal,—yes, under unreasonable—stresses, up to 200.000 volts.

The joint is stronger than the cable!

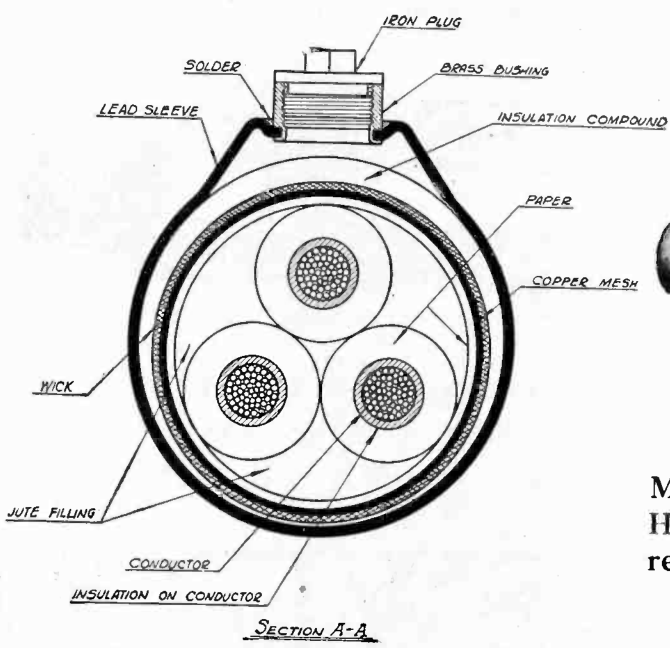
It will stand indefinitely a 50 000 volt potential.

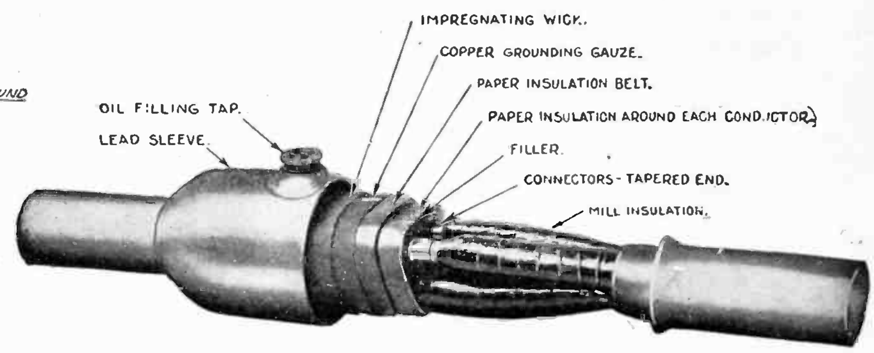
The purpose of the copper gauze stocking is to provide continuous metallic cover around the solid insulation to protect the latter against electrostatic charges, even if some of the petrol compound leaves the joint and still there is a free access through the holes of the gauze for the compound.

The stocking being soldered in spots to the splice establishes a metal sheath around the joint which is the same potential as the lead armor.

### SPECIFY WHEN ORDERING

To supply this joint for any specific type of cable, it is necessary to have a description of the cable on which the joints are to be used, size and shape of the conductor, thickness of insulation around each conductor and the belt, outside diameter and thickness of cable sheath, and also phase potentials.



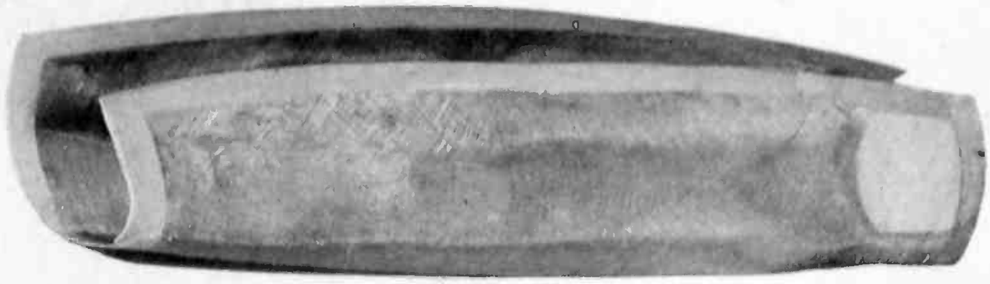

Detailed View Metropolitan Oil-Filled Cable Joint

**Make your specification sheets to call for the Metropolitan H. T. Cable Joint, which is supplied in single packages ready for the splicer.**

# METROPOLITAN DEVICE CORPORATION

MANUFACTURERS OF MURRAY PROTECTIVE DEVICES

**1250 Atlantic Ave., Brooklyn, N. Y.**



# ELECTROSTATIC SHIELDS

in

# Metropolitan

High Tension

# CABLE JOINTS

(MURRAY PATENTS)

## HIGH TENSION TESTS

When you use this Metropolitan Cable Joint you know that tests have proven the joint to stand up under abnormal,—yes, under unreasonable—stresses, up to 200.000 volts.

The joint is stronger than the cable!

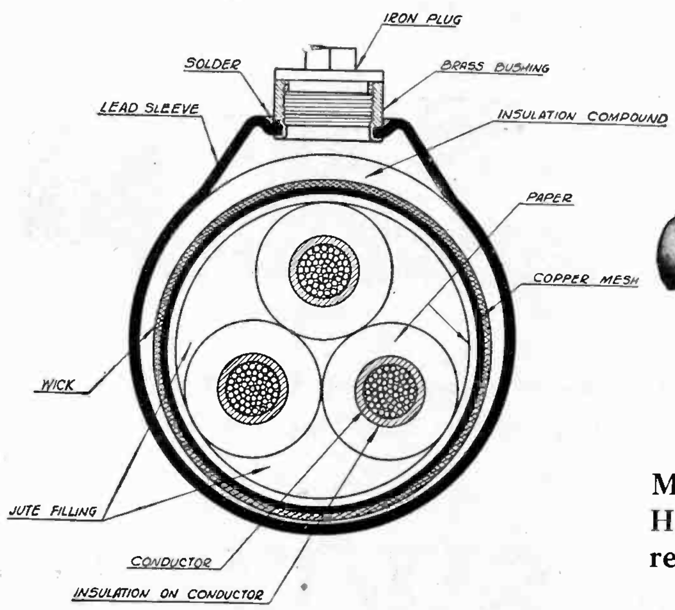
It will stand indefinitely a 50 000 volt potential

The purpose of the copper gauze stocking is to provide continuous metallic cover around the solid insulation to protect the latter against electrostatic charges, even if some of the petrol compound leaves the joint and still there is a free access through the holes of the gauze for the compound.

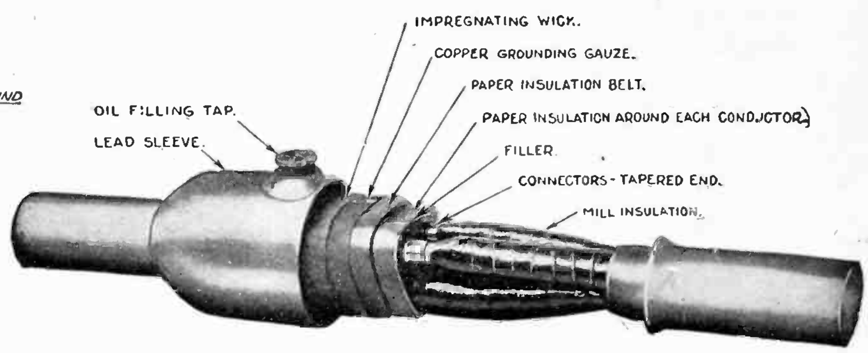
The stocking being soldered in spots to the splice establishes a metal sheath around the joint which is the same potential as the lead armor.

## SPECIFY WHEN ORDERING

To supply this joint for any specific type of cable, it is necessary to have a description of the cable on which the joints are to be used, size and shape of the conductor, thickness of insulation around each conductor and the belt, outside diameter and thickness of cable sheath, and also phase potentials.




SECTION A-A



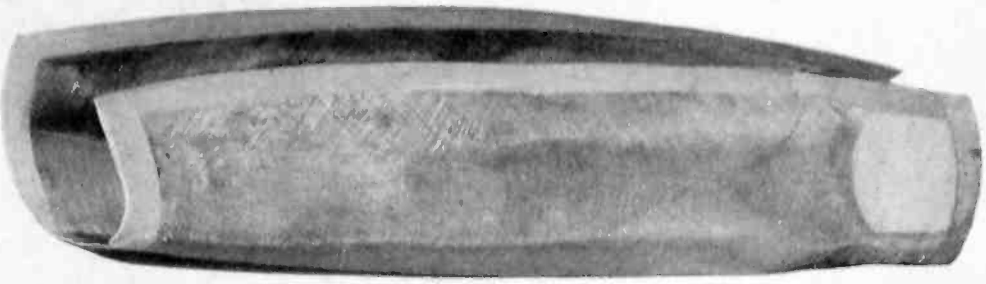

Detailed View Metropolitan Oil-Filled Cable Joint

**Make your specification sheets to call for the Metropolitan H. T. Cable Joint, which is supplied in single packages ready for the splicer.**

# METROPOLITAN DEVICE CORPORATION

MANUFACTURERS OF MURRAY PROTECTIVE DEVICES

**1250 Atlantic Ave., Brooklyn, N. Y.**



# ELECTROSTATIC SHIELDS

in

# Metropolitan

## High Tension

# CABLE JOINTS

(MURRAY PATENTS)

### HIGH TENSION TESTS

When you use this Metropolitan Cable Joint you know that tests have proven the joint to stand up under abnormal,—yes, under unreasonable—stresses, up to 200.000 volts.

The joint is stronger than the cable!

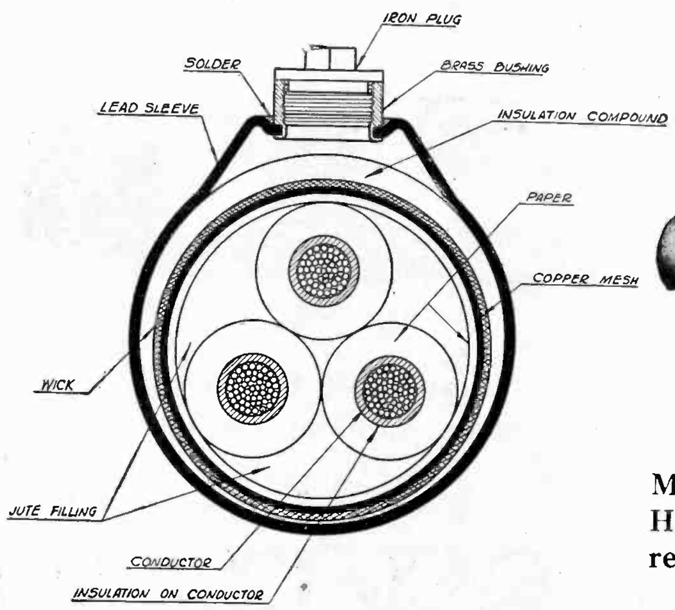
It will stand indefinitely a 50 000 volt potential

The purpose of the copper gauze stocking is to provide continuous metallic cover around the solid insulation to protect the latter against electrostatic charges, even if some of the petrol compound leaves the joint and still there is a free access through the holes of the gauze for the compound.

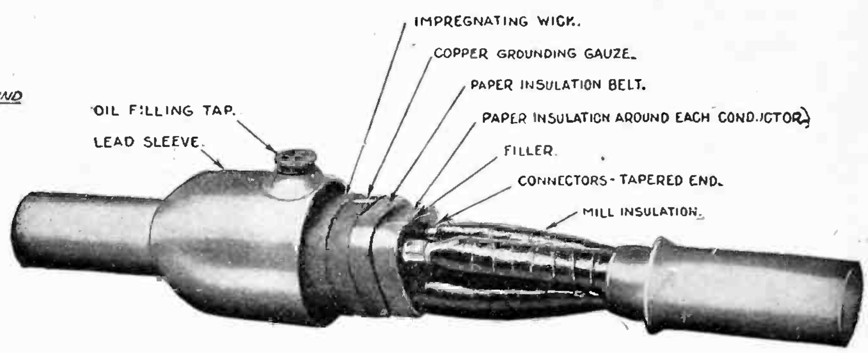
The stocking being soldered in spots to the splice establishes a metal sheath around the joint which is the same potential as the lead armor.

### SPECIFY WHEN ORDERING

To supply this joint for any specific type of cable, it is necessary to have a description of the cable on which the joints are to be used, size and shape of the conductor, thickness of insulation around each conductor and the belt, outside diameter and thickness of cable sheath, and also phase potentials.




SECTION A-A




Detailed View Metropolitan Oil-Filled Cable Joint

**Make your specification sheets to call for the Metropolitan H. T. Cable Joint, which is supplied in single packages ready for the splicer.**

# METROPOLITAN DEVICE CORPORATION

MANUFACTURERS OF MURRAY PROTECTIVE DEVICES

**1250 Atlantic Ave., Brooklyn, N. Y.**