Places to be Visited During the A. I. E. E. Winter Convention

1. Teletypewriter Operating Room of the American Telephone & Telegraph Company

2. Hudson Avenue Station of the Brooklyn Edison Company

3. Outdoor Lighting Demonstration Model of City Block at the Edison Illuminating Institute

4. 160,000-kW Turbo-Generator at the Hell Gate Station of the United Electric Light & Power Company

5. One-inch Meter Gear Magnified for Inspection in the Westinghouse Meter Works

6. Sound Picture Projector at Bell Telephone Laboratories

7. Carrier Telephone Equipment at Bell Telephone Laboratories
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MEETINGS

of the

American Institute of Electrical Engineers

WINTER CONVENTION, New York, N. Y., January 28-February 1, 1929

REGIONAL MEETING, Middle Eastern District No. 2, Cincinnati, Ohio, March 20-22, 1929

REGIONAL MEETING, South West District No. 7, Dallas, Texas, May 7-9, 1929

SUMMER CONVENTION, Swampscott, Mass., June 24-28, 1929

PACIFIC COAST CONVENTION, Los Angeles, Calif., September 3-6, 1929

REGIONAL MEETING, Great Lakes District No. 5, Chicago, Illinois, December 2-4, 1929

For future A. I. E. E. Section Meetings see page 72.

MEETINGS OF OTHER SOCIETIES

New York Electrical Society, Engineering Societies Building, New York, N. Y., January 9, 1929

The American Society of Civil Engineers, Annual Meeting, Engineering Societies Building, New York, N. Y., January 16-18, 1929

The American Institute of Mining and Metallurgical Engineers, Annual Meeting, Engineering Societies Building, New York, N. Y., February 18-21, 1929
IS Your Section a Success?

We can hardly expect to find complete unanimity as to what constitutes success but all will agree that a section which keeps high the enthusiasm of its members is well on its way to winning the laurel crown.

What activities provide the fuel that feeds the fires of enthusiasm? Some of them were well set forth by Mr. Potter, Chairman of the St. Louis Section, and reported on page 927 of the December JOURNAL. He puts his finger on the MAJOR OPPORTUNITY—THE DEVELOPMENT OF THE INDIVIDUAL ENGINEER. A man of forty is ordinarily a more valuable member of society than a youth of twenty because he has had the benefit of growth based on experience and contact with his associates. Section activities offer particularly rich opportunities for growth but they come mainly through personal performance, such as carrying program or committee responsibilities. It is the consciousness of the resulting growth, of the spreading horizon and clearer vision, that stirs the enthusiasm.

A study of the programs of the sections seems to indicate that only few reflect a recognition of the opportunity referred to. As a means for providing lecture platforms and forums for technical or more popular subjects, many of the sections could not be improved upon, and often the attendance shows that a popular chord has been struck. Lecture or demonstration meetings have a very definite and valuable place in section activities. They are informative, they help to interpret engineering work to the public and they keep some members interested who otherwise might not be. However, in terms of the larger possibilities they only scratch the surface and in so far as the programs bring only a small executive committee into action, the personal activity benefit is very limited.

Experience teaches that that executive committee is serving best which does no more than decide on policies and that delegates practically all activities to well chosen committees thereby giving the latent talents of the younger members particularly an opportunity for play. Such committees could include some or all of the following: program, membership, reception, finance, graduates follow-up, publicity, discussion, prizes, cooperation with Branches, attendance, civic reports or problems.

The general plan should be mapped out so these committees will have something to do and so that "something" will offer a maximum of personal contacts and opportunities for personal development. This does not require any strain on the imagination. The size of the section and other local conditions will determine the best committee plan.

Participation in such activities helps the engineer to fit himself for larger opportunities, for national committee service, for greater usefulness in civic organizations, as well as for more effective service in his daily work. He will be an enthusiastic engineer and citizen.

A section made up of enthusiastic members is a successful section. An organization made up of successful sections is a power that brings credit and helpfulness to the entire profession.

R. F. Schuchardt
President.
The Institute Publications.

What Changes Should be Made?

The question as to what can be done to improve still further the Institute publications was discussed at length during the recent meeting of the Publication Committee. The policy in effect since January, 1928, of publishing the TRANSACTIONS quarterly and printing papers in abridged form in the JOURNAL, with complete copies available upon request of those desiring more detailed information, has solved many of the physical problems of the committee. As a further development of the committee's work it is now proposed to consider means of making the contents of the publications more valuable to the membership. It is felt, for example, that the JOURNAL would be more widely read and referred to if in addition to the present contents, special features were added in the hope that they would be of general interest to the entire membership.

Some of the suggestions already under consideration by the committee are:

(a) That a section in the monthly JOURNAL be devoted to a review of progress in the art of electrical engineering. Under this or possibly a more appropriate heading could be included short articles on achievements in engineering and related fields. Some of the articles might be abstracts from other publications, and others might be important news items of interest to electrical engineers. Such a digest could give a fairly good perspective of the general progress in engineering and would stimulate interest, broaden the usefulness of the JOURNAL, and increase the number of readers.

(b) That space be allotted in the JOURNAL for correspondence. This would afford an opportunity to present brief discussions on topics of interest. Under this heading short comments on Institute activities could properly be included, such as the work of the various technical committees, the Institute Standards, Section and Branch work, and many other matters of special interest to the membership.

(c) Publication of an article each month on a timely subject by some prominent scientist would be a splendid addition to our JOURNAL if it could be accomplished.

(d) A question-and-answer department might be established in which Institute members could submit questions of interest to electrical engineers, and answers could be solicited from other members for publication in a later issue.

The features briefly mentioned are merely illustrations of some of the ways in which the Institute Publications can be made more valuable, and no doubt there are other plans that will accomplish the same purpose. An invitation is therefore extended to all the members to forward to Institute headquarters, New York, not only comments and criticisms on the suggestions presented here, but also to submit in a specific and concrete form any other recommendations they may have to offer. The members should avail themselves of this opportunity to express their opinions as to the manner in which this most important activity of the Institute will more fully meet their needs.

It should be understood that substantial improvements cannot be made without corresponding increase in expense, and therefore could not be put into effect until after the committee had made its definite recommendations to the Board of Directors with an estimate of the cost, followed by approval of the Directors accompanied by favorable action upon the necessary appropriation. It is hoped by the committee that a sufficient number of replies containing specific suggestions will be received by February 1 to warrant the preparation of a preliminary report to the Board of Directors.

Publication Committee,
W. S. Gorsuch,
Chairman

Carrying
Peak Loads

On most utility systems the costs of carrying the peak load are high, and many methods have been suggested to reduce them. The best method is to study load distribution and sell energy under conditions that reduce peak load, but there is a limit to this method that is soon reached on many properties. Then it becomes necessary to study peak loads from the point of view of maximum system economy in power generation.

At the recent A. S. M. E. convention in New York Prof. A. G. Christie discussed the peak-load problem and indicated many economic and operating advantages in favor of the use of the steam accumulator. These held especially well for systems with modern stations and large peak loads of short duration. Essential system savings are made by having low fixed charges on peak-load facilities and low total costs on base-load plants. A combination of peak-load and base-load stations gives the minimum system power-production costs.

It is unsafe to generalize on the use of the steam accumulator as the cheapest and best peak-load-carrying device. Systems are different and have variations in service standards, in generating-plant reserve and in station first costs and operating costs. But just because the idea of using a steam accumulator is new is no reason for rejecting it for peak-load operation. Even the Diesel engine with its high first cost has been advocated as a peak-load-carrying agency on some systems. The logical procedure is to make a study of each property concerning the utilization of all methods and devices to reduce power costs and then to use the one that offers the most possibilities.—Electrical World.
Ionization Studies in Paper Insulated Cables—II

BY C. L. DAWES*, H. H. REICHARD† and P. H. HUMPHRIES‡

Synopsis.—The power dissipated as ionization loss in impregnated-paper-insulated cables is much more harmful than the power dissipated in the solid dielectric. The paper presents methods of separating this ionization loss from the total dielectric loss. This separation is based on the assumption that the power loss in the solid dielectric varies as the square of the voltage, even above ionization. To verify this assumption, samples of wood-pulp paper, impregnated with three different cable compounds under such conditions as to remove nearly all traces of occluded gases, were made up. These tests showed that up to 300 volts per mil, and at room temperature, the power factor and capacitance are substantially constant, and that the power loss varies as the square of the voltage.

Measurements of the electrical properties of ionized air films showed that above the ionization voltage the power loss is a linear function of the voltage. Power curves of cables can thus be analyzed into two components; one giving the loss in the solid dielectric and one giving the loss in the ionized air films. This analysis is verified with glass cable models. The power-factor curve and the energy current of the cable can each be analyzed into three simple components and extrapolated if desired. The character of the capacitance curve, which varies in different cables, is determined by the positions and thicknesses of the gas films.

PROCEDURE

The dielectric-loss measurements which are given in this paper were made on a bridge, the principle of which was given in Part I of the paper.† This bridge will be described shortly in a paper‡ before the Institute. The dielectric medium of paper-insulated cables consists of impregnated paper, the impregnating material, and thin gas films which may be air or gases from the impregnating material all in series. In this article, the insulating paper and the impregnating material will be referred to as the solid dielectric and the air and vapors as gases.

The variation of the dielectric characteristics of the solid material with voltage is quite different from the variation of the dielectric characteristics of the gaseous films with voltage. This fact provides a means of separating each of these two losses from the total loss in a cable. This is important, for, as is well known, the energy which is dissipated in the gas films is very insidious and destructive in its effects on the dielectric; hence it is much more harmful to the life of the cable than the energy dissipated in the solid material.

DIELECTRIC CHARACTERISTICS OF THE SOLID MATERIAL

The separation of the losses within the cable dielectric can be accomplished only when the dielectric characteristics of cable paper, impregnated under conditions that remove essentially all occluded gases, are known.3,‡ Samples for this purpose were made up consisting of 12 circular sheets of impregnated paper. These were tested between flat circular electrodes, of 11.9-in. (28.4-cm.) diameter. Special apparatus was constructed permitting both the paper and compounds to be dried and treated by vacuum and temperature separately, and the sample to be prepared without occluding gases.

Three different compounds were chosen for impregnating the paper and producing test samples. These compounds were supplied by three different cable manufacturers. The first compound is a light oil, specially prepared so that amorphous constituents are removed, and is designated as compound A; the second is a paraffin-base cylinder-oil compound of medium viscosity at room temperature; the third is a petroleum base, containing a small percentage of rosin, and has considerable viscosity at room temperature.

FIG. 1—CHARACTERISTICS OF WOODPULP PAPER IMPREGNATED WITH COMPOUND A, FREQUENCY 60 CYCLES, TEMPERATURE 19.5 DEG. CENT.

Tests were made over a considerable range of frequencies and temperatures, but for the purpose of this paper, the results obtained at room temperature and at a frequency of 60 cycles per second only are necessary. The power factor, the dielectric loss in milliwatts per cu in. and the dielectric constant of Compound A as functions of voltage gradient are given in Fig.1. Similar characteristics were obtained for the other two compounds. In Fig. 1 there is no indication of an ionization voltage. The power factor remains essentially constant at all voltages. There is a very slight increase in capacitance which, up to 300 volts per mil, is less than 1 per cent. These same conditions were found to hold with the other two samples. Hence it...
appears very probable that with the most careful im-
pregnation, removing nearly all traces of occluded air,
at gradients up to 300 volts per mil and at room tem-
perature, the power factor and capacitance of impreg-
nated paper are essentially constant; the power loss
varies as the voltage squared.

Dielectric Characteristics of Gas Films

Considerable investigation of the electrical properties
of air films has been conducted independent of
cable research. The air film is tested under conditions of
"restricted ionization," the current flow being limited
by a slab of Pyrex glass. In Fig. 2 are given the following
characteristics of a 0.3745-mm. (14.75-mil) air film as a
function of current: the voltage gradient, and the
power loss and the capacitance per cu. cm. These
characteristics show that the voltage gradient below
ionization is proportional to the current. After ioniza-
tion has begun, the rate of increase of voltage gradient
becomes less and less until the voltage gradient ulti-
mately becomes substantially constant. After ioniza-
tion begins, the relation between power loss and current
and between capacitance and current are nearly linear.

Power Characteristics of Gas Films Distributed
in Cable Dielectric

Within the cable dielectric, the gas films are dis-
tributed indiscriminately throughout the insulation.
Each of these gas films will become ionized as soon as its
voltage gradient exceeds a certain critical value. The
power loss characteristic of each film then becomes
linear, similar to the characteristic shown in Fig. 2.
Consider, five concentric gas films, a, b, c, d, and e,
distributed radially outwards through the insulation,
gas film a being adjacent to the copper and e adjacent to
the sheath. Assume that the voltage on the cable is
being raised, and that the change in capacitance of the
cable is so small that the current is practically propor-
tional to voltage. Below the ionization voltage, the
loss in the gas films is zero. When the voltage gradient
across a reaches its critical value at $E_1$, (Fig. 3), the
power loss in this film will be linear with further increase
in voltage, as shown by the straight line a. As the
voltage is further raised, film b becomes ionized at
voltage $E_2$ and the relation of its power loss to voltage
is given by the straight line b. In a similar manner,
films c, d, and e ionize at voltages $E_n$, $E_2$, and $E_3$, and
their power characteristics are given by lines c, d, and e.

The total loss at any voltage is found by adding the
ordinates of the curves.

In the actual cable, where the air films are very thin,
the power curve up to voltage $E_3$ will be concave
upwards. Above voltage $E_3$ (point f on curve) the air
films have all become ionized and the power curve
becomes linear.

Analysis of Cable Power-Curve

Fig. 4 shows the three well-known characteristic

![Figure 3: Power Loss in Cable Dielectric Due to Successive Gas Films](image-url)

![Figure 4: Characteristic Curves of Cable No. 12](image-url)
Curves of a 10-ft. length of 500,000-circ. mils, 16/64-in. paper, 8/64-in. lead, single-conductor cable with copper shielding tape. The power curve \( P \), the power-factor curve and the capacitance are plotted against kilovolts. An examination of these curves shows that this cable has some ionization.

In Fig. 5 this same power curve \( P (a\,b\,d) \) is plotted on logarithmic paper. Up to 12.5 kV., the ionization voltage, this logarithmic power characteristic is a straight line having a slope of 2.0. This shows that below the ionization voltage the power loss varies as the square of the voltage. This loss must all occur in the solid dielectric, so that this portion of the curve confirms the results obtained with the compounds and given in Fig. 1. A discontinuity occurs at point \( b \), the ionization voltage, and the characteristic from \( b\,e\,d \) now becomes a broken line. If it be assumed that above the ionization voltage the power loss in the solid dielectric still continues to vary as the square of the voltage, the loss in the solid dielectric will with little error be given by the line \( b\,c \) where \( b\,c \) is the continuation of line \( a\,b \).

The difference between the curves \( a\,b\,e\,d \) and \( a\,b\,c \) must be the power loss in the ionized gas films. This difference is transferred and plotted in Fig. 5. It is a linear curve and its equation is of the form

\[
P_i = K_1 (E - E_0)
\]  

where \( K_1 \) is the slope of the line \( = \tan \beta \), Fig. 4, \( E \) the voltage, and \( E_0 \) the intercept of the line with the voltage or \( X \)-axis. \( K_1 \) \( E_0 \) is the intercept of the line, when extended, with the power or \( Y \)-axis. Likewise, the dielectric power curve \( P_d \) is plotted in Fig. 4. Its equation is of the form

\[
P_d = K E^2
\]  

The equation for the total power-loss curve \( P \)

\[
P = K E^2 + K_1 (E - E_0)
\]

It is to be noted in Fig. 4 that the ionization curve \( P_i \), obtained analytically, is identical in character with the curve of Fig. 3, obtained synthetically. The power curves of a large number of cables have been similarly analyzed and the same relationships have been obtained in every case. In Table I are given the constants of Cable 12, and of three other cables having varying degrees of ionization.

![Fig. 5—Logarithmic Plot for Fig. 4](image)

\[\begin{array}{cccc}
\text{Cable} & 14 & 12 & 8,
\text{A} \\
\hline
K & 1.21 \times 10^{-10} & 2.38 \times 10^{-8} & 4.05 \times 10^{-4} \\
K_1 & 1.67 \times 10^{-10} & 8.8 \times 10^{-2} \\
E_g & 1.67 \times 10^{-11} & 8.8 \times 10^{-3} \\
E_0 & 1.6 \times 10^{-12} & 8.8 \times 10^{-6} \\
\end{array}\]

This tabulation shows that the cables with highest ionization loss have the largest values of the ionization constant \( K_i \), which is the slope of the ionization curve. (See Fig. 4.) Cable A, whose value of \( K_i \) is 6.9 times that for Cable 12, has a much smaller dielectric-loss constant \( K \).

In the opinion of the authors, the constants \( K, K_1 \) and \( E_0 \) are criteria for cable quality. The foregoing analysis gives a simple method for the determination of the power dissipated in cables for voltages far in excess of values determined experimentally. It is merely necessary to extrapolate two straight lines, the line \( a\,b\,c \), Fig. 5, to obtain the power loss in the solid dielectric and the straight line \( P_i \), Fig. 4, to obtain the power dissipated in ionization.

**Cable Models**

In order to verify the foregoing method of analysis, it was deemed advisable to apply them to cable models composed of Pyrex glass tubing and intervening air spaces. With such models, it is possible to determine the dielectric properties of the glass alone, which leaves only one unknown quantity,—the dielectric properties of the gas film. Data taken with two such models, one having a single concentric air space and another having three such air spaces in series verified in every particular the results obtained with actual cables. In each case the ionization power-loss curve becomes linear, after complete ionization has been attained.

**Power-Factor Curve**

It follows from the equation (3) that the power factor

\[
P. F. = \frac{K E^2 + K_1 (E - E_0)}{E^2 C \omega}
\]

where \( \omega \) is 2\( \pi \) times the frequency. Since the variation of capacitance \( C \) with voltage is small, equation (4) gives a means of extrapolating the power-factor curve without actually carrying the cable to the high stresses that would be necessary to determine the curve experimentally.
If equation (4) be differentiated with respect to voltage, it can be shown that if the term $E \frac{dC}{dE}$ is small compared with $2C$, the point of maximum power factor occurs when $E = 2E_0$. This condition is closely approximated in Cable 12, Fig. 4.

Equation (4) may be divided into three terms.

$$P. F. = \frac{K}{C \omega} + \frac{K_1}{E \omega} - \frac{K_1 E_0}{E^2 C \omega}$$  \hspace{1cm} (5)

Each of these terms represents a simple curve. These component curves are plotted in Fig. 6, which also shows the resultant power-factor curve extrapolated far beyond the data obtained experimentally.

CURRENT CURVE

The energy current

$$I = \frac{P}{E} = \frac{KE}{C} + K_1 - \frac{K_1 E_0}{E}$$  \hspace{1cm} (6)

Neglecting change in capacitance, the first term is proportional to the voltage and is the solid dielectric energy current. The second and third terms are the two components of the ionization energy current. The ionization energy current is a rectangular hyperbola having the current axis as one asymptote and a horizontal line $+ K_1$ units from the voltage axis and parallel to it as the other asymptote. The ionization energy current thus approaches $K_1$ as a limit.

CAPACITANCE CURVES

The curve showing the increase in capacitance in cables after ionization begins may take three different forms. It may be practically a straight line, it may be concave upwards, or it may be concave downwards, Fig. 4. Fig. 2 shows that after ionization begins, the increase in capacitance of ionized air films is substantially linear.

In the cable, the ionized gas films are in series with the solid dielectric and in series with one another. Hence the resultant capacitance is a reciprocal relationship that is not simple. The significance of the capacitance curves of cables will be given later after obtaining further experimental data.

CONCLUSIONS

1. The power dissipated as ionization loss in cable insulation is more harmful than the power dissipated in the solid dielectric.
2. At room temperature and up to from 250 to 300 volts per mil, the power factor and capacitance of cable insulating paper impregnated with typical compounds are essentially constant with variation in voltage provided nearly all occluded gas has been removed.
3. The relation of power loss to voltage in thin gas films is substantially linear for voltages above the ionization voltage.
4. In single-conductor cable insulation above the ionization voltage the relationship of ionization power to voltage is a curve which is concave upwards until all the gas films are ionized. With further increase in voltage the relationship becomes linear.
5. It is possible to analyze the power curve of cables into two components, one giving the loss in the solid dielectric, and the other giving the loss due to ionization. The ionization power curve so determined becomes linear.
6. It thus becomes possible to express the power curve by a simple equation and to extrapolate it if necessary.
7. The constants of the power equations may be criteria of cable quality.
8. The analysis of power loss into two components one giving the power dissipated in the solid dielectric and the other giving the power dissipated in ionization, is confirmed by tests made with glass cable models.
9. It becomes possible to express the power-factor curve by a simple equation, to analyze it into three simple components, and to extrapolate it.
10. The energy current of a cable can be analyzed into three simple components, a term nearly proportional to the voltage, a constant term, and a term inversely proportional to the voltage.
11. The character of the capacitance curves depends on the thickness and distribution of the gas films within the cable insulation.

The authors are indebted to D. W. Roper, F. M. Farmer, and W. F. Davidson, members of the Paper-Cable Research Committee, for their suggestions and counsel during the progress of this investigation; to the several cable companies for their cooperation in supply-
ing cable samples and compounds; and to Prof. H. E. Clifford of the Harvard Engineering School for his advice and suggestions during the progress of these investigations.

Bibliography


Synopsis.—This paper presents a brief outline of the development and application of magnetic analysis for the nondestructive testing of iron and steel and their products. The subject is treated under the following headings: Historical development, Experimental results, Practical commercial applications, and Conclusion.

Introduction

The use of electrical methods for the measurement of non-electrical quantities, such as temperature, displacement, time, etc., is quite common. In the majority of such applications, these methods provide the most convenient and accurate means for making the desired determinations. The time is approaching, if indeed it has not already arrived, when magnetic analysis should be included in the list. The term “magnetic analysis” has been adopted to distinguish magnetic tests made with a view to their interpretation in terms of structure, mechanical characteristics, or soundness of ferrous materials from those made solely for the purpose of determining magnetic properties as such. The term connotes, therefore, not only the process of testing but also the analysis of the results from the point of view of mechanical characteristics. Although the development of such magnetic testing methods has not by any means reached a satisfactory state of perfection, their practicability has been demonstrated sufficiently well at least in a few cases to warrant the expectation that they will ultimately have a much wider application and thus meet the need which is becoming more and more urgent for a reliable nondestructive testing method.

That there is a close connection between the magnetic properties of ferrous materials and their other physical properties has long been recognized, and many investigations have been made for the purpose of discovering the nature of the connection. It is only in recent years, however, that investigations along this line have been undertaken with the definite object in view of developing practical magnetic testing methods for routine inspections and for the study of the phenomena associated with the thermal and mechanical treatment of steel.

It is the purpose of the present paper to trace briefly the development of magnetic analysis, to indicate its present status and to suggest lines along which further investigation might profitably be directed.

Historical Development

Pioneers in the development of magnetic analysis were Burrows and Fahy, who, in the latter part of 1911, undertook at the Bureau of Standards under the joint sponsorship of the Bureau and the Pennsylvania Railroad, an investigation on spring steel. This investigation was continued over a period of about five years, during which time its scope was somewhat extended to cover preliminary experiments on the applicability of magnetic analysis to various forms of steel products. Three papers were published giving the results of this investigation. Burrows also published a paper in which the experimental evidence on the relationship between magnetic and mechanical properties recorded prior to 1916 was summarized. From the evidence presented he concluded that there was every reason to believe that the two sets of properties are intimately connected and that practical research and inspection methods could be developed. During this same period other papers were published having a definite bearing on the problem.

In 1918 the American Society for Testing Materials authorized the formation of a technical committee to be known as Committee A-8 on Magnetic Analysis with Dr. Burrows as its Chairman. This committee was composed initially of investigators already working in the field, but from time to time its membership...
has been strengthened by the addition of members who have subsequently become actively interested in the development of magnetic analysis. The committee has functioned primarily as a clearing house for the interchange of ideas and experience among its members who have carried on individual investigations on various phases of the subject; but it has itself also carried out a number of investigations of a general and fundamental nature. A considerable proportion of the literature available on the subject of magnetic analysis has been contributed by members of this committee, either independently or through the auspices of the committee.

A second major source of technical literature is papers published by the Bureau of Standards. In general, the work of the Bureau has been directed along the more fundamental lines although some work on practical applications has been carried out.

Worthy of special mention is the work of de-Forest. This ingenious experimenter has confined his attention in general to the development of methods employing alternating currents, and has brought out a number of applications of considerable interest and wide applicability.

Most of the work definitely belonging in the field of magnetic analysis has been done in the United States. There has however, been some interest in other countries. In this connection the work of Honda in Japan, and of Fraichet in France, should be especially mentioned. Honda has employed magnetic methods in the study of structural transformations occurring during heating and cooling, and, with his associates, has published a great many papers on the subject. He is probably the first one to use the term "magnetic analysis" but he employed it, in a limited sense, to denote only the single phase in which his work is preeminent. The work of Fraichet has consisted mainly of the study of relations between magnetic and elastic properties with special reference to the determination of the elastic limit by magnetic means.

Experimental Results

In discussing the results of investigations in the field of magnetic analysis, it will be found convenient to consider the following topics: Fundamental correlation, tests for general quality, detection of flaws, alternating-current methods, and thermomagnetic analysis.

Fundamental Correlation. In his paper published in 1916, on the correlation of magnetic and mechanical properties of steel Burrows enunciated what he believed to be the fundamental principle of magnetic analysis as follows: "There is one and only one set of mechanical characteristics corresponding to a given set of magnetic characteristics, and, conversely, there is one and only one set of magnetic characteristics corresponding to a given set of mechanical characteristics." He goes on to say: "Although there is no evidence to refute the preceding rather broad statement, the utility of this generalization is decidedly limited by the complexity of the relations due to the large number of variables and the lack of sufficient quantitative data. Even with these limitations, magnetic testing, in conjunction with mechanical testing, may be expected to be of considerable value in determining mechanical properties." Unfortunately, some have made extravagant claims based on the first part of this statement while overlooking entirely the caution as to the inherent limitations due to the complexity of the relationships involved and the lack of fundamental data. As a rule, such claims are detrimental rather than advantageous, as failure to substantiate them has a tendency to discredit the whole proposition and deter some from entering the field.

In the attempt to discover fundamental correlations between the two sets of properties, it has been the general practise to make magnetic measurements by some well-known testing method on specially prepared samples. The results of these tests are then correlated either with the heat treatment or with the results of mechanical tests subsequently made on the same samples. Such correlation is not easy because the magnetic properties are in themselves complex. Attempts have been made to simplify the problem by using certain critical values, such as maximum permeability, induction corresponding to a specified value of magnetizing force, residual induction, coercive force and the like, as criteria. These attempts have not been very successful and it has been found necessary to consider the magnetic properties as a whole in drawing conclusions. Another lesson that has been learned is that it is generally not safe to draw too definite conclusions from the results of correlating magnetic properties with heat treatment alone, for we can never be assured that some accidental factor has not entered into the heat treatment and thus produced mechanical properties not normally associated with the specified heat treatment. Too much emphasis cannot be laid upon the necessity for proper metallurgical control in correlation investigations. The results of experiments in which this factor has not been adequately cared for must necessarily have but limited value in the quantitative sense.

Space does not permit a detailed discussion of the results of all the investigations recorded in the technical literature. These results, however, are in the main concordant and the following general conclusions may be drawn:

1. Any treatment which alters to a measurable extent the mechanical properties of a piece of steel at the same time appreciably alters its magnetic characteristics, though not necessarily to a corresponding degree.

2. The nature of the effect of various treatments on magnetic properties is generally similar for different types of steel; but this is not a universal rule, as notable exceptions have been observed.
3. Although the magnetic and mechanical properties appear to be functions of the same variables,—that is, composition and structure,—there are certain secondary effects, notably that of mechanical strain, which exert an influence on the magnetic properties out of all proportion to their effect on the mechanical properties. This is an important point which should never be overlooked in the search for laws of correlation.

Tests for General Quality. In their final application, tests for general quality must be applied to manufactured products of various shapes and sizes, and for this reason, a solution of the problem calls for a considerable amount of ingenuity in the design of apparatus for the testing of irregular shapes. In this type of application it should not be necessary to await the establishment of definite laws of correlation, for if pieces of steel having identical magnetic properties also have identical mechanical characteristics, it should only be necessary to compare the pieces under test magnetically with one known to have the requisite mechanical characteristics and which may therefore be taken as a standard of quality. A considerable number of investigations have been carried out as to the applicability of magnetic analysis for the testing of various products on this basis. Among the products investigated are cutlery, small tools, ball bearing races and balls, small case-hardened chain, and twist drills.

Encouraging results have been obtained in the majority of cases, but the obstacle in the way of practical application on a commercial basis is usually the effect of secondary influences as noted above. In other words, the test generally fails on the side of safety, but leads to the rejection of an excessive amount of good material. This should not be considered to imply that the outlook is hopeless, but only that the problem is not so simple as it might appear at first glance. The need for a satisfactory nondestructive test is so great that efforts in this direction should not be abandoned until every possibility has been exhausted. And the fact that successful application has been accomplished in even a few cases leads to the conviction that the general problem is not impossible of solution.

The Detection of Flaws. A large proportion of the failures of steel parts in service is due not to poor general quality of the materials but to the presence of hidden flaws or defects. It is for the detection and location of hidden flaws that a reliable nondestructive test is most needed. For this reason, a considerable amount of attention has been given to this phase of magnetic analysis, and at least one successful application has been recorded. A large number of different products such as steel rails, rifle-barrel steel, rifle barrels, ball-bearing races, and welded chain have been the subject of study. One of the most important problems is that of the test of welds, for the applicability of welding is seriously limited by the lack of a suitable test for quality of the weld.

The usual test for the detection of flaws consists in an exploration for the determination of the degree of magnetic uniformity of the specimen. Abrupt changes in magnetic permeability may be the result of flaws; on the other hand, they may indicate the presence of internal strain or may result from relatively unimportant surface conditions. The problem therefore, at least in part, is to discover some way of differentiating between the indications due to strain and those due to actual flaw. A partial solution has been found in the fact that variations due to strain are less in magnitude under high values of magnetizing force than for low or medium values. Unfortunately, the sensitivity to the effect of real flaws is materially decreased when high magnetizing forces are used. A great deal of work remains to be done on this important problem.

Alternating Current Methods. For routine inspection on a commercial scale, alternating current methods appear to have some practical advantages. The quantitative interpretation of the magnetic results is generally more difficult than for the ordinary direct-current methods, due primarily to the phase relations involved. With standardized equipment and arbitrarily chosen limits, however, these difficulties are of minor importance.

During the course of an investigation on high-speed steel carried on by Committee A-8 of the A. S. T.M., several methods were studied by different members of the committee. Although the results of the investigation left much to be desired in the way of definite correlations, the alternating current methods developed by deForest seemed to offer the most encouraging field for further study. Two types of inspection have been developed. In the earlier form, the sample under test is compared with a standard by means of an inductance bridge using a separately excited a-c. galvanometer as a detector. By adjusting the phase of the current in the galvanometer field with respect to the induced voltages, it is possible to obtain readings on the galvanometer which depend mainly on the difference in permeability of the two specimens, the difference in hysterisis loss, or various combinations of the two factors. Thus it may be seen that in addition to speed in operation, the method offers great flexibility.

The second method consists of the use of an oscillograph, preferably of the cathode ray type, with which the magnetic differences are shown graphically and appear as closed figures or loops of various shapes and sizes. By adjusting the phase of the time coordinate, it is possible to emphasize the difference in any particular part of the hysteresis loop. This method, first adapted to magnetic analysis by deForest, has been discussed with respect to its more theoretical aspects by Spooner. From the evidence already presented, it would appear that these two types of alternating-current testing provide exceedingly valuable methods for the application of magnetic analysis both in the laboratory and on a commercial scale.
Thermomagnetic Analysis. Thermomagnetic analysis consists of the study of magnetic changes which occur during heating or cooling of a specimen. While not properly classed as a nondestructive test, thermomagnetic analysis should be considered as one phase of magnetic analysis. Its development and application have received little attention in the United States, but in the hands of the Japanese investigator Honda it has proved to be an exceedingly valuable tool for the study of the phenomena associated with the heat treatment of steel. Apparatus for the application of thermomagnetic analysis has been set up recently at the Bureau of Standards and it is hoped that this phase of magnetic analysis will be developed further.

Practical Applications. The methods of magnetic analysis have found some practical application both in the laboratory and in commercial routine inspection. In the laboratory, the applications have been of two kinds. As a research tool for the study of the constitution and structure of ferrous materials, it has found use which will undoubtedly be extended. Indeed, it may well be that in this connection magnetic analysis will find its most valuable application. Magnetic tests have been used also in the laboratory in conjunction with long-time mechanical tests, such as endurance tests and tests upon the effect of elevated temperatures on mechanical properties. In tests of this sort, it is of great importance to be sure that all of the specimens used are initially in the proper condition and that they contain no flaws. Under such circumstances, the rejection of some good material is of less consequence than the acceptance of unsatisfactory material, since the results on such material may be not only valueless but even misleading.

In the realm of commercial routine inspection there are three outstanding examples; the inspection of small case-hardened chain, the testing of small heat-treated forgings, and the examination of steam turbine bucket wheels. The first two are applications of the two types of alternating-current tests developed by deForest for the American Chain Company. The third mentioned method is a d-c. exploration test developed by the General Electric Company with the collaboration of Dr. Burrows.

In the testing of case-hardened chain, the inductance bridge method is used. The phase of the galvanometer field current is so adjusted as to give readings which experience has shown are proportional to brittleness. Readings which lie outside of certain specified limits indicate material which is either too brittle or too soft. This method for the control of the heat treatment of the manufactured product has been in use for over five years, several thousand individual specimens being inspected each day.

For the inspection of small heat-treated forgings, the oscillograph method is utilized. Experience has shown what form of loop indicates a satisfactory condition of the material. Variations from this form, greater than a certain amount, indicate defective material.

One form of apparatus for testing turbine bucket wheel forgings is shown in Fig. 1. The forging under test is rotated on its own axis between the poles of an electromagnet which can be adjusted to any given position on the radius of the circular forging. The magnetic flux passes across the air-gap between the pole tips, in which air-gap the disk is rotated. Any variation in the magnetic quality of the material in this air-gap is indicated by means of a sensitive galvanometer connected to coils on the specially designed pole tips. In most cases, the value of magnetic explorations for the detection of flaws and irregularities is limited by the effects of strain and other obscure conditions. This test, however, is not applied until the disk has been heat treated for the removal of strain, and machined to final dimensions, and hence, operates under the most favorable conditions. Although rejections are very few, in view of serious damage and sometimes even loss of life resulting from failure, it is exceedingly important that no defective piece be left in the finished machine.

CONCLUSIONS

From the foregoing rather cursory outline of the history and development of magnetic analysis, it is evident that the subject is one of great interest both from the point of view of commercial application and that of scientific investigation. The problem is not a simple one, as it involves not only the complex magnetic properties of materials, but also their composition and structure which determine the mechanical properties. The more rapid development of magnetic analysis has been hindered by a number of factors, some of which may be inevitable, but others of which might be obviated,—at least to some extent.

With relation to the magnitude of the problem in all its phases, the number of workers in this field is very small, and their activities have extended over such a broad area that general progress has been necessarily slow. More workers and better coordination would do much to remedy the situation. One circumstance
which may be inevitable, but which, nevertheless, operates to retard development, is the tendency for most workers to cover each discovery and application as fully as possible with patents. The potential new worker in this field,—particularly in industrial laboratories,—is somewhat uncertain as to his own status, and in this case the tendency is to await further development in the hope that such development as may interest him can be made on a secure basis.

Above all, the need is for more fundamental work. The possibilities in the way of practical applications are definitely limited by the lack of fundamental data. To be of maximum value, such fundamental investigations must be planned and carried out not only from the standpoint of the magnetic phenomena but also from the point of view of the metallurgical principles involved. This involves the closest cooperation between the magnetic investigator and metallurgist. One of the most important phases of the problem is the study of the so-called secondary effects, which greatly influence the magnetic properties without a correspondingly great effect on the mechanical properties.

The outlook, on the whole, is decidedly encouraging. Magnetic analysis has already proved of use in research on the treatment and structure of steel and for routine inspection on a commercial scale. There seems to be no reason why future progress should not be more rapid, and the hope that magnetic analysis may be found more and more useful as time goes on appears to be amply justified.

Abridgment of

The Diverter Pole Generator

BY E. D. SMITH

Synopsis.—This paper describes a new type of generator developed to overcome certain limitations inherent in the shunt and the compound generator, when used for charging batteries by the constant potential, the modified constant potential, and the floating methods.

The advantages of the constant-potential, the modified constant-potential, and the floating method of battery charging are quite generally recognized. These systems require a source of direct current of constant voltage.

The following characteristics are desirable in a constant potential battery charging generator.

1. It should preferably have a flat voltage curve which does not rise with increasing current at any point, otherwise stability of the correct charging voltage cannot be maintained without manual adjustment.

2. It should operate safely as a motor without speed-up or polarity reversal during feed-back from the battery.

3. It should preferably have a slight rise of voltage with decreasing current near zero load as a means for curbing a tendency to swing over to discharge during light loads.

4. When floated on bus-control circuits, which are subject to heavy momentary loads, at some point above full load the voltage should abruptly droop to protect the generator from the high peaks by shifting them to the battery, otherwise the generator will be damaged.

5. After the occurrence of these peak loads the generator voltage should return to its original value.

6. Commutation and efficiency should compare favorably with current standards.

The shunt generator is inadequate as its voltage falls too greatly with increasing load. Voltage regulators, when sufficiently sensitive, are necessarily delicate, and being susceptible to external conditions are difficult to keep properly adjusted.

The compound-wound generator fulfils some of the conditions but has its limitations. In case of feed-back from the battery the generator will motorize and run at an excessive speed and thus may cause damage. This is due to reversed current in the series coils bucking the shunt winding and lowering the field strength.

Also, the voltage curve, Fig. 1, of a flat compound generator is too convex for constant potential battery charging. With this typical curve it is difficult to charge at any rate between zero and that corresponding

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to the maximum voltage point, unless resistance is interposed between the generator and battery. In fact, any reduction of the charging current below the value corresponding to maximum voltage will usually be followed by a downward surge to discharge.

The voltage characteristic of the compound generator is curved, since the necessary magnetic changes produced by the series winding take place in the main magnetic circuit in accordance with the magnetization curve of the machine. Usually in obtaining satisfactory design it is necessary to work at least partly on the curved portion of the magnetization curve and the compound generator reflects this curvature in its voltage characteristic.

The following is a description of a generator designed for the specific purpose of meeting the exacting requirements necessary in a constant potential generator for battery charging.

In this generator, as shown in Fig. 4, a small diverter pole, (1) spaced midway between the main poles, has a magnetic bridge connecting it to one of the main poles. Magnetic flux from the main pole will leak across this bridge to the diverter pole. A restricted section at 2 in this bridge performs two functions: first, it limits the leakage, and second it serves as a magnetic choke, whereby it is possible to regulate the magnetism passing to the armature from the inner face of the diverter pole at 3. This regulation is possible since practically the whole of the main field ampere-turns acting on the diverter pole are concentrated in overcoming the reluctance at this one restricted section, so that any reduction of the flux through this restricted section will release ampere-turns expended here and raise the magnetic potential at 3 and consequently increase the magnetism passing to the armature at this point. At no-load, substantially all magnetic flux crossing the bridge will take the low reluctance path through the diverter pole (1) back to the frame without passing through the armature. A coil in series with the load circuit surrounds the diverter pole. As the load current increases, this coil, opposes and reduces the passage of magnetic flux through the diverter pole (1) to the frame.

The decrease of flux through the restricted section at (2), attending any reduction of flux through the diverter pole, (1), produces, as above stated, a rise in the magnetic potential at (3). The result is that part of the magnetic flux leaking across the bridge will take the air-gap path to the armature at (3), Fig. 5, adding its value to the main pole flux and compensating for the voltage drop in the generator.

No variation of flux from the main pole to the armature occurs as there is no change in the magnetic potential at the main pole air-gap. This follows, since neither the main pole nor the frame is highly saturated and the small variation of flux through these parts, due to the change of flux through the diverter pole, produces no appreciable variation in ampere-turns of the main field excitation expended on this part of the main magnetic circuit.

A flat voltage curve is obtained since the magnetic changes produced by the series winding take place only in the diverter pole (1), and as the flux density here is kept low these changes occur on the low straight portion of the magnetization curve, thus eliminating most of the curvature from the generator voltage characteristic.
These magnetic changes occurring in the diverter pole take place from a higher to a lower density on increasing the current output of the generator. This is the reverse of the occurrence in the compound generator, and the effect is to invert whatever part of the magnetization curve appears in the generator voltage characteristic, producing a concave instead of a convex voltage curve. By the proper adjustment of the diverter pole winding an almost straight curve is obtained with a slight rise on approaching zero load.

When motorizing, the main field strength is maintained substantially at its full value, as reversed current in the series coil can divert no further leakage due to saturation of the bridge restriction at (2). Also, any tendency for the diverter pole (1) to establish itself as an independent pole opposite in polarity to the main pole is limited to a safe value since the diverter pole already carrying the leakage flux quickly approaches saturation at any increase of flux through it, and safe operation as a motor is assured.

At some value of the load current the ampere-turns on the diverter pole equal those on the main pole and at this time the magnetic flux leaking across the bridge to the diverter pole is all re-diverted across air-gap (3), and there is no further leakage flux for an increased current to re-divert to the armature.

What occurs when the load is increased beyond this point is best illustrated by some recent tests.

The machine tested was a 1½-kw. generator, designed for floating with a 129-volt bus control battery. For the tests, this generator was equipped with a pair of movable exploring brushes by which the voltage around the commutator could be checked (step by step) and the flux distribution determined.

Fig. 6 shows the flux distribution when the generator was operating with brushes up, shunt fields separately excited at a constant value and various currents passed through the diverter pole coils. This shows that the regulating flux is produced only at the diverter pole.
Fig. 8 shows that with any increase in the load current beyond the cut-off value of 14 amperes, instead of an increase in the diverter pole field there is a definite and decided collapse. With this collapse of the diverter pole field the terminal voltage falls and hence the main field excitation is reduced which accounts for the reduction of the main pole flux. The solid line of Fig. 3 shows the voltage regulation for this machine.

It appears from these tests that when the ampere-turns on the diverter pole exceed those on the main pole, the flow of magnetism through the diverter bridge is reversed. Magnetism now flows from the diverter pole to the main pole and not from the main pole to the diverter pole. Under these changed conditions the magnetizing action of the armature assists the flow of magnetism through the bridge instead of opposing it. In fact, under heavy load, the magnetism does actually reverse and pass from the armature to the bridge, and joining with the main pole flux, passes back to the armature at the rear pole tip, constituting cross magnetism, while the magnetism from the diverter pole crossing the bridge flows backward through the main pole to the frame returning to the diverter pole without passing through the armature.

When the load on the generator decreases a descending excitation is produced in the diverter pole coils and due to the effect of hysteresis this descending excitation leaves a slight residual magnetic field passing from the diverter pole face to the armature. This accounts for the voltage being slightly higher after an overload than before, as shown in Fig. 3.

Good commutation is assured as the diverter pole provides a commutating field of the correct direction for improving commutation and this field varies with the current output as in an interpole generator.

The efficiency will equal that of a similarly rated compound interpole generator since the excitation on the main poles will equal the shunt and series excitation and diverter pole excitation will be the same as that of the interpole of the compound generator.

Figs. 12 and 13 illustrate the pole and the complete field assembly of the diverter pole generator.

The characteristics of this generator are desirable for many battery charging applications.

In telephone exchanges when floated in parallel with the main battery, the generator maintains the voltage within the close limits required for correct operation of the equipment and furnishes the current directly to the exchange without its passing through the battery. Considerable economy is effected by the saving of power and in the increased life of the battery, and also by a saving of labor through the elimination of the necessity of manual voltage regulation.

When several batteries are charged in parallel by the constant potential or modified constant potential method, as in recharging of vehicle and automobile batteries, the advantage of constant voltage, coupled with the ability to operate safely as a motor without polarity reversal or speed up during power failure is quite apparent.

In control bus operation, where a small generator is connected and operated continuously in parallel with a battery for switch operation, all of the desirable characteristics of this generator are utilized to advantage.

The flat voltage characteristic insures maintenance of correct floating voltage under varying load conditions with minimum supervision.

The ability to motorize safely without speed up or polarity reversal gives security during power interruptions.

The slight rise in voltage with decreasing current near zero load and the recovery momentarily to a slightly higher voltage after an overload combines to produce the desired stability of the correct floating voltage at the light load which constitutes the normal operating condition.

The sharp droop in the voltage just above full load amply protects both the generator and motor from danger of overload during switch operation.

The high voltage recovery after overload prevents the gradual diminishing of the generator voltage and
CARRIER TELEPHONE SYSTEM FOR SHORT TOLL CIRCUITS

BY H. S. BLACK, Associate, A. I. E. E.

Synopsis.—This paper describes a new carrier telephone system which is designed for use in the telephone plant as a substitute for open-wire line construction for circuits of shorter lengths than could be economically spanned by multi-channel types of carrier systems in use for longer distance transmission. This new system, which is known as the type D carrier telephone system, provides one additional talking circuit per pair of wires. The equipment is adapted to provide facilities quickly, and is capable of being moved readily from one location to another when temporary facilities are desired. The system employs a novel and original modulation circuit which is fully described in the complete paper.

INTRODUCTION

One of the important developments in telephone engineering during the last decade has been the practical application of high-frequency currents for the transmission of telephone and telegraph messages over circuits simultaneously carrying other traffic. For the transmission of speech by this method, the band comprising the frequency components in the voice of the speaker, which in the ordinary telephone circuit is transmitted by electrical currents of the same frequencies, is translated into a band of high-frequency currents. These high-frequency or "carrier" currents are above those transmitted by the ordinary voice-frequency channel, and so may be sent over a pair of wires that is being used for the transmission of speech frequencies. At the receiving end, the bands of high-frequency currents are separated from each other and from the voice currents on the same pair of wires by electrical filters, so that each delivers its message independently.

Since 1918, the date of the first commercial installation of carrier telephone equipment, engineering and installation of carrier systems has progressed steadily. In the paper on Carrier Systems on Long Distance Telephone Lines, it was shown how developments of recent years have greatly extended the use of carrier telephony on the longer circuits in the Bell System. There is also a considerable field of use for carrier telephony on the shorter open-wire toll circuits; that is, those ranging upward from about 50 mi. in length.
The type D carrier telephone system has been developed to fill this need.

**General Arrangement and Functioning of System**

In order to provide a carrier system which would be sufficiently low in first cost and maintenance to effect economies when used in place of wire construction for these shorter circuits, special consideration has been given to reducing the amount of apparatus required and at the same time providing a system of such stability that very little maintenance would be required. This has been accomplished by making the system a single-channel system—one which provides only one additional talking circuit per pair of wires,—by employing comparatively low carrier frequencies, and by including several new design features. The provision of only a single channel results in a simpler and less expensive design for the filters; the use of low carrier frequencies results in decreased line attenuation and reduces the cost of line transpositions and carrier loading which may be required; while the new design features are of such a nature as not only to simplify the apparatus but to increase the stability of the circuit as well. Daily adjustments necessary with carrier systems operating over greater distances have been eliminated. The complete equipment for each system terminal is assembled as a unit which is wired and tested at the factory before shipment, thereby reducing engineering and installation costs.

The new electrical features which have been incorporated in this system consist principally of (1) the use of an arrangement for producing carrier current whereby modulators and demodulators are self-oscillating; that is, the same vacuum tubes function both as oscillators and modulators or as oscillators and demodulators, thus economizing in the use of tubes and power; (2) the use of a new method of modulation and demodulation requiring the expenditure of a relatively small amount of plate battery power; (3) the elimination of grid batteries in the modulator and demodulator circuits by the use of grid current to produce grid biasing voltage; (4) the use of the modulator-oscillator circuit as a source of signaling current supply; and (5) the use of a ballast resistor to maintain the filament current within suitable limits. These new arrangements have resulted in economy in equipment as well as in a system of high stability. Economies also have been effected by the use of improved types of paper condensers in place of mica condensers in certain parts of the circuit, and by the use of unpotted coils where the requirements are such as to permit of this being done.

Like other recent carrier systems, this one uses different high-frequency bands for transmission in opposite directions. It is a carrier suppressed system, and a single sideband only is transmitted. As shown in Fig. 1, the lower sideband of a carrier of 10,300 cycles is used for transmission in one direction, and the lower sideband of a carrier of 6,867 cycles for transmission in the opposite direction.

The type D carrier telephone system has been provided in two general arrangements; the first employs certain basic equipment only and is suitable for operation over circuit lengths up to about 125 mi.; the second employs the basic equipment together with terminal amplifiers and other additional equipment and is suitable for use for circuits up to about 200 mi. in length. The latter arrangement, which is known as the type D-A system, is also used in some cases for circuits under 125 miles in length in order to equalize transmission levels with respect to those of other carrier systems operating on the same pole line. This is sometimes necessary because the normal levels of long-haul carrier systems are higher than those provided by the type D system without an amplifier. Also, there are certain circuit layouts involving type D systems only, which may require level equalization by means of the amplifier.

A schematic of one terminal of a basic type D system is shown in Fig. 3. When subscribers are connected to the two terminals of the carrier circuit, speech frequencies from the talking subscriber pass into the hybrid coil, and are impressed upon the grids of the modulator tubes. The application of speech frequencies to the modulator, with carrier frequency present, results in modulation, the principal products of which are the upper and lower sidebands. By means of the balanced connection of the modulator output transformer, the carrier frequency is almost entirely suppressed and only a negligible amount appears in the output circuit. The output from the modulator passes to the modulator band filter where the upper sideband and other unwanted frequencies are suppressed and the lower sideband is permitted to pass on to the line through the high-pass line filter. The low-pass line filter prevents the high-frequency current from passing at the local terminal to a subscriber who may be talking on the voice-frequency line circuit on which the carrier is superimposed.

At the receiving terminal, the transmitted sideband passes through the high-pass line filter and the demodulator band filter to an input transformer which impresses it on the grids of the demodulator tubes. Application of these sideband frequencies to the demodulator, with the carrier frequency present, results...
in a reproduction of the voice frequencies applied at the sending end. The various undesired high-frequency currents present in the output of the demodulator are suppressed by the low-pass filter in the output circuit. The voice currents pass to the hybrid coil and thence to the switchboard and the listening subscriber.

The design of the modulator and demodulator circuits is such that a novel and original scheme of modulation and demodulation results. Grid biasing voltage is obtained by rectifying in the grid circuit a small portion of the applied carrier wave. The two tubes oscillate in parallel, the amplitude of the oscillations being controlled by the design of the oscillator coil instead of the usual feed-back resistance, and the portion of the carrier wave rectified is sufficiently small so that the grid biasing voltage is nearly equal to the peak value of the oscillations. Referring to Fig. 26, it will be seen that the grid biasing voltage for the modulator is -100 volts, whereas, the usual grid voltage, if this type of tube is operated as an ordinary plate circuit modulator is -18 volts. Due to this high negative grid potential, only a portion of the carrier and voice voltages applied to the grids is effective in varying the plate current. The result of a mathematical analysis of this portion of the grid voltage is shown in Fig. 32. This figure is a diagram of voltages, which, if applied to the grids as shown, would produce the same result in the plate circuit as the carrier and voice voltages during the ringing period so that a separate source of 1000-cycle signaling current is not required. In order to signal over the carrier circuit, the modulator is unbalanced and the oscillator frequency reduced by 1000 cycles. The resulting high-frequency output is then interrupted at a 20-cycle rate. The receiving portion of the signaling circuit consists of an arrangement designed to respond to 1000-cycle current interrupted at a 20-cycle rate.

Transmission Considerations

The use of relatively low carrier frequencies has been an important factor in effecting economies. Low carrier frequencies, in addition to reducing the amplifi-
cation which the equipment must provide, insure better transmission stability over the line. Low carrier frequencies reduce the carrier loading and line transpositions which may be required. Representative transmission characteristics of the band filters and line filters are shown in Fig. 11.

The high degree of inherent stability which has been secured in the design of the system has made it practicable to omit apparatus for the adjustment of amplification, frequency, and filament current usually provided with carrier equipment, thereby simplifying the system and reducing its cost. The variations of transmitting and receiving amplification with plate battery fluctuations from 125 to 135 volts are not more than 0.1 TU. Variations in transmitting and receiving amplification with filament battery fluctuations from 20 to 28 volts are even less. Combined transmitting and receiving amplification changes with tube changes do not exceed approximately 1 TU. These are, however, of lesser importance as tubes are changed very infrequently. This high degree of stability results from the self-compensating properties of the self-oscillating circuits.

A comparatively inexpensive transposition system has been designed to permit the maximum number of type D systems to be operated on the same pole line. This system provides for the use of type D carrier systems on as many as four crossarms. When it is applied to lines on which no other type of carrier facility will be operated, it permits the use of basic type D systems on all pairs with the exception of the pole pairs. With slight modifications, it provides for the operation of two three-channel type C-S carrier telephone systems, one system on each of the outside phantom groups of the top arm, and, in addition, either a carrier telegraph or a type D-A carrier telephone system on the other pair of each of these phantom groups. Type D-A systems may also be operated on all other pairs of the line except on the pole pairs. Carrier telegraph systems may generally be operated on one or more of the pole pairs. The former transposition arrangement for the basic system, therefore, permits the operation of a total of 16 type D systems on a four-arm
lead, and the latter arrangement with the long-haul systems permits the operation of two three-channel carrier telephone systems, 14 type D-A systems, and, in favorable cases, four 10-channel carrier telegraph systems on the same number of pairs, in addition to the grounded d-c. telegraph and the telephone facilities ordinarily obtained. Fig. 6 illustrates the relative positions of these facilities on the four crossarms.

**Equipment Features and Typical Installations**

The equipment for the basic type D system has been divided into five principal units: the signaling unit, channel unit, modulator band filter, demodulator band filter, and line filter set. The apparatus for each of these units is assembled on a panel 19 in. wide and of sufficient height to provide the required mounting space. These panels are mounted on a rack and wired together, the leads which go to points outside of the bay being wired to a terminal block located at the top of the rack. The wiring required at the time of installation consists only in cabling from this terminal block to the distributing frame and to the sources of power supply.

A typical assembly of a type D carrier terminal is shown in Fig. 13. This arrangement employs a floor mounted rack approximately 7 ft. high and includes all of the equipment comprising the carrier terminal with the exception of the power supply. The two box-like units near the bottom of the rack are the band filters. Directly above the band filters are the channel unit, signaling unit, relay adjusting unit, and jack panel, in the order named. Above the jack panel are the line filters and certain balancing equipment which is required when voice repeaters are used on the voice-frequency circuit on which the carrier system is superimposed, or on the circuit obtained by the carrier system. This particular assembling is of advantage in temporary installations and in offices of low ceiling heights. Where greater economy in floor space is desired, an assembly which provides the equipment for two type D carrier terminals on a rack 11½ ft. high is used.

Similar assembly arrangements are provided for the type D-A system. In this case, an amplifier and an auxiliary filter panel are required in addition to the apparatus listed above.

Due to the features of its design and arrangement whereby it may be furnished as a complete self-contained equipment requiring relatively little engineering and installation work, the type D system is useful in providing facilities quickly, and, where temporary facilities are required, is capable of being readily moved from one location to another. This has already proved to be an advantage of some importance to the telephone companies. The establishing of facilities on an emergency basis during the recent flood in New England is one example of this sort. Another occurred in New York State when after a line break had interrupted service over the normal route, two terminals were transferred quickly from one office to another thereby increasing the facilities via the latter office. A number of cases have occurred also in which type D equipment has been used to provide facilities for sudden growth in oil fields. While this use of the system forms a comparatively small part of its field of application, it is an advantage which, at times, may be of considerable importance. The principal use of the system is to provide additional facilities which are required as a result of permanent traffic growth where these can be
provided more economically by means of this system than by stringing additional wire.

CONCLUSIONS

With the development of the type D carrier telephone system, the art of carrier telephony has been brought to the point where it can be used to advantage in providing telephone facilities for much shorter circuits than have been economical heretofore. Type D systems now in service are operating principally over distances of about 75 to 200 mi., although in certain cases where the conditions are favorable, systems as short as about 50 mi. are in use. The exact distance beyond which it is more economical to employ this carrier system than to string additional wire, is, of course, dependent upon the conditions applying to each particular case. For greater distances, up to the limit of the operation of the system, the economies effected by its use increase quite rapidly.

The performance of the type D system is comparable with that of a corresponding wire circuit. The form of the equipment is such that it is well adapted to the various office conditions, it can be used to provide facilities quickly, and can be transferred readily from one location to another in case of emergency.

On June 1, 1928, approximately 125 type D carrier telephone systems were in service and operating satisfactorily. It is expected that by the end of 1928 the number of systems in use will have increased to about 225. The growth in short open-wire toll circuits is such that there is a considerable field of application for this system.

Abridgment of

Reduction of Sheath Losses in Single-Conductor Cables

BY HERMAN HALPERIN and K. W. MILLER

Synopsis.—The use of single-conductor lead-covered cable for high-voltage, three-phase transmission lines results in sheath losses ranging from 25 to 300 per cent of the conductor losses for cables installed in separate ducts, unless special methods for the reduction of the losses are used. Some of these methods, while practically eliminating sheath losses, cause a-c. sheath potentials which may be injurious. In this connection, the authors have developed a new bonding scheme and a new bonding device both of which appear to have marked advantages. This article consists of a general discussion relative to the reduction of sheath losses, with special reference to laboratory tests, and to field work on 132 mi. of single-conductor cable of the Commonwealth Edison Company.

The economics of sheath losses and of the methods for their practical elimination are discussed. The theories of sheath losses and induced voltages are outlined and correlated, and new formulas and curves are developed. An analytical and graphical comparison of sheath bonding connections is presented. Investigations are reported on tests regarding the nature and extent of possible corrosion of sheaths caused by a-c. sheath voltages.

I. INTRODUCTION

As shown by an increase from 4 to 8 per cent of the total installed cable in the United States from 1926 to 1927 the use of single-conductor, lead-covered, underground cable for high-voltage three-phase potentials has been growing rapidly. If the cables are installed in separate ducts and operated with solidly bonded sheaths, the sheath losses will range from 25 to 300 per cent of the conductor losses, thereby considerably decreasing the carrying capacity and increasing operating costs. If the sheaths are made discontinuous and bonded in special ways to prevent sheath currents, then problems arise to provide satisfactory insulating joints, bonding apparatus and bond-

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II. ECONOMICS

The elimination of the sheath losses in 750,000-cir. mil, single-conductor, 66-kv. three-phase, 60-cycle cables, installed in conduits with other cable, increases the average yearly carrying capacity from approxi-
mately 50,000 to 60,000 kv-a., or about 20 per cent. Since the total investment cost of the installed cable is approximately $60,000 per mile of line, the increased investment value due to the elimination of sheath losses is approximately $12,000 per mile of line. An additional saving is made in the cost of reduced sheath losses which is about $1000 per mile per year, assuming 55,000 kv-a. average yearly rating and a 60 per cent load factor. Capitalized at 10 per cent per year, this represents an additional investment saving of $10,000 per mile of line.

Extra investment is required for (1) insulating joints, (2) insulated cable saddles and bond wire, (3) special fireproofing to minimize corrosion due to a-c. voltages, and, in some cases, (4) bonding devices such as reactors or transformers. The additional investment cost required per manhole is about $65 for the first three items and $125 to $250 for all four items. Using even all four items and assuming 12 manholes per mile, the average additional cost of eliminating sheath losses is about $1500 per mile. This cost is only one-eighth of the increased value of a 66-kv. line due to the increased rating, or, in effect, the cost of the losses saved would pay for the additional investment in one or two years.

For 12-kv. lines, the standard practice in Chicago is to install three 1,750,000-cir. mil cables per phase in one conduit. In this case the increase in carrying capacity obtained by the elimination of sheath losses is about 70 per cent.

Induced sheath voltages are proportional to cable length, and because of a-c. electrolysis, it may be destructive to operate with sheath voltages exceeding 12 volts to ground. Without bonding devices, this limit is reached with about 500-ft. lengths on the 66-kv. cables, or, under practical conditions, with about 13 manholes per mile. If a series type of bonding device, (Fig. 2E), or a cross-bonded star-ground type of con-

![Comparison of Connections and Resulting Sheath Voltages, Current, and Losses for 12-kV. and 66-kV. Three-Phase 60-Cycle Single-Conductor Cables](image)

1. Lengths of sections 1, 2, and 3 are 330, 400 and 470 ft. for 66-kv. cables and 55 per cent as long for 12-kv. cables.
2. Cable (1) 1,750,000 cir. mils, 12 kv.; flat arrangement with 6 in. between centers; 20,000-kv-a. load per circuit.
3. Cable (2) 750,000 cir. mils, 66 kv.; flat arrangement with 6 in. between centers; 66,000-kv-a. load per circuit.
4. Voltage profiles are for outer cables on connections B, E, and F, and profiles are for section 1-C, 2-B, and 3-A for connections C, D, and G.
5. Impedance drops are for fault current of 3000 amperes returning over sheaths with manholes every 400 ft.

The Commonwealth Edison Company has found it desirable to increase the maximum conduit lengths up to the length of a standard city block; that is, about 660 ft. This reduces the average number of manholes per mile from 13 to 9 and thereby saves over $4000 per mile of conduit on account of reduced number of manholes and joints, and costs of installation. The increased investment cost for the necessary bonding devices for connection Fig. 2G is approximately $600 per mile.
In view of this large saving, the company is trying over 90 H & M sheath bonding transformers for installation in new conduit built in 1928 where the sections of conduit are 550 to 700 feet long.

III. SHEATH VOLTAGES AND LOSSES

The induced sheath voltages in single-conductor lead-covered cables on a-c. circuits vary logarithmically with the ratio of distance between cable centers to sheath radius, directly with the frequency and magnitude of the conductor currents, and directly with the length of section between insulating joints.

The calculated induced voltages for the 66- and 12-kv. cables of the Commonwealth Edison Company are shown in Fig. 2B. In general, for cables in contact in one duct, the voltages at rated loads are less than one volt per 100 ft., while for cables in adjacent ducts, the voltages are 1 to 5 volts per 100 ft.

At line terminals, the configuration of lengths to potheads is usually complicated and the induced voltages are affected by the locations of the buses. Because calculations are difficult and usually give results that are too low, estimates based on past experience are the most reliable guides to such cases.

If single-conductor cable sheaths are solidly bonded, the induced voltages cause currents to flow in the sheaths. Such voltages are neutralized where generated and practically no voltage will exist between the sheaths.

The sheath currents and losses are graphically shown in Fig. 2 for the 66- and 12-kv. cables of the Commonwealth Edison Company. In general, if cables are in separate ducts and sheath losses are eliminated, the carrying capacity is increased from 15 to 70 per cent, or for a given load, the copper temperature is decreased from 5 to 45 deg. cent. For cables in contact, the sheath losses, including the proximity effect, are 1 to 15 per cent of the conductor loss's.

Formula and curves for determining induced sheath voltages and sheath losses with solid bonding are given in the complete paper for one circuit and for two parallel circuits having cables in various combinations.

IV. METHODS OF REDUCING SHEATH LOSSES

When each phase of a given three-phase line is to be carried in a separate metal-covered cable, one of the following methods might be used for materially reducing the sheath losses:

A. The sheath resistance might be greatly increased with solid bonding. The sheath loss varies approximately inversely as the resistance. However, no suitable plastic metal having a resistivity several times that of lead is known.

B. If the conductivity of the solidly bonded metal sheath is greatly increased for example by adding copper wire armoring, the sheath losses can be made less than with no armoring. This method is too expensive for any but very unusual installations.

C. If a two-conductor concentric or "D" cable is used for each phase, with the two conductors connected to opposite ends of the transformer phase winding, no sheath voltages are induced. This method is virtually six-phase and complicated and appears to have merit only for transmission of large amounts of power at low voltages.

D. Special sheath bonding connections discussed in detail below appear to be most practical for general conditions.

V. SHEATH BONDING METHODS

A. General Considerations. The major considerations in the selection of methods and devices for special bonding are as follows:

1. Elimination of sheath losses and increase of carrying capacity.
2. Reduction of normal induced voltages between sheaths and to ground to keep corrosion due to direct voltages at a minimum.
3. Limitation of abnormal sheath voltages during failures to the lowest possible values.

These objects must be accomplished without causing objectional features, such as excessive cost, interference with drainage to prevent d-c. electrolysis, or production of harmonic currents leading to telephone interference.

B. Solid Bonding. If the sheaths are solidly bonded (Fig. 2A), the installation is simple and avoids the introduction of new methods and apparatus. If the cables are in separate ducts or farther apart, the sheath losses will cause serious reduction in carrying capacity and increase in operating cost.

C. Bonding One End Only to Auxiliary Cable. Sheath losses may be eliminated by connecting only one end of every length of sheath to some auxiliary cable (Fig. 2B) or to the sheaths of other adjacent cables. This connection requires either the use of an extra duct and a cable at considerable expense or placing dependence on other cables, which may not be permanent. One bond is more apt to become open by accident or mistake than bonds at each end and the cable sheath may be left "floating" with the possibility of acquiring dangerous potentials. The Company uses this method, however, for very irregular lengths on station properties.

D. Cross Bonding. Emanuel devised the method where the sheaths are cross-bonded continuously along a line. (Fig. 2C). The voltages to ground are uncontrolled and may become excessive, depending upon the chance succession of unequal cable lengths. In order to avoid excessive sheath potentials, it is not desirable to confine returning failure currents to a single cable sheath for the entire distance between the failure and the line terminals, as is done in this method.

Kirke and Searing devised a method of cross-bonding (Fig. 2B) in which the cables are solidly bonded in every third manhole and transposed in the two intermediate manholes. The sheath voltages each trace the three sides of a voltage vector triangle starting at ground potential and returning to the same potential. If the cable spacing is not equilateral, or if the cable lengths are not equal, the induced voltage triangles will not close and the residual voltage is neutralized by circulating current over the three lengths. Usually the resulting sheath currents are small and the sheath losses less than two per cent as great as for solid bonding.

This method has the advantages of simplicity and
low cost, and has been used in over 90 per cent of the work of the Commonwealth Edison Company. Although insulating joints are required in two-thirds of the manholes the Company has installed them in all manholes in order that special devices could be readily installed later if the voltages to ground (which are 100 per cent of induced voltage with cross-bonding) proved too high.

E. Resistance Bonding. Emanuelli and Capdeville set forth the principle of reducing potentials between sheaths to 50 per cent by using impedances connected in series with the cable sheaths and by grounding the coil mid-points (Fig. 2E). The impedance of the device is made considerably higher than the impedance of the sheaths, so that little sheath current will flow and the sheath losses will be negligible. Atkinson later introduced the use of saturated iron core reactors to limit the value of sheath voltage during failures to the saturation voltage of the coils.

Although reactance coils accomplish their intended functions they introduce the following objectionable features:

1. Since they are single-phase and operate near the saturation point, triple-harmonic exciting currents are introduced into the sheath circuits, and may cause telephone interference.
2. The iron core may become saturated with d-c. flux caused by stray railway currents, thereby increasing losses and causing even harmonics in the exciting current, which may result in telephone interference.
3. During return flow of failure current along an isolated section of line, an excessive sheath potential may be caused by the addition of the reactor voltage drops (limited only by saturation) to the sheath voltage drops.

F. Resistance Bonding. Resistances may be connected as shown in Fig. 2E. They have several times the losses of equivalent reactance devices. Since they must have thermal storage to withstand failure currents of a few thousand amperes, they are relatively large and expensive. They do not have the desirable voltage limiting characteristic for minimum voltage drop during the return flow of line failure current. Finally, resistance bonding would greatly complicate protection against d-c. electrolysis.

G. Partial Current Flow Bonding. Either series resistance or reactance may be chosen of such values that any desired percentage of the sheath current with sheaths solidly bonded will be allowed to flow. In general the method is not attractive.

H. Single-Phase Transformers. Single-phase transformers have been suggested for sheath bonding (Fig. 2F). The iron core is placed either inside or outside of the joint sleeve and around the copper conductor, which acts as a single turn primary. The secondary is connected across the insulating joint to oppose the induced sheath voltage. This method has serious mechanical disadvantages and introduces practically all the disadvantages described for single-phase reactors.

1. H & M Sheath Bonding Transformers. In order to retain the advantages of 50 per cent reduction in the voltages between cable sheaths and to ground by using connection 2-E, or a 40 per cent reduction by using the newly devised connection 2-G, and at the same time not to incur the disadvantages listed for reactance or resistance bonding, the H & M three-phase sheath bonding transformer (Fig. 4) has been devised by the authors.

The normal three-phase reactance of the primary coils is high, only a small exciting current flows, and losses are negligible. The secondary coils function normally only as a tertiary winding preventing the flow of triple harmonic currents in the sheaths. During a failure, the single-phase failure current returns nearly equally divided on the three cable sheaths and in parallel through the three primary coils. Because of the secondary winding, the device then behaves exactly as a short-circuited transformer and the series reactance of the transformer is due to leakage flux only (not saturation flux) with the result that the reactance drop is minimum in value.

As the stray direct currents flowing in the three sheaths and coils will be practically equal, the d-c. flux must return through an air path; hence, these stray currents will have no undesirable effect on the a-c. characteristics of the transformers. Since the transformer coils present very small resistance to the flow of direct current, they will introduce no complications into d-c. electrolysis mitigation. The three-phase transformer allows large economies in size, weight, and convenience of installation.

In the scheme of connections (Fig. 2G) devised by the authors, the cable sheaths are cross-bonded continuously throughout a line, with the center of the vector triangle of sheath voltages grounded by star-connected transformers spaced at every second manhole. Under practical conditions, the sheath voltages to ground are reduced about 40 per cent by this connection. For this connection, there is a saving in investment cost, since only half as many coils are required, and since the coils may be wound for about 60
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per cent as much voltage as for the series connection.

J. General Comparison. In order to make a general comparison of the various schemes, Fig. 2 has been prepared. The profiles apply only to the normal voltage on the cable sheath. The maximum voltages occur in all cases in the manholes where the insulating sleeves are installed. Also there are shown sheath currents and voltages for normal operation and sheath voltage drops for failure currents.

Voltage tests have been made on all 12- and 66-kv. single-conductor cables bonded for the elimination of sheath losses, and on several short sections of line specially bonded for tests. In all cases the measured sheath voltages check those calculated by the ordinary logarithmic formulas within 10 per cent. No measurable difference in sheath voltages was obtained for any of the connections with the cables dry or submerged in water. Tests have been made on connections A, B, D, E, and G of Fig. 2 and on some other less promising connections not shown. Tests were made using single-phase Atkinson saturated core reactors and H & M three-phase sheath bonding transformers; both devices being rated at 22 volts per phase. The test voltages for all cases confirmed the theoretical values.

VI. INSULATING JOINTS

In any method of reducing sheath losses by special bonding, insulating joints are required. Several designs using different methods of construction are now on the market.

The H & T insulating sleeve has been used for almost all of the work of the Commonwealth Edison Company. Fig. 7 shows one of its applications. No leaks have occurred in these insulating sleeves in service, and several which had operated for over two years under water with 15 to 35 volts across the Bakelite were inspected and all found to be in good condition.

When a common oil reservoir is used for all three joints, insulators must be used in each of the three oil pipe lines. Suitable insulators are available.

VII. A-C. ELECTROLYSIS

The principal problem introduced by a-c. sheath voltages is the production or increase of sheath corrosion. The extensive laboratory and field tests of the Commonwealth Edison Company indicate the principal factors to be as follows:

a. Current density, which is dependent on the sheath voltages and on the resistivity of the surrounding manhole water, conduit, and fireproofing.

b. The chemical nature of the water, ducts, and fireproofing.

c. Superimposed d-c. potentials.

d. Temperature.

For the concrete conduit with precast concrete ("stone") ducts and for the rope and cement fireproofing (with and without asbestos tape next to the load sheath) the range of resistances found was as follows:

<table>
<thead>
<tr>
<th>Resistance to Ground Per Ft. of Cable* SHEATH—OHMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bare cable sheath in manhole water</td>
</tr>
<tr>
<td>Wet fireproofing on cable</td>
</tr>
<tr>
<td>Cable sheath in submerged ducts</td>
</tr>
</tbody>
</table>

*Over-all diameter — 2.8 in.

Tests showed that the resistivities decreased about 15 per cent if the temperature was increased for 15 to 25 deg. cent. and 50 per cent for a change from 10 to 40 deg. cent. The increase of corrosion with temperature which was found appears to be due to stimulation of chemical activity as well as to an increase of current density.

Hayden3 found that a-c. electrolysis could be greatly reduced or even removed by superimposing a negative d-c. voltage about 1½ per cent of the a-c. voltage. Tests made in Chicago indicate the converse is true and that precaution is necessary to prevent the sheaths from becoming positive to earth if a-c. sheath voltages are present.

Secondary chemical reactions which are very difficult to analyze or predict appear to be chiefly responsible for the corrosive effects of a-c. voltages. So called self-corrosion which may be caused by chemicals from the surrounding soil or conduit structure, by differential galvanic action, or by impurities in the

ead, may be stimulated by a-c. potentials. Pitting is the most serious result and cannot be properly evaluated by weighing tests.

From two years of laboratory tests and field experience, it appears that for cables submerged in water in a-c. potential of 12 volts between sheath and ground, there is a practical safe limit for Chicago.

Similar corrosion problems may be encountered when lead-covered cables with or without a fibrous covering are buried in the earth. The various methods for reducing sheath losses and possible corrosion described in this article for cables in ducts are equally applicable to buried cables.

VIII. Conclusions
1. For cables separated as in ducts the elimination of sheath losses results in increased load ratings of 15 to 20 per cent and in decreased total cable losses of 20 to 75 per cent.

2. Experiments have verified the calculated sheath voltages for the various bonding connections.
3. If sheath voltages on regular sections of cable must be reduced because of corrosion due to a-c. electrolysis, it appears very desirable to use the bonding connections shown in Fig. 2a or 2b for which the three-phase sheath bonding transformer seems most suitable.
4. Satisfactory insulating joints are essential for the practical elimination of sheath losses and successful designs are available.
5. Alternating current electrolysis is a complicated phenomenon and few definite conclusions can be drawn. Field tests and experience in Chicago indicate that 12 volts to ground is a practical safe limit.

ACKNOWLEDGMENT
The authors wish to express their appreciation of the very helpful assistance given by Messrs. D. W. Roper, Karl Horine and their assistants in obtaining the field and laboratory data.

Forces on Magnetically Shielded Conductors

BY J. H.MORECROFT and ALVA TURNER

Synopsis.—The results of some simple experiments are given to show how the magnetic force, acting upon a current-carrying conductor in a magnetic field, is affected as the conductor is shielded by surrounding it by a permeable shield. It is shown that the force on the conductor practically disappears if it is put inside of an iron pipe, but that the pipe experiences a force—the sum of the forces in the pipe and that in the conductor being the same as that in the unshielded conductor.

The idea is extended to the conductors in a slotted armature. It is shown that as the conductor is placed more deeply in the slot the force diminishes to a minimum and then experiences a slight rise at the bottom of the slot.

THE ordinary electric motor develops torque because of the interaction of the flux from the field poles and the current-carrying conductors in its armature. These conductors are generally imbedded in slots. An interesting question, the answer to which is not apparent is,—Do the conductors themselves develop the turning effort of the armature and then transmit it to the shaft by pressing on the sides of the slots, or is the force developed directly in the iron core of the armature? An argument at the lunch table furnished the basis for the following simple experiments.

A rigid conductor was suspended in an adjustable transverse field and current passed through it; the mechanical force tending to push the conductor across the field was measured. The conductor was then threaded through an iron pipe, with a bore large enough to be held free from the conductor. The pipe was of sufficient length to extend beyond the edges of the magnetic field in which the conductor was lying. In this way the conductor, through practically all of its active length, was shielded from the magnetic field.

The force was again measured and found to have only a small fraction of the value it possessed when no pipe surrounded the conductor; evidently the pipe furnishes such a low reluctance for the flux that practically none appears inside the pipe where the conductor is lying. That some force appears is due to the imperfect shielding of the pipe, its length being insufficient to eliminate completely the effect of the field fringe, and probably due to that part of the field of the conductor which lies outside the pipe.

While shielding the conductor from the outside field, the iron pipe does not in any way affect the strength of field set up by the current in the conductor at points outside the pipe; that is, if the conductor, carrying a certain current and giving a field of 100 gauss at a point 5 cm. distant from the conductor when no pipe is used, is surrounded by a thick iron pipe of 8-cm. outside diameter (so that the point 5 cm. distant lies outside the pipe), the flux density at the 5-cm. point will still be 100 gauss. And of course the same statements holds good for points between the conductor and the inner surface of the pipe. In so far as the magnetic field of the conductor is concerned the iron pipe has no effect on its strength except inside the material of the pipe; here the flux density is increased by an amount proportional to the permeability of the iron.

With the conductor inside the pipe, it developed but little force in our experiment, but the question arises—How about a force on the pipe? Does this experience a force tending to make it move transversely in the field?

The apparatus was arranged as indicated in Fig. 1
which gives a view looking at the end of the conductor. 

N and S are the poles of a powerful electromagnet, having an air-gap about 6 in. long. The conductor was supported centrally in the field, knife-edge supports and a calibrated spring permitting us to measure the downward force when current was passed through the conductor.

The pipe was held in a bridle which prevented it moving parallel to the field of the magnet, but permitted the measuring of the force tending to move it up or down across the field.

The results given on the curve sheet must be regarded as qualitative only, as we did not know the magnetic characteristic of the ion used in the pipes, and made no corrections for change in the reluctance of the magnetic circuit, as different pipes were used.

Fig. 2 shows the force in grams acting upon the unshielded conductor, as the current through it was held constant at 25 amperes and the density of the field of the electromagnet was changed from 180 to 800 gauss.

The conductor was then enclosed in a pipe having an inner diameter of 2.22 cm. and wall thickness of 0.80 mm. The current was again held at 25 amperes and

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**Fig. 1**

**Fig. 2**—Force on Unshielded Conductor

**Fig. 3**—Force on Unshielded Conductor

<table>
<thead>
<tr>
<th>Sizes of pipe used for shielded:</th>
<th></th>
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<tbody>
<tr>
<td>Inside diameter</td>
<td>Wall</td>
</tr>
<tr>
<td>A—2.20 cm.</td>
<td>0.080 cm.</td>
</tr>
<tr>
<td>B—2.06 cm.</td>
<td>0.318 cm.</td>
</tr>
<tr>
<td>C—2.70 cm.</td>
<td>0.318 cm.</td>
</tr>
<tr>
<td>D—1.11 cm.</td>
<td>0.318 cm.</td>
</tr>
</tbody>
</table>

**Fig. 4**—Transverse Force on Pipes Specified in Fig. 3

**Fig. 5**—Force on Conductor in Slot

Current in conductor—25 amperes
Dimensions of slot—2.7 cm by 7.45 cm.
Field current:
- Curve A—1 amperes
- B—2 amperes
- C—3 amperes
- D—4 amperes

**Fig. 6**—Flux Density on Center Line of Slot

Field current—1 amperes

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the force in the conductor was measured, giving the
curve marked A in Fig. 3. Evidently the pipe cuts
down the force in the conductor to about \( \frac{1}{4} \) its value
with no enclosing pipe.

Three other pipes were tried, \( B \) having inner diameter
of 2.06 cm. and wall of 3.18 mm.; \( C \) having 2.70 cm.
inner diameter and 3.18 mm. wall; and \( D \) having 1.11
cm. inner diameter and 3.18 mm. wall. The force
for each case was measured and is given in Fig. 3. Evidently pipe \( A \), with its thin wall, tends to saturate
at the higher field strengths; this decreases its shielding
action and results in greater force in the conductor.

In Fig. 4 are shown the curves for transverse forces
acting on the different pipes, the conductor inside the
pipe carrying 25 amperes. There is an evident ten-
dency for pipe \( A \) to reach saturation,—and even the
other pipes show the effect to some extent.

If the force on the conductor itself inside the pipe
is now added to the force on the pipe, the sum gives a
total force just the same as that given by the conductor
itself, unshielded. The shielding, therefore, simply
transfers the force from the conductor itself to the
shielding material.

An experiment was arranged to measure the force
on conductors strictly as they are used in armatures;
Fig. 5 shows the apparatus used. An iron “slot”
was built up, having about the dimensions of the slot
of an actual armature. The conductor was then placed
at different positions in the slot and its force again
measured, the current in the conductor being 25 amperes,
as it was for all the other curves. The curves given
in Fig. 5 show at once that the mechanical forces in the
conductors in the bottom of the slots of a machine are
almost negligible compared to those for the top
conductors.

In Fig. 6 is shown the experimentally determined
flux density throughout the depth of the slot (with one
ampere in the field), and the conductor forces are
proportional to these densities.

Therefore the conclusion is reached that each con-
ductor on the armatures of a motor contributes the
same turning effort to the shaft; however, the con-
ductors in the lower part of the slot give their force
directly on the armature core while those near the top
of the slot deliver their force through the compression
of their insulating covering.

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**Insulation**

The Opportunity for Research

**BY J. B. WHITEHEAD**
Fellow, A. I. E. E.

CONSIDERING the wide range of types of electric
circuit, it is at once evident that an equally wide
variety of properties,—electrical, mechanical,
and thermal,—is demanded for their insulation. Ex-
periment and research directed toward improvements
in insulation, therefore, have an almost unlimited field
of opportunity. An enormous mass of experimental
data from experienced investigators has already been
presented. So wide is the problem, however, that
these data have not only failed to place the design of
insulation on a satisfactory engineering basis, but still
leave it as probably the most important problem con-
fronting the electrical engineer of today. The life of
electric equipment is often limited to that of its insu-
lation, and the consequences of failure are usually dis-
astrous and costly.

In large measure, insulation as we have it today is the
result of empirical and cut-and-try methods rather than
based on fundamental knowledge. Manufacturers and
engineers have made a splendid record of discovery and
improvement. There is, however, little of law, order,
and fundamental knowledge as guide posts for further
progress. Indeed, we may say that only a few general
principles have been discovered, such as the importance
of the elimination of air and moisture and the limitation
of high temperature. Beyond this, we have only the
results of the patient purification and selection of
materials, as related to special forms of insulation and
manufacturing processes. In many cases, the control
of materials as regards uniformity of product is still
wanting, and close engineering design is still in the
remote future. Liberal factors of safety are necessary
to cover the ever present weak spot, thus increasing
material, filling valuable space, and adding weight,
size, and cost.

What is the explanation? We know very little as to
the nature of the fundamental properties of dielectrics.
The perfect dielectric as conceived by Faraday does not
exist. We can improve the dielectric properties of
many materials, and we have even invented new com-
pounds with desirable thermal, electrical, and mechani-
cal advantages; but all in their best forms still have
electrical conductivity, dielectric absorption and loss,
and show more or less rapid deterioration under electric
stress. In spite of the splendid record of manufacturers
and engineers in the improvement and control of dielec-
tric materials, it is increasingly evident that the possi-
blities of the empirical study of these materials are
about exhausted, and that further advances can come
only from a more intimate knowledge of those underlying and ever-active phenomena associated with a state of electric stress in a dielectric.

The situation thus appears to offer fine opportunity to the pure research worker. Little is known of these fundamental processes, and the rewards of deeper knowledge leading to their control would be very great. On the other hand, the experimental difficulties are enormous. In fact there is probably no field in which the control of the conditions of experiment is more difficult, and the interpretation of observation more liable to error. A survey in any aspect of the great mass of data already acquired yields so little definiteness of result and presents so many apparent inconsistencies, that coordination aiming at even empirical laws is clearly impossible. Physicists have attempted to explain the conductivity of liquid dielectrics in terms of the more firmly established laws of gases. The results are not impressive and the problem of solids is scarcely approached. Moreover, the refinement of method necessary to these studies, in itself indicates a different type of problem from those confronting us in electrical insulation. Extreme processes of purification, refinement, and the conservation of these properties, impose great difficulties and expense in the handling of large quantities of materials under ordinary manufacturing methods.

It might almost be said that the present problem in dielectric research is a further knowledge of the fundamental laws of materials in a partially pure state; quantitative data as to the effect of different amounts of impurities most difficult to eliminate; the influences most active in the progressive changes in the properties of dielectrics; and the nature of the electric carriers involved in the conductivity of liquids, oils, greases, and composite solids, under conditions of relative purity attainable by the best manufacturing processes.

The aim of this paper is to make a few definite suggestions of present problems for research; in fact to propose a program under which various experimenters may work under a coordinated plan, with mutual support and the avoidance of duplication of effort. Since the field is so large, the scope of the suggestions has been limited to some of the more conspicuous aspects of the general problem.

HIGH-VOLTAGE INSULATION

There are few more important problems than those involved in the insulation for high-voltage circuits. All dielectric processes are intensified at high stress. Moreover, those properties of high-voltage insulation which apparently lead to its limitations,—namely, conductivity, absorption, and loss,—also play dominating parts in many types of insulation for lower voltages, such as all forms of communication and radio equipment. Therefore, by their nature studies in the high-voltage field will throw light on the many other classes of problem.

Probably the two most important characteristics of high-voltage insulation are high electric strength and long life; i.e., slow deterioration. On neither of these properties is there any sound fundamental knowledge, either as to their ultimate nature or their predetermination and control in composite materials. The last ten years, however, have produced some very remarkable results as to the general character of the underlying processes which offer great promise of reward for further careful experiment.

DIELECTRIC STRENGTH

The confusion of data on the dielectric strength of solid materials is well known. Such simple questions as the changes of dielectric strength with thickness and temperature show wide variation not only among different experimenters, but in the results of single workers. The last ten years have seen a remarkable series of investigations on this subject by such workers as Günther-Schultz, Wagner, Gruenwald, Dreyfus, Gabler, Rochow, Mundel, Rogowski, Smekel, Joffé, Böning and others. The results indicate clearly that direct experiments on breakdown strength, even under conditions most carefully controlled, cannot of themselves lead us to a knowledge of the nature of the underlying processes. The confusion and variations of data show that the controlling causes lie deeper, involving the type and mode of motion of electric charges through the molecular cage work constituting the structure of the dielectric.

There is some suggestion that this recent outpouring of important work on dielectric strength was precipitated by the so-called pyroelectric theory of Wagner, although engineers had long before recognized the hot spot in insulation as the forerunner of breakdown. Wagner's proposal was so sketchy,—so faulty in its assumptions,—that it at once led to sharp criticism and to a more careful analysis of conditions surrounding temperature rise within the mass of a dielectric. Supplemented by the more careful analyses of Dreyfus, Rochow, Gabler, and others, it became immediately evident that this proposal goes no further than to point out the influence of temperature elevation on breakdown strength, and says nothing as to the nature of the ultimate process of breakdown.

Making use of the results of the X-ray analysis of crystals, Schmidt, Smekal, and Rogowski have made very important studies of the relation between the theoretical breakdown strength of solids and those as observed in experiment. Until this work, discrepancies between these two figures, have been of the order of 20 to 100 times. On the assumption of a loose or porous composition and the presence of cleavages in crystals whose patterns are known, Rogowski has shown that under the laws of gases, the motion of ions in an electric field may be sufficient to upset the temperature equilibrium of a crystal, leading to secondary ionization and progressive breakdown at values of electric stress corresponding to those of practise. The presence of these microscopic cleavages in crystals...
has also been definitely shown by other methods, with evidence as to their approximate dimensions. Proceeding in a somewhat different manner, Böning proposes a theory of breakdown of other forms of solids, such as due to the accumulation of space charge, and local high stress owing to a conductivity of electrolytic character. He thus utilizes conditions more nearly simulating those obtaining in the insulation of practise. Similarly, Günther-Schultz proposes a theory of breakdown of liquid dielectrics, which, in effect, proposes the acceleration of a free moving ion, leading to temperature elevation sufficient to create a gaseous space, and thus giving opportunity for the movement of more powerful gaseous ions leading to cumulative secondary ionization.

The outstanding feature in all the work thus briefly outlined is the increasing attention focused on the motion of ions as the underlying cause of breakdown. No dielectric is free of conductivity. Conductivity means the motion of ions, and consequently every dielectric has already within it the potential causes of breakdown. Obviously conductivity may be present without the possibility of secondary ionization, or at least the latter may be in such small amounts as to be limited in the area of its influence. It is easy to see, however, that even if breakdown is not imminent, local conductivity may lead to local changes, both physical and chemical, in the structure of the dielectric, with increased conductivity, increased dielectric loss, more rapid deterioration, and shorter life.

Simple methods for studying these recent theories of the mechanism of breakdown do not suggest themselves immediately. A proper study of Rogowski’s suggestion would involve various forms of a crystal lattice pattern, in relation to submicroscopic fissures of different dimensions. It might be possible to determine the relation between internal gas space, molecular structure, and dielectric strength, but the difficulties would be great. In the case of liquids, the suggestion of Günther-Schultz should be susceptible of test. If the suggestion is correct, variations in breakdown strength should be found among liquids having different vapor pressures and when subjected to radio-active or other influence stimulating the production of ions, or bearing on the process of gaseous ionization.

As suggested above, however, the breakdowns of practise are the culmination of processes of disintegration and deterioration of the insulating material. For the present, at least, the control of these processes is more important than a knowledge of the final mechanism of breakdown, interesting of itself though that may be. They are in all probability due to the joint influence of electric stress, the original chemical structure of the material, and small amounts of impurities never completely eliminated. Dissociation, conduction, electrolytic action are insidious and cumulative sappers of the structure of any dielectric. Thus, the problem of dielectric strength, in the light of present knowledge, is the preservation of an original value, rather than a search for higher values, and so merges itself into that other important property of insulation—long life.

**DIELECTRIC LOSS AND LIFE**

Progressive deterioration under sustained electric stress is one of the commonest troubles of electrical insulation. These changes invariably mark the steps toward ultimate failure. They are usually accompanied by corresponding increases in dielectric loss. As a consequence, much experimental study has been devoted to the laws governing dielectric loss. These studies have resulted in a fair understanding of the variations of loss with voltage, frequency, temperature, etc., under otherwise constant conditions. They tell us nothing, however, of the ultimate nature of the loss, nor of the underlying processes of change.

A more promising avenue of attack appears to lie in the phenomenon of dielectric absorption between which and dielectric loss a very close correlation exists, as based both on experiment and on theory. The nature of the phenomenon of residual charge or absorption is not understood. Maxwell’s theory is inadequate and no other completely satisfactory explanation has been proposed. Probably there are several possible causes, but the most promising appears to be a retarded motion of electrolytic or other type of ion accumulating as space charge near the electrodes. Anderson and Keane have reported a brief analysis of this idea, showing that the variations in ionic density necessary to account for absorption as observed are not very great. This effect has been noted by Warburg and others for liquids, and by Joffé for certain crystals. There are few data on the various solid composite materials so interesting from the standpoint of electrical insulation. From this point of view, absorption arises in conductivity which takes on a distinctly anomalous character in most dielectrics. Another view is that absorption or residual charge is due to a slow polarization of the dielectric, the conductivity at all times having a definite value. This view is an old one, supported by the work of J. Curie, and latterly has been emphasized by Joffé and his co-workers. The proposal affords excellent opportunity for experimental test.

Both absorption and anomalous conduction are easily studied, and it would appear that we have here an interesting and promising field not only for uncovering some of those processes involved in the progressive deterioration of dielectrics and insulation, but also for further knowledge of the nature of the phenomena themselves.

Research in this field would therefore naturally take the direction of further studies of the causes of dielectric absorption, with particular reference to the movement of ions and electric charges inside the body of the dielectric. These are not easy problems, but among other methods of attack may be suggested studies in the variation of potential gradient of dielectrics under stress and the possible non-uniform occurrence of space charge.
The presence of a definite polarization e. m. f., as suggested by Curie, Joffé, and Euguchi, and the location or nature of its origin, seems an especially promising line of attack. Research should take the direction of studies of the variations of this phenomenon with temperature, viscosity, and with added impurities, such as air and water, and particularly with variations of chemical composition. This would be especially important, not only in its fundamental character, as bearing on theory, but also from the standpoint of improvement in the insulation of practise.

The use of impregnated paper for high voltage insulation gives this material a special interest. It possesses dielectric absorption which has not been completely studied. Many problems are therefore suggested. Data are wanted as to the relative importance of the paper and the compound in determining the final absorption and loss, together with their variations as related to voltage and temperature. The separate origin of the reversible and irreversible components of the absorption current should be traced. The variations of these quantities with sustained electric stress should be studied for both continuous and alternating stress, and methods should be developed for studying their influence on oxidation, electrolytic action, polymerization, redistribution of material, variation in potential gradient, and the presence of space charge; the mutual influence of paper density, moisture content, and power-factor—voltage relations; the influence of pressure on conductivity and on gaseous ionization in impregnated paper. A pressing question at this time is whether the increasing loss and deterioration of impregnated paper insulation is due to the decomposition or polymerization products themselves, or to a condition, such as the presence of free ions, arising in the process of chemical change.

INSULATING LIQUIDS

The early work of Warburg, and since his time of others, has indicated that the conductivity of liquid dielectrics often shows evidence of pure electrolytic character. Others, such as Schröder, Schering, Mie, Jaffe, Van Der Beijl, have studied the character of the free ions occurring in poorly conducting liquids, and have attempted to explain the phenomenon of conductivity in liquid dielectrics in terms of the more definite laws governing conduction in gases. In general, however, liquid dielectrics, even when carefully prepared, must be considered to have a very complex character, possessing to some extent not only electrolytic conduction, but also containing other types of ions possessing a wide range of mobility, and which are usually attributed to the presence in dissociated forms of other materials, such as, for example, water.

The purpose of the physical research, thus briefly described, is directed toward the basic nature of the processes involved. Little has been done in orderly method toward linking up these fundamental researches with the properties of liquid dielectrics, such as used for the electric insulation of engineering application. Little or no reference is found, for example, to an initial high value of charging current, decreasing rapidly with time after the application of voltage, similar to the absorption current in a solid dielectric. Such currents are known to occur in liquids, and the theories proposed do not clearly account for them. It has been stated that liquid dielectrics show no residual charge and that the principle of superposition does not apply. This statement needs further supporting evidence, particularly in the case of commercial insulation. The work of Tank, Joffé, and of Sinjelnikoff and Walther has indicated that certain liquid dielectrics have for a given stress an initial limited maximum value of charging current, which decreases more or less rapidly and they have attempted to link this value with the electric loss under alternating stress. Variations of conductivity or current during extremely short intervals of time following variations of electric stress, constitute the most important factor bearing on dielectric loss, power factor, phase difference, etc., and in all probability on the permanence of the structure of the insulation.

Obviously the liquids offer the best opportunity for the study of the motion of ions. As already indicated much work has been done in this direction on very pure liquids. We now need information as to the changes in the mass, mobility, and other properties of these ions, with increasing amounts of original impurities. Such data paralleled with short time measurements on charge and discharge currents, and on alternating loss, should go far toward indicating a method for the selection of liquids of greatest stability and longest life. Other promising problems are the relative power of various types of ionizing influence, X-rays and other electromagnetic radiation; oils, for example, deteriorate under light. Space charge, absorption, and perhaps polarization are readily observed in liquids; studied in relation to temperature and to electric stress for both long and short time intervals they should yield important fundamental knowledge.

A SUGGESTION FOR PROGRESS

If the point of view of the foregoing paragraphs is correct it would appear that an essential feature of future research in electrical insulation should be the study of the size, motion, and other characteristics of mobile ions, their accumulation as space charges, and their relation to the chemical constitution, origin, and subsequent states of the dielectric material. There will be other important problems but those of the type mentioned must be attacked if further fundamental knowledge is to be our aim.

The suggestions for experiment under the several foregoing headings have been quite general, but they may readily be expanded into a list of specific problems. It will be found at nearly every point, however, that the method and technique of the more desirable ex-
in the question of insulation, it is evident as aspects of the applications of electric science, the question of further progress depends more and more on the discoveries of the pure scientist, so now in particular, in the question of insulation, it is evident that we must live more and more closely in contact with the current progress in the field of pure physics. A combined physicist, chemist, and engineer obviously offers the best chance for rapid progress. Failing this combination in one man, collaboration between electrical engineer and physicist offers the next best promise. Here, however, is another difficulty, for in recent years the physicist has not been attracted by the problems of dielectrics and insulation. From the literature one receives the impression that the physicist attributes the anomalies of insulation to the presence of impurities, and that this being the case dielectric absorption is still to be explained by Maxwell’s theory, and that if it were possible to secure substances sufficiently pure they would possess the characteristics of Faraday’s original conception. Pure physical research in the field of dielectrics seems to be limited at the present time to studies of specific inductive capacity in its relation to modern theories of the nature of the structure of the atom. One phase of this work explains specific inductive capacity in terms of the shifting of electron orbits within the atom. Another phase, due to Debye and his followers, finds that the specific inductive capacity, or a part of it, arises in an inherent dissymmetry of the arrangement of electrons and positive charges in molecules, resulting in a definite polarity of the latter, thus forming a so-called electric dipole. The electrets of Euguchi, showing a permanent electrification similar to permanent magnetism, fall into this class. Important and stimulating as these discoveries and theories are in their extension of our knowledge of the nature of the ultimate structure of matter, they as yet throw little light on the phenomena arising in the dielectrics which must be used for insulating purposes. For example, none of them makes suggestion of the nature of dielectric absorption and loss. There is no doubt, however, that those physicists who have been drawn to the problem of the dielectric atom would in all probability be attracted by that of dielectric loss, if its magnitude and importance could properly be brought before them. It becomes the duty, therefore, of the research engineer to seek out those physicists and chemists working in the field of dielectrics and to stimulate their interest by setting forth the importance of our problems and the insufficiency of present physical theories to account for them. This, next to the continued prosecution of our program of direct attack, I regard as the most important opportunity of the committee. The foregoing outline of the problem of insulation, and the opportunity offered for research, has been brought together as the result of an effort, as Chairman of the Committee on Electrical Insulation of the National Research Council, to prepare a list of specific problems for experimental attack, and a plan for its general prosecution in various research laboratories, as far as possible under coordinated control for mutual aid and the avoidance of the duplication of effort. The committee invites the participation of all research workers interested in this field. It will gladly submit the list of its problems and give information as to work already under way. It is also in position to suggest possible sources of financial support for problems in its program when there is good promise of capable and active prosecution.

LOOKING BACKWARD

Today it is apparently permitted that one take an occasional glance at the things that have been left behind in the climb up from the past without suffering the penalties imposed upon the ancients. Pillars of salt have given way to a show of reason. Foresight, is, however, denied to an amazing degree. Several weeks ago we commented upon the progress in radio communication and the legal penalties imposed upon some far-sighted promoters and engineers. A recent issue of Coal Trade throws an interesting backward glance at a comment of fifty years ago. In a report upon contemporary trade conditions in its issue of October 30, 1878, it was stated:

"Anthracite sales are booming. Bituminous-coal dealers also are reporting satisfactory business. Gas coals are without any special movement as the season is nearly over. Mr. Watkins, president of the Chicago Gas Light & Coke Company, ‘does not anticipate any shrinkage in the profits of his company by reason of Edison’s alleged discovery of a means to economically utilize electric light.’ He says that he has carefully watched the operations of this noted inventor and is unable to see that a method has been established which will furnish light to a large number of consumers at a rate that will enter into any active competition with gas."

One may blush for Mr. Watkins, or his shade, but the same thing is being done today. Who will believe that newspapers will soon be a thing of the past, their place being taken by synchronized television and radio in every home? Who is rash enough to foresee that cities will be no more—since speedy transportation may place us all within minutes of wherever we may desire to go? Who concedes even the remote possibility of a development that will render generating stations and transmission lines useless except as museum pieces? Who dares—yet inevitable change is waiting just around the corner. Today’s certainties are tomorrow’s amusing, long-dead jests.—Electrical World.
Synopsis.—This paper sets forth the features of squirrel-cage motor design which differentiate it from standard motors. Much of the paper is devoted to the two-speed motor with two separate stator windings having speed ratios of 2/1, 3/1, 4/1 and 6/1. The two-speed motor with a single winding is limited to the 2/1 ratio. Higher ratios are necessary for high elevator speed and low and accurate landing speed.

The elevator motor is subjected to continual starting and stopping. The effects of inertia in such service are considered in connection with motor heating.

The proper division of slot area between the two stator windings and the problem of building a rotor with proper characteristics on both speeds are explained.

Noise elimination is necessary in elevator motors. The effect of this requirement in design is considered.

The effect of rotor skew is compared to the effect of distributed winding in the stator. The quantitative effect of skew is embodied in a constant called "skew factor."

The possibility of transformer effects between the windings of a two-speed motor is explained and methods of correcting to eliminate circulating currents are indicated.

* * * * *

The induction motor as developed for elevator drive is a highly specialized type of machine. Slip-ring motors have been used, but the complications of control and the difficulty in eliminating noise have caused them to give way to the high-resistance squirrel-cage type. The high-resistance rotor can be designed to give the maximum torque when starting and the torque per ampere is high. Another advantage of the high-resistance rotor is that it reduces the stator heating during a change of speed.

For a low-speed elevator the stator is usually wound for a single speed. For higher speeds the motor is built for two speeds since at high elevator speeds it is more difficult to make accurate landing. In the case of two-speed motors, the high-speed winding is generally used for starting and running and the low-speed for retarding and landing. The speed ratio required for the two windings should be greater the higher the speed of the elevator. Common speed ratios are 2-1, 3-1, 4-1, and 6-1. The high speed usually has four poles or more and the low speed 48 poles or less. The speed-torque and current-torque curves of a representative motor are shown in Fig. 2.

Inertia Loads

In order to understand the design problems in this motor, it is necessary to grasp the fundamental ideas of the type of load the motor is required to handle. Consider the simple mechanical arrangement consisting of a motor driving a drum over which is hung a cable carrying an elevator cage on one end and a counterweight on the other. The counterweight is usually enough to counterbalance the weight of the cage and a certain portion of the capacity load. The energy relations involved in the accelerating and retarding of an induction motor with a pure inertia load are easily derived.

The mechanical power output of the rotor is given by mechanical power output = $K \omega T$

where $\omega$ and $T$ are the angular velocity and the torque respectively and $K$ is a constant depending upon the system of units. From elementary induction-motor theory the electrical power input to the rotor is given by

Electrical power input = $K \Omega T$
Where \( \Omega \) is the angular velocity at synchronous speed. Since the load is inertia only

\[
T = \frac{I}{g} \frac{d \omega}{dt}
\]

Where \( I \) is the equivalent moment of inertia of the rotor and is determined by transferring all of the kinetic energy of the moving parts of both motor and connected load to the rotor. The energy relations for the rotor during change of speed may then be set up as

Mechanical energy output = \( \frac{KI}{g} \int \omega \frac{d \omega}{dt} dt \)

\[
= \frac{KI}{2g} (\omega_2^2 - \omega_1^2)
\]  \( (1) \)

Electrical energy input = \( \frac{KI}{g} \int \omega \frac{d \omega}{dt} dt \)

\[
= \frac{KI}{g} (\omega_2 - \omega_1)
\]  \( (2) \)

The expression (1) simply states that the mechanical output of the rotor during change of speed is equal to the change of kinetic energy. The above expressions are general. Their significance will become clear if certain special cases are considered.

**ROTOR EFFICIENCY DURING ACCELERATION**

If an induction motor comes up to synchronous speed from standstill

\[
\omega_1 = 0 \quad \omega_2 = \Omega
\]

In this case rotor output = \( \frac{KI \Omega^2}{2g} \) \( (3) \)

rotor input = \( \frac{KI \Omega^2}{g} \) \( (4) \)

It is thus seen that

Rotor loss = kinetic energy

This relation is true whenever the rotor or stator resistance and whatever the flux density. Indeed all of these quantities may be variables during the process of acceleration.

**ROTOR EFFICIENCY DURING RETARDATION**

In elevator operation the process of retardation from high speed consists of throwing over to the low-speed winding. Reference to the curve in Fig. 2 will show the situation. With the high speed in operation the elevator with pure inertia load is operating at point A. After the shift to low speed it is operating at B and the rotor is subjected to retarding torque. The rotor is retarded until it is in low-speed synchronism at C.

The energy relations for this process may be derived from expressions (1) and (2) in which is substituted the new synchronous speed \( \Omega/Z \). Also

\[
\omega_3 = \Omega/Z \quad \omega_1 = \Omega
\]

Substituting in (1) and (2) there results

rotor mechanical output = \( \frac{KI}{2g} \left( \frac{\Omega_2^2}{Z^2} - \Omega_1^2 \right) \) \( (5) \)

rotor electrical input = \( \frac{KI}{g} \left( \frac{\Omega}{Z} \left( \frac{\Omega}{Z} - \Omega \right) \right) \) \( (6) \)

The negative signs show that the machine is now a generator with mechanical input, derived from the change in kinetic energy and electric output from the rotor to the stator.

If the rotor electrical output \( \frac{KI}{g} \Omega^2 \frac{Z - 1}{Z^2} \) be divided by the high-speed kinetic energy from expression (3) there will result an expression showing the portion of the high-speed kinetic energy which is returned to the stator by regenerative braking. This expression is

\[
\frac{\text{energy returned}}{\text{high-speed kinetic energy}} = 2 \left( \frac{Z - 1}{Z^2} \right)
\]  \( (7) \)

It is now possible to make up a table showing what becomes of the kinetic energy of the rotor and load when a shift is made to low speed and when after low-speed synchronism is reached mechanical brakes are applied. The unit of energy is the kinetic energy at high-speed synchronism.

<table>
<thead>
<tr>
<th>( Z ) (speed ratio)</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original kinetic energy</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Portion returned to stator from (7)</td>
<td>0.5</td>
<td>0.44</td>
<td>0.37</td>
<td>0.28</td>
</tr>
<tr>
<td>Portion lost in mechanical brake</td>
<td>0.35</td>
<td>0.11</td>
<td>0.06</td>
<td>0.03</td>
</tr>
<tr>
<td>Portion lost in rotor winding</td>
<td>0.25</td>
<td>0.45</td>
<td>0.57</td>
<td>0.69</td>
</tr>
<tr>
<td>Rotor loss per cycle</td>
<td>1.25</td>
<td>1.45</td>
<td>1.57</td>
<td>1.69</td>
</tr>
</tbody>
</table>

The last line shows the units of energy going into rotor loss for one complete cycle consisting of starting on high speed, changing to low speed and applying a brake. If the mechanical brakes be applied and the winding disconnected before low-speed synchronism is reached, they will absorb a disproportional amount of energy and the portions returned to the stator and lost in the rotor will be reduced.

**STATOR LOSSES**

So far, emphasis has been laid upon rotor loss and little has been said concerning stator losses. The reason for this is that with a high-resistance rotor most of the power loss is in the rotor. Once the rotor loss is known.

\[
= \frac{KI}{g} \omega^2 \frac{Z - 1}{Z^2}
\]
for inertia loads the stator loss is not difficult to determine since

\[
\begin{align*}
\text{Stator loss} & = \text{stator resistance} \\
\text{Rotor loss} & = \text{rotor resistance}
\end{align*}
\]

where the rotor resistance is the value after being transformed to the stator. The above expression shows the advantage to the stator of the high-resistance rotor in the matter of stator loss on inertia load.

Quite obviously, then, the rotor and associated parts should have the smallest moment of inertia possible consistent with good design. Welded steel spiders which, in one case, weigh 43 lb. apiece displaced cast iron spiders which weighed 89 lb. apiece.

The problem of dissipating the heat evolved in the motor is accentuated by the fact that the ventilation is materially cut down owing to the accelerating and retarding features of the service which keep the average speed of the motor at less than one-half of the high speed. The areas of all air passages through the machine should be four or five times greater than for standard motors. This has been made possible to large extent by using arc welded steel instead of cast iron for frames. The stator is provided with ventilating fins welded in place which are in the path of the air issuing from the motor. See Fig. 1.

NOISE ELIMINATION

Noise elimination is of paramount importance in elevator motors. The magnetic hum so characteristic of ordinary induction motors becomes an insidious nuisance in a location where people must live with it. Hotels, apartments, offices and hospitals demand noiseless operation. The predominant cause of noise in induction motors is the existence of harmonics of both flux and current. The interaction of these currents and fields sets up periodic forces which in turn move the bars and teeth enough to produce noise. Pitch or coil span is known to have a vital connection with the production of harmonics and since the 5th and 7th tend to have the greatest magnitudes it is well to keep them as low as possible. This can be done by making the pitch or span equal to approximately 5/6 of a pole pitch. The number of slots per phase per pole is closely connected with the production of harmonics. Here again Fourier’s analysis shows considerable improvement in this regard of a motor having two slots per phase per pole over one having a single slot per phase per pole. For this reason one should set two slots per phase per pole as the absolute minimum if one is to have a quiet motor.

ROTOR SKEW

An interesting problem arose in connection with the skewing of the rotor rods. It is common practise among all manufacturers to skew rotors. This has two effects which it is desired to utilize. The first and most important is that with a properly skewed rotor there are no positions of the rotor where it tends to remain locked in position due to the variation in magnetic reluctance of the air-gap as the rotor is turned. This effect, sometimes known as “cogging” produces pulsations in torque if allowed to become of too great magnitude by improper amount of skew. A second effect desired from rotor skew is to reduce noise resulting from the pulsating torque. Then a third effect forced itself into the problem of design.

The effect of skewing the rotor rods is the same as that due to the distribution of a phase group in the stator over a plurality of slots, except here the distribution is continuous instead of discontinuous as in the stator.

In the case of skewed rotor rods it will be seen that each elementary length of rotor rod has an infinitesimal voltage generated in it which is out of phase with that generated in the next adjoining element. The voltage generated in the rod is the integrated voltage of these infinitesimal voltages generated in them which are out of phase just the same as the voltages induced in adjacent slots of the stator are out of phase. The elemental vector voltages plotted end-on-end lie along the arc of a circle. The sum is the chord.

In the case of a two-speed motor with two separate fields sets up periodic forces which in turn move the rotor where it tends to remain in positions of the rotor where it tends to remain locked in position due to the variation in magnetic reluctance of the air-gap as the rotor is turned. This effect, sometimes known as “cogging” produces pulsations in torque if allowed to become of too great magnitude by improper amount of skew. A second effect desired from rotor skew is to reduce noise resulting from the pulsating torque. Then a third effect forced itself into the problem of design.

The effect of skewing the rotor rods is the same as that due to the distribution of a phase group in the stator over a plurality of slots, except here the distribution is continuous instead of discontinuous as in the stator.
In the two windings will show that the minimum amount of heat will be evolved in the stator windings when the ratio of the copper cross-sections of the two windings is equal to the ratio of energy (not power) losses in the two windings. That is,

\[
\frac{A_1}{Q_1} = \frac{A_2}{Q_2}
\]

where \(A\) and \(Q\) represent the cross-sectional area of copper in the slot and the energy losses respectively and the subscripts identify the winding with which the particular quantity is associated.

**Transformer Effects in Two-Speed Stators**

The design of the stator winding in a two-speed two-winding motor is subjected to limitations which are not present in a single winding motor because of the transformer effects between the windings.

A full account of the analysis necessary to cover the subject of elimination of harmful transformer effects is long enough to form a paper in itself so the present paper will limit itself to brief explanations of methods, followed by tabulated results which would be obtained by extensions of the methods.

**Elimination of Circulating Currents in the High-Speed Winding**

We will first concern ourselves with transformer effects in the high-speed winding induced by operating the low-speed winding.

**Correction by High-Speed Coil Pitch.** If the speed ratio is, for instance, 2 it is evident that if the high-speed coils are wound full pitch the two conductors forming a turn will have e.m.f.s. induced in them 360 deg. apart and the turn e.m.f. will be zero. We may generalise and say if the speed ratio is \(Z\) the e.m.f. per turn of the high speed will be zero if the high-speed pitch is

\[
\frac{2}{Z}, \frac{4}{Z}, \frac{6}{Z} \text{ etc., where } Z \text{ is always taken } > 1 \text{ and may be fractional or integral.}
\]

The designer may, however, not wish to use the coil pitch demanded by this type of correction because it may be a pitch conducive to noise from harmonics or it may be a pitch not physically attainable with the number of slots at his disposal.

**Correction in the Phase Group.** In case the induced voltage per turn is not zero, the voltage per coil will be the turn voltage multiplied by the number of turns. The coils which make up a phase group are equally distributed over 60 electrical deg. in an ordinary three-phase winding. When the low speed is operating this 60 deg. is changed to \(60 \times Z\) deg. This condition can be very simply shown by vectors in Figs. 5 and 6.

Group voltages on the high speed will be zero for

| 3 phase (60 deg. distribution) when \(Z = 6, 12\) or any multiple of 6 |
| 3 phase (120 deg. distribution) when \(Z = 3, 6\) or any multiple of 3 |
| 2 phase when \(Z = 2, 4\) or any multiple of 2 |

**Correction by Group Connections.** In those cases where neither the turn voltage nor the group voltage can be made zero, care is necessary in connecting the groups in series-parallel connections because circulating currents may be set up. These may be eliminated by making total voltage of the groups in a series leg equal to zero or by making all series legs which are paralleled have the same transformer voltage in magnitude and phase. Figure 7 shows the arrangement of group voltages of the high speed winding when the high speed is operating. The groups of one phase are numbered 1, 2, 3, 4 etc. consecutively around the stator.

In a three-phase high-speed winding the voltages \(A, B, C\) generated in the various slots of a phase group are spread over 60 electrical degrees only when the high speed is in operation. When the low speed is operating those vector voltages are spread over \(60 \times Z\) deg. spacing between adjacent vectors is 180 deg. If the low speed is now allowed to operate the spacing between adjacent vectors becomes 180 deg. \(\times Z\). Fig. 8 shows the condition when \(Z = 4\). Among the various orders of connecting the groups of a phase in series the adjacent and the alternate connections are most common. In the adjacent connection, adjacent poles are connected...
in series. In the alternate connection, alternate poles are connected in series.

Table II shows the number of poles of the high-speed winding which must be in series in each leg to produce zero transformer voltage when the low speed is operating.

Fig. 9 shows the condition illustrated above when the alternate connection is tried when \( Z = 4 \). Table II predicts circulating currents and we see from the figure that they will exist.

### Table II

<table>
<thead>
<tr>
<th>( Z )</th>
<th>Adjacent connection</th>
<th>Alternate connection</th>
</tr>
</thead>
<tbody>
<tr>
<td>2, 4, 6, etc.</td>
<td>2</td>
<td>Impossible</td>
</tr>
<tr>
<td>3/2, 5/2, 7/2 etc.</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>4/3, 8/3, 10/3 etc.</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>5/3, 7/3, 11/3 etc.</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>5/2, 7/4, 9/4 etc.</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>9/5, 8/5, 12/5 etc.</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>7/5, 9/5, 11/5 etc.</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

It will be noted that the foregoing tabulation does not contain any speed ratios where \( Z \) is an odd number. The reason for this is that if the speed ratio is an odd number, it is impossible to connect the series circuits so that the voltage in a series leg is zero. See Fig. 10. This does mean, however, that there is a transformer voltage generated in each phase which voltage appears at the terminals of the machine. This fact may have a vital bearing on the type of control used with the motor.

### Elimination of Circulating Currents in Low-Speed Winding

A little thought will show that it is impossible to annul the transformer voltage in the low-speed winding by the first two devices used in the high-speed winding, that is, by choosing a particular coil pitch or by having the voltages in a group add to zero. The only recourse in eliminating trouble in the low-speed winding is to make sure that circulating currents cannot occur in any parallels by so connecting the proper poles in series that the transformer voltage of a series leg is made zero just as was done in the high-speed winding. The following table will show the proper number of poles to be connected in series to obtain zero leg voltage for the various speed ratios and the two commonest types of connection, that is, adjacent poles in series and alternate poles in series.

### Table III

<table>
<thead>
<tr>
<th>( Z )</th>
<th>Adjacent connection</th>
<th>Alternate connection</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>3/2</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>4, 4/3</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>5/3</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>5/2, 5/4</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>6, 6/5</td>
<td>12</td>
<td>6</td>
</tr>
<tr>
<td>7, 7/3, 7/5</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>7/2, 7/4, 7/6</td>
<td>14</td>
<td>7</td>
</tr>
</tbody>
</table>

At the October meeting of the Administrative Board of American Engineering Council it was decided to oppose H. R. 7344 which is a bill authorizing the President of the United States to detail engineers of the Bureau of Public Roads of the Department of Agriculture to assist the governments of the Latin-American republics in matters of highway. The reason for this opposition is that the bill disguises the appropriation of Federal funds for the benefit of foreign countries and permits a double payment of salaries to certain Federal employees.
Abridgment of
The Transmission of High-Frequency Currents for Communication Over Existing Power Networks
BY C. A. BODDIE
Associate A. I. E. E.
and R. C. CURTIS
Non-member

Synopsis.—The use of high-voltage power lines for carrier-current communication presents a number of difficulties not met in the use of simple communication circuits. This paper tells how these difficulties may be overcome without resorting to complicated transmitting and receiving equipment. The advantages of employing tuned choke coils are described. These chokes are used to isolate the communication channel from the remainder of the power system which gives in effect a simple communication circuit between communicating points.

HIGH-voltage power lines are constructed with such strength that they are in general superior to any communication circuit except underground cable. Experience has demonstrated that power lines withstand storms, sleet, and floods long after all other circuits are carried away. In view of the vital necessity of communication to a power company, it is but natural that the power line should be used as a communication circuit because of its mechanical superiority. Except for short distances, it also offers an economic superiority.

The method of utilizing a power line as a telephone circuit is to superimpose high-frequency currents on the power conductors. These currents are transmitted over the line as ordinary alternating currents. They are produced and received by equipment similar to the usual space radio apparatus.

In considering the power line as a communication circuit it is immediately apparent that such a circuit differs from the usual telephone line. The principal difference is that the line is operated at high voltage. This gives rise to more or less noise due to spitting insulators and similar effects. In addition the line is not a simple circuit connecting the transmitter and receiver. In practice a power line is usually part of an extensive high-voltage network with loops, taps, and spurs. Such a network is not a constant and stable system from a communication point of view because of more or less continuous changes due to switching. In general, every time a switch is opened or closed in any part of the system, it makes a change in the communication circuit.

These factors are now generally recognized although at the time this type of communication was first undertaken, the importance of some of them was not fully appreciated. In some cases it was found that the natural changes in line characteristics due to switching were so great that a satisfactory communication circuit could not be obtained.

Efforts have been made to solve this problem by modifying the communication apparatus. Modifications tending to reduce the number of frequencies per channel and the introduction of special systems of modulation have greatly increased the amount and complexity of the equipment.

By its very nature power line communication equipment should be kept just as simple and reliable as possible. Instead of complicating the equipment it is proposed to correct the trouble at its source by stabilizing the power line. The method is to insert high-frequency resistances into the power line at such points as are necessary to block off detrimental circuits and provide a clear circuit for the channel desired.

Apparatus for this purpose has been developed which has proved simple and effective. This apparatus consists of an inductance coil very similar to those ordinarily used for lightning arrester work together with the necessary tuning equipment. These tuned circuits do not absorb energy at the power frequencies nor in any way disturb the power system.

In order to appreciate the problem presented by a power network some of the properties of transmission lines at high frequencies may be noted.

A line of great length does not act like a large capacity or a large inductance but rather as a pure resistance. Experience has demonstrated that power lines withstand storms, sleet, and floods long after all other circuits are carried away. In view of the vital necessity of communication to a power company, it is but natural that the power line should be used as a communication circuit because of its mechanical superiority. Except for short distances, it also offers an economic superiority.

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mately the characteristic impedance. Suppose it is desired to provide a communication channel between A and F, it is seen by inspection that 50 per cent of the current fed into the system at A is transmitted towards B. The part transmitted in the opposite direction is lost since it contributes nothing to the desired channel A-F.

When a wave reaches a junction of two long lines a division of current takes place such that \( \frac{1}{2} \) of the original current is reflected towards the sending end while \( \frac{3}{4} \) is transmitted down each branch line, the total being \( \frac{3}{4} \) greater than the original.

The net effect of the subdivision of current at the junction points is to reduce the current at F to \( \frac{2}{27} \) of its initial value. This is equal to the attenuation of slightly less than 300 mi. of simple circuit as seen from Fig. 2. In addition there is the loss due to the normal attenuation in the line.

Consider the case shown in Fig. 4 of a long line with a 4-mi. spur line connected on at B. The impedance of the 4-mi. spur line at frequencies commonly used is shown in Fig. 5. The reactance curve is seen to be a typical tangent curve except for the higher values. The reactance curve reaches a maximum and then passes through zero instead of following the tangent curve to infinity.

The impedance presented by a 4-mi. spur varies over a wide range. The impedance at 46.5 kilocycles is 26,000 ohms and at 58.1 kilocycles 29.3 ohms. The impedance then rises again to a maximum of 21,200 ohms at 69.7 kilocycles. The interval between the points of maximum and minimum impedance as given by equation (19) is

\[
\frac{V}{4 l} = \frac{186,000}{4 \times 4} = 11,600 \text{ cycles}
\]

It should also be noted that the impedance between 52.5 kilocycles and 63.7 kilocycles is less than the characteristic impedance of the line and will in this band of frequencies absorb considerable energy in addition to the loss in the main line due to reflections.

The impedance of the spur line at 58.1 kilocycles is so low that less than 4.5 per cent of the current arriving at B is transmitted down the line towards the receiving apparatus at C. The effect of such a spur line is equivalent to the loss incurred in a line of over 300 mi. in length. It should be noted that at certain frequencies the effect of a single short spur line is greater than that due to the many subdivisions shown in Fig. 3.

At other frequencies the impedance of the spur line is very high and at these points has little or no effect on the transmission of energy from A to C. The frequencies at which these points of maximum and minimum transmission occur are a function of the length of the spur line. If a number of such spur lines of varying length is connected to the main line it may be impossible...
to find a single frequency that will be satisfactory for communication.

A set of resonant line chokes may be installed in the spur line at the point where it connects to the main line. The minimum effective impedance of the spur line can thus be raised and the diversion of energy reduced to any desired amount.

Another condition often encountered is that of two or more parallel paths of slightly different lengths. At certain frequencies the current arriving by one path is exactly out of phase with the current arriving by the other. If the paths are of nearly equal length the amplitudes of the arriving currents will be very nearly equal. The two will then combine in such a way as nearly to cancel each other, leaving only a very small resultant to act on the receiver.

This condition may be corrected by inserting a set of resonant line chokes in one of the lines to prevent the flow of current by that path. Sometimes this procedure is objectionable because either of the lines may be opened during the normal operation of the system.

By inserting reactances at one or more points along the line the phase of the currents arriving at the receiving end can be shifted so that the resultant acting on the receiver is an appreciable portion of that delivered to the receiving end of the line. The construction of these phase shifting reactors is similar to the resonant line chokes. The tuning of the circuit is such as to present a reactance of the required value. In this way use is made of both the available paths. The opening or failure of one of the lines does not materially affect the communication channel.

In Fig. 6 is shown another condition met in practice in which $F$ is energized either by way of $C$ and $D$ or by $E$. The loop is not maintained closed in normal operation of the power system. The communication channel is from $A$ to $F$.

If the loop is opened at $C$, $D$, or $E$ the effect is that of two spur lines connected across the communication channel. If the loop is opened at $B$ or $F$ the effect is that of one spur line. It is necessary to provide for communication over either circuit so that high impedance line chokes cannot be used at $B$ and $F$ to isolate one circuit.

The corrective measures in this case consist of installing at $B$ and $F$ in both circuits, resonant line chokes adjusted to an impedance such that a considerable amount of current can pass through the circuit to $F$. At the same time the impedance is high enough to prevent an excessive amount of current flowing when the circuit becomes part of a spur.

The effect of spur lines is very detrimental. The short lines cause excessive transmission loss over wide bands of frequencies and the longer lines cause distortion due to the rapid variation of impedance with frequency. All types of telephone communication utilizing high-frequency currents require the transmission of a band of frequencies rather than a single frequency. The width of the band may be reduced to some extent by employing special types of modulation. The best that can be accomplished in this direction will not reduce the width of the band below 2000 cycles. This gives only a minor improvement without providing a general solution to the problem.

The detrimental effects of spur lines may be obviated by making certain changes in the transmission system. Any desired frequency can then be used, distortion is eliminated, wide fluctuations in signal level are prevented, and complications in the transmitting and receiving apparatus are avoided.

These results can be accomplished by inserting in the power conductors, equipment which will carry the power current without loss and at the same time introduce high impedances to the communication currents.

The impedance of some types of transformers is quite low at high frequencies. Other types have been encountered in which the impedance varies with the instantaneous values of the power current giving the effect of modulation on the high-frequency currents. These conditions may be remedied by the use of the resonant line choke to prevent any appreciable amount of high-frequency energy being absorbed in the undesirable circuits.
Power lines are now being studied very carefully before any attempt is made to install power line telephone equipment. Actual tests have demonstrated the validity of the commonly accepted theory of lines for high frequencies. By applying accepted analytical methods, the important features of the line characteristics may be determined. If these are found to be unsatisfactory, corrective impedances are inserted at such points as will give the desired results.

**Resonant Line Chokes**

Physically the resonant line chokes are dividing into two classes. The single layer type is used for introducing moderate amounts of resistance into the power line and the double layer type for introducing a high resistance to isolate an undesirable circuit. The single layer resonant line choke consists of an inductance coil similar to a standard lightning arrester choke and the necessary tuning equipment. The double layer type is similar except that the number of turns on the inductance coil has been doubled by the addition of another layer of winding.

The tuning equipment diagram of connections is given in Fig. 16. The condenser C₁ is used to tune the main inductance coil L₁ to the frequency it is desired to obstruct. An additional tuned circuit L₂, C₂ coupled to the main coil L₁. It also contains an adjustable resistance R₂. The function of the second circuit is to broaden the resonance curve so as not to injure modulation. By tightly coupling the second circuit to the first, the system is made to tune to two frequencies. In this way a single choke can be made to block two frequency bands. By varying the adjustment of this circuit the impedance presented by the choke can be changed from a high impedance over a narrow band of frequencies to a moderate impedance over a wide band of frequencies.

A typical impedance curve for the double layer type of choke is shown in Fig. 17. Chokes are placed in each of the line conductors so that the total line-to-line impedance is of the order of 12,000 ohms as compared to the line characteristic impedance of 825 ohms. It is evident that a circuit isolated by this type of choke cannot divert any appreciable amount of the communication current.

In Fig. 18, curve No. 1 shows the resistance curve of a single layer choke adjusted to give a moderately high resistance at two frequencies. By the use of this type two channels can be cleared. A resistance of approximately 400 ohms per choke is sufficient to limit the current in an undesirable circuit to a value that will not seriously affect the communication channel. The adjustment may be changed so as to give a very flat impedance curve as shown in curve 2, Fig. 18. This is a very valuable characteristic, and is used where it is necessary to stabilize a power system and still transmit through the chokes as in the case shown in Fig. 6.

**Conclusion**

The ideal condition for a high-frequency telephone system is to have the line a simple circuit directly connecting the points between which communication is required. This ideal may be approximated as closely as desired by isolating the channel from the rest of the power system. This is made possible by the installation of resonant line chokes at appropriate points. Some of the advantages gained are:

1. Increased stability.
2. Improved quality of speech transmitted.
3. Reduction in the noise level due to the greater energy delivered to the receiver.
4. Freedom from variation in signal due to switching.
5. Simple transmitting and receiving equipment satisfactory on complex systems.
6. Increased reliability.
7. Ability to transmit through practically any type of system.
8. Ability to utilize all lines between communication points.
9. Interference with equipment on adjacent power systems can be eliminated.
10. Reduction in field work at the time of installation.

The application of the established line theory to the analysis of power lines has materially advanced the art of telephone communication over power lines. It is now possible to predict with reasonable accuracy what frequencies can be successfully transmitted over a given power network. This materially reduces the extensive field work which has often been necessary when making an installation. If the analysis shows that there are conditions which prevent the use of the desired frequency bands, corrective measures may be taken by installing resonant line chokes at suitable points. System limitations are largely overcome by this procedure and the field of application of high-frequency communication materially increased.

**Abridgment of System Stability as a Design Problem**

**BY R. H. PARK* and E. H. BANCKER**

*Associate, A. I. E. E.

Synopsis.—Under modern conditions of operation the ability of the component machines of a power system to hold in step during system disturbances has become of major importance in the choice of system layout and machine design. This situation has greatly stimulated activity in the study of the problems involved. This paper reviews the general problem in the light of recent analytical and experimental studies made by the authors. The subject matter of the paper is grouped according to the following headings:

Part I reviews the factors affecting stability, including generator short-circuit ratio, voltage regulators, excitation systems, neutral impedance, governors, amortisseurs, intermediate condensers.

Part II gives methods of calculating stability, under the following headings: preliminary calculations, idealized case of two machines, general case of two machines, extension to include more than two machines, simplified method of calculating tie lines.

The appendixes include an example illustrating the method of calculation in a particular case.

Originally the maximum power output of synchronous apparatus was fixed by the maximum current which the machines could supply without excessive heating, while the maximum power which could be transmitted economically over a transmission line was determined by the allowable losses in the line.

However, as progress was made in the design of electrical machinery and as the voltages at which power was transmitted were increased, it was found that the line and machine reactances must be held low enough to avoid the possibility of pull-out or instability, whether occasioned simply by excessive loads or by system disturbances.

Practically, this situation was met principally by designing generators with short-circuit ratio sufficiently high, and line reactance low enough to meet ordinary requirements. At the same time, however, the latent economic advantages in view have greatly stimulated interest in the development of means auxiliary to these, by which increases in stability of operation can be economically effected.

Further, in order to make possible the design of systems on a rational basis there has been an active demand for more accurate methods of calculating stability. The present paper gives first, a brief review of the principal factors affecting the stability of power systems; then, a summary of some of the methods of calculation which the authors have employed in the study of practical systems.

**Part I**

**Review of Factors Affecting Stability**

a. Generator Short-Circuit Ratio. In general, the maximum power that can be delivered by a synchronous generator depends upon the character of the load circuit to which the generator is connected. By way of illustration, suppose that a turbo alternator is supplying power for an induction motor load connected directly to its terminals, and suppose that as the induction motor load is gradually increased, the generator terminal voltage is maintained substantially constant by occasional manual adjustment of the generator's exciter field rheostat. Neglecting saturation, if the induction motor is of normal design, and is supplying a constant torque load, the torque at instability is found to vary in this case with generator per unit reactance, as shown by the lower curve of Fig. 3.

On the other hand, if the load torque is proportional...
to the square of the speed, i.e., to \((1-\delta)^2\), as would occur substantially with a fan or centrifugal pump load it is impossible to find any condition under which the motor can be unstable. However, there is a maximum torque which can be carried in this case. This is shown by the upper curve of Fig. 3.

It will be seen that for constant torque load the generator synchronous reactance must not exceed approximately 1.20 for stability at full load. In practice, the effects of saturation and of any shunt load will be to permit a higher value of machine reactance with stability. Were the induction motor replaced by a synchronous motor the generator and motor per unit synchronous reactances could not exceed unity for stability at full load, while if the generator and motor are separated by a transmission line it is necessary that their reactances be less than unity for stability under the same conditions. Actually, of course, as mentioned in the previous instance, the effects of saturation and of impedance load are to reduce the requirements as to low synchronous reactance, or what is substantially the same thing, high short-circuit ratio. Nevertheless,

even considering this circumstance, the fact remains that machines which are to be operated with manual control of excitation require in general a short-circuit ratio in the neighborhood of unity, especially if ability to operate through severe system disturbances is desired, while if long distance transmission over high-voltage lines is involved a short-circuit ratio considerably higher than unity may be found advantageous.

When synchronous machines were first being built this limitation was not felt, since the requirements for inherent voltage regulation necessitated construction with high short-circuit ratio. The advent of the Tirril regulator largely disposed of this necessity. This circumstance, together with the development of improved designs permitting greater current loading of the armature, has established a considerable inducement toward the use of machines of low ratio both from the standpoint of reduction in first cost and improvement in efficiency. On the other hand, power transmission developments have tended to demand a high ratio.

b. Voltage Regulators. If the excitation voltage can be continuously varied in proper phase relation to the machine terminal voltage it is possible to operate above the limit of stability with hand control. Recent tests have shown that when an appropriate type of regulator is employed a large gain in stability is available both under steady and transient conditions. Thus, Fig. 4 shows the gain in steady-state stability due to such a regulator as a function of the length of the transmission circuit. In the case of system disturbances the regulator has an additional function to perform; viz., to effect rapidly a substantial increase in the exciter

1. Bibliography 11.
voltage, thus reducing the decrease of field flux linkages which would otherwise occur, or actually causing them to increase. In practise the gain to be anticipated in stability through faults depends both upon the regulator's ability to effect rapid increases in excitation and upon its ability to resume "balancing" after the initial phase of the disturbance is past.

The magnitude of the gain to be anticipated in practise is illustrated by Figs. 4 and 5.

Besides its effect in increasing the stability of machines of normal design, the regulator should make possible the utilization of machines of lower short-circuit ratio than would otherwise be practicable, for by its action it provides the stability that could not otherwise be obtained in machines of this type.

The regulator has a further field. It may also be applied with benefit to synchronous motors and frequency converters, especially when severe load surges are to be encountered. The gain to be anticipated should be especially great with this class of apparatus since it operates substantially from an infinite bus; i.e., there is no transmission line.

c. Excitation Systems. The gains in stability which can be effected by a voltage regulator of a given type depend upon the rate of voltage build-up of the exciter, and upon its operating and ceiling voltages.

The available data indicate that if normal ceiling voltage is available, a moderate speed of excitation,—say 150 to 200 volts per sec.2 for large machines—is sufficient in the usual case to prevent pulling out of step on other than the first swing of the machine rotors. In general, the gain due to a higher speed of build-up than this is small in comparison with the gain obtainable with the speed of excitation referred to, since with these higher speeds, the time available for modifying the rotor flux linkages is small (of the order of \( \frac{3}{4} \) sec.). Thus, careful step-by-step calculations were made in the case of three representative systems in which waterwheel generators feed load centers over transmission lines of respectively 60, 120, and 250 mi. The results showed that the power which can be carried without pull-out on the first swing of the machine rotors, after the occurrence of a line to ground fault on the generator bus, is only from four to six per cent more with excitation sufficient to maintain constant rotor linkages3 than can be so carried with a speed of excitation sufficient to prevent pull-out on the second swing, i.e., about 150 to 200 volts per sec. This conclusion is borne out by the test data in Fig. 6 which shows the gain in transient stability as a function of exciter speed for a line to ground fault on one of two 250-mi. lines.

As these data were taken with small machines the excitation speeds shown should be multiplied by a factor less than unity in order to pro-rate them to correspondence with large machines. This factor probably ranges from 0.5 to 0.6.

On the other hand, in some cases, and especially in connection with synchronous condenser stations, it may be desirable to secure additional stabilizing action by building up the machine excitations to a very high value within a fraction of a second. To achieve this result requires a new type of exciter; one with a high ceiling voltage, and with a correspondingly high speed of build-up.

d. Neutral Impedance. The generally admitted circumstance that the majority of transmission line lightning flashovers establish arcs from one line to ground, and thus that this type of fault is of primary importance in determining the transient stability of transmission systems, suggests the desirability of using current limiting resistors or reactors in the high-voltage transformer neutrals, or as an equivalent grounding the neutral, and designing the transformer for high-impedance to ground current.

Obviously any means for reducing the magnitude of the system fault current is beneficial from a stability standpoint. In general, however, it is desirable that enough reactive current be permitted to flow to allow rapid selective relaying by ground current relays, and to avoid the possibility of arcing grounds. Consideration is invited to the greater use of reactors instead of the usual resistors. In principle, a reactor in the neutral is no more likely to cause excessive system voltages than a grounding transformer is, that is, precautions against excessive voltages are not necessary unless the reactor approaches the dimensions of a Petersen coil. Also even with a Petersen coil there does not appear any source of danger which cannot be overcome with relative simplicity. In most cases, however, very large gains in stability are obtainable with reactors which do not even approach to the Petersen coil value, i.e., to a value such that the reactor current equals the fault charging current.

2. For 250-volt fields. One-half as much for 125-volt fields.
3. Equivalent to about 600 volts per sec. with a normal ceiling exciter.
The principal advantage of reactors as compared with resistors is their greater reliability, usually lower cost, and the fact that in case of line to ground fault they tend to increase the phase to ground voltage on the clear phases to a much lower extent. This last factor which is illustrated in Figs. 7 and 8 is of great importance in connection with duty on lightning arresters. In order to obtain an appreciable gain in stability the resistance must be considerably greater than the system reactance viewed from the point of fault. Referring to the figures this means that the voltages to be anticipated from a clear phase to ground are necessarily \( \sqrt{2} \) or more times normal voltage.

With a reactor this is not the case, and in fact a marked gain in stability can be obtained with a value of reactance such that clear phase to ground voltage is say less than 20 per cent more than normal.

Although the use of grounding reactors of high enough reactance to approach the Petersen coil value has not been recommended generally, it is felt that in a large number of cases the use of Petersen coils may nevertheless be desirable, provided that suitable precautions are taken to prevent the occurrence of excess voltages during switching.

e. **Governors.** In a considerable number of instances momentary system disturbances have been followed by prolonged hunting due to "pumping" of the steam turbine governors. This condition usually arises when the regulation of the governors, that is, the speed range from no-load to full load with synchronizing spring fixed, is unduly low. To avoid hunting of this character it is desirable that the regulation be four per cent or above.

f. **Amortisseurs.** In general any damping influences in a system tend to improve stability, and especially in connection with systems involving a number of independent machines each of which is capable of swinging more or less independently of the others. Further, when high resistance lines are involved, stable operation of laminated pole machines without damping windings may be impossible under some load conditions. A consideration of these factors suggests the general desirability of equipping water-wheel generators with low resistance amortisseur windings.

g. **Intermediate Condensers.** The use of synchronous condensers or of synchronous condensers in combination with shunt reactors is sometimes preferable to the construction of additional overhead line. In such cases, however, it is probably desirable that use be made of a balancing type of voltage regulator, as the stabilizing influence of the condenser is greatly increased in this way. Thus, shop tests on a model 500-mi. line show the following results:

Gain in steady power limit over hand control value with no condenser,

- a. With regulator on generator and motor but no condenser 21 per cent.
- b. With intermediate condenser equal in size to generator and motor but hand control on all machines 25 per cent.
- c. With intermediate condenser and regulator on all machines 99 per cent.
**Abridgment of**

**High-Voltage Phenomena in Thunderstorms**

BY MARCEL A. LISSMAN

Associate, A. I. E. E.

Synopsis.—Lightning phenomena are analyzed in the light of laboratory experience with high-voltage phenomena in the atmosphere. Special emphasis is placed on the effect of space charges in producing high local stresses when mobilized through channels of high conductivity caused by high temperatures. A detailed analysis is included of the steps through which air at atmospheric pressure passes when, due to applied electric stresses, its electric properties change from those of a non-conductor to those of a highly conducting body—perhaps many times as conducting as a metallic conductor at ordinary temperature, and then again resumes its original non-conducting properties.

The electrical quantities involved in thunderstorms are of an order of magnitude different from those encountered in ordinary engineering experience. In the laboratory, sparks 20 ft. in length have been obtained with an applied potential of 2,000,000 volts, 60 cycles. Compared with a lightning flash several miles in length these results seem puny indeed. Yet the results obtained in the laboratory enable us to analyze the phenomena occurring in nature, and thus obtain a clearer mental picture of the mechanism involved in the formation of lightning flashes.

The conductivity of the atmosphere is due to the presence of ions which, when acted upon by an electric field, give rise to a displacement current. If it were not for these charged particles, air would be a perfect insulator. Ions are always present in the atmosphere, as they are formed spontaneously due to the action of traces of radio active matter, cosmic rays, etc. However, the conductivity which these sources of ions lend to the atmosphere is so small that it has no engineering significance. When the saturation current is not reached, that is, when the ions are not removed by the field as fast as they are formed, then the current through the air is proportional to the voltage gradient and to the cross-section of the path. In symbols, the relation is

\[ I \propto G \cdot A \]

where \( I \) is the current, \( G \) the voltage gradient, and \( A \) the cross-section of the path considered.

Relation (1) represents the behavior of air under low voltage stresses.

When the voltage is gradually raised, the saturation current is soon reached. The voltage can then be raised considerably without change of current. However, as soon as the voltage gradient at some point in the field reaches 76 kv. per inch, the current suddenly increases. Thus is due to the cumulative effect of collision ionization.

Ions present in the field are then so accelerated between collisions as to possess sufficient kinetic energy to produce new ions when they collide with neutral atoms. The rate of formation of ions is thus enormously accelerated. The clouds of ions thus formed are referred to as space charges and greatly disturb the original electric field. The action of space charges upon the electric field is always such that it prevents the gradient from rising above the critical value of 76 kv. per inch where the stress is most intense. Outside the region of breakdown the gradient is increased above the value it would have for the same applied voltage if the space charge were not present. This is illustrated in Fig. 1, a and b. The body \( A \) is at a positive potential and \( B \) at a negative potential, the configuration being such that the electric field diverges from \( A \). If the potential between \( A \) and \( B \) is raised, the gradient in the neighborhood of \( A \) soon reaches the critical value for air.

Collision ionization then enormously increases the supply of ions in that region. The negative ions travel toward \( A \) and become discharged. The positive ions travel toward \( B \) and form a space charge. At \( 1B \) the applied potential is much greater than at \( 1a \), yet the gradient in the neighborhood of \( A \) has not been increased. However, the gradient between the space charge and \( B \) is greatly increased, as shown by the additional lines of force originating on the space charge and terminating on negative charges at \( B \).

When collision ionization takes place in a restricted region of a divergent field, the resulting phenomena are referred to as corona. Even though the initial electric field might have been symmetrical, the appearance of corona shows a strong tendency of the corona current toward concentration into preferred paths of restricted cross-section compared to the cross-section which seems available from mathematical considerations. This
tendency results in the formation of corona streamers. It may be represented in symbols by the relation

\[ g \propto A \cdot F(i) \]  

(2)
or the conductance, \( g \), varies as the cross-section of the path and some function of the current density, \( i \). The function \( F(i) \) is such that the increase in conductance resulting from an increase in current density more than offsets the decrease due to the reduction in cross-section.

The formation of corona streamers is the first stage in the building up of preferred discharge paths of restricted cross-section. The various manifestations of corona, such as light, sound, and chemical changes, show that considerable ionic activity is present in corona streamers. Physicists give us plausible reasons why such intense ionic activity in corona streamers should have a tendency to lower the critical gradient of cumulative collision ionization. Some results obtained by them with the discharge tube suggested that the bluish light observed was not due directly to the recombination of ions. At the low pressures used, the velocity of the ions due to the electric field would be such that the Doppler effect should be observed. As this is not the case it has been concluded that the sources of light were neutral atoms not affected by the electric field, and consequently at rest. An explanation which has been proposed is that when ions of opposite sign recombine to form neutral atoms, i.e., when a positive nucleus recaptures a lost electron, the quantum of energy radiated is in the form of very short wavelengths outside the visible spectrum. These rays are supposed to have a very limited range. They have the power to excite neutral atoms; that is, they furnish sufficient energy to a neutral atom to lift one of its electrons from an inner stable orbit to a less stable outer orbit, where the electron possesses potential energy with respect to the nucleus. The electron upon falling back to a more stable orbit radiates this energy at a longer wave length which falls in the visible spectrum. It is this light emanating from neutral atoms which is observed.

With the above in mind, we must consider that the intense ionic activity in a corona streamer is due to the active recombination of ions constantly taking place. Due to such active recombination a considerable number of neutral atoms in the streamer are excited, that is, the electron has already been furnished part of the work required for complete ionization. For these excited atoms a collision of lesser magnitude, corresponding to a lower voltage gradient, will suffice to complete the work of ionization.

As the current density in a streamer further increases, temperature begins to play a more important part. In the final stage, a high degree of conductivity, perhaps greater than that of metallic conductors of the same cross-section, is imparted to the filamentary channels due to the very high temperature attained as the result of the large amount of energy released per unit volume in the conducting path. It is probable that when the temperature in the filament is sufficiently high, the violent thermal agitation of the gas suffices to keep up a supply of ions great enough to account for the high conductivity attained. This final stage in the condensation of the discharge into narrow filamentary channels lends itself particularly well to analysis and will be discussed here, but it must be remembered that the change from the initial corona streamer is gradual and not in distinct steps.

Let us assume that a discharge is being transmitted from \( a \) to \( b \), Fig. 2, along a cylindrical path. Some heat will be generated by the passage of the discharge. At low temperatures the heat will be dissipated mostly by conduction or convection across the cylindrical boundary surface. We can reasonably assume that the conductance of the path varies in some manner with the temperature, \( T \). This will be the case when the thermal agitation of the gas becomes so high that a certain proportion of the collisions will result in ionization. Theoretically, for any temperature above absolute zero, some velocities will be sufficiently high to cause ionization, but the probability of such velocities at low temperatures is vanishingly small. However, this probability increases rapidly with the temperature. The ions when free are acted upon by the electric field and subjected to a drift which is superimposed upon the random thermal agitation and is equivalent to a current. Thus the path has some of the properties of metallic conduction. The current will depend upon the proportion of free ions, and this in turn will depend upon the temperature. We can therefore write

\[ g \propto A \cdot F(i, T) \]  

(2a)
or the conductance varies as the cross-section of the path and some function of the current density and temperature.

This relation is essentially unstable, because the temperature reached is caused by the energy loss per unit volume, and therefore depends on the current density, and the current density for a given voltage gradient depends on the conductivity which increases in some fashion with the temperature.

Coming back to the cylindrical path \( a-b \), Fig. 2, the heat generated by the passage of the discharge must at first be dissipated mainly by conduction or convection through the cylindrical boundary. Therefore, the
temperature reached in the interior will be higher than the average, so that the degree of ionization will also be higher. As the conductivity increases with the ionization, the current density will not remain uniform but will be higher where the temperature is higher. This means that in a restricted region of the path along its axis the rate of dissipation of energy will be increased, causing a further increase of temperature. This process continues until some limiting action takes place, so that finally the discharge will be concentrated in a narrow thread-like filament and will require a smaller voltage gradient than initially.

The limiting action referred to is not far to seek.

When the temperature is very high, radiation has a greater influence upon cooling the filament than conduction. The radiation of a black body varies as the fourth power of the absolute temperature, and such a relation is more than ample to limit the path to a finite cross-section by limiting the temperature which the filament might attain.

In a thundercloud, positive and negative charges are distributed throughout great volumes of cloud in the form of large ions having low mobilities. It is convenient to represent the stress to which the intervening air is subjected by drawing lines from any suitable unit of positive charge to a similar unit of negative charge, as shown in Fig. 3. In Fig. 3 the lines are drawn from a positively charged portion of cloud to a negatively charged portion, or the neutral plane might be considered to represent the ground surface, in which case the negative charge is an electrical image of the positive charge—a great help in computing the field between a charged body and the ground.

If in Fig. 3 we consider the neutral plane to be the ground surface, it is seen that the stress is smallest at the ground because the lines of force are farthest apart there. This will always be the case, as the lines of force must either originate or end on the charges in the cloud depending upon the polarity—a pure convention—but will then spread apart in such a manner that the permit-

tance of the path between cloud and earth is maximum. Due to irregularities at the ground surface there will no doubt be high local stresses, but even if breakdown takes place, this as a rule will result only in the formation of a local space charge which will be sufficient to relieve the stress, because the volume of overstressed air is small. Breakdown will generally take place in the cloud due to the wind shifting the charges in such a manner that a large volume of air becomes overstressed. This is necessary in order that sufficient energy be available for the formation of filaments of high conductivity. These conducting paths then transmit the high stresses to their end points and lengthen by successive breakdown of the air.

The manner in which a filament of high conductivity transmits the stress to its end points will now be illustrated. Fig. 4A shows the lines of force in a parallel field, the voltage gradient being considerably below the critical value for air. Let the dotted line represent a channel of high conductivity caused by thermal dissociation. This channel contains both positive and negative ions in equal numbers so that their total effect upon the external field is zero. The ions continually form and recombine, the percentage of atoms ionized at a given temperature of the channel remaining constant. While the ions are free they are acted upon by the electric field, so that a small unidirectional shift is superposed upon their random thermal agitation, the positive ions shifting towards one end of the filament and the negative ions shifting towards the other end.

This takes place along the whole length of the channel, and although each ion may shift only slightly, if their number is large the total effect might represent a very large current. Due to this shifting caused by the electric field, ions of one sign will accumulate at one end of the filament and ions of the opposite sign at the other end. Such an excess of ions of one sign at the ends of the filament alters the original field in a manner shown at 4B. It is seen that the gradient at each end of the filament has been considerably increased, while the gradient along the filament, which causes the shifting action, has been decreased.

If the energy initially stored in the dielectric is too small, the shifting action in the filament will cease as soon as the voltage gradient along the filament falls to a sufficiently low value. This will happen before the
critical gradient for air has been reached at the end points. The conductivity of the filament is due to the high temperature caused by the passage of the current in a very restricted channel, and as soon as the current decreases the filament will cool and its resistance will increase. This will decrease the current still further, resulting in additional cooling and increase in resistance. This action will continue at an accelerated rate until all traces of the path have disappeared, just as if a switch had suddenly been opened.

On the other hand, if the energy stored in the dielectric is sufficiently high, then the critical gradient for air will be reached at the end points before the gradient along the channel has fallen to the point where the resulting current fails to maintain thermal dissociation in the channel. As soon as the critical gradient is reached at the end points, collision ionization takes place and corona streamers form radiating outward from the point. As a rule, thermal dissociation will first become effective in one of these streamers. When this takes place large currents will flow along this streamer in the manner outlined above, resulting in a considerable reduction in the voltage gradient. The high gradient required to maintain the action along the other corona streamers having collapsed, the activity in them will stop. Fig. 4c illustrates the lengthened channel, showing already an accumulation of charges and increased gradients at the end points. The channel continues to grow in this manner as long as the gradients at its end points reach sufficiently high values to cause local breakdown of the air.

The conductivity reached in a channel where thermal dissociation takes place depends solely on the current density and resulting temperature, so that the gradient along the channel may fall to a value as low as a few hundred volts per foot, while the original gradient may be as high as 100,000 volts per foot. Thus, as soon as the conducting channel reaches a length of several hundred feet, the energy available to cause breakdown at its end points becomes very large. The voltage gradient accumulating at the end points is limited by the breakdown strength of air which results in lengthening the channel. The voltage used up in this manner might reach five million volts. For a strong initial field, the rate of breakdown and lengthening of the filament increases.

The channel will continue to increase in length, branching out in the clouds wherever the necessary gradient is available, until the potential of the cloud has been so reduced that the current density in the channel can no longer be maintained, when the action stops in the manner outlined above. Fig. 5 illustrates a cloud discharged in this manner. The dotted lines show where the conducting filaments were located. It will be seen that the initial charges are still located in the cloud. Wherever the gradient was sufficiently high, ionization channels formed which planted space charges of opposite sign throughout the body of the cloud. The potential of the cloud has thus been considerably reduced. The gradient between opposite charges in the cloud is still quite high, and the charges gradually neutralize each other due to convection. However, the resultant gradient between cloud and earth has fallen to such a low value that it cannot permit the growth, or even maintain, conducting channels.

It remains to indicate what bearing the above analysis may have on the possible application of a scale factor to laboratory experiments in lightning protection. Even the tallest lightning rods distort the general field of a thundercloud to such a slight extent, that they scarcely can have any influence on the instigation and guidance of a lightning flash. Whenever a lightning flash originates in the clouds and grows toward a lightning rod, during the period of growth the gradient at the rod increases, at first slowly, then more rapidly as the end of the conducting channel comes closer to the rod. When it approaches within less than 100 feet from the rod, the gradient at the rod might reach a value of the order of 300,000 volts per foot. This is illustrated in Fig. 6. The voltage gradient and volume of overstressed air at the rod then becomes sufficiently great to permit the formation of a streamer of high conductivity starting out from the rod and growing in the general direction in which the field is most intense. When this occurs, the gradient between the ends of the
growing lightning flash and the streamer from the rod may reach values several times as great as the gradient in any other direction, and the two ends therefore grow towards each other until they ultimately connect. This explains why lightning hits elevated points which initially do not sufficiently distort the original field to guide the flash.

Similar considerations show why some lightning transients on transmission lines may have steep wave fronts of the order of a few microseconds. If a lightning discharge strikes very close to a transmission line, the voltage gradient at the point of nearest approach first increases slowly, reaches a maximum and then suddenly collapses in the time required for the flash to bridge the last 100 feet or so of the gap. The latter time depends upon the driving power behind the flash; that is, the energy initially stored in the electric field of the thundercloud.

The Graphic Solution of A-C. Transmission Line Problems

BY F. M. DENTON
Fellow, A. I. E. E.

Foreword.—The success of the series capacitor in increasing the load capacity, as well as improving the regulation of those a-c. transmission lines on which it has been tried, promises to lead to its wide adoption. The high loading and excessive short-circuit currents entailed by the series capacitor have to be cared for by safety devices, and in order to be able to design and properly locate such devices, it becomes essential to predetermine the values of current and voltage at every point along the line.

Synopsis.—A step-by-step method is described for drawing the complete polar vector diagrams of current and voltage in an a-c. transmission line supplying a given load. Its chief novelty consists in the use of celophane tissue instead of ordinary drawing paper. Such tissue is easily obtained commercially, as it is used chiefly for wrapping candy boxes. It is transparent, thin and flexible and takes ink well.

The usual implements, such as scales, protractors, triangles and compasses, are unnecessary. The required vector scales, impedance triangles, and multiplying triangles are laid out in ink upon a sheet of squared paper mounted on a drawing board, and the vector diagram is produced on the superimposed celophane by tracing, the celophane sheet being shifted as required in determining successive points on the vector diagram.

It is true that no step-by-step method is as accurate as the mathematical method, but the method described takes only some one or two per cent as much time as the mathematical method and with practice becomes as accurate as working conditions demand.

The ideal method of finding the magnitudes of the current and voltage at points along an a-c. transmission line is the mathematical method; but anyone who has used that method knows that it consumes much time.

Because of the slowness of the mathematical method the straight forward step-by-step graphical method is preferred; but it also is slow and its results are inaccurate. The inaccuracy of the step-by-step method as ordinarily carried out is due partly to the mechanical difficulties of drafting and largely to the "rule and dividers" method generally employed for measuring and transferring the increments of current and voltage.

The present paper describes a novel method of drafting which makes drafting tools unnecessary, and by reducing the operations to a minimum, ensures both speed and accuracy.

Theory of the Method

A cable or other transmission line having given electrical constants is delivering alternating current of given frequency to a fixed load of given constants, and it is required to draw a complete vector diagram showing the current, the voltage at every point along the line, and their phase relationship. Fig. 1 gives an example of such a diagram. \( O \ I_L \) is the vector of current taken by the load and \( O \ V_L \) the vector of voltage at the load terminals. The lower curve is the locus of the extremities of the current vectors for points up to 30 mi. distant from the load end of the line, the distances in miles being marked as shown. For instance, the line drawn from 0 to 10 on the lower curve is the vector of current in the line at a point 10 mi. away from the load when the load current is \( O \ I_L \). At this point in the line, the line voltage is shown by the vector 0-10', the point 10' being taken on the voltage (upper) locus. Thus the power...
factor of the load as measured at the load terminals is the cosine of the angle $V_L \theta I_L$, while the power factor measured at a point 10 mi. away from the load is the cosine of the angle $10 \theta - 10'$. Step-by-step methods of building up such diagrams assume that over some short length of line—often one mile is short enough for practical accuracy—the value of the line voltage may be reckoned equal to the voltage at the end of that short length. For example, it would be assumed that the line voltage one mile away from the load terminals is equal to the load voltage. With this preliminary assumption, the charging current and the leakage current in that one mile of line are calculated and added vectorially to the load current $O I_L$. The current vector thus obtained is multiplied by the impedance of one mile of line and the product represents the increment of voltage which has to be added vectorially to the load voltage in order to get the true line voltage one mile away from the load terminals. This value of the line voltage is supposed to act up to a point two miles from the load and the charging current and leakage current in the second mile can thus be calculated. The vector sum of these currents is now added vectorially to the current vector previously obtained and we thus find the line current two miles away from the load.

Succeeding increments of current and voltage are obtained in a similar way.

**Proposed New Procedure**

The chief novelty of the procedure lies in the use of celophane instead of paper for the vector diagrams. It is as transparent as clear glass, as thin as tissue paper and takes ink well. Its perfect transparency makes possible both speed and accuracy. A sheet of celophane of any convenient size may be used, but for accurate work it should be large, say, 30 in. square. For convenience in handling, the sheet should be glued to a frame made of stout drawing paper. Upon this sheet of celophane is drawn the vector diagram $V_L O I_L$ of the load, any convenient scale being used for current and voltage.

A large sheet of accurately ruled squared paper (millimeter squares are convenient) is fixed upon a drawing board and upon it are glued, at properly chosen angles, a pair of strips of celophane, each ruled with a clear straight line, marked off as a millimeter scale. Two triangles are drawn upon the squared paper, by aid of which the current and voltage vectors may be multiplied by the required constants for obtaining the increments of voltage and current.

The process of drawing the vector diagrams is best explained by reference to an actual example:

An overhead telephone line has a "go-and-return" resistance of 110 ohms per mile (that is to say the wire itself has a resistance of 55 ohms per mile) $r = 110$.

The go-and-return inductance per mile is $L = 0.0056$ henry.

The insulation resistance measured between one mile of "go" conductor and the corresponding mile of "return" conductor is $R = 0.08$ megohm.

The capacity between conductors per mile is $K = 0.0009$ μf.

The load has a resistance of 120 ohms and an inductance of 0.13 henry and requires a current of 25 milliampere.

The frequency of the a-c. being transmitted is 1300 cycles per second.

Load diagram (Fig. 2):

\[
2 \pi f l = 2 \pi \times 1300 \times 0.13 = 1061 \text{ ohms reactance.}
\]

\[
z = \sqrt{120^2 + 1061^2} = 1065 \text{ ohms impedance.}
\]

25 milliamperes will require a load potential difference of 0.025 x 1065 = 26.63 volts, and this potential difference will lead on the current by $(\tan^{-1} 1061/120 =)$ 83 deg. - 33'.

Impedance per mile of line:

\[
X = 2 \pi f L = 8160 \times 0.0056 = 45.7 \text{ ohms,}
\]

\[
hence,
Z = \sqrt{R^2 + X^2} = \sqrt{110^2 + 45.7^2} = 119 \text{ ohms.}
\]

\[
\tan \phi = X/R = 45.7/110 = 0.416, \text{ and } \phi = 22 \text{ deg.} 35'
\]

Susceptance, leakage conductance and admittance per mile:

\[
\text{Susceptance, } B = 2 \pi f C = 81 \times 60 \times 9 \times 10^{-9} = 73.4 \times 10^{-4} \text{ mho.}
\]

\[
\text{Leakage conductance, } G = 1/(0.08 \times 10^6) = 12.5 \times 10^{-6} \text{ mho, and}
\]

\[
\text{Admittance, } Y = \sqrt{G^2 + B^2} = 74.5 \times 10^{-4} \text{ mho.}
\]
\[ \tan \phi = \frac{B}{G} = 5.86, \text{ whence } \phi = 80 \text{ deg. } 19'. \]

Hence, for one mile intervals we have:

- Increment of voltage,
  \[ dV = \frac{ZI}{\sin 22 \text{ deg. } 35'} = \frac{1191}{\sin 22 \text{ deg. } 35'} \]

- Increment of current,
  \[ dI = \frac{V}{\cos 80 \text{ deg. } 19'} = \frac{0.075}{\cos 80 \text{ deg. } 19'} \]

We mount a large sheet of millimeter paper on the drawing board—(Fig. 3)—and having made two strips of celophane, each about one inch by five inches and with a central longitudinal line divided, a few centimeters of its length, into millimeter divisions, we fix one of these conveniently as at A in Fig. 3 so that the zero of its scale lies on a crossing of the squared paper while its center line makes the angle 22 deg. 35' with the horizontal.

The other celophane strip is fixed, at say, B so that its center line makes an angle of 80 deg. 19' with the vertical.

Choice of scale for load diagram:

The scales of volts and amperes may be chosen to suit the size of the diagram. In our example, we take 2.5 millimeters per volt and per milliampere. Then writing:

- Magnitude of increment of voltage, \( dV = 1191 \), where \( I \) is in amperes, or 0.119 \( I \), where \( I \) is in milliampere, and magnitude of increment of current, \( dI = 0.075 V \) where \( V \) is in volts, we make use of two multiplying triangles, the one for finding \( dV \) having a ratio of base to height of 1 to 0.119 and the other, for finding \( dI \), having the ratio 1 to 0.75.

The base of the former should be at least as many centimeters long as the longest current vector is likely to be in milliampere, while the base of the latter should be as many centimeters long as the longest voltage vector is likely to be in volts.

In our example, the two triangles were drawn upon one common base 30 cm. long.

For speed and ease of reading the vertical scales of the multiplying triangles may preferably be a multiple of the horizontal scales. In Fig. 3 the vertical scales are four times as open as the base scales, so that a vertical height of one centimeter means one milliampere or one volt.

**PROCEDURE**

We superimpose the celophane sheet upon the sheet of squared paper, and so measure the length of \( OI \) which we find to be 6.25 cm. as it represents 25 milliampere to a scale of 2.5 mm. per milliampere.

Applying the line \( OI \) to the base of the multiplying triangle, we read off a vertical height of 3.1 cm. from the point \( I \) to the hypotenuse of the 0.119 triangle. This gives \( dV = 3.1 \text{ cm.} = 3.1 \text{ volts}. \)

Shifting the celophane sheet into such a position that while \( OI \) coincides with one of the horizontal lines of the squared paper the point \( V \) lies on the point \( A \) we put a dot of ink on the celophane at the point 3.1 volts (= 7.75 mm.) as seen on the scale A. Call this point \( V_1 \) (Fig. 4). Next measure the distance \( O \) to \( V_1 \) by laying the celophane sheet on the base of the multiplying triangle and measure the vertical height, 2.1 cm. (= 2.1 milliampere) to the 0.075 hypotenuse.

Now move the celophane so that while \( OV \) lies along a vertical line of the squared paper the point \( I \) falls on \( B \) and put an ink dot at the point 5.25 mm. (= 2.1 milliampere) along the \( B \) scale.

Continuing in this manner any number of successive points may be found. Fig. 5 takes the diagram to a distance of twenty-two miles from the load, one point being given at the end of each mile.

**GAS LIGHTING IN PARIS**

Manufactured gas—though more costly in France than in America—continues to dominate the field of illumination in Paris, according to George Reclus, Chief Engineer of the Societe du Gaz of the French capital, who was a visitor in Chicago recently.

The Parisian lighting system is comprised of 80 per cent of gas installations and 20 per cent electric, M. Reclus stated.—Trans. I. E. S.
Abridgment of

Some Problems in High-Voltage Cable Development

BY E. W. DAVIS*
Member, A. I. E. E.

INTRODUCTION

A large amount of research work on high-voltage cable is being carried on throughout the country. It is generally recognized that duplication of effort can be reduced and general progress increased by comparison and common discussion of the independent investigations.

In order to encourage such cooperation, a few of the problems that are receiving attention in a manufacturer's laboratory are briefly presented herewith, effort being made to include a maximum amount of actual test data and a minimum amount of description and discussion.

MEASUREMENT OF DIELECTRIC LOSS AND POWER FACTOR

In order to obtain increased sensitivity, the high-voltage bridge of Dawes and Hoover has been installed in addition to the three-phase dynamometer method already available. The necessary high-voltage air condenser was constructed with three vertical plates, each 50 in. by 74 in.

The bridge was made applicable to three-phase measurements by development of the connection given in Fig. 1,† the only disadvantage of which is that a balance without the cable connected must be taken for each test voltage.

DETERMINATION OF INSULATION QUALITY

Considerable experimental work is in progress with the object of improving the quality of cable insulation. It is obvious that the reliability of the experimental indications is entirely limited by the reliability of the criterion of quality that is used. The most reliable test in common use for such purposes is the overvoltage life test on small cable samples, (often only 10 ft. long), at room temperature, with the cable ends in a cone of transformer oil.

Considerable experience with this test suggests that because of the great contrast between its conditions and those in service, it may not always give a true indication of relative quality. It is becoming an accepted fact that the cause of most premature failures in service is due fundamentally to the presence of shrinkage voids in the insulation that are formed by the shrinkage of the compound when it cools. While the service conditions, (extreme temperature changes with the insulation approaching a constant enclosing volume condition), encourage this void formation, the life test conditions (constant temperature with the insulation at the ends of the sample exposed to constant pressure) tend to discourage the void formation. Due to the different contraction and viscosity characteristics of the different compounds, this tendency may vary with different compounds.

Table I shows the results of life tests on cable saturated with three different compounds at each of several testing conditions. It is seen that the life is in general increased by conditions unfavorable to void formation and decreased by conditions favorable to void formation, the tendency varying with the compounds. In connection with the influence of conditions No. 2 on the cylinder oil, it has generally been found that when the life test is interrupted for several hours, the life will be increased, the cause being apparently the same in both cases—the application of sufficient heat to liquefy the compound and improve the void distribution. The relative independence of the resin compound to testing conditions also merits attention.

![Table I](image)

Investigation of the life test is in progress with the object of improving its reliability, possibly by some such modification as No. 4.

The ionization test or variation of power factor with voltage at room temperature has received considerable attention.
attention as an indication of insulation quality. Fig. 2 shows a comparison between the life test on several cables and an ionization test made just before the life test. While differing in type, dimensions, impregnating procedure, and treatment previous to the life test, the cables were all impregnated with the same compound. The ionization tests were made at 24 deg. cent. and the life test at 20-26 deg. cent.

It is seen that 17 of the 19 samples in Fig. 2 indicate a fair relation between the ionization and life test, a flat power-factor curve in general corresponding to a long life. However, the two resaturated samples of Fig. 2 show up exceedingly well on ionization, but definitely deficient on life. Thus the life test and ionization test do not always agree.

Fig. 3 shows the room temperature power factor at 40 volts per mil versus the life on the same samples. It is evident that this power factor and the life test show a complete lack of agreement.

Air Resistance of Paper

One of the most important properties of the paper is its compactness or denseness. This is usually measured by timing the passage of a given volume of air through a definite area of the paper, under a known pressure, and is known as the air resistance of the paper.

Fig. 4 shows that the air resistance has a pronounced influence on the dielectric strength of the saturated paper in sheet form and that the influence is independent of the kind of fiber, kraft, or manila. The papers shown in Fig. 4 represent 12 different manufactures and, therefore, should be representative.

Table II indicates that the paper air resistance also has a pronounced influence on the dielectric strength of the completed cable. Both cables of each pair were alike in all respects except the air resistance of the paper.

Fig. 5 shows that the air resistance has a marked influence on the penetration of the compound into the paper, the higher the former the slower the latter. The penetration rate of the compound is important to the manufacturer in its influence on the time necessary for saturation of the insulation.

Selection of Compound

As the power factor of the compound has a controlling influence on the power factor of the cable, the deterioration of the compound power factor with heating is of importance.

Without the presence of air, it is insignificant in comparison with the deterioration in the presence of air.

Fig. 6 shows the relative power-factor deterioration of some representative compounds in the presence of air. Each sample was aged in the same shape container so that the area exposed to the air was always the same. All containers were immersed in an oil bath. Natural air circulation through the oven was provided. The temperature distribution was found to be uniform within the bath. The curves show that there is material difference between compounds and that sometimes a blend of compound will show more deterioration than its separate constituents. While the compounds containing resin show more deterioration at first, they eventually show marked improvement.

As the formation of the voids that are so harmful to the quality of impregnated insulation is caused primarily by the contraction of the compound on cooling, the volume change of the compound with temperature is important. Fig. 7 shows this characteristic for a few typical compounds. It is seen that all the compounds are alike when in a liquid state, but that when they solidify, the volume change approximately doubles. Therefore on cooling from 50 to 25 deg. cent., a petrolatum should form more voids than a cylinder oil.

The viscosity of the compound below 50 deg. cent. is of great importance because of its great influence on the formation and distribution of the shrinkage voids and on the drainage of the compound. Fig. 8 shows this property on some typical compounds. It is seen that the movement of a petrolatum through the insulation should decrease sooner and more abruptly with decreasing temperature than that of a cylinder oil. Therefore, the petrolatum should begin to form voids at a higher temperature than the cylinder oil.

As no available viscosimeter was found for this range of viscosity, one was developed. It is substantially a weighted plunger sinking down into a cylinder slightly larger than the plunger, the cylinder being filled with the compound. The time for the total fall of the plunger is taken as the "pressure viscosity." This test has been found of considerable value in comparing compounds.

Because of greater simplicity in preparation and testing, miniature samples of insulation (thickness of 50 mils and less) are in considerable use for laboratory comparison of compounds. When tested immersed,
these samples represent almost ideal conditions for void elimination and when tested unimmersed, their failure is usually caused by expulsion of compound. Because of the extreme contrast between each of these conditions and service conditions, it is believed that results of this test are of doubtful value in comparing compounds.

It is now recognized that the formation of gas and $X$ by compounds in the presence of corona (ionized voids) can only be eliminated by the development of a compound of sufficient chemical stability under these conditions. As the immediate development of such a compound is not promising, improved control of the void formation and distribution merits further consideration as a possible means of minimizing the dangerous gas formation and harmless $X$ formation.

**Mechanism of Void Formation and Ionization**

Under this heading are given some preliminary conceptions and test results that, while admittedly not conclusive, were thought of sufficient interest for subjection to general discussion.

**A. Influence of Void Pressure and Size on Ionization.**

The upper solid curve in Fig. 9 shows the dielectric strength of air at atmospheric pressure. While the greater part of this curve was taken from an Institute paper, the relations have been well established by several investigators independently. The application to this curve of Paschen's law (breakdown of air constant as long as the product of the gap length and absolute pressure is constant) gives the dielectric strength at other pressures as shown.

The dotted lines represent the voltage across each void in insulation 300 mils thick at 100 volts per mil total stress. When this voltage exceeds the ionization voltage (solid curves), the void will be ionized. The curves show that increase of void pressure and more complete distribution of voids (many small instead of few large voids) both tend to decrease the possibility of ionization.

**B. Void Pressure Versus Air Content.**

Let $V_c =$ the volume of compound immediately surrounding a void, the compound that is subjected to a decreased pressure resulting from the formation of the void.

Let $V_v =$ volume of the void.

Let $P_v =$ pressure of the void in cm. absolute.

Let $a =$ air content of the compound in fraction of compound volume, the air at atmospheric pressure.

Maximal solubility of the air in the compound $= 13$ per cent.

$$V_v = \frac{76 a V_c}{P_v} - .13 V_c \text{ or } P_v$$

$$P_v = \frac{76 a V_c}{V_v + .13 V_c}$$

If $\frac{V_c}{P_v} = R$ Then $P_v = \frac{76 a R}{1 + .13 R} \quad (1)$

$P_p =$ (the pressure at which the air separates from the compound)

$$= \frac{76 a}{0.13} \quad (2)$$

Equations (1) and (2) indicate that $P_v$ is dependent on $a$ and $R$; as $R$ increases, the value of $P_v$ increases, approaching the critical pressure $P_p$ as a limit. $P_v$ is usually less than $P_p$ because of the incomplete distribution of pressure through a stiffening compound.

If $V =$ viscosity of the compound and $K$ a proportionality factor

$$R = \frac{K}{V} \quad (3)$$

When $R =$ 1000 pressure distribution can be taken as reasonably complete as from (1) $P_v =$ 99 per cent of $P_p$.

If a pressure viscosity of 20 sec. (thin transformer oil) is taken as representing complete pressure distribution

$$K = 1000 \times 20 \text{ and (3) becomes } R = \frac{20000}{V},$$

allowing the approximate determination of $R$ for any viscosity.

The curve in Fig. 10 was plotted for a pressure viscosity of 145 by solving (3) for $R$, then solving (1) for $P_v$ and obtaining the compounding total void volume possible without ionization from Fig. 9. The relation shown in Fig. 10 should be independent of the viscosity-
temperature characteristic of the compound because, other conditions being equal, the voids should begin to form at the same viscosity regardless of the temperature.

This curve is of considerable interest because it indicates that, in general, an air content in the neighborhood of 10 per cent is more desirable than one around 2 per cent.

C. Void Size Versus Moisture.

For the same total void volume, the size of each void is dependent on the distribution of the voids, many small or few large. It is evident that the more complete distribution (smaller voids) is desirable because it decreases the tendency to ionization.

When an enclosed volume of compound shrinks, the molecules of the compound are torn apart at some point (their cohesion is overcome), and a void is formed there. As the shrinkage continues, this void increases in size. As the surface of the void enlarges, some expenditure of energy is necessary to rearrange the molecules at the boundary of the void and compound. As the void becomes larger, this expenditure of energy increases. When the energy necessary to enlarge the void becomes greater than the cohesion of the compound, molecules somewhere else in the compound will be torn apart and a new void formed. This would indicate that a decrease in cohesion should increase the number of voids and, therefore, decrease the size of each void. As the surface tension of water is materially less than that of the compounds, the presence of moisture in the compound may appreciably decrease its cohesion.

SUMMATION

1. Reliability of insulation quality determination is essential to satisfactory progress in high-voltage cable development. The most reliable test available at present for this purpose is the overvoltage life test, but there is some evidence that even this test may not always give a true indication of insulation quality. Efforts are being made to increase its reliability by causing failure on test, by exaggeration of the causes of failure in service, rather than by increase of the operating voltage alone.

2. While the ionization test is usually in fair agreement with the overvoltage life test as an indication of insulation quality, there are some instances, as that of a resaturated cable, where an indication of quality by the ionization test is not confirmed by the life test.

3. The air resistance of the paper has a material influence on the dielectric strength of the cable, regardless of whether the paper is kraft or manila.

4. While voltage tests on miniature samples of insulation are of considerable value along some lines, they are not believed to be a reliable basis for comparison of compounds.

5. The interdependence of the contraction-temperature and viscosity temperature characteristics of the compound in their controlling influence on the formation of voids should receive more general consideration.

6. Tentative indications are found that a decrease in air content of the insulation might increase the tendency to ionization because of the resulting decrease in void pressure.

7. Data are shown suggesting that ionization might be decreased by the presence of moisture in the insulation because of the resulting more complete void distribution and consequent smaller size of each void.

References


Abridgment of

Power Limit Tests
On Southeastern Power and Light Company's System

BY S. MURRAY JONES
Associate, A. I. E. E.
and
ROBERT TREAT
Member, A. I. E. E.

Synopsis.—Calculations and tests on small models have indicated that power systems at or near the theoretical power limit could not be operated safely, since any slight disturbance would cause instability with the resultant separation of the power transmission system. Very often, tests on small models do not closely check the results obtained on the real system; therefore, as a result of certain troubles which occurred on the Southeastern Power & Light Company's system in 1925, apparently due to instability, it was decided to attempt to determine by actual tests the amounts of power which could be safely carried over certain transmission lines, and to compare the results with the calculated values. The General Electric Company offered to cooperate with the engineers of the Southeastern Power & Light Company in conducting such tests, and made them of further value by suggesting experimentation with certain schemes of high-speed excitation which could be applied to the generator excitation systems, in an effort to increase the maximum power limit which could safely be carried over the transmission lines. This paper presents the results of these tests and the conclusions to be drawn from them.

INTRODUCTION

During the Fall of 1925, there existed a very serious water shortage in Georgia and the Carolinas. The Alabama Power Company had a normal amount of water for that season and sufficient steam reserve capacity to be able to deliver power over its two tie lines into the Georgia and Carolina systems. The two tie lines which are the ones on which the tests were conducted were loaded to capacity.

There were some 300 miles of transmission line between the Alabama Power Company's plants and the Georgia Power Company's plants in Northeast Georgia.

It was necessary to set the relays to operate on values as low as 60,000 kv-a. This was close to the amounts of power which were being carried over each line during the times of peak load. Interruptions occurred in which both lines opened. Final analysis indicated that these lines were becoming unstable due to a reduction in voltage at one end or the other from short circuits external to the line.

After many discussions between the engineers of the General Electric Company and the Southeastern Power & Light Company, it was found desirable to make certain tests on these tie lines during the Spring of 1927.

DESCRIPTION OF TESTS

The object of the tests may be summarized as follows:
A. To obtain the maximum power limit of the south line (test line) as a check on the value predicated from calculations.
B. To determine the maximum carrying capacity of this line under normal operating conditions with Martin Dam connected to the Alabama Power System.
C. To determine the efficacy of various kinds of regulators including the standard regulators installed at the plant and of increased speeds of exciter build-up.

Three distinct kinds of tests were decided upon:

a. Steady-state pull-out between Martin Dam and the Georgia system, both with Martin Dam alone connected to the test line, and with Martin Dam and the test line connected to the Alabama system. When Martin Dam was connected to the Alabama system, the north line remained open.
b. Suddenly applied load by loading up the two tie lines in parallel and then tripping the north line to...
determine how much could thereby be shifted to the test line without causing loss of synchronism.

c. Short circuit, obtained by closing a 110-kv. bus-tie oil circuit breaker at the high tension terminals of the Martin Dam transformers on a line-to-neutral short circuit of predetermined duration. The short circuit contained practically zero resistance. Tests involving short circuits were made with the north line open, but with Martin Dam both isolated and connected to the Alabama system.

TEST PROCEDURE

The test line was a 110,000-volt single circuit from the Martin Dam plant in Alabama to the Boulevard Substation near Atlanta, Georgia. This line is one of the important tie lines between the Alabama and Georgia systems.

For obtaining the test data, oscillographs and portable laboratory type indicating meters were located at Martin Dam, and graphic meters were installed at Gadsden, Newman, and Boulevard.

Continuous telephone communication was held between the plant superintendent at Martin Dam and the chief load dispatcher of the Alabama and Georgia systems. As the proper load was reached the oscillographs were started. If the test line failed to become unstable or appeared to reach instability too rapidly, the tests were repeated with a slightly larger or smaller load as the individual case dictated.

CURVES AND TABLES OF RESULTS

From the oscillograph records it is possible to obtain a very comprehensive qualitative idea of the phenomena accompanying the disturbances. The oscillograms of power were obtained on a three-unit instrument, each unit of which consisted of a three-phase assembly of wattmeter elements.

TABLE I

<table>
<thead>
<tr>
<th>Test No.</th>
<th>Excitation</th>
<th>Ratio test to calc.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test megawatts</td>
<td>as percentage of maximum for line alone</td>
<td></td>
</tr>
</tbody>
</table>

TABLE II

<table>
<thead>
<tr>
<th>Test No.</th>
<th>From test</th>
<th>Corrected to 110 kv.</th>
<th>Excitation</th>
<th>No. gen. used at Martin Dam</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>104</td>
<td>110</td>
<td>Hand control</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>104.5</td>
<td>110</td>
<td>Form Y std. exc.</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>102</td>
<td>110</td>
<td>Form W std. exc.</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>104</td>
<td>110</td>
<td>Form K-24 std. exc.</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>104</td>
<td>110</td>
<td>Form K-24 std. exc.</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>102.7</td>
<td>113.8</td>
<td>Form Y 500 V/sec</td>
<td>3</td>
</tr>
</tbody>
</table>

1. See text regarding thyratron grid control.
maximum power at the generator end occurs slightly after the systems have started to fall out of step and is somewhat greater than when the receiver is at the maximum. The absence of a second harmonic in these curves is owing to the method of calculation, and does not detract from their value for comparative purposes.

In certain of the tables, reference is made to control of the Martin Dam generators by types W and Y regulators. The type W regulator is that described by Messrs. R. E. Doherty, C. A. Nickle, and R. M. Carothers in papers presented at the St. Louis Regional

### TABLE III

<table>
<thead>
<tr>
<th>Test No.</th>
<th>No. Martin Dam machines</th>
<th>Estimated maximum power in kw.</th>
<th>Corrected to 110 line kv.</th>
<th>Duration of short circuit in seconds</th>
<th>Volt-sec. rise during 1st half swing of gen.¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>2</td>
<td>Alabama System not connected to test line</td>
<td>28.000 31,460 0.857 33.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>2</td>
<td></td>
<td>28.000 31,300 0.882 34.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>2</td>
<td></td>
<td>29.000 32,400 0.833 29.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>2</td>
<td></td>
<td>32.000 35.900 0.815 42.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>2</td>
<td></td>
<td>32.000 36,100 0.807 2.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>2</td>
<td></td>
<td>33.000 36,000 0.807 1.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>2</td>
<td></td>
<td>39.000 40,200 0.825 49.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>2</td>
<td></td>
<td>48.000 49,000 0.605 31.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>2</td>
<td></td>
<td>55.000 56,000 0.433 48.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>2</td>
<td></td>
<td>22.500 23,100 0.915 35.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>2</td>
<td></td>
<td>23.000 23,700 0.907 35.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>2</td>
<td>Alabama System connected to test line</td>
<td>55,000 58,500 0.652 67.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>2</td>
<td></td>
<td>55,700 58,700 0.682 16.7</td>
<td></td>
<td></td>
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</tbody>
</table>

¹ See Appendix I.

### TABLE IV

<table>
<thead>
<tr>
<th>Test No.</th>
<th>Martin Dam machines</th>
<th>Estimated maximum power in kw.</th>
<th>Corrected to 110 line kv.</th>
<th>Excitation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>114.0 102.0</td>
<td>36,000 37,500</td>
<td>0.652</td>
<td>Form Y—Standard Exciter</td>
</tr>
<tr>
<td>6</td>
<td>113.5 102.0</td>
<td>36,000 37,600</td>
<td>1.000</td>
<td>Form K—24 Exciter</td>
</tr>
<tr>
<td>7</td>
<td>114.0 104.0</td>
<td>36,000 37,200</td>
<td>0.652</td>
<td>Hand control</td>
</tr>
<tr>
<td>20</td>
<td>113.0 105.0</td>
<td>36,000 37,000</td>
<td>0.652</td>
<td>Form Y—250 V/sec.¹</td>
</tr>
<tr>
<td>23</td>
<td>110.0 102.0</td>
<td>35,000 36,000</td>
<td>0.652</td>
<td>Form Y—500 V/sec.¹</td>
</tr>
</tbody>
</table>

¹ See text regarding thyratron grid control.

### NOTES ON TEST RESULTS

It should be borne in mind that the results herein presented were obtained on commercial power systems under actual conditions of operation, and mostly during times of peak load. This condition precluded the attainment of results of an accuracy approaching laboratory precision.

The relationship between generated and perceived power is presented in Fig. 13. It will be noted that the

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**Figure 10**—Test No. 25A. Comparison of calculated and test values of instantaneous power during line-to-neutral short circuit on Martin Dam High-Tension Bus.

**Figure 12**—Test No. 7A. Comparison of test and calculated values of instantaneous power during sudden increase in load by tripping North Line.

**Figure 13**—Calculated power angle curves for test lines and systems under conditions of test No. 10.

1. See Appendix I.

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For this reason, the new regulators probably could not show their maximum efficiencies.

It was possible to carry with fixed excitation amounts of power nearer the maximum theoretical limit than had been anticipated. The margin left for improvement owing to the different excitation systems proved to be considerably less than expected. Considering this, and the unfavorable condition as regards thyratron grid control, as well as the possible errors in the test results owing to the conditions under which they were made, no conclusive data were obtained on the efficiency of the new regulator, or of high-speed excitation.

Tests were made, with the short circuit maintained for differing times, and the results are shown graphically in Fig. 19. It is expected that similar results would be obtained if it had been possible to try shorts with varying amounts of resistance and reactance simulating conditions when a fault occurs at some distance from the station, but they would not necessarily be comparable in magnitude.

**CONCLUSIONS AND SUMMARY**

The safe loading of the test line for operating conditions, considering that the north line may be tripped at any moment as a result of a disturbance on it, appears to be about 35,000 kw. From the standpoint of maintaining synchronism during short circuits on other circuits, the safe loading of the test line depends on the duration of the short circuit, and for a one-second duration appears to be about 35,000 kw.

The gain in power which could be carried with the increased speeds of excitation used in these tests appears to be not great. Further consideration is given to the effect of excitation speeds in Appendix I, contributed by F. R. Longley, who has made most of the mathematical computations.

The use of a voltage regulator showed a small gain in steady-state power limit over the value with fixed excitation.

While the Alabama and the Georgia systems showed a fair degree of damping when made to oscillate with respect to each other by load increases, there was very little damping evidenced when the oscillation was between Martin Dam and either of the two systems. This would indicate the desirability of providing water-wheel generators with amortisseur windings.

A reduction in the duration of short circuits increases the amount of power which can be carried during a short circuit.

Information was secured concerning the equivalent constants of the system which permit very close mathematical checks on the results attained.

The authors desire to express their appreciation of the assistance rendered by the executives of the companies concerned, in granting permission to make the tests; to the operators, load dispatchers, maintenance crews, and engineers of the operating companies for whole-hearted cooperation in carrying out the tests; and to members of the Engineering Department of the General Electric Company for valuable assistance in working up the data, and for many pertinent suggestions as to methods of analysis and interpretation.

**Appendix I**

**THE EFFECT OF EXCITATION UPON THE MAXIMUM POWER THAT CAN BE CARRIED THROUGH A TRANSIENT DISTURBANCE**

BY F. R. LONGLEY

Associate, A. I. E. E.

An increase in rotor flux of the proper amount will
avoid the wild swings of the rotor which throws synchronous apparatus out of step following single-phase short circuits. The rise in flux must be obtained before the rotor reaches the maximum angle of its first swing, which usually occurs in approximately one-half a second. Let

\[ e = \text{change in slip ring volts (see Fig. 21)} \]
\[ i = \text{rise in field current produced by } e \]
\[ t = \text{time} \]
\[ L = \text{inductance of field circuit} \]
\[ R = \text{resistance of field circuit} \]
\[ \phi = \text{rise in field flux} \]
\[ k = \text{a constant} \]

The inductance of the fields of large alternators is so great that for periods of time less than half a second, the increased resistance drop, \( i R \), is small when compared to the inductive drop, \( L \frac{d i}{d t} \), and may be neglected in the formula:

\[ e = L \frac{d i}{d t} + i R \]

so that

\[ e \approx L \frac{d i}{d t} \]
\[ i \approx \frac{1}{L} \int_{t_1}^{t_2} e \, dt \]
\[ i = k \phi \]

and

\[ \phi \approx \frac{1}{k L} \int_{t_1}^{t_2} e \, dt \]

The integral \( \int_{t_1}^{t_2} e \, dt \) is the shaded area in Fig. 21 and is entirely independent of the shape of the volt-time curve. The area under the volt-time curve has the unit, volt-seconds. If the rise in volt-seconds is known at any moment, and the phenomenon has not lasted for more than half a second, then the rise in flux is immediately known, for the two are directly proportional.

The relation between volt-seconds and the transient stability limits at Martin Dam are shown in Fig. 20.

### AN EASY METHOD OF APPROXIMATING THE SQUARE ROOT

The following description of a novel method of approximating square root has been contributed by C. H. Willis, Department of Electrical Engineering, Princeton University.

The frequent occurrence of the radical \( \sqrt{a^2 \pm b^2} \) in electrical calculations makes the solution of this expression a matter of importance. The method described below for handling this expression provides a simple and easy manner of obtaining an approximate solution. If one of the numbers be three times as great as the other, the accuracy of the approximation will be greater than the accuracy of a direct calculation on a 10-in. slide rule.

The radical \( \sqrt{a^2 \pm b^2} \) may be expanded by the binomial theorem into the infinite series:

\[ \sqrt{a^2 \pm b^2} = a \pm \frac{b^2}{2a} \pm \frac{b^4}{8a^2} \pm \frac{b^6}{16a^3} \pm \cdots \]

This series is very rapidly convergent if \( a \) be greater than \( b \), and under this condition we may write,

\[ \sqrt{a^2 \pm b^2} = a \pm \frac{b^2}{2a} \]

If we assume a circuit with a resistance of 153 ohms and a reactance of 11 ohms, we may obtain the impedance by inspection as;

\[ Z = \sqrt{153^2 + 11^2} = 153 + \frac{121}{306} = 153.4 \]

The answer correct to three decimal places is 153.395.

It is not always so easy to obtain the solution by inspection but the solution has been reduced to squaring one number and dividing by twice another, which is a considerable gain over the direct method.

If we assume a circuit whose impedance is 175 ohms and whose reactance is 14 ohms we may obtain the reactance by inspection as;

\[ X = \sqrt{175^2 - 14^2} = 175 - \frac{196}{350} = 174.4 \]

The answer correct to three decimal places is 174.439.

The approximation here would be much closer if the true value of the fraction were used rather than the value obtained by inspection.

This method is also very useful in obtaining irrational square roots. If we desire the square root of 190 this may be written as a perfect square plus or minus a remainder. Thus by inspection we have;

\[ \sqrt{190} = \sqrt{196 - 6} = 14 - \frac{6}{28} = 13.8 \]

The answer correct to three decimal places is 13.784.

The accuracy of this method of approximation increases rapidly as \( a \) increases in size with respect to \( b \). When \( a \) is as great as 3 \( b \) the error caused by using the approximation rather than the true value is less than 0.2 per cent. When \( a \) is less than 3 \( b \) the approximation gives only a rough estimate, but if \( a \) is greater than 3 \( b \) the approximation is more accurate than a direct calculation on a 10-in. slide rule, and it is much easier to obtain the approximate solution.
INSTITUTE AND RELATED ACTIVITIES

The A. I. E. E. Winter Convention

Comprehensive Program of Technical Sessions and Inspection Trips

A well-rounded program of important technical sessions and enjoyable recreation is offered in the Winter Convention to be held in the Engineering Societies Building, New York, January 28 to February 1. Technical sessions, inspection trips, a lecture, a medal presentation, a dinner-dance and a smoker constitute the features of this attractive program which is outlined in further detail in following paragraphs.

Technical Sessions

The technical papers deal with some of the liveliest topics in electrical engineering. The principal subjects will be dielectrics, electrophysics, cables, transmission, lightning, circuit breakers, communication, induction motors, other electrical machinery, measuring instruments and electrical measurement of non-electrical quantities. Forty-two papers will be presented in nine sessions. Details are given under the program of events.

One especially interesting session will deal with a new type of circuit breaker which employs no oil and in which heavy currents are interrupted very quickly. This session will be held on Wednesday morning, January 30.

Inspection Trips

A large number of very interesting trips are being arranged. Wednesday afternoon, January 30, has been set aside for trips though several of the trips may be made at other times by prearrangement.

Tickets must be secured in advance for all trips before 4:00 p.m. on the afternoon preceding the day on which the trips will be made. Tickets may be obtained at the Inspection Trip desk.

One especially interesting trip will be made at a new type of circuit breaker which employs no oil and in which heavy currents are interrupted very quickly. This session will be held on Wednesday morning, January 30.

Trip for Wednesday Afternoon

160,000-kw. turbo-generators. Hell Gate Generating Station, United Electric Light & Power Co.

Technical show at Bell Telephone Laboratories.

Demonstration of talking motion pictures and equipment and delayed transmission and band-pass filter circuits.

Western Electric Company cable plant at Kearny, N. J.

West Orange switching station, Hudson 132-kv. switching station and Kearny generating station of Public Service Electric & Gas Co.


Hunts Point gas plant, Consolidated Gas Company.

Harrison Lamp Works and Edison Illuminating Institute of General Electric Co.

New Diesel electric ferryboat.

Plant of the American Telephone Telegraph Co.

Daily Trips

(10 a.m. and 2 p.m. starting Tuesday afternoon, except first trip as noted below)

Telediography—Long Lines Department of the American Telephone Telegraph Company

Demonstrations 10 a.m. and 2 p.m. Wednesday and at 10 a.m. Thursday and Friday.


The Electrical Testing Laboratory of the program of events.

East River generating station of New York Edison Co.

System operator's office at Waterside Station, New York Edison Co.

Hudson Avenue generating station with inspection of network unit, Brooklyn Edison Co. Research Laboratory, Brooklyn Edison Co.

Medal Presentation

The presentation of the Edison Medal for achievement in electrical engineering is planned for Wednesday evening, January 30.

Dinner-Dance

A dinner-dance will be held in the Ballroom of the Hotel Astor on the evening of Thursday, January 31. This annual event, the Winter Convention Dinner-Dance, has proved so thoroughly enjoyable in the past that its popularity is assured. Besides an excellent dinner the committee promises the splendid music of the "Venetian Gondoliers." Tickets will be $6.00 per person. Reservations may be made for tables seating eight people.

Smoker

The Smoker to be held in the auditorium of the Engineering Societies Building on Tuesday evening, January 29, will be particularly attractive this year due to the type of program which has been arranged. The main feature of the evening will be a musical organization from one of the larger colleges: The humorist, Evan Davies, who is well known as the "Virginia Judge" through radio Station W. O. R., has been obtained. Other numbers equally as good are being arranged and will be announced later. The evening will be concluded with a buffet supper served by the well known caterer, Louis Sherry. Tickets will be $2.00.

High-Tension Cable Testing Facilities in Brooklyn Edison Research Laboratories

(Can be seen during Winter Convention)

Reduced Railroad Rates

Reduced rates for railroad transportation will be available under the certificate plan to members and guests who attend the Convention. Under this plan only half fares need be paid on the return trip over the same route provided 250 certificates are deposited by members at the Registration Desk. The rates apply to all members who attend the Convention and to dependent members of their families.
Each member or guest should obtain a certificate when purchasing his one-way ticket to New York. He should explain to the ticket agent that he wishes the certificate authorized by the passenger associations for the Winter Convention of the Institute.

On arriving at the Convention the certificate should be deposited at the Registration Desk. Here it will be held for validation by a railroad representative and if 250 certificates are validated, the validated certificate will later be returned to the owner. By presenting the validated certificate when buying a return ticket only half-fare will be charged.

Local ticket agents should be consulted regarding conditions affecting this plan, as it applies only within certain dates depending on the territory.

Everyone whose one-way fare is over 66 cents should get a certificate whether or not he intends to use it. By neglecting to do so he may deprive others of considerable saving.

Register in Advance
Each member will save time for himself and the committee in charge if he will register in advance by mail.

Hotel Reservations
Reservations for hotel rooms should be made in advance in order to secure satisfactory accommodations. Members should write directly to the hotels which they prefer.

Committees
The general 1929 Winter Convention Committee is as follows:

PROGRAM OF THE WINTER CONVENTION

Schedule of Events
MONDAY, JANUARY 28
Morning: Registration and Committee Meetings
2:00 p.m. Session on Dielectrics and Electrophysics

TUESDAY, JANUARY 29
10:00 a.m. Session on Cables
2:00 p.m. Session on Transmission and Lightning
8:00 p.m. Smoker and Entertainment

WEDNESDAY, JANUARY 30
10:00 a.m. Session on Protective Devices
2:00 p.m. Inspection Trips
2:30 p.m. Board of Directors’ Meeting
8:30 p.m. Medal presentations

THURSDAY, JANUARY 31
10:00 a.m. Two Parallel Sessions
(a) Communication
(b) Induction Motors
2:00 p.m. Session on Electrical Machinery
7:00 p.m. Dinner-Dance

FRIDAY, FEBRUARY 1
10:00 a.m. Session on Electrical Measurement of Non-Electrical Quantities
2:00 p.m. Session on Instruments and Measurements

Technical Sessions
SESSION ON DIELECTRICS AND ELECTROPHYSICS
January 28, 2 p.m.

This session will contain four papers dealing with dielectric absorption, power factor and dielectric constant of viscous dielectrics, corona ellipses, and flux linkages. The papers are as follows:
Anomalous Conduction as a Cause of Dielectric Absorption,
J. B. Whitehead and R. H. Marvin, Johns Hopkins University
Flux Linkages and Electromagnetic Induction in Closed Circuits,
L. V. Bewley, General Electric Co.
Corona Ellipses, V. Karapetoff, Cornell University.
Power Factor and Dielectric Constant in Viscous Liquid Dielectrics,
D. W. Kitchin, Simplex Wire & Cable Co.

SESSION ON CABLES
January 29, 10 a.m.

Five papers are scheduled for this session on the subjects of high-voltage cable development and research, ionization studies in paper-insulated cables, and elimination of losses and sheath voltages in single-conductor cables. The papers are as follows:
High-Tension Underground Cable Research and Development,
G. B. Shanklin and G. M. McKay, General Electric Co.
Some Problems in High-Voltage Cable Development, E. W. Davis and W. N. Eddy, Simplex Wire and Cable Co.
Reduction of Sheath Losses in Single-Conductor Cables, Herman Halperin and K. W. Miller, Commonwealth Edison Co.

SESSION ON TRANSMISSION AND LIGHTNING
January 29, 2 p.m.

Lightning researches in the field and in the laboratory, and the theory of traveling electric waves will be the subjects covered in the five papers of this session. The papers are as follows:
A Graphical Theory of Traveling Electric Waves between Parallel Conductors, V. Karapetoff, Cornell University
Progress in Lightning Research in the Field and the Laboratory, F. W. Peek, Jr., General Electric Co.
Protection of Transmission Lines from Interruption by Lightning, by 1927-28 Subcommittee of Power Transmission & Distribution Committee

EAST RIVER GENERATING STATION OF NEW YORK EDISON COMPANY
(Can be seen during Winter Convention)
SESSION ON PROTECTIVE DEVICES  
January 30, 10 a.m.

A new type oil-less heavy-duty circuit breaker—its theory, construction and test—is the subject of three papers for this session, and the fourth paper will be on automatically reclosing high-speed d-c. breakers.


STEP-UP TRANSFORMERS FEEDING 132,000-_VOLT CABLE AT HELL GATE STATION OF UNITED ELECTRIC LIGHT & POWER COMPANY  
(Can be seen during Winter Convention)


SESSION ON COMMUNICATION  
January 31, 10 a.m.

Applications of radio in aviation, influence of moisture and impurities in textile insulations, application of purified textile insulation to central-office wiring, and vector representation of wave filters are the subjects for this session.


Influence of Moisture and Electrolytes upon Textiles as Insulators, R. R. Williams and E. J. Murphy, Bell Telephone Laboratories.


SESSION ON INDUCTION MOTORS  
January 31, 10 a.m.

The capacitor motor, low-starting-current induction motors, and calculation of no-load core losses are the subjects of the five papers planned for this session.

The Condenser Motor, B. F. Bailey, University of Michigan.


Line-Start Induction Motors, C. J. Koch, General Electric Co.

Calculating No-Load Core Losses in Induction Motors, Thomas Spooner, Westinghouse Electric & Mfg. Co.

SESSION ON ELECTRICAL MACHINERY  
January 31, 2 p.m.

Five papers are planned for this session dealing with insulation tests on electrical machinery before and after placing in service, influence of temperature on commutators, transient conditions in electrical machines and transformers, and the two-reaction theory of synchronous machines.


Transient Analysis of A-C. Machines, Yu H. Ku, Massachusetts Institute of Technology.


SESSION ON ELECTRICAL MEASUREMENT OF NON-ELECTRICAL QUANTITIES  
February 1, 10 a.m.

Magnetic analysis of materials, measurement of flow, use of the oscillograph in measuring non-electrical quantities, study of noises in electrical apparatus, and application of electricity to navigation are the subjects for this session.


Application of Electricity to Navigation, R. H. Marriott, Consulting Engineer.


MANUFACTURE OF CABLE IN PLANT OF WESTERN ELECTRIC COMPANY  
(Can be seen during Winter Convention)


SESSION ON INSTRUMENTS AND MEASUREMENTS  
February 1, 2 p.m.

Totalizing meters, remote metering, high-accuracy current transformers, a 132-kv. shielded potentiometer, and a precision regulator for alternating voltage are the subjects of this session.


Totalizing of Electric System Loads, P. M. Lincoln, Cornell University.
A New High-Accuracy Current Transformer, M. S. Wilson, General Electric Co.
A Precision Regulator for Alternating Voltage; H. M. Stoller and J. R. Power, Bell Telephone Laboratories.

**Final Stage in Making Lead-Covered Cable in Western Electric Company Plant**
*(Can be seen during Winter Convention)*

**Future Institute Meetings**

During the year 1929 there will be held six Institute meetings, including three National Conventions and three Regional Meetings.

The three National Conventions will be the Winter Convention to be held January 28 to February 1 (see complete announcement elsewhere in this issue), the Summer Convention to be held in Swampscott, Mass., June 24-28, and the Pacific Coast Convention to be held in Los Angeles, September 3-5.

Regional meetings will be held in Cincinnati, March 20-22; in Dallas, May 7-9, and in Chicago, December 2-4.

More complete information regarding these meetings will be published in later issues of the *Journal*.

**Plans for World Engineering Congress, Tokio, Japan, are Actively Progressing**

October—November 1929.

As previously announced, a World Engineering Congress will be held in Tokio, Japan, beginning October 29, 1929, and continuing about ten days, followed by trips to various places of engineering and scenic interest throughout Japan.

The object of the Congress is to effect an international exchange of the latest knowledge of the sciences and practises of engineering, and to bring together the leaders who are directing the trend of engineering activities, thereby initiating and promoting international cooperation and comprehension of engineers throughout the world.

A Committee on American Participation in the Congress was organized many months ago and various subcommittees on finance, technical program, transportation, entertainment, membership, etc., have been actively at work for several months. The interest already shown by engineers both in this country and abroad indicates a large attendance.

Dr. Masawa Kamo, Professor of Mechanical Engineering in the Imperial University at Tokio, and Chairman of the Organizing Committee of the Congress, was in New York early in December after visiting various countries of Europe in the interest of the Congress. The Committee on American Participation gave a dinner in his honor at the Engineers' Club, New York, on the evening of December 8, when reports were made by the various American committees, and Dr. Kamo gave an exceedingly interesting account of the plans being made in Japan for the visiting engineers and members of their families from foreign countries.

The Transportation Committee reported that the "official" ship will be the President Jackson, sailing from San Francisco October 11.

Dr. Kamo was told by Dr. Elmer A. Sperry, Chairman of the American Committee, that the attendance of a large delegation of American engineers was already assured.

A "second announcement" in the form of a booklet giving information regarding the program, and the excursions that will follow the technical sessions has recently been issued by authorities of the Congress in Japan. This booklet, together with application forms for membership in the Congress, transportation and hotel accommodations, etc., will be forwarded to any engineer applying to Mr. Maurice Fiolland, Executive Secretary of the American Committee, at 33 West 39th Street, New York, N.Y. Early application is desirable because of the limited number of those who may participate in the Congress as well as in some of the numerous trips which are to be taken.

**International Conference on Large High-Voltage Electric Systems**

Announcement has been received that the next session of this Conference, usually held biennially, will be held from June 6 to June 15, 1929, in Paris. This Conference was instituted in 1921, under the auspices of the International Electrotechnical Commission.

In the previous conferences of this large international organization, American representatives have taken a prominent part. The United States National Committee of the I. E. C. commends the Conference to American engineers, and requests members of the American Institute of Electrical Engineers and allied organiza-
Edison Medal Awarded to Frank B. Jewett

AWARD TO BE MADE AT THE WINTER CONVENTION

The Edison Medal has been awarded by the Edison Medal Committee of the American Institute of Electrical Engineers to Dr. Frank B. Jewett, "for his contributions to the art of electrical communication." It is planned to present the medal to Dr. Jewett at a session of the coming Winter Convention of the Institute in New York, probably on Wednesday evening, January 30th.

The Edison Medal was founded by associates and friends of Mr. Thomas A. Edison, and is awarded annually for "meritorious achievement in electrical science, electrical engineering, or the electrical arts," by a committee consisting of twenty-four members of the American Institute of Electrical Engineers.


Dr. Frank B. Jewett, Vice-President, American Telephone and Telegraph Company, and President of Bell Telephone Laboratories, Inc., was born at Pasadena, California, September 5, 1879. He graduated in 1898 from Throop Polytechnic Institute (now the California Institute of Technology). He then took up graduate work at the University of Chicago under Professor A. A. Michelson, receiving his Doctor of Philosophy Degree in 1902. Later he was instructor in physics and electrical engineering at Massachusetts Institute of Technology, and in 1904 joined the staff of the American Telephone and Telegraph Company. He was given charge of the engineering research work, thus beginning his record of brilliant attainments in the telephone field. From 1908 to 1912, Dr. Jewett was Transmission and Protection Engineer, and under the direction of John J. Carty, then Chief Engineer, was given responsibility for working out the methods which led to the introduction in telephone service of phantom duplex cables. In 1912 he became Assistant Chief Engineer of the Western Electric Company, and in 1916 Chief Engineer, having charge of the research laboratories and all engineering in connection with Western Electric manufacturing. Six years later he became Vice-President of the Western Electric Company.

In 1917 Dr. Jewett was commissioned Major in the Signal Corps, U. S. Reserves. He was promoted to the grade of Lieutenant Colonel, and for his brilliant service received the "Distinguished Service Medal." In 1925 he was elected Vice-President of the American Telephone and Telegraph Company in direct charge of Development and Research. At the same time, he was made President of the Bell Telephone Laboratories, Inc.

Dr. Jewett is a Fellow of the American Institute of Electrical Engineers, of which he was President during the year 1922-23. He has been a worker on many Institute committees, and is at present a member of the Public Policy Committee and the Committee on Code of Principles of Professional Conduct, and representative on the Electrical Advisory Committee of the American Standards Association, the U. S. National Committee of the International Electrotechnical Commission, and the Division of Engineering and Industrial Research of the National Research Council. Dr. Jewett is also a member of many other scientific and engineering organizations.

A. I. E. E. Directors

Meeting

The regular meeting of the Board of Directors of the American Institute of Electrical Engineers was held at Institute headquarters, New York, on Friday, December 7, 1928.


The minutes of the Directors' meeting held October 18, 1928, were approved.

Announcement was made of the gift to the Institute, by Gillett & Johnston of Croydon, England, bell founders of the Louvain Carillon, of a bell as a souvenir of the Carillon, and a resolution of acceptance and appreciation was adopted.

Action of the Executive Committee, under date of November 15, on applications for Student Enrolment, election to membership, and for transfer to higher grades, was ratified.

A report was presented of a meeting of the Board of Examiners held November 8, and the actions taken at that meeting were approved. Upon the recommendation of the Board of Examiners, the following actions were taken: 190 Students were enrolled; 83 applicants were elected to the grade of Associate; 28 applicants were transferred to the grade of Member.

In accordance with Section 22 of the Constitution, relating to members of 35 years standing, Messrs. Frank E. Smith and E. S. Webster were added to the list of "Members for Life" by exemption from future payment of dues.

The Board ratified approval by the Finance Committee for payment of bills for the month of November amounting to $826,890.21.

In accordance with the procedure specified in the revised Constitution and By-laws, a resolution was adopted fixing the date
and place of the 1929 Annual Meeting of the Institute, to be held at Swampscott, Mass., on Tuesday, June 25, during the annual Summer Convention.

Upon the recommendation of Student Branch Counselor delegates at the Summer Convention in June, 1928, and of the Committee on Coordination of Institute Activities, a resolution was adopted authorizing an annual appropriation not to exceed $2000 for the purpose of mimeographing student papers presented at student conventions, not more than $250 to be expended by any one Geographical District in a calendar year, and all such mimeographing to be done under the immediate supervision of the Committee on Student Activities of the District in which the papers are to be presented.

Existing by-laws of the Institute were revised and new by-laws were added, covering various matters as recommended by committees and officers, all of which had been approved by the Law Committee. (The revised By-laws will be published in the 1929 Year Book, and any member who desires may obtain a pamphlet copy upon application to Institute headquarters.)

Upon the recommendation of the Standards Committee, Graphical Symbols for Telephone and Telegraph Use, prepared by a subcommittee of the Sectional Committee on Scientific and Engineering Abbreviations and Symbols, were approved for adoption as an Institute Standard and for transmission to the American Standards Association.

Mr. E. B. Craft was reappointed a representative of the Institute on the Library Board of the United Engineering Society, for the four-year term commencing January 1, 1929.

Mr. C. O. Bickelhaupt was appointed to serve on the Assembly of American Engineering Council, representing the Institute, for the two-year term commencing January 1, 1929, in place of Mr. A. G. Pierce, who had declined reappointment for that term.

Written and oral reports were received from A. I. E. E. Delegates F. A. Allner and E. C. Stone to the International Conference on Bituminous Coal held in Pittsburgh, November 19-24.

Other matters were discussed, reference to which may be found in this and future issues of the Journal.

Scientific Conquests of 1928

At the January 9, 1929, meeting of the New York Electrical Society Doctor H. H. Sheldon, Chairman of the Department of Physics of Washington Square College, New York University, will give the third annual talk in review of progress in science and engineering during the preceding year. The exact title for the meeting will be "Scientific Conquests of 1928." The speaker will illustrate his lecture with a number of specially arranged demonstrations; among which will be—the train that obeys its "master's voice," the use of an oxidizing agent as a fire extinguisher, the photoelectric cell as a traffic cop, a night watchman, etc. Each year this meeting, with its review of science, has proved of unusual interest to both the technical and non-technical man. The Society extends an invitation to members of the Institute to attend as its guests. Meeting will be held in the Engineering Auditorium, 29 West 39th St., New York at 8:15 p.m., Wednesday, January 9, 1929.

Polytechnic Institute Extends "Open-House" Invitation

On Friday, January 11, between the hours of 4:30 and 10:00 p.m. The Polytechnic Institute of Brooklyn will hold its annual "open house" reception to which it extends a cordial invitation to all.

At this time, the laboratories and shops of the Institute will be in operation and there will be student guides to accompany guests through the buildings. A moving picture "OPPORTUNITY," portraying engineering in the important fields of civil, electrical, mechanical and chemical operation will be presented.

Empire State Gas and Electric Association Electric Section Meets

The annual meeting of the Electric Section of the Empire State Gas and Electric Association will be held on January 10th and 11th at the United Engineering Society's building, 20 W. 39th Street, New York City.

Chairman A. J. Treasumi of the Associated Gas and Electric Companies and his Managing Committee have developed a very interesting program. For information on the details of the meeting, address C. H. R. Chapin, Secretary, Empire State Gas and Electric Association, Grand Central Terminal, New York City.

A. I. E. E. STANDARDS

A. I. E. E. STANDARDS APPROVED AS AMERICAN STANDARDS

Three additional A. I. E. E. Standards have just been approved as American Standards under the procedure of the American Standards Association. Those just approved are: No. 11, "Standards for Railway Motors;" No. 17, "Standards for Railway Control and Locomotive Control Apparatus;" and No. 36, "Standards for Storage Batteries." The addition of this group makes a total of sixteen Standards accepted as American Standards.

Another group of Standards are being revised and will shortly come up for approval as American Standards. Of this group No. 5, "Direct Current Generators and Motors," No. 9, "Induction Motors;" No. 10, "D-C. and A-C. Fractional Horsepower Motors," have been in Sectional Committee procedure for a long period and are about ready for submission to A. S. A. Another group of five are to be submitted to revision by Sectional Committees, not yet organized; they are: No. 19, "Oil Circuit Breakers;" No. 33, "Electrical Measuring Instruments;" No. 37, "Welding Apparatus;" No. 38, "Resistance Welding Apparatus.

Switchboards and Switchgear: A Working Committee of the A. I. E. E. Standards Committee under the chairmanship of George Sutherland of the Queens Electric Light & Power Co. is making very rapid and satisfactory progress in the development of Institute Standards for switchboards and switchgear. It is expected they will shortly submit the results of their work to the Standards Committee for approval.

Graphical Symbols for Telephone and Telegraph Use: At the meeting of the Board of Directors of December 7 the "Report on Graphical Symbols for Telephone and Telegraph Use" was approved as an A. I. E. E. Standard. This report was developed by a subcommittee of the Sectional Committee on Scientific and Engineering Symbols and Abbreviations working under the procedure of the American Standards Association. This pamphlet will be published shortly by the Institute.

Hydraulic and Aeronautical Symbols: Reports of two subcommittees of the Sectional Committee on Scientific and Engineering Symbols and Abbreviations were approved by the Directors of the Institute at their meeting of October 18, 1928. When approval is obtained of the other four sponsors these two reports will be submitted to A. S. A. for final approval as American Standards. The Institute does not feel it necessary to publish these reports as they are entirely outside the electrical field.

Elmer A. Sperry now President of the A. S. M. E.

At the recent Annual Meeting of The American Society of Mechanical Engineers, held early in December 1928, the inauguration of Mr. Elmer A. Sperry, as the Society's new President took place.
A. I. E. E. Nominations

The National Nominating Committee of the Institute met at Institute Headquarters, New York, December 6, and selected a complete official ticket of candidates for the Institute offices that will become vacant August 1, 1929.

The committee consists of fifteen members, one selected by the executive committee of each of the ten Geographical Districts, and the remaining five elected by the Board of Directors from its own membership.

The following members of the committee were present:


Mr. B. Gherardi was unanimously elected chairman of the committee.

The following is a list of the official candidates:

FOR PRESIDENT
Harold B. Smith, Professor of Electrical Engineering, Worcester Polytechnic Institute, Worcester, Mass.

FOR VICE-PRESIDENTS
Southern District: W. S. Rodman, Professor of Electrical Engineering, University of Virginia, University, Va.
North Central District: Herbert S. Evans, Dean, College of Engineering, Professor of Electrical Engineering, University of Colorado, Boulder, Colo.
Pacific District: C. E. Fleager, Assistant Vice-President, Pacific Telephone & Telegraph Company, San Francisco, Calif.

FOR DIRECTORS
J. E. Kearns, Electrical Engineer, General Electric Company, Chicago, Ill.
William S. Lee, Vice-President and Chief Engineer, Duke Power Company, Charlotte, N. C.
Charles E. Stephens, District Manager, Westinghouse Electric & Manufacturing Company, New York, N. Y.

FOR TREASURER
George A. Hamilton, Elizabeth, N. J., (re-nominated).

The Constitution and By-Laws of the Institute provide that the nominations made by the National Nominating Committee shall be published in the January issue of the Institute Journal, and provision is made for independent nominations as indicated below:

CONSTITUTION
Sec. 31. Independent nominations may be made by a petition of twenty-five (25) or more members sent to the National Secretary when and as provided in the By-Laws; such petitions for the nomination of Vice-Presidents shall be signed only by members within the District concerned.

BY-LAWS
Sec. 22. Petitions proposing the names of candidates as independent nominations for the various offices to be filled at the ensuing election, in accordance with Article VI, Section 31 (Constitution), must be received in accordance with Article VI of the Constitution and sent by the National Secretary to all qualified voters during the first week in March of each year, the names of the candidates shall be grouped alphabetically under the name of the office for which each is a candidate.

National Nominating Committee
By F. L. Hutchinson,
Secretary

Biographical Sketches of Candidates

FOR PRESIDENT
Harold B. Smith

Professor Harold B. Smith was born at Barre, Massachusetts, May 23, 1869. He was graduated from Cornell University with the degree of M. E. in Electrical Engineering in June, 1891, and remained as graduate student until December, 1891.

In January, 1892, he was appointed Professor of Electrical Engineering in charge of the department at the University of Arkansas. Resigning from this position in December, 1892, he became Head Designer and Electrical Engineer for the Elektron Manufacturing Company, Springfield, Mass. From September, 1893, to June, 1896, he was Director of the Electrical Engineering at Purdue University. He has held his present position as Professor of Electrical Engineering and Director of the Department at Worcester Polytechnic Institute since 1896.

Professor Smith retained a connection with the Elektron Manufacturing Company as a consulting engineer until 1902, and did consulting work for several other organizations at various times. Since 1905 he has served as a consulting engineer for the Westinghouse Electric and Manufacturing Company.

He was Chairman of the International Group, Jury of Awards in Electrical Engineering, at the St. Louis Exposition in 1904. During the years 1917-19 he was an associate member of the Naval Consulting Board and Consultant of the Special Board of the Navy on Anti-Submarine Work.

He has been a pioneer in the development of high-voltage power transmission systems and equipment, has carried on many researches involving advanced conceptions of dielectric phenomena and stress distribution, and holds numerous patents. He has contributed many papers to the transactions of the societies and other engineering publications.

Professor Smith's Institute activities are as follows: Associate 1881; Member 1901; Fellow 1913; Director 1920-24; Vice-President 1924-26; Chairman of Sections Committee 1924-27; and member at various times of the Coordination, Education, Electrophysics, Law, Instruments and Measurements, Sections, Student Branches, Edison Medal, Research, Meetings and Papers, and a number of special committees. He is at present Chairman of the Committee on Code of Principles of Professional Conduct.

His other memberships include the American Society of Mechanical Engineers (Member), Institution of Electrical Engineers (Great Britain), Society for the Promotion of Engineering Education, American Association for the Advancement of Science, Fellow Sigma Xi, and Tau Beta Pi.

FOR VICE-PRESIDENTS

E. C. Stone

Edmund C. Stone was born in Charlestown, N. H., on December 8, 1882. He was graduated from Harvard University, receiving the degree of A. B. in 1904 and of S. B. in 1905.

On leaving college Mr. Stone became an engineering apprentice at the works of the Westinghouse Electric & Manufacturing Company, East Pittsburgh, Penna., in 1905, and in the following year received an appointment as Designing Engineer in the Transformer Division of the Engineering Department.

In 1911 Mr. Stone joined the Alleghany County Light Company, which two years later became the Duquesne Light Company, with which company he has been associated ever since.

In 1913 he organized the System Operating Department of the Duquesne Light Company and remained System Operator until 1919, at which time he was appointed Assistant to the General
Manager. In 1922 he was made Planning Engineer in charge of planning the physical development of the power system.

On January 1, 1927, Mr. Stone was appointed Manager of System Developments in charge of planning, engineering, statistics, valuation work, and student engineering training, which position he now holds.

Mr. Stone has been active in Institute work. He was chairman of the Pittsburgh Section in 1922-23 and has been a Director since 1925, this term expiring in 1929. He has served as Chairman of the Elective Devices Committee, Chairman of the Standards Subcommittee of the Electrical Machinery Committee and as a member of other Institute Committees as follows: Research Committee on Technical Activities, Meetings and Papers, Power Generation, General Power Applications, and Law, being still a member of the last three. He has been on the Advisory Engineering Staff of the International Elec-

trical Commission for several years.

In 1925-26 Mr. Stone was Chairman of the Electrical Apparatus Committee, N. E. L. A., and, since July, 1927, has been Chairman of the Engineering National Section of the N. E. L. A. He has also contributed three important papers, dealing respectively with parallel operation of power plants, methods of power system grounding, and oil circuit breaker design and performance, to the TRANSACTIONS of the Institute.

During the past three years, Mr. Stone has been on the faculty of the School of Business Administration of the University of Pittsburgh and conducted a series of courses on the economics of public utilities. In 1927 he was appointed graduate lecturer in the Sheffield Scientific School of Yale University.

He is a member of the Harvard Club of Western Pennsylvania, Chamber of Commerce of Pittsburgh, Engineers Society of Western Pennsylvania and the Association of Iron & Steel Electrical Engineers.

W. S. Rodman

Walter Sheldon Rodman, Professor of Electrical Engineering in charge of the School of Electrical Engineering at the University of Virginia, was born in Wakefield, Rhode Island, on September 1, 1883. He was educated in the public grade and high-school of his native town and entered Rhode Island State College in the fall of 1900, graduating with the degree of B. S. in E. E. in June, 1904. For four years following graduation, he was engaged as Instructor in Mathematics, Physics, and Electrical Engineering at R. I. State College, where in 1907 the degree of M. S. in E. E., the first advanced degree ever awarded at the institution, was conferred upon him by the University of Nebraska in June, 1928.

In the fall of 1910, appointment was made as Adjunct Professor of Electrical Engineering at the University of Virginia, followed in 1913 by an Associate Professorship and in 1917 by the Professorship, in which office service is still being rendered. Mr. Rodman joined the Institute in 1907, was transferred to the grade of Member in 1912, and became a Fellow in 1928. He was one of the charter members of the Southern Virginia Section, serving continuously to date on its Executive Committee, and for the past three years has been Chairman of that Section. The University of Virginia Branch was organized by him in 1912, and since the office of Counselor was inaugurated, he has been active in that capacity at Virginia. He served one year as a member of the Committee on Student Branches. During the present year, he is a member of the National Sections Committee and of the Executive Committee of District No. 4.

His other memberships include Tau Beta Pi, Theta Tau, Phi Sigma Kappa, Pi Gamma Mu, Phi Kappa Phi, Phi Beta Kappa, Society for the Promotion of Engineering Education (Vice-President 1926-27), Illuminating Engineering Society, American Association of University Professors, and Fellow of the American Association for the Advancement of Science.

Herbert S. Evans

Herbert S. Evans, Dean of the College of Engineering and Head of the Department of Electrical Engineering of the University of Colorado, was born in Richardson County, Nebraska, on July 20, 1875.

After his early education in the local schools, he attended Morrill College, Kansas, for one year, 1891-1892, and then took up the study of Electrical Engineering at the University of Nebraska, where he received the B. S. (E. E.) degree in 1900, and the E. E. degree in 1900. While working toward his E. E. degree, he was in charge of the electrical work for the C. I. & Q. Railroad in Nebraska, and became a Fellow in 1901. At this time he was appointed instructor in electrical engineering at his alma mater, and was later promoted to adjunct professor. The honorary degree Doctor of Engineering was conferred upon him by the University of Nebraska in June, 1928.

In September, 1905, after a summer with the General Electric Company at Schenectady, New York, he was appointed Professor of Electrical Engineering and head of the department at the University of Colorado. This position he held until the fall of 1910, when, upon the resignation of Milo S. Ketchum, he was chosen Dean of the College of Engineering. As head of the College, Dean Evans came especially well qualified, for he had been acting dean during 1909-1910, and again during the trying war period of 1917-1919. At this time, too, he demonstrated unusual administrative ability as Director of all the S. A. T. C. activities at the University of Colorado.

Dean Evans joined the Institute in 1905 and was transferred to the grade of Member in 1909. He is a past chairman of the Denver Section.

In addition to the work of his immediate position, Dean Evans always has shown a broad, active interest in his profession and in state and local affairs. He is one of the outstanding citizens of Boulder, having served on the city council since 1917, and being keenly interested and active in church work.

He was formerly chairman of one of the technical sections of the National Electric Light Association, and vice-president and member of the Council of the Society for the Promotion of Engineering Education. His other memberships include Sigma Xi, Tau Beta Pi, and Sigma Tau. He has contributed numerous articles to engineering publications.

C. E. Fleager

Clarence E. Fleager was born May 23, 1879, at Sheldon, Illinois, where he attended the public schools. He was graduated from the University of Illinois, Class of 1899, with the degree of B. S. in Electrical Engineering. On June 1, 1899, he entered telephone work at Chicago, Ill., and since has been continuously engaged in the telephone business.

After experience in nearly all branches of the telephone work, he was in 1910 appointed Division Plant Engineer, in 1917 Plant Engineer, in 1925 Chief Engineer, and in August, 1928, Assistant Vice-President, the position he now holds, all with The Pacific Telephone and Telegraph Company at San Francisco.

His experience with the telephone business has covered all phases of operation, engineering, and construction, and he has been in charge of numerous projects on the Pacific Coast. It was under his engineering supervision that the first transcontinental telephone line was opened for service in 1915. He has also taken an active part in the valuation and other work in connection with the regulation of the company's rates in the States of Washington, Oregon, and California from 1915 to date.

Mr. Fleager is a prominent member of the Engineers' Club of San Francisco, and has taken an active part in service and social clubs around San Francisco Bay.

He joined the Institute as an Associate in 1911 and in 1926 was transferred to the grade of Fellow. He has served on the
Executive Committee of the San Francisco Section and on the National Membership Committee.

Charles E. Sisson

Charles Everett Sisson was born in Ida, Ontario, Canada, October 25, 1873. He graduated from the University of Toronto in applied science and engineering in 1905.

Before his graduation, he had spent about one and one-half years in the Test Department of the Canadian General Electric Company, Ltd., and was employed by that company at Peterboro, Ontario, as Junior Designing Engineer from 1905 to 1911, and as Transformer Engineer in charge of transformer design during the following ten years. Since 1921 he has been Transformer Engineer with the same company at the Davenport Works, Toronto, and has been in charge of transformer, electric steam generator, and industrial electrical heating design. He is one of the leading designing engineers in Canada.

Mr. Sisson joined the Institute in 1919, and was transferred to the grade of Member in 1928. He was Chairman of the Toronto Section during the administrative year 1927-28.

FOR DIRECTORS

J. E. Kearns

John Edward Kearns was born at Canajoharie, N. Y., November 30, 1879, and received his education at the Canajoharie High School, Clinton Liberal Institute, and the University of Michigan, taking a course in electrical engineering at the latter.

Taking up engineering work with the General Electric Company, he was employed in drafting and testing 1902-3, design in the Direct-Current Engineering Department 1903-06, engineering and commercial work in the Power and Mining Department 1906-10, and in the Central Station Department 1910-15. Since 1915 he has served as Electrical Engineer in the Chicago office of the General Electric Company and has been in charge of special sales engineering work.

Mr. Kearns joined the Institute in 1907 and was transferred to the grade of Member in 1921. He is a Past Chairman and Secretary of the Chicago Section, and is at present Chairman of the National Membership Committee of the Institute.

He is a member of the National Electric Light Association, and has represented his company for many years as a member of the Technical Apparatus Committee of that association. As such representative, he assisted materially in the preparation of some of the standards of the A. I. E. E. He was formerly a member of the Board of Directors of the Western Society of Engineers and President of the Michigan Engineers Club of Chicago, as well as Vice-President of the Chicago Alumni Association of the University of Michigan.

W. S. Lee

William States Lee was born in Lancaster, South Carolina, January 28, 1872, and was awarded the degree of C. E. by the Citadel, the Military College of South Carolina, in 1894.

Following his early engineering experience he was appointed Resident Engineer of the Anderson (S. C.) Light and Power Company in 1897; Resident Engineer of the Columbus (Ga.) Power Company in 1898, and Chief Engineer of the latter in March, 1902. In March, 1903, he was appointed Chief Engineer and in October of that year Vice-President and Chief Engineer of the Catawba Power Company, Charlotte, N. C. This Company was a subsidiary of the Southern Power Company and in 1903 he became Chief Engineer of the latter company. He later received the appointment of Vice-President and Chief Engineer, which position he held for about fifteen years. He is at present Vice-President and Chief Engineer of the Duke Power Company.

Among Mr. Lee's other connections the following should be included: President and Chief Engineer of the Piedmont and Northern Railway Company; Vice-President and Chief Engineer, Great Falls Power Company, Watertown Power Company, Western Carolina Power Company, Catawba Manufacturing and Electric Power Company, Duke Power Company, Ltd., Quebec Development Company, Ltd.; Director, American Cyanamid Company; and Trustee of the Duke Endowment. He has also engaged in practise as a Consulting Engineer, with an office in New York City.

He has been a pioneer in high voltage hydroelectric power development and transmission, and is inventor of the Lee Ptolemy. His Institute activities are as follows: Associate 1904; Member 1907, Fellow 1913; Director 1911-14, and member for several years of the Committee on Power Transmission and Distribution, Standards Committee, and Committee on Power Generation, being still a member of the latter two.

Mr. Lee's other Society memberships include American Society of Mechanical Engineers, American Society of Civil Engineers, and the Engineering Institute of Canada.

C. E. Stephens

Charles E. Stephens, Northeastern District Manager, Westinghouse Electric & Manufacturing Company since April, 1925, has had a wide experience with the electrical industry since entering the Westinghouse organization when hardly more than a boy. His success has been one merited through hard work and diligent study both of the engineering and sales features of the business.

Mr. Stephens was born in Ferris, Texas, November 19, 1882, and attended the Ferris Institute. Becoming enthusiastic over the future of the electrical industry, he applied for a position with the Westinghouse Company in 1900, and he was placed in the Company's shops at East Pittsburgh as an apprentice. Here he gained a great amount of practical experience in electrical manufacturing practice, which he augmented by technical study. Mr. Stephens had the wisdom while on the apprentice course to follow the policy of securing work in as many different departments of the factory as possible, in order to broaden his knowledge.

Leaving the student work, Mr. Stephens finally gained an appointment in the Testing Department, from which he was later transferred to the Engineering Department. His work there was the design of molds for armatures and coils, for which his shop experience especially fitted him. After a short while he was assigned to motor insulation design and development.

After a relatively short time in this capacity, he was made Manager of the Arc Lighting Section of the Engineering Department, and then was promoted to the position of Illuminating Engineer of the General Engineering Department.

Leaving Engineering work, he was then made Manager of the Illuminating Section of the Sales Department, from which position he was transferred in 1917 to the New York office, as Manager of the Supply Department. Later he was made Manager of the Central Station division of the New York office, and in 1925 was made Manager of the district, the largest within the Westinghouse district sales divisions.

Mr. Stephens is now serving on the Board of Directors of the Institute and as a member of the Finance Committee. He is a past Vice-President of the Illuminating Engineering Society, and a member of several clubs and associations.

FOR TREASURER

George A. Hamilton

George Anson Hamilton, a charter member of the Institute, was born in Cleveland, Ohio, December 30, 1843. He early showed great interest in electricity.

In 1861, he became a messenger at Salem, Ohio, but two months later was made manager of the Atlantic and Great Western Railroad office at Ravenna. Illness forced him to relinquish this position in 1863, but upon his recovery he went to Pittsburgh as operator and manager of the Inland Company. In 1865, he became manager of the United States Telegraph Company's office at Franklin, Pa., but returned to Pittsburgh in 1866 as chief operator and circuit manager, and remained until 1873 when
In 1889, he accepted a position with the Western Electric Company, being given supervision and care of the department for the production of fine electrical instruments, which position he retained until his retirement in 1909.

Mr. Hamilton was the first Vice-President of the Institute (1884-86), and has been its National Treasurer since 1905, and a Fellow since 1913. He has for many years been a member of the Edison Medal and Executive Committees. His other memberships include Institution of Electrical Engineers (Great Britain), Société Française des Électriciens, Société Française de Physique, and Société Belge d' Astronomie.

**American Engineering Council**

**LEGISLATIVE MEASURES OF INTEREST TO ENGINEERS**

During the first few days in which Congress was in session the following bills of interest to engineers were introduced:

H. R. 14146 granting the consent of Congress to the county of Allegheny, Pa., to construct a bridge across the Monongahela River between the city of Pittsburgh, Allegheny County, Pa., and McKees Rocks, State of Pennsylvania. By Mr. Campbell; to the Com. on Roads.

H. R. 14143 to provide for consolidations, mergers, and cooperative marketing and in the control and disposition of the surplus of mineral oils on the dutiable list. By Mr. Howard of Oklahoma; to Com. on Ways and Means.

H. R. 14469 granting the consent of Congress to the county of Allegheny, Pa., to construct a bridge across the Youghiogheny River between the borough of Versailles and the village of Boston, in the township of Elizabeth, Allegheny County, Pa. By Mr. Kelly; to Com. on Interstate and Foreign Commerce.

H. R. 14471 to extend the time for the construction of a bridge across the Ohio River, between the North Side, Pittsburgh, and McKees Rocks Borough, in the county of Allegheny, in the Commonwealth of Pa. By Mr. Porter; to Com. on Interstate and Foreign Commerce.

H. R. 14472 to extend the time for the construction of a bridge across the Mississippi River at or near the city of Vicksburg, Miss. By Mr. Collier; to Com. on Interstate and Foreign Commerce.

H. R. 14473 granting the consent of Congress to the city of Aurora, State of Illinois, to construct, maintain and operate a bridge across the Fox River within the City of Aurora, State of Illinois. By Mr. Reid; to Com. on Interstate and Foreign Commerce.

H. J. Res. 329 to create a commission for the revision of the shipping laws of the U. S. By Mr. LaGuardia; to Com. on Rules.

H. J. Res. 330 requesting the President to propose the calling of an international conference for the simplification of the calendar, or to accept, on behalf of the U. S., an invitation to participate in such a conference. By Mr. Porter; to Com. on Foreign Affairs.

H. R. 14655 to amend an act entitled "An act to provide that the U. S. shall aid the States in the construction of rural post roads and for other purposes" approved July 11, 1916, as amended and supplemented, and for other purposes. By Mr. Colton; to Com. on Roads.

H. R. 14673 to enable the Postmaster General to make contracts for the transportation of mails by air from island possessions of the U. S. to foreign countries and to the U. S. and between such island possessions and to authorize him to make contracts with private individuals and corporations for the conveyance of mails by air in foreign countries. By Mr. Kelly; to Com. on Post Offices and Post Roads.

H. R. 14674 authorizing the sale of surplus power developed under the Grand Valley reclamation project, Colorado. By Mr. Taylor; to Com. on Irrigation and Reclamation.

S. 4601 to amend the act entitled "An act to provide that the U. S. shall aid the States in the construction of rural post roads and for other purposes," approved July 11, 1916, as amended and supplemented, and for other purposes. By Mr. Oddle; to Com. on Post Offices and Post Roads.

S. 4002 to establish a Federal Farm board to aid in the orderly marketing and in the control and disposition of the surplus of agricultural commodities in interstate and foreign commerce. By Mr. McNairy; to Com. on Agriculture and Forestry.
OPPOSES MOVEMENT TO TRANSFER GEODETIC WORK TO DEPARTMENT OF THE INTERIOR

Acting upon the report of its President, A. W. Berresford, legislation to transfer the geodetic work of the U. S. Coast and Geodetic Survey from the Department of Commerce to the Department of the Interior will be actively opposed by the American Engineering Council.

After a careful investigation of the situation, Mr. Berresford declared he could see little or no advantage and much potential disadvantage in such a proposal, since the work of the Geodetic Survey can be and is being coordinated with that of the Geological Survey so that the need of the latter is already being met.

The work projected for the United States is only 60 per cent logical Survey so that the need of the latter is already being met. The Survey can be and is being coordinated with that of the Geodetic Survey so that the need of the latter is already being met.

The significance and usefulness of the Louvain carillon has been broadened by recent exchange of the following letters:

Louvain Memorial

More About Louvain Memorial

Recently the four national societies of Civil, Mining, Mechanical and Electrical Engineers each received from Gillett & Johnston, makers of the memorial carillon and clock in the Louvain Library tower, a bell similar to the small bells of the carillon, suitably inscribed as a souvenir of the memorial.

The significance and usefulness of the Louvain carillon has been broadened by recent exchange of the following letters between the Committee on War Memorial to American Engineers and the University of Louvain.

My dear Monsignor Ladeuze,

Reflection since our return from Belgium has brought to mind a suggestion for the weaving of a strong thread into the fabric of our international friendship. We would not presume to indicate how and when your carillon might be played upon the Louvain carillon in honor and in memory of these Belgian engineers. In this way, we should like to join in our memorial the Belgian engineers with the engineers of the United States of America who gave their lives for the cause of Liberty in the Great War.

Sincerely yours,

EDWARD DEAN ADAMS, Chairman

Monsignor P. Ladeuze, Rector

University of Louvain

Louvain, November 13th, 1923.

My dear Mr. Adams,

Monsignor Ladeuze instructed me to answer your letter dated 24th October. The University of Louvain deems it a splendid and noble idea to have the carillon playing on certain days also in memory of the Belgian engineers who died in the service of our country in the Great War. It would, indeed, be weaving a strong thread in the fabric of our international friendship.

Therefore, the University of Louvain is in full accordance with the proposal, and it seems a good thing that the carillon should play to the memory of the Belgian engineers who fell in the war, on the 4th of August, anniversary of the invasion of Belgium, and also on the 11th of November, Armistice Day.

This proposal is entirely in the line of what is said in the articles of the "Deed of Gift," and it covers admirably the Memorial, which the American Engineers erected at the University to be a token of everlasting friendship between them and the University of Louvain.

Believe me, my dear Dr. Adams, with kindest regards.

Yours affectionately,

L. VAN DER ESSEN, Sec., Univ.

PERSONAL MENTION

CHARLES S. RUFFNER, President of the Mohawk Power Corporation, was recently elected President of the Empire State Gas and Electric Association. Mr. Ruffner has been connected for almost thirty years with electric light and power industries. He was appointed Vice-President of the Mohawk Power Corporation in 1903 and has been a Fellow since 1913.

H. U. HART, who has been General Manager and Chief Engineer of the Canadian Westinghouse Co., Ltd., has been appointed Vice-President of that organization. Mr. Hart joined the Institute in 1903 and has been a Fellow since 1913.

ROBERT P. KING, Past-Chairman of Springfield, Mass., Section, and for several years Works Engineer of Westinghouse Elec. & Mfg. Co. (East Springfield Works), has joined the engineering division of Du Pont Rayon Co., Buffalo, N. Y.

WILLIAM W. TEPPT, who has been Chief Engineer of the Commonwealth Power Corporation for the last five years, has resigned, to devote his entire time to his Consulting Engineering practice. He continues his residence and official headquarters in Jackson, Michigan, where he has resided for many years.

RICHARD I. WILSON has resigned from the Underground Transmission & Distribution Division of The Philadelphia Electric Company to accept a position as Sales Engineer with the Standard Underground Cable Co., a Division of the General Cable Corporation.

JAMES R. WERTH has just been appointed Commercial Manager for the State of Sao Paulo, Brazil, for The Empresas Electricas Brasileiras, at Sao Paulo, Brazil, an Electric Bond & Share property. He was formerly Head of the New Business Division of the Florida Power & Light Company, also an Electric Bond & Share property.

B. S. ROBINSON, formerly engineer for W. R. Cramer & Company, Inc., has been made Assistant Editor of The Electrical World. For the past 8 years Mr. Robinson has been with the Telegraph and Signal Department of the Pennsylvania Railroad and the same department of the Philadelphia Electric Company, with two years in the Engineers Corps of the United States Army.
Edwin W. Pettit, recently with the Illinois Central Railroad as Assistant Engineer in connection with the Chicago Terminal Improvements, reports the completion of the design and partial operation of a new all-electric water pumping station for the City of Chicago. This station will be capable of pumping 100 million gallons of water per day and is the first station to be built for electrical operation from the start.

Obituary
Phillip V. Bergen, Chief Electrical Inspector for the Bronx Gas and Electric Company, died at his home on November 12, 1928. Mr. Bergen was born at Westchester, N. Y., July 29, 1894, and was for eight years with the General Public Utility Electrical Engineering Work in the employ of the Bronx Gas and Electric Company, for which he was Electrical Inspector, Assistant to the Engineer of Distribution and in his last capacity of Chief Electrical Inspector. He joined the Institute in 1926 as an Associate.

Edward Preston Clifford, Vice-President of the Bell Telephone Laboratories, Inc. and a member of the Institute since 1911, died at his home, 830 Seventh Avenue, New York, N. Y., Sunday afternoon, December 6.

He was a native of New York City and his early education was secured through school and private home tuition until his entry into the business world in 1892, when he joined the forces of the Western Electric Company. Through a series of positions, he rose from office boy to cashier of the New York office; then chief clerk for the Chicago, Philadelphia, and New York branches; assistant manager of the New York division; until, in 1911, he was made manager, with supervision over the Boston, Philadelphia, and Pittsburgh houses. In 1917 he was made eastern district manager. During the war, the engineering department was called upon to investigate many problems in connection with aircraft, submarine detection, artillery sound ranging, and radio, and to handle the multiplicity of commercial matters incident to this expansion. Mr. Clifford, on July 1, 1918, was called first as office manager, and a year later, as commercial manager. When the engineering department was incorporated in the Bell Telephone Laboratories, Mr. Clifford was elected vice-president in charge of the general staff, and in this capacity he built up the force of some 275 expert mechanics, at the same time caring for the maintenance of buildings aggregating 530,000 square feet of floor space. His ambition was to give his men, in addition to their own professional skill, an interest in and knowledge of the more technical side of the Laboratories work, thus to enable them to comprehend the importance of the scientist and apply their own craftsmanship more effectively, relieving their associates of a vast burden of detail. His work included the administration of a budget of more than $15,000,000, and close relations with the American Telephone and Telegraph Company and the Western Electric Company.

Mr. Clifford was a member of the Telephone Pioneers of America, The Railroad Club, the American Yacht Club and the New York Athletic Club.

Nelson J. Young, Assistant Electrical Engineer of the Rochester Gas and Electric Company and an Associate of the Institute, died November 11, 1928 at Rochester, N. Y.

Born at Saugeties, New York, June 27, 1886, Mr. Young, after passing through public school, attended Pratt Institute and evening courses in Electrical and Mechanical Engineering at Columbia, Mechanics Institute of New York City and the Brooklyn Polytechnic Institute, as well as special laboratory courses given by the Brooklyn Edison Company. He was with the Western Electric Company from 1903 to 1905, first in the blue print room and then in the drafting room; then he joined the Dime Street office of the New York Edison Company as draftsman but was soon made a squad foreman, which position he held for four years. From 1914 to 1916, Mr. Young did some work on himself in another field and at the expiration of that time, entered the employ of the Detroit Edison Company as an electrical designer in charge of the electrical squad in the drafting room. A portion of 1917 was spent with J. A. Crowley Steel Company of Detroit, (through the courtesy of the Detroit Edison Company) installing two Greenwald-Dixson furnaces; then he joined the engineering department of the Electric Bond & Share Company, and for the latter part of the year 1918, he was with the Ordinance Department of the United States Government on the design of electrical equipment for the Aberdeen Proving Ground. He then was engaged by the United Gas and Electric Engineering Corporation as chief draftsman for three years and then as construction engineer in full charge in the field of installations of both electrical and mechanical apparatus in coal stations and substations from the plants located at Leavenworth, Kansas, New Orleans, La., and Wilkesbarre, Pa.

Through the United Gas and Electric Engineering Corporation, he then went to the Lockport Light Heat and Power Company as superintendent of Power and Construction. He joined his last company the early part of 1927. He was a member of the National Electric Light Association, the Lockport Lodge No. 67, F. and A. M., the Buffalo Consistory A. A. S. R. and the Eastern Order of Odd Fellows. Mr. Young had been an Associate of the Institute for four years.

Death of Mrs. Schuchardt
Mrs. Ada Briggs Schuchardt, wife of R. F. Schuchardt, President of the American Institute of Electrical Engineers and Electrical Engineer of the Commonwealth Edison Company, Chicago, died at the family home on Monday morning, December 24 of pneumonia. She had been ill only two days. On the previous Friday she had gone to a railroad station to meet her son, William, a freshman at Amherst, who was arriving home for the holiday season; on Saturday morning she was stricken with influenza, which developed rapidly into pneumonia.

Besides her husband and son, Mrs. Schuchardt is survived by a daughter, Betty. She was a member of a number of women's clubs and had been active in civic affairs. Funeral services were private.

A. I. E. E. Section Activities

FUTURE SECTION MEETINGS

Cleveland


Columbus

Detroit-Ann Arbor

Indianapolis-Lafayette
Institute and Related Activities

Pittsburgh


San Francisco


Seattle

Address by an engineer of the American Telephone & Telegraph Co. January 15.


Sharon


The Role of Physics in Industry, by L. O. Grondahl, Director of Research, Union Switch & Signal Co. February 5.

Vancouver

Students' Night. University of British Columbia Students. February 5.

Washington


PAST SECTION MEETINGS

Akron


Boston

Practical and Simple Theories of Dielectric Action, by C. L. Kasson, Boston Edison Co. After presentation of the paper the Edison Company's laboratories were open for inspection and demonstrations were given. A dinner preceded the meeting. November 8. Attendance 79.


Chicago


Cincinnati


Cleveland


Connecticut


Dallas


Denver

Scientific Discoveries and Experiences in the Gobi Desert of Asia, by Dr. C. P. Berkey, Professor of Geology, Columbia University. Illustrated with slides. Meeting preceded by a dinner. November 9. Attendance 71.


Detroit-Ann Arbor

The Importance of High-Voltage Measurements, by Wm. W. Tefft, Vice-President and Chief Engr., Commonwealth Power Corp.

Methods of Measuring Extra High Voltages, by Prof. C. Francis Harding, Head, School of Elec. Engg., Purdue University; A New Automatic Recording Cathode-Ray Oscillograph, by R. H. George, Research Associate, Elec. Division of Engg., Purdue University; and Installation and Use of the Automatic Recording Cathode-Ray Oscillograph for Recording Lightning Transients on the Consumers Power Company System, by J. R. Eaton, Transmission Engr., Consumers Power Co. Illustrated with slides. The meeting was preceded by a banquet with music and entertainment and followed by a demonstration of the cathode-ray oscillograph. An inspection trip to the Blackstone Substation and the Electrical Laboratory of the Consumers Power Company and the radio manufacturing plant of the Sparks-Withington Company was arranged during the afternoon for the delegation of students from the University and State College who attended the meeting. November 13. Attendance 265.


Erie

Silk, by Mrs. Carolyn R. Lewis, Publicity Director, H. R. Mallinson Co. Following the talk motion pictures of the silk industry were shown. November 20. Attendance 150.

Fort Wayne


Houston

Repairs to Electrical Machinery, by A. U. Kater, President, Houston Armature Works. The meeting was preceded by a dinner. November 14. Attendance 33.

Indianapolis-Lafayette


Ithaca


Kansas City


The Report on the Street Railway Situation, by P. C. Groner, President, Kansas City Public Service Co., and

Lehigh Valley

The Properly Right of the Engineer, by M. J. Martin, Attorney, and
t Trains Control, by C. S. Williams, D. L. & W. Railroad. In the afternoon an inspection trip was taken through the shops of the D. L. & W. A dinner also preceded the meeting. October 19. Attendance 98.

Anthropite Problems, by E. H. Suender, Vice-President, Madeira, Hill & Co., and


Los Angeles

Recent Research Work in Aeronautics, by Prof. A. A. Merrill, Instructor in Experimental Aeronautics, California Institute of Technology. The meeting was preceded by a dinner. October 30. Attendance 122.

Louisville


Lynn


Mexico


Minnesota


Nebraska


New York


Niagara Frontier

On invitation of the Engineering Society of Buffalo, a demonstration of electric are welding of the structural steel work of the new office and bank building of the Tonawanda Power Company. At North Tonawanda, N. Y., was witnessed, The Western New York Section, American Welding Society and Electrical League of the Niagara Frontier also cooperated. August 16.


Televox, the Electrical Man, by J. L. McCoy, Westinghouse Electric & Mfg. Co. The meeting was in cooperation with the Engineering Society of Buffalo. October 16. Attendance 400.


The Manufacture of Steel, by G. A. Richardson, Bethlehem Steel Co. In the afternoon an inspection trip was made to the Lackawanna Plant, followed by a dinner at the Hotel Statler. The societies invited to participate in the meeting were: The Engineering Society of Buffalo and the Affiliated Societies; Niagara Section, the Institute of Radio Engineers; Toronto Section, A. I. E. E., and Niagara, Hamilton and Toronto Branches, Engineering Institute of Canada. October 25. Attendance 150.

Pittsburgh


Pittsfield

The Romance of Power, by C. M. Ripley, General Electric Co. Illustrated with slides. The speaker was entertained at dinner previous to the meeting. November 6. Attendance 65.

Modern Developments in Physics, by Dr. Saul Dushman, General Electric Research Laboratory. The speaker was entertained at dinner previous to the meeting. November 20. Attendance 110.

Portland


St. Paul

Evidence


Rochester


St. Louis


Seattle

Economics of Interconnection, by O. L. LeFever, General Supt., Northwestern Electric Co., and


Sharon


Springfield

A. I. E. E. Student Activities

ELECTRICAL SHOW AT MONTANA STATE COLLEGE

The Montana State College Branch held an electrical show on Saturday night, December 8, 1928, for the purposes of demonstrating to the public the wide and varied field of electricity and giving the students more practical training in the laboratory. The attendance was about 275.

A program including the following twenty-six exhibits was supplied by the juniors and seniors in electrical engineering: speaking arc lamp, artificial lightning, eddy current cooking demonstration, tin can motor, electrical spot welding, electrical forge—(2), electrical chieh hatching, electrical fish pond, electrical flowers, electrical smoke precipitation, reversing motor, oscillograph demonstration, street car motor and control, series arc lamps and generators, automatic telephone, radio controlled car, artificial telephone line demonstration, electrical meter operation, high frequency currents, X-ray demonstration, magneto voltage test, lifting magnet, mercury arc rectifier, winking lights, radio set.

CONVENTION OF STUDENT BRANCHES IN OHIO

A very interesting and successful Student Convention was held at Ohio State University, Columbus, Ohio, December 7 and 8, 1928. Five of the six Branches in the state participated, the four visiting Branches being represented by delegations ranging from nine to twenty-eight students.

FRIDAY AFTERNOON

Following a luncheon, an inspection trip was conducted through the Engineering Laboratories, Radio Station WEAO, Experiment Station, University Power Plant, Stadium, Industrial Engineering Shops, and the Chemistry Department.

FRIDAY EVENING

At the dinner meeting held on Friday evening, the principal speaker was D. T. Fister of the Jeffrey Manufacturing Company, whose address on the subject "Patents and Their Relation to Engineering" was greatly enjoyed by the 110 persons who were present. It was followed by a lively and beneficial discussion.

A résumé of A. I. E. E. Student Activities was given by Professor F. C. Caldwell, Counselor, Ohio State University Branch, and Chairman of the Committee on Student Activities of the Middle Eastern District. Professor H. B. Dules, Counselor of Case School of Applied Science Branch, gave a brief talk upon his experiences in Student Branch work.

SATURDAY MORNING

Résumé of Branch Activities:
W. A. Thomas, Chairman, Case School of Applied Science Branch.
C. C. Kelch, Chairman, Ohio University Branch.
H. F. Rice, Chairman, Ohio Northern University Branch.
G. W. Trout, Secretary, Ohio State University Branch.
C. D. Tinley, Chairman, Municipal University of Akron Branch.

The following papers were presented by students:
Arc Welding, W. C. Sanow, Case School of Applied Science.
Student Publications, C. C. Keller, Ohio State University.
Railway Electrification, W. C. Henkel, Ohio Northern University.
Development of a New High Temperature Solder, E. M. Sanow, Ohio State University.
The Verigraph, Harmon Shively, Municipal University of Akron.

The above talks were followed by discussions by the Counselors. The attendance at this session was about 160.

Saturday afternoon plans for the Convention were made under the supervision of a general committee, of which Robert H. Spry, Chairman of the Ohio State University Branch, was Chairman.

BRANCH MEETINGS

Municipal University of Akron


Motion picture, "Conowingo." Seven members expressed their intention to attend the Student Convention at Ohio State University. December 5. Attendance 15.

Alabama Polytechnic Institute

Business meeting. Discussion of plans for an inspection trip and a smoker. November 8. Attendance 44.

INSTITUTE AND RELATED ACTIVITIES

Duke University

Regional Meeting of the A. I. E. E. at Atlanta, by Prof. W. J. Seeley, Counselor, and

Dredge, Purpose and Value of the A. I. E. E., by Prof. S. R. Schroeder, Dept. of Elec. Eng., Motion passed that the program committee assign definite dates for each member of Branch to give a paper. November 16. Attendance 16.

Georgia School of Technology


Four reels of motion pictures on radio and construction of transformers. November 10. Attendance 60.

Business Meeting: Reports of various committees regarding the same, inspection trips, etc. December 4. Attendance 15.

University of Iowa


The Duties of a Safety Engineer, by Earl Flamman, Student. September 26. Attendance 44.


Kanass State College

Summer Experiences with the Central Station Institute, Chicago, by Prof. R. G. Kieffer, Counselor. Made an announcement in regard to the two sections of the Branch and the A. I. E. E. Regional meeting. Lester Means, General Electric Co., gave a talk on the opportunities offered by the General Electric Company to college graduates. October 18. Attendance 76.

Storage Batteries, by Mr. Herro, Student, and Johns and Personalities, by Prof. R. G. Kieffer, Counselor. Film—“Back at Westinghouse with Kansas State Boys.” November 1. Attendance 73.

Summer Experiences with the Central Station Institute of Chicago, by Professor R. G. Kieffer, Student, Lester Means, General Electric Co., gave a brief talk regarding the General Electric Company. October 18. (Evening).

Television, by A. W. Vance, Student. Moving pictures—“Back at Westinghouse with the Kansas State Boys.” November 1. (Evening).

University of Kansas


University of Kentucky


Electric Motor for Power Factor Correction, by a Student.

Mercy Are Rectifiers Substations, by a Student, and Electric Energy-Power to Prosperity, by a Student. December 5. Attendance 40.

Lafayette College


Lehigh Institute

INSTITUTE AND RELATED ACTIVITIES

Jan. 1929

Business Meeting. It was decided to urge students to present papers of technical nature at regular Branch meetings and prepare papers for the regional meeting of District No. 5. November 26. Attendance 11.

Louisiana State University


University of Louisville
Business session, followed by talk by Chairman Samuel Evans on his trip to Atlanta and Washington and the papers delivered at the Regional Meeting in Atlanta. November 22. Attendance 10.

University of Maine

Massachusetts Institute of Technology


School of Engineering of Milwaukee

University of Missouri
The General Electric Student Training Course, by C. M. Wallis, Instructor, and The Maximum Limits of Power Transmission, by J. H. Cooper, Student. The Branch decided to select, for presentation at the Regional Meeting at Dallas, two papers from a number to be submitted by various students. October 29. Attendance 33.

Montana State College

Great Northern Railway Electrification in the Cascades, by E. L. Melvin Ziegler; Secretary, Harold W. Giesecke. November 14. Attendance 69.

University of Nevada

Newark College of Engineering

University of New Hampshire


Philadelphia Electric Company, by Mr. Stevens, alumnus. Mr. Smith, alumnus, gave a talk on various services given by the Western Union Telegraph Company. December 4. Attendance 34.


College of the City of New York


New York University


North Carolina State College

University of North Carolina

University of North Dakota


Ohio Northern University
Railroad Electrification, by W. G. Hensel, Student, and The Engineer as the Employer Sees Him, by P. D. Luikart, Student. Plans made for attending the Student Convention at Ohio State University on December 7 and 8. November 22. Attendance 28.


Ohio State University

Ohio University
Inspection trip through the new automatic-equipped telephone building of the Athens Home Telephone Co. The following officers elected: Chairman, Clarke Kenney; Vice-Chairman, Melvin Ziegler; Secretary, Harold W. Giesecke. November 14. Attendance 13.

Oklahoma A. & M. College
Three reels—"The Benefactor." Charman E. L. Weathers discussed the programs planned for this year and the benefits derived from Branch membership. November 15. Attendance 31.

Oregon State College
Three reels—"The King of the Rails." November 19. Attendance 64.
University of Pittsburgh
F. R. Garman, Bell Telephone Company of Pa., demonstrated several different types of loud-speakers using an electric phonograph pick-up with a power amplifier. Two reels of films—"The Big Little Fellow" and "Voices Across the Sea." Light refreshments. October 26. Attendance 53.
The Importance of Cooperative Work and the Engineer's Training, by R. J. Anthony, Student, and
Wheels, by H. K. Fried, Student, and

Princeton University
Carboloy and High-Speed Cutting Tests in Relation to Electrical Engineering, by I. H. Dixon, Student, and
Automatic Train Control, by Mr. Murray, Student, and

Rensselaer Polytechnic Institute
Three reels—"Manufacture and Use of Weston Meters." October 18. Attendance 80.

Rhode Island State College

Rose Polytechnic Institute
Talks on the Conference on Student Activities of Great Lakes District held at Chicago on December 3, by Prof. C. C. Knippmeyer, Counselor, Chairman Dowen, and Mr. Moenkel and Mr. Bailey of the Program Committee. December 7. Attendance 34.

Rutgers University

University of South Carolina

South Dakota State School of Mines
Construction of 200-Mile Natural Gas Line, by R. M. Burnham, Student, and

University of South Dakota
Selection and Use of Motors, by Chairman C. R. Cantonwine. December 3. Attendance 11.

University of Southern California

Stanford University
Electric Ships, by W. G. Howland, Student; The High-Voltage Coolidge Tube, by D. H. Ring, Student, and
Lightning, by W. H. Duncan, Instructor in Elec. Engg. The opinion of the members was asked regarding the desirability of student talks and it was strongly recommended that they be continued. November 8. Attendance 20.

Swarthmore College

Syracuse University
Difficulties Due to Low Pressure Heads in Power Generation, by Mr. Barrows, Student, and
Mercury-Arc Power Rectifiers, by Mr. Bohm, Student. October 23. Attendance 22.
The Surge Recorder Photograph, by Mr. Belayeff, Student, and
Television, by Mr. Bryant, Student. October 30. Attendance 22.
Photo-Electricity, by Mr. Casavant, Student, and
The Cathode-Ray Oscillograph, by Mr. Goldstein, Student, and
The Manufacture of Hydrogen, by Mr. Martin, Student, and

University of Tennessee
Lightening Experimental Station at Claibourne, Tenn., by Mr. Sparks, Westinghouse Electric & Mfg. Co. November 8. Attendance 86.
Motion pictures—"Driving the Longest Railroad Tunnel in the Western Hemisphere" and "Power Transformers." November 22. Attendance 69.

Texas A. & M. College

University of Texas
Film—"Manufacture of Insulated Wire." November 8. Attendance 11.
Experiences with the Southwestern Bell Telephone Company during the Past Summer, by Archie Straten, Senior. November 22. Attendance 11.

University of Utah

University of Vermont
Talking Movies, by R. F. Bigwood, Student, and
Transformers, by Prof. L. P. Dickinson, Counselor. Film. November 27. Attendance 15.

Virginia Polytechnic Institute
Reports on Regional Meeting at Atlanta, Ga., October 29-31, by J. L. Rothge, Chairman and Prof. Claudius Lee, Counselor. It was decided to make the meetings more helpful by having papers presented by students, mainly. Appointment of Program Committee. A committee to prepare program for the next meeting was appointed. November 9. Attendance 30.
Washington University


University of Washington


West Virginia University

The following papers were presented by Students: High Voltage Insulators, by L. F. Ouseare; Canawha River Dam and Power Plant, by W. C. Warman; Protective Grounds, by C. B. Seibert; A Mammoth Railroad Fill, by A. P. Feere; Adjustment of 258-Ton Rotors, by R. N. Kirchner; Lodgepole Pines for Line Poles, by C. E. Movers; and Carbology, by R. L. Williams. Critics were C. A. Bowers, Jr., M. C. Clark, and T. D. Nixon. November 12. Attendance 28.


The following papers were presented by Students: The Electrolytic Zinc Plant of the Sullivan Mining Company, by W. C. Warman; Improved Radio Beacon for Airplanes, by C. B. Seibert; Electric Detonators, by F. E. Davis; and Electricity and the Student, by J. S. Merritt. December 3. Attendance 32.

The following papers were presented by Students: The Increased Consumption of Electricity in Rural Districts, by T. R. Cooper; Why Rivets and Bolts in Transformer Cores Should Be Insulated, by T. D. Nixon; Hydro-Electric Development along the Ohio River, by L. F. Ouseare; World's Power Resources, by M. S. Diaz; Use of Steel in Switchboard Design, by W. H. Sutton and W. S. Bosley; Field Balancing of Rotors, by C. C. Coulter; Oxy-acetylene Welding, by F. D. McGinnis. The critics were Ivan Dannoy, G. I. Burner, W. S. McDaniels, and N. S. Gidding. December 10. Attendance 25.

Worcester Polytechnic Institute


University of Wyoming


Motor Controllers, by Mr. Joslin, Student. Appointment of Executive, Membership, Publicity, Program and Engineers Open House Committees. General get-together meeting with refreshments followed the program. November 25. Attendance 18.

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, NOV. 1-30, 1228.

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.

AERIAL PHOTOGRAPHY; a comprehensive survey of its practice and development.

By Clarence Winchester and F. L. Willis. Boston, American Photographic Publishing Co., 1928. 236 pp., illus., plates, 10 x 8 in., cloth. $10.00.

Contains a wealth of practical information upon aerial photography which will be decidedly useful to all those interested. The material and apparatus now available is described in detail, the authors giving the results of their wide experience. In the final section the applications of aerial photography to surveying, mapping archaeology and other sciences are indicated.

ATLAS DER LETZTEN LINIEN DER WICHTIGSTEN ELEMENTE.

By Fritz Lowe. Dresden u. Leipzig, Theodor Steinkopff, 1928. 44 pp., plates, tables, 9 x 6 in., cloth. 12.-r.m.

This atlas is especially prepared to meet the practical needs of those engaged in spectrum analysis. It gives the lines that are still apparent when elements are present in only small amounts in mixtures, alloys, solutions, etc., and covers only that part of each spectrum which is of interest to the analyst. Four spectra for concentrations of 1%, 0.1%, 0.01% and 0.001% are given for each element. The illustrations are very clear, and the price is moderate.

BILDUNGSWERTE DER TECHNIK.

By Hermann Weirich. Berlin, V. D. I. Verlag, 1928. 151 pp., illus., 8 x 6 in., cloth. 7.-r.m.

An able argument for the educational value of technical training. The author discusses current misconceptions concerning the relative importance of scientific and humanistic studies, calls attention to the contributions of technology to civilization and culture, and discusses its place in general education.
The first chapter explains the principles of operational calculation and the care selection of the material give unusual interest to the book.
ENGINEERING SOCIETIES EMPLOYMENT SERVICE

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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 expected to be filled will not be forwarded.

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POSITIONS OPEN

PHYSICIST, with Ph. degree in physics for research work on radio and vacuum devices. Apply by letter stating age, nationality, training, experience, and salary expected. Location, New York City. X-6526.

ELECTRICAL ENGINEER with electric locomotive and air-brake experience for assistant superintendent of maintenance on electric railroad, in Chil, South America. Apply by letter, stating age, married or single, education, experience, references and desired salary. X-6535.

DISTRIBUTION ENGINEER, as assistant in engineering department of public utility, must have at least three years' experience in engineering or operating department of public utility on distribution work. Undergraduate experience desirable. Apply by letter giving age, experience, salary expected and enclose a small photograph. Location, Eastern New York. X-6136.

MEN AVAILABLE

GRADUATE, Cooper Union Night School '28 (B. S. in E. E.) desires position with engineering organization. Has had field experience with motors and control. Available two weeks notice. C-5299.

ELECTRICAL ENGINEER 15 years' high and low voltage experience, covering design, construction, installation, service and maintenance. Recently superintendent 3500 electrical hp plant, under joint management of the national societies of Civil, Mining, Mechanical and Electrical Engineers cooperating with the Western Society of Engineers. Seeks connection with public utility or industrial concern, or would consider sales position, with some training. Middle west or California preferred. C-1989.

ELECTRICAL ENGINEER, 30, married, technical university graduate; 15 years' broad experience in design, projecting, estimating, construction and supervising on power plants, outdoor and indoor substations and industrial plants installation. Desires position with industrial concern, engineering organization or public utility. Available immediately. Prefect Eastern location. C-2011.

TECHNICAL GRADUATE, B. E. and M. E. 31; 14 years of general engineering experience, including three years of teaching. Would like to take up research, teaching or appraisal and evaluation work with public utility. Future prospects considered more important than initial salary. Best references. Available immediately. C-5214.

ELECTRICAL ENGINEER, with four years' public utility experience desires connection with management engineering or with the general manage- ment of an investment house. Experience has been principally in general system development, economic and cost analysis. Salary, $4000-$5000. Location, New York City. C-5002.


ELECTRICAL EQUIPMENT INSPECTOR, 25, married, and experienced with factory acceptance tests on wire and cable, telegraph apparatus and power relay protective equipment. Available immediately. C-3907.

ELECTRICAL ENGINEER, 28, single. Graduate Electrical Engineer. With General Electric Company 3 1/2 years, including test and one year's research on automatic equipment; good experience in underground and overhead distribution. Desires location with utility or engineering organization. Location, immaterial. Available upon reasonable notice. C-5273.

ELECTRICAL ENGINEER, 28, single. Graduate Electrical Engineer. With General Electric Company 3 1/2 years, including test and one year's research on automatic equipment; good experience in underground and overhead distribution. Desires location with utility or engineering organization. Location, immaterial. Available upon reasonable notice. C-3907.

ELECTRICAL ENGINEER, 26, single. Graduate Electrical Engineer. With General Electric Company 3 1/2 years, including test and one year's research on automatic equipment; good experience in underground and overhead distribution. Desires location with utility or engineering organization. Location, immaterial. Available upon reasonable notice. C-3762.

ELECTRICAL ENGINEER, 29, married. Engineer and operator, maintenance man, test engineer and assistant electrical engineer on substation construction. Location, East or Southeast. C-5186.


ELECTRICAL ENGINEER, of wide experience in power house and industrial plant design and construction, is open for a new opportunity in the field of sales engineering. Available immediately. Location, New York City. C-5201.

ELECTRICAL ENGINEER, 29, married. Graduate G. E. test course; one year's experience in electrical engineering; 5 years' diversified electric utility experience as switchboard operator, maintenance man, test engineer and assistant electrical engineer on substation construction. Location, California. C-5186.

ELECTRICAL ENGINEER, 30. Married with two small children; 10 years' experience in electrical design; desires position in a large electrical company. Location, New York City. C-5186.

ELECTRICAL COMMUNICATIONS TECHNICIAN. 30, married. B. S. in E. E., three years sales engineering with manufacturing and construction work, with a large public utility. Desires position in an industrial organization. Location, New York City. C-5186.

ELECTRICAL COMMUNICATIONS TECHNICIAN, 30, married. B. S. in E. E., three years sales engineering with manufacturing and construction work, with a large public utility. Desires position in an industrial organization. Location, New York City. C-5186.

ELECTRICAL COMMUNICATIONS TECHNICIAN, 30, married. B. S. in E. E., three years sales engineering with manufacturing and construction work, with a large public utility. Desires position in an industrial organization. Location, New York City. C-5186.

ELECTRICAL ENGINEERING GRADUATE, married. B. S. in E. E., 10 years' experience as electrical engineer. Desires position with a prominent electrical manufacturer. Location, New York City. C-5186.


STUDENTS ENROLLED

Achmoud, Robert E., University of Missouri
Andrews, Charles M., Jr., Virginia Polytechnic Institute
Bahr, Paul Albert, Lehigh University
Balas, Clyde D., Mississippi A. & M. College
Bank, John F., Massachusetts A. & M. College
Barlow, Donald J., University of California
Bathebomb, Charles F., Northeastern University
Baum, Willard U., Drexel Institute
Baszler, Carl L., University of North Dakota
Baxter, W. A., University of North Carolina
Berig, Leon, Northeastern University
Blair, Howard, Lewis Institute
Bove, George H., Stevens Institute of Tech.
Bowers, George R., Drexel Institute
Brooks, Charles J., Univ. of North Dakota
Bridges, John J., Louisiana State University
Brick, Frederick, Ohio University
Brooks, Cuyler W., Georgia School of Technology
Brooks, Henry R., Case School of Applied Science
Brooks, Albert L., Ohio University
Brooks, Howard, University of North Carolina
Brown, Howard V., Case School of Applied Science
Brouse, Harold L., Case School of Applied Science
Bugh, Golen E., Virginia Polytechnic Institute
Burrage, Henry J., Rhode Island State College
Burnett, William C., University of North Carolina
Burns, Arthur, Harvard University
Cailian, Casimir, Lewis Institute
Caparone, Mike J., Pennsylvania State College
Chapman, William R., University of Virginia
Charrier, George M., University of North Dakota
Coenen, Thomas F., Case School of Applied Science
Conson, William H., New York University
Cookes, Henry R., Case School of Applied Science
Coyle, Charles P., Michigan State University
Cummins, Howard F., University of Colorado
Daniel, Joseph T., Lehigh University
Davies, Elmer L., University of Michigan
Diehl, Stanley C., Lehigh University
Di Forio, Frank, Brooklyn Polytechnic Institute
Di Julio, William W., Virginia Polytechnic Institute
Dowis, William J., University of Colorado
DuBose, James H., University of Tennessee
Emery, W. E., Lehigh University
Engvall, Edmund R., California Institute of Technology
Ensey, Gustave A. D., Bucknell University
Estler, Kenneth E., New York University
Farbman, William W., Virginia Polytechnic Institute
Fegley, William P., University of Cincinnati
Ferguson, John H., Swarthmore College
Feuchter, Robert F., Lehigh University
Fishburne, Clarence L., Jr., University of South Carolina
Florence, Robert D., University of North Dakota
Fullerton, James K., Worcester Polytechnic Inst.
Gallup, Royal K., Worcester Polytechnic Institute
Garrison, Harry C., Columbia University
Geiger, Frederick P., Lafayette College
George, Ruel B., Lehigh University
Glass, Gustav E., University of North Dakota
Glover, Ralph P., University of Cincinnati
Gould, Wendell, State College of Washington
Grabenstein, Louis, University of Cincinnati
Gracie, Howard W., University of Cincinnati
Green, Albert L., Ohio University
Gross, Ernest T., Jr., University of North Carolina

INSTITUTE AND RELATED ACTIVITIES

Hamilton, Harry F., Ohio University
Hammon, Millard W., Mississippi A. & M. College
Harder, Gordon J., University of Wisconsin
Hassell, David C., Swarthmore College
Hayes, Charles R., Jr., Unive. of North Carolina
Hassel, William J., Jr., Newcom College of Engg.
Hastman, R. M., Drexel Institute
Herman, Lester C., Lehigh University
Hills, Walter E., Northeastern University
Hines, Henry J., Jr., University of North Carolina
Holt, Joseph W., Jr., University of North Carolina
Hoober, William D., Columbia University
Hosin, Caroll E., University of Maine
Horstmann, Albert W., University of Cincinnati
Houtch, William I., Clemson Agricultural College
Hume, Paul O., University of Michigan
Jaffe, Jacob J., Worcester Polytechnic Institute
Jeffries, Joseph, Jr., Lehigh University
Johnson, Charles S., Northeastern University
Johnson, Robert R., Engineering School of Milwaukee
Jones, William C., Northeastern University
Keating, Frank E., Engg. School of Milwaukee
Kellers, Frank J., Clemson Polytechnic Institute
Kennedy, Robert H., University of South Carolina
Kirk, Charles P. J., Lehigh University
Kien, Lorenz M., Newcom College of Engineering
Kuroe, John H., Virginia Polytechnic Institute
Kutz, Stephen A., Lehigh University
Lauber, Max M., Georgia School of Technology
Lawton, Charles F., University of Michigan
Littlefield, Raymon W., Northeastern University
MacGregor, Charles W., University of Michigan
Malin, Clifford T., Engg. School of Milwaukee
Martin, Jack E., Georgia School of Technology
Massow, George, Detroit Institute of Technology
Matto, Uno A., Worcester Polytechnic Institute
McConnell, Robert C., Univ. of North Dakota
McManan, John S., University of North Dakota
McLeary, Andrew G., University of Tennessee
McWear, Joseph J., Newcom University
Middleton, J. Edward, University of Cincinnati
Miller, Arthur F., University of North Dakota
Miller, Carl E., University of Cincinnati
Mills, Francis L., Detroit College of Technology
Mitchell, Ralph H., University of Michigan
Morris, Henry D., University of Cincinnati
Mosher, John L., Worcester Polytechnic Institute
Motley, Earl A., University of Colorado
Motley, Sam L., Texas A. & M. College
Moyers, Eugene E., University of Tennessee
Mussel, Charles F., Northeastern University
O'Callaghan, Jerome J., University of Cincinnati
Olsen, Oscar F., Georgia School of Technology
Olson, Ronald W., University of North Dakota
Olsen, Einar L., University of Missouri
Oman, Nils J., Worcester Polytechnic Institute
Parrott, William G., Jr., Clemson Agricultural College
Pavey, Wilfred T., University of Cincinnati
Passe, Ronald E., University of Michigan
Perry, Frank C., University of Missouri
Pierce, Brister B., Louisiana State University
Pierce, Floyd P., Ohio University
Poffenbarger, Ernest L., University of South Carolina
Quarles, Gifford G., University of Virginia
Quat, Joe F., University of Cincinnati
Renter, Herman H., Coedsen University
Richie, Charles E., Georgia School of Technology
Riley, James F., University of Louisville
Romeo, John P., Virginia Polytechnic Institute
Roberts, Edwin L., Lehigh University
Robert, Walter F., Virginia Polytechnic Institute
Robinson, Harris A., University of Pennsylvania
Roddy, Vincent S., Case School of Applied Science
Roche, Milton T., Clemson Agricultural College
Rosenbrock, Homer, Ohio Northern University
Sanmolias, John, Lewis Institute
Schlitzo, Anthony G., Ohio Northern University
Schmidt, Paul C., Worcester Polytechnic Institute
Schneidler, Harold D., Arizona University
Schroeder, Fred C., Jr., Pennsylvania State College
Shallinmorrigan, Orson, P., University of Colorado
Sharp, William B., University of North Carolina
Shulman, Benjamin, University of South Carolina
Siegard, Robert E., Virginia Polytechnic Institute
Sherwood, Theodore W., Univ. of North Dakota
Silverbord, Lawrence H., Worcester Polytechnic Institute
Singer, H. F., Lehigh University
Skinner, Charles H., Engg. School of Milwaukee
Smith, Fredric F., Case School of Applied Science
Snelson, Marion L., Ohio Northern University
Squire, Edmund M., New York University
Standing, Henry A., University of Colorado
Starr, Randall M., Unive. of North Carolina
Stein, George E., University of South Dakota
Strockelber, Louis R., Univ. of North Dakota
Straw, Thomas F., Lehigh University
Stricklin, Mississippi C., University of Washington
Sterling, Robert A., Lehigh University
Steele, William P., Case School of Applied Science
Stuffle, George W., Missouri School of Mines
Thomas, Marvin I., University of Illinois
Tiedeman, Edward, University of North Dakota
Torbit, James G., Mass. Institute of Technology
Trapp, Henry J., University of Cincinnati
Turner, Charles A., Massachusetts Institute of Technology
Van Ham, Walter C., Ohio University
Volland, Leonard L., Case School of Applied Science
Vroom, William H., Lehigh University
Walcenko, Taito K., Worcester Poly. Institute
Walters, Marvin R., University of Virginia
Waters, Vernon O., University of Colorado
Weibahn, Ira, New York University
Weis, Edward H., Lehigh University
Welshon, J. D., Clemson Agricultural College
West, Virgil, University of North Dakota
Wickersham, Wilford H., Havard College
Williams, David C., University of Tennessee
Willie, Herbert L., A. & M. College of Texas
Wilson, Maurice A., University of Michigan
Wilson, Wenda O., Akron University
Wlshel, Walter H., Northeastern University
Witt, Morris, Georgia School of Technology
Woodward, John D., Lehigh University
Wortman, William J., Univ. of North Carolina
Zelenka, Louis G., Louisiana State University
Ziegler, Melvin F., Ohio University

Total 190.
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**MEMBERSHIP COMMITTEE**
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**SECRETARIES**

**STANDARDS COMMITTEE**

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**EDISON MEDAL COMMITTEE**

**LAMME MEDAL COMMITTEE**

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**HEADQUARTERS COMMITTEE**

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R. D. Evans, A. E. Silver, Harland C. Forbes,
F. M. Farmer, L. G. Smith, C. L. Fortescue,
K. A. Hawley, H. C. Sutton, Percy H. Thomas,
P. F. Chane, H. R. Summerhayes,
E. K. Hagen, H. R. Woodrow, Chairman,

PROTECTIVE DEVICES
E. A. Hester, Chairman, 436 Sixth Avenue, Pittsburgh, Pa.
Raymond Bailey, Vice-Chairman, N. Y. Edison Co., 13th St. & Irving Place, New York, N. Y.
J. S. Hagan, E. W. Dillard, A. C. Cummins,
E. T. J. Brandon, V. J. Brain, Secretary, N. Y. Edison Co., 13th St. & Irving Place, New York, N. Y.

RESEARCH
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Outdoor Substations.—Special Publication 57. Describes a radically new type of high-voltage, outdoor substation, with rotating buses which also function as switch-operating mechanisms. An outstanding feature of the station is that all heretofore idle insulators, connections and joints have been eliminated, resulting in a marked reduction in the number of insulators heretofore necessary. Delta-Star Electric Company, 2400 Block Fulton Street, Chicago, Ill.

Transformers.—Bulletin 160. 52 pp. Describes Wagner distribution transformers in single-phase and three-phase, pole-type and substation-type, in ratings up to and including 500 kva. One-half of the catalog is devoted to a detailed description of the design and construction of Wagner distribution transformers and the remainder of the catalog is devoted to ratings, shipping weights, prices, etc. Wagner Electric Corporation, 6400 Plymouth Avenue, St. Louis, Mo.

NOTES OF THE INDUSTRY

The Ohio Brass Company, Mansfield, O., announces the appointment of Mr. Mathews as district sales manager. Power Utilities Division, for the New England territory, with offices in the little building, 90 Boylston Street, Boston, Mass.

The James R. Kearney Corporation, St. Louis, announces that through the past support and patronage of its products, it is able to announce a new line of equipment, called Kearney Electric Hot Line Tools and Accessories. These tools eliminate the hazards of live line maintenance. They are made in the U. S. A. by Tip's Tool Company, Incorporated patent rights.

The Synthane Corporation, incorporated in September 1928, is completing the building of its plant at Oakes, near Philadelphia, and expects to commence production of laminated Bakelite products in the early spring. R. R. Titus, formerly Vice-President and General Manager of the Diamond State Fibre Company and the Celoron Company of Bridgeport, Pa., heads the corporation as President, with J. B. Kittenhouse as Vice-president and George J. Lincoln, Secretary and Treasurer.

Wagner Electric Corporation, St. Louis, has appointed Mr. Matthews to the sales force of its Chicago branch office. Mr. Matthews has previously been active in the electrical field, being connected with such organizations as the Michigan Bell Telephone Company, the Armstrong Cork & Insulation Company and the National Electric Products Corporation. N. H. Spencer has been added to the Dallas, Texas, sales force. Mr. Spencer has held several managerial posts with power companies. His last position was with the Pittsburgh Transformer Company, with whom he was connected for the past eight years.

Gerard Swope on the Business Outlook for 1929.—The following statement has been issued by Gerard Swope, President of the General Electric Company. “The electrical manufacturing business for 1928, on the whole, has been quite satisfactory, with an increase in volume of about seven per cent. It is remarkable that the use of electric current in the homes and on the factories continues its high rate of increase from year to year. The 1928 rate of increase is about eight per cent and, as stated last year, this is becoming one of the best indices of general and industrial conditions in America. Basic economic conditions are sound, inventories not unduly expanded, credits and collections satisfactory, earnings of labor are high, and employment steady, all of which presage a favorable outlook for 1929.”

New Conduit.—A new kind of conduit has been announced by the Electrical Division of Steel and Tubes, Inc., Cleveland, Ohio, a subsidiary of the Republic Iron & Steel Company. This new product is under the 1928 National Electrical Code as “electrical metallic tubing.”

Steel tubes Electrical Metallic Tubing is a thin wall, rigid conduit having all of the characteristics of the so-called heavy, standard conduit but with a lighter wall. Its use as a rigid conduit is based upon the fact that it has been sanctioned by the 1928 National Electrical Code. It will bear the underwriters’ label. The wall of this new conduit is approximately one-third the thickness of standard conduit. It is used without threading, connections being made by means of a union compression type coupling. Part of this coupling may be used as an adapter to connect the conduit to any standard threaded or threadless fitting.

Three New Boilers for East River Station.—New York Edison Company and the companies associated with it in supplying electric service in metropolitan New York, have closed a contract with the International Combustion Engineering Company for three boilers that will be the largest ever built. They are to be installed in the East River Generating Station of The New York Edison Company and will supply steam to drive the largest single shaft, single unit electric generating machine in the world, a 160,000 kilowatt turbo-generator, now being constructed by the General Electric Company.

The over-all height of the boilers, which are of the Double Ladd type with fin tube water walls, will be 95 feet, with furnaces 23 feet wide and extending back 65 feet. Each will supply a maximum of 800,000 pounds of steam per hour at a temperature of 700 degrees Fahreneheit at 425 pounds per square inch pressure. Delivery of the boilers is expected to start in about four months, and the unit will be placed in operation about September 1, 1929.

Richard M. Kerschner, associated with Hubbard & Company for the past sixteen years, succumbed to a heart attack on December 8, 1928, at his home in Zellinople, Pa. Mr. Kerschner joined the sales department of Hubbard & Company in 1914, later becoming sales manager. In 1924 he supervised the building of the New Hubbard factory at Oakland, Cal., remaining in charge there until 1927 when he returned to Pittsburgh to assume charge of the Department of Development and Research in which position he was active up to the time of his death. He had built up a host of friends throughout the central station men of the country.
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Much importance is now being placed in this vault unit as instanced by its use here in a large modern “movie”. On the day preceding the opening of this theater, the vault unit prevented a serious service interruption by automatically throwing over from normal feed to the emergency feed.

This vault unit is a double throw oil switch having on and off position for either feed. It can be furnished for hand operation, for remote manual or electrical control or with full automatic throw-over mechanism.

The vault unit is equipped with by-passes through which load may be carried on either feed with every part of the oil switch dead. These by-pass connections can also serve as a tie between the two feeds, the tie and the load feeding through or by-passing the oil switch as desired.

Its automatic throw-over to emergency with automatic return to normal or preferred circuit, with no possibility of hunting, makes a transformer vault equipped with this unit most desirable for serving important loads.

Simple and safe to operate—submersion proof.
All live parts enclosed. Economical of floor space.

Write Us for Suggestions on Layouts

G&W ELECTRIC SPECIALTY CO.
7780 Dante Ave., Chicago, Ill.

More than Protection
POTHEADS and BOXES

Please mention the JOURNAL of the A. I. E. E. when writing to advertisers.
They were first installed in 1913 on a 70-kv. line. In April, 1923, the customer reported: "No deterioration after close watching and careful tests". Two years later the report came in: "To date they show absolutely no signs of deterioration". Today the same report holds good. That is the story of O-B Insulator No. 12552. Fifteen years ago this design deviated from all accepted standards, yet it won a "place in the sun"—a leadership that has grown with the years. Today, because of the O-B balanced design principle, No. 12552 continues to serve best.

Ohio Brass Company, Mansfield, Ohio
Canadian Ohio Brass Co., Limited
Niagara Falls, Canada

Ohio Brass Co.

Please mention the JOURNAL of the A. I. E. when writing to advertisers.
If you are interested in a 66-132 K.V. outdoor substation which eliminates one half the number of insulators required by the usual type—make a little journey to our factory and see the new Type "F".

If you cannot come to Chicago the next best thing is to write today for our new Publication No. 57.

DELTA-STAR presents:

A new, 66-132 K.V., Outdoor Substation

(See the ELECTRICAL WORLD, December 15th, pages 1194-1195)

It challenges the imagination!  It is a distinct advance in design!

It is unlike any other substation! It is a creation, a new idea embodying the utmost in simplicity, economy, flexibility and in style.

To comprehend this new type, all former ideas of high tension substations must be set aside.

There are outstanding features such as rotating combination switching busses—but one which will arouse your interest is this:

Where one hundred insulators had to be used in the past only fifty are necessary now.

Write us today!

DELTA-STAR ELECTRIC COMPANY, 2400 Block, Fulton St., Chicago, Illinois.

Please mention the JOURNAL of the A. I. E. E. when writing to advertisers.
Another KUHLMAN Installation

Three 2000 Kva. Kuhlman Transformers on the lines of a large power company.

The fact being emphasized by this installation series is simply that Kuhlman Transformers are day-after-day doing their work well in central stations, substations, industrial plants, theatres, railroads and a host of other special fields.

Each installation is additional testimony to the complete reliability and high operating efficiency of Kuhlman Transformers.

When you are in the market for transformers get in touch with the Kuhlman office nearest you.
Monel Metal Bolts for Transmission Equipment

The Public Service Corporation of Northern Illinois, like many other large public utility companies, has learned that there is no substitute for dependability—particularly in the bolts used in the assembly of outdoor switching equipment.

The Public Service Corporation, in its many years of experience, has discovered that bolts must be strong, tough, corrosion-resistant, and immune to the weather. There is only one available material that combines all these essential properties—Monel Metal.

Monel Metal bolts have a tensile strength that averages well over 100,000 pounds per square inch. They are not subject to corrosion-cracking. They will not rust. They will not twist or become distorted in the jaws of a turning wrench.

Practically, every day sees a new large user specifying Monel Metal bolts. More and more, representative companies are turning to Monel Metal as a solution for some of their most perplexing problems. Monel Metal is available in all commercial forms including rod, tubing, sheet, angles, forgings, castings, wire and wire products—it can be obtained on short notice from any one of fifteen distributors located at central points.

You are invited to consult our engineers about using Monel Metal in your equipment. Why not write today?

SEND FOR BOOKLET—"FOR SEVERE SERVICE"

Monel Metal is a technically controlled Nickel-Copper alloy of high Nickel content. It is mined, smelted, refined, rolled and marketed solely by The International Nickel Company, Inc. The name “Monel Metal” is a registered trade mark.
The design and construction of Locke Multi-part Pin Type Insulators is a definite science. Long experience has dictated the characteristics necessary and sustained experiment and research have furnished the technique to meet these requirements. Locke 1044 Insulator is representative of the entire line: It is standard on thousands of miles of important transmission lines here and abroad. When you specify Locke Insulators for your lines you are specifying insulators that for thirty-five years have set the standard of quality by which all insulators are judged.

LOCKE INSULATOR CORPORATION
BALTIMORE, MARYLAND

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The extremely high insulative value of Matthews Fuswitches is illustrated in this photograph. It was taken in the marshes, where most lines are insulated four times above normal voltage because of the salt fogs. The wet process bushings and mountings used on Matthews Fuswitches give highest flashover value and the Tidewater Cypress housing gives maximum insulative protection. Write for Bulletin 502.

W. N. MATTHEWS CORPORATION
Engineers and Manufacturers
3706 Forest Park Blvd., St. Louis, U. S. A.
Offices in All Principal Cities

MATTHEWS FUSWITCHES
and DISCONNECTING SWITCHES
INTERCHANGEABLE

Rupturing Capacity
40 Times Rating.
No Radio Interference.
Fast Blowing Fuses
45% of Marked Rating.
Will Not Overheat
or Blow Glass on Dragging Overhead.
Wet Flashover
Values Four Times
Voltage Rating.
Housing Absolutely
Guaranteed for Ten Years.

Please mention the JOURNAL of the A. I. E. E. when writing to advertisers.
The U. S. A. is only a few minutes wide

An Advertisement of the
American Telephone and Telegraph Company

In the gold rush year of '49 a stage-coach succeeded in crossing the continent in about three months. Two decades later, for the first time, an unbroken stretch of railroad lay from New York Harbor to San Francisco Bay, and America was seven days wide. Today, by telephone, that entire width is only a matter of minutes. And these few minutes represent a round trip, taken in the ease of office or home.

The Bell System is ever busy reducing the width of America and the distance between cities. For example, during 1929 it will add to its lines nearly 2,000,000 of the new permalloy loading coils for correcting and maintaining the speeding voice currents.

Seven thousand miles of new inter-city cable, $40,000,000 worth, will be added to the System to protect against storms and other slowing up influences.

In the last five years 350 major improvements, as well as thousands of others whose aggregate importance mounts high, have been made in telephone central office equipment.

Improved operating practices have eliminated the necessity of your "hanging up" and being called back in 95 per cent of toll and long distance calls, adding new speed and ease to out of town calling. You hold the wire and the operator does the rest.

Since New Year's Day, 1927, the average time for completing all out of town calls has been cut 35 per cent and at the same time the per cent of error has been further materially reduced.

There is no standing still in the Bell System. Better and better telephone service at the lowest cost is the goal. Present improvements constantly going into effect are but the foundation for the future's greater service.

"The Telephone Books are the Directory of the Nation"

Please mention the JOURNAL of the A. I. E. E. when writing to advertisers.
Lapp Fog Type Insulators
Solve Knotty Situations

No good fairy nor silver spoons put Lapp insulators in such important places. These engineers try to boil the conversation out and deal with facts. Facts and value may arrive from anywhere; many, many times they hail from Le Roy.

Lapp insulators get in AND STAY IN where insulators are bought free from prejudice and precedent.

Have you a little precedent in your office?

ALL LAPP PORCELAIN is Vacuum Processed. Greater uniformity, strength and long life.

LAPP INSULATOR CO., INC., LE ROY, N. Y., U. S. A.

Please mention the JOURNAL of the A. I. E. E. when writing to advertisers.
A new leader in its class—
The Switchboard Type FK-33

This 4500-volt, 200- or 400-ampere breaker for small stations or industrial installations is built double-, triple-, or four-pole; single- or double-throw.

It is
Inexpensive
Compact
Easy to operate

It has
Small over-all dimensions
Bushings of non-breakable material
An interrupting rating of approximately 20,000 kv-a.

The bushings consist of treated, wound, impregnated insulating cylinders permanently aligned to obtain definite position of the contacts, which require no adjustment.

The breaker can be supplied for back-of-panel, panel-frame, or remote mounting on pipe framework or flat surface.

G.E oil circuit breakers have behind them the services of a nation-wide organization of specialists and a permanent source of renewal parts. For complete descriptive information on the new Type FK-33 oil circuit breaker, ask the nearest sales office for a copy of publication GEA-1021.
WHY SHOULD YOUR CABLE SUFFER

When it can be pulled with

half the strain

in about

two-thirds the time

and with

one-third the lubricant—

using

Minerallac No. 150 ?

Write for Bulletin No. 120

MINERALLAC ELECTRIC COMPANY
25 North Peoria Street
CHICAGO, ILL.
FERRANTI
TRANSFORMERS

7500 K. V. A., 66000/35000 volt, 3-phase self-cooled transformer with 6600 tertiary winding and equipment for changing taps under load.

FERRANTI, INC.
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This new STANDARD Catalogue is ready for you.

Mail this coupon to nearest District Office for your copy.

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STANDARD UNDERGROUND CABLE CO.
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General Offices: Pittsburgh, Pa.
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U-RE-LITE has distinct advantages not present in any other type of electrical protective apparatus. Is there any other equipment on the market which can be described as having all of these features?

1. **No oil to leak, carbonize, burn or explode.**
2. **Immersed in air—a self-restoring medium.**
3. **Inherent simplicity—resulting in low cost installation and maintenance.**
4. **Practically unlimited rupturing capacity—as proven on test.**
5. **Steel encased—entire safety to the operator regardless of load conditions or short circuits.**
6. **Adaptable—for across the line starting and also affording:***
   - **Instant protection against short circuits while running or when being closed.**
   - **Timely protection from sustained overload.**
   - **Effective protection against single phasing.**

Please mention the JOURNAL of the A. I. E. E. when writing to advertisers.
Have you investigated this unique insulating material?

PerhAPS you are actively seeking a more satisfactory insulating material. Perhaps there exists the need for more efficient insulation than afforded by your present equipment.

In any case, the performance record of "PYREX Glassware merits your most careful investigation.

Replacing porcelain, earthenware and molded products, PYREX Products are providing perfect insulation in face of unusually difficult conditions.

Acid fumes, smoke or salt fogs cannot affect PYREX Glassware. High chemical stability renders it immune to corrosion.

Extreme temperatures leave PYREX Glassware unharmed.

Exceptionally low coefficient of expansion makes it indifferent to great heat or sudden temperature changes. Dust, dirt and soot do not accumulate on its diamond-hard, super-smooth surface.

PYREX Glassware also possesses a dielectric strength from 15 to 35 percent greater than porcelain—a power loss lower than any insulation with the exception of pure fused quartz—and a surface conductivity so low as to be practically negligible.

Corning engineers have successfully solved problems for many of the country's greatest industries, even going so far as to develop special products. Their cooperation may lead to valuable improvements in your own business, whether in the product itself or in production methods. Write for the booklet "PYREX Industrial Products" which gives complete technical information.

Corning Glass Works
Industrial and Laboratory Division
Corning, New York

Please mention the JOURNAL of the A. I. E. E. when writing to advertisers.
Use Reactors

TO LIMIT SHORT-CIRCUIT CURRENTS AND TO PERMIT PARALLEL OPERATION OF GENERATORS

Economical operation requires that all the generators of a station be connected in parallel; control of short-circuit currents demands that they be segregated.

These two conflicting requirements are met by dividing the bus into sections, each section having its group of feeders and generators, the bus sections being connected through current-limiting reactors. Thus connected, the bus sections operate in synchronism and, during normal operation, transfer power as required.

When a short circuit occurs on one section, the reactors give three-fold protection. (1) They reduce the damage at the short circuit by limiting the current that can be transferred; (2) they protect the bus-sectionalizing circuit breakers; (3) they localize the short circuit to the section on which it occurred, and maintain service on the other sections by preventing excessive drop in bus voltage.

Transformer Efficiency

in the Cottrell Process

Efficient operation of the Cottrell Process of Precipitation depends, in a large measure, upon the transformer used. Many leading public utility and other industrial plants have found that American Transformers give the most efficient and economical service for the Cottrell Process. A number of these companies are still using the original American Transformer installations after ten years of service! Data concerning these installations together with Bulletin 1110-J describing the latest type, will be sent upon request.

There is an American Transformer for every industrial service. The advice of our engineers on your problem entails no obligation.

*Names upon request

American Transformer Company
176 Emmet Street
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Representatives

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These transformers are built in sizes from 250 kva. to 50 kva., and the standard high-tension voltages are 75000, 70000, 65000, 60000 and 55000.
TREND IN

LENGTH 21.2 FEET

MODEL 1922

15,000 AMPERE SET

CONSISTING OF

2 GENERATORS

7500 AMPERES EACH

GENERAL ELECTRIC SYNCHRONOUS MOTOR 400 R.P.M.

SEPARATE EXCITER LOCATED ELSEWHERE

CHANDEYSSON ELECTRIC CO., ST. LOUIS

Please mention the JOURNAL of the A. I. E. E. when writing to advertisers.
DESIGN

LENGTH 11.4 FEET

MODEL 1928 100 R.P.M.

15,000 AMPERE GENERATOR

WITH DIRECT CONNECTED EXCITER

GENERAL ELECTRIC SYNCHRONOUS MOTOR 100 R.P.M

CHANDEYSSON, ELECTRIC CO., ST. LOUIS

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DURING the six years of the Charles A. Coffin Foundation for annually rewarding excellence in the operation of electrical utilities, the Gold Medal has been won three times by companies under the executive management of Stone & Webster, Inc. The successful companies are Northern Texas Traction Company, Puget Sound Power & Light Company, and Virginia Electric and Power Company.

STONE & WEBSTER INCORPORATED

Please mention the JOURNAL of the A. I. E. E. when writing to advertisers.
Tramp Iron—The Trouble Maker In Your Coal Pile—Remove it With a Separator Magnet

Tramp iron that gets into your coal at the mine, in transportation and while in storage at your plant, can cripple your whole boiler room when it gets into the crusher, pulverizer or stokers. Yet you can easily convert this ever-present tramp iron menace into a salvagable asset and insure yourself of a constant supply of clean coal by installing an EC&M separator magnet.

Placing a separator magnet over your conveyor removes all of this iron and insures a supply of clean coal, and only clean coal, to your crusher or stokers. The magnet, to secure the best magnetic separation, should be installed at an angle above the head pulley with its face tangent to the coal stream as it leaves the conveyor belt.

Inexpensive and easy to install, an EC&M Separator Magnet pays for itself many times over in the protection of equipment.

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Many Dossert Connectors in this little substation

The letter tells the story

GET THIS BOOK — it's Free

DOSSETT & COMPANY
H. B. Logan, Pres.  242 West 41st St., New York

Please mention the JOURNAL of the A. I. E. E. when writing to advertisers.
Service Brackets

The growing demand for a more sightly and trouble-proof service drop has brought into use, service cable in multiple conductor styles. These service cables are made up of two or more wires under one braid. A drawback to the use of such cables in the past has been the lack of suitable brackets or supports for anchoring them. The cables not being flexible like single wires could not be served up in the usual manner. They demand a simple form of anchorage not requiring tie wires, yet giving the proper insulating qualities and sufficient holding power.

The Peirce Wedge-Grip Service Bracket is the answer. Jaws of Bakelite wedged in a tapered steel shell hold the cable in a vise-like grip. The shell, in turn, is anchored to the pole or house by a Copper-weld wire bale. This bale is quickly removed for threading through an eye or around a secondary rack bolt by simply swinging it through 180°, which frees it from the steel shell. Reversing this operation locks it securely.

Screw Eye No. 3925 provided with a broad base for withstanding sidepull, makes an ideal anchorage in wood. For attaching to masonry, Stock No. 3926 is used, consisting of a 3/4-inch eye bolt with a 3/4-inch Peirce Expansion Nut.

The No. 3920 Bracket is furnished with flat Bakelite Jaws for flat duplex cable. No. 3922, for round three wire cable, is supplied with a grooved jaw.

For house connections in wood, screw eye No. 2925 is used. A secure anchorage in masonry is provided by using No. 3926, a 1/4 inch Eye Bolt equipped with a 3/4 inch Peirce Expansion Nut.

For connections to secondary circuits at the pole end, a convenient method is to hang the bale of the Service Bracket over the bolt of the secondary rack as shown at the right.

Hubbard and Company
Pittsburgh * Oakland, Cal. * Chicago

Please mention the JOURNAL of the A. I. E. E. when writing to advertisers.
Conowingo Switching Station of the Philadelphia Electric Company showing installation of Burndy Connectors fitted as specified with Monel Metal bolts.

Our advertisement in the December issue of this magazine erroneously gave credit for equipping this substation to another manufacturer.

For places so inaccessible and important as the high tension bus of Conowingo, Burndy Connectors were selected by Day & Zimmermann, the engineers. Monel Metal clamping bolts were specified. Burndy Connectors are used for both copper tubing and cable at Conowingo, one of the four 220,000-volt substations equipped with Burndy Connectors during the past year.

Types of Connectors Used at Conowingo

Please mention the JOURNAL of the A. I. E. E. when writing to advertisers.
Many noteworthy installations of Condit type FO-40 oil circuit breakers have given their users magnificent performance and invite your consideration.

Wherever service is most exacting—buyers most discriminating—you will find Condit type FO-40 breakers.

CONDIT ELECTRICAL MFG. CORPORATION
Manufacturers of Electrical Protective Devices
BOSTON, MASS.
Northern Electric Company
Distributor for the Dominion of Canada

Specifications: 2,000 amperes or less; 88,000 volts; 73,000 volts; 50,000 volts; 37,000 volts; 25,000 volts. Interrupting capacity 1,500,000 Kva or less. Breaker illustrated in 25,000 Volt B size.

Please mention the JOURNAL of the A. I. E. E. when writing to advertisers.
ANNOUNCING
THE NEW
Fansteel
Transformer

FANSTEEL announces the addition to its line of a new transformer—Type RU.
Type RU—capacity 500 V.A.—is made in various models for use with 110 to 550 volt 25 to 100 cycle supply.
This new transformer is furnished for battery charging or general purpose requirements. Taps permit regulation of the output. It is tested at 10,000 volts for break-down.
We are also prepared to furnish outdoor transformers in models to meet all general purpose requirements in capacities up to \( \frac{3}{4} \) K. V. A.

Fansteel Products Co., Inc.
North Chicago, Illinois

Gentlemen: Please send me complete information on Balkite Chargers and Fansteel Transformers.

Name________________________
Company_____________________
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Position_______________________

INDIVIDUAL INSTRUCTION CARDS FOR TESTING FACTORY-BUILT RADIO SETS

An Added Service of the WESTON MODEL 537
A. C. and D. C. Radio Set Tester

These Instruction Cards, by covering the specific testing requirements of individual receivers, make the Model 537 a still more useful test set for the service man.
They save the service man's time by giving a complete outline of procedure for testing the principal makes of factory-built sets and, in addition, give the socket voltages and tube plate current for every stage throughout the set, as well as the comparative grid test on the various tubes.
The Model 537 is designed to meet the service requirements of every type and kind of radio receiver. Its use, however, is reduced to still greater simplicity when testing any particular make of set in conjunction with its individual instruction card.
Write to us and we will be pleased to acquaint you with full particulars. Or, better still, address your inquiry to your radio jobber, supply house or our nearest representative—and ask for a demonstration.

WESTON ELECTRICAL INSTRUMENT CORPORATION
584 Frelinghuysen Ave. Newark, N. J.

PIONEERS SINCE 1888

Weston

INSTRUMENTS
Now built in the United States, the Lincoln Maximum Demand Meter comes to you fully approved by Canada.

Thousands of installations on Commercial and Power loads have uniformly proved its simple thermal principle of operation. Sealed by the Canadian Government for a period of six years, its reliability is accepted throughout the Dominion.

The various Lincoln types, indicating and graphic, are fully described in a new bulletin ready for mailing upon your request. This book includes a discussion of demand measurement and of many items which will interest you. Write for your copy today, please.

LINCOLN METER COMPANY, INC.
SPRINGFIELD, ILLINOIS

DERBY AUTOMATIC FIRE ALARM SYSTEM

Derby Supervisory Panel—Holland Vehicular Tunnel

Derby Supervisory Apparatus was specified for the Holland Vehicular Tunnel, where the mechanical equipment is the best obtainable. This panel was built to supervise the System of Derby Fire Sentinels installed in the sump motor rooms.

Derby Systems are approved and recommended by all recognized authorities and specified by architects and engineers. The Derby Apparatus is rugged and reliable. Our patented circuit provides constant electrical supervision of the system.

Write for general information and catalog

AMERICAN
FIRE PREVENTION BUREAU, INC.
One Madison Avenue, New York, N. Y.

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BURKE Positive Grip Connectors

The only connector which can be partially assembled on the ground.

Made from high conductivity copper Tobin Bronze or Monel Metal Bolts.

Bulletin on Request.

BURKE ELECTRIC CO.
ERIE, PA.

Offices in Principal Cities
Pacific Coast—JONES-LYMAN, INC., San Francisco, Los Angeles

Standard Type K Disconnecting Switch—The most widely used product of this company—A standard specification with many large power companies on the Pacific and Atlantic coasts—Inexpensive to install and requiring no maintenance of any sort.

45 KV 3-pole unit with group control.

Pacific Electric Manufacturing Corp.
3617 THIRD STREET, SAN FRANCISCO, CALIF.

Representative in Principal Cities.

KEARNEY
MANUFACTURERS OF
Preheated Certified Malleable Iron Screw Type Anchors
Outdoor Type Fuse Switches, Disconnecting Switches, Choke Coils, and Combinations, 7500 and 15000 volts
Aluminum, Copper, and Galvanized Iron Guy Wire Clips
Extension Sleeve Twisters with Interchangeable Dies
Solderless Service Connectors
Expulsion Porcelain Plug Cutouts
Tap Off Clamps

Write for Catalog

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BORING
Symbol of Quality
Magnet Wire

"The Nation's Finest Value in Magnet Wire."
Plain Enamel Single Silk Covered
Single Cotton Enamel Double Silk Covered
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Please mention the JOURNAL of the A. I. E. E. when writing to advertisers.
Anaconda Hollow Conductor

rope lay construction

Anaconda Hollow Conductor Cable was recently installed in the plant of one of the largest paper companies of Canada, as a connection from the bus structure to the moveable electrodes of pulp boilers. For this use maximum conductivity combined with strength and flexibility, was essential.

The type of Hollow Conductor illustrated is known as "Hollow Rope Lay Annealed Copper Cable." It has a conductance equivalent to 2,000,000 c. m. annealed copper at 20 degrees C.

The diameter of the individual wires forming the ropes is .0972 inch—of the rope itself, .2916 inch—of the complete cable, 2.024 inches. Area of the complete cable, 1.6195 square inches. Weight of the complete cable, per 1,000 feet, 6,443 pounds. Approximate breaking strength, 44,800 pounds. Coefficient of expansion, .0000094 per degree F.

The American Brass Company
Anaconda Copper Mining Co.

General Offices: 25 Broadway, New York
Chicago Office: 111 West Washington St.

Anaconda
WIRE PRODUCTS

Please mention the JOURNAL of the A. I. E. E. when writing to advertisers.
SAUTER
**Electric TIME SWITCHES**

These "astronomic" time switches are carried in stock for circuits of:

- 250 Volts: 10, 25, 40, 60, 100, 200, 300 Amps.
- 4600 Volts: 25 and 50 Amps.
- 8000 Volts: 25 and 50 Amps.

Ask for new catalog S-1.

R. W. CRAMER & COMPANY, INC.
136 Liberty St.
New York City

---

In 12 years we have re-wound something like 50,000 transformers . . . . .

Most of these have been for well known utility companies that use our service as a regular part of their transformer maintenance. Year after year they send their work to us, because they know we have the facilities and experience to a regular factory job.

In addition to this service we have about 4,000 rebuilt transformers in stock for immediate shipment. All sizes from 1 to 1000 KVA, 110 to 66,000 volts; guaranteed electrically correct and at 30% to 60% off new prices.

WE BUY MODERN TYPE TRANSFORMERS—ANY SIZE—ANY QUANTITY

---

SUNDH ELECTRIC COMPANY

**SUNDH**

Automatic Starters
Circuit Breakers
Float Switches
Hand Starters
Magnet Switches
Pressure Regulators
Remote Switches
Speed Regulators
Transfer Switches
Valve Control

SUNDH ELECTRIC CO., INC.
Parkhurst St. at Ave. C
NEWARK, N. J., U. S. A.

Branch Offices or Sales Representatives in Principal Cities

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**UNIQUE THIN LEAD COLORED PENCILS**

Perfect for checking, figuring, sketching, marking blueprints, etc. Leads as thin as in No. 2 black pencil—easily sharpened to a needle point.

20 COLORS
all primary colors and shades
12 colors (Asst. No. 1116) per box $1.00
24 pencils (Asst. No. 1117) per box $2.00
At all dealers or write direct
AMERICAN LEAD PENCIL CO.
524 Willow Ave., Hoboken, N. J.

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See Preceding Issue of Journal of A. I. E. E. for ad of

**ROLLER-SMITH COMPANY**

Electrical Measuring and Protective Apparatus

MAIN OFFICE:
12 Park Place, NEW YORK
Bethlehem, Penna.

WORKS:

Offices in Principal Cities in the United States and Canada
Representatives in Australia, Cuba and Japan

INSTRUMENTS
CIRCUIT BREAKER RELAYS
of all Types for all purposes

---

Please mention the JOURNAL of the A. I. E. E. when writing to advertisers.
THE design, construction, and materials used means you can depend on a Moloney Transformer for any installation, generation, transmission, or distribution.

Now with our new, large and modernly-equipped plant in full operation, we are serving industry to even greater advantage than ever before. Specify Moloney Transformers—they will contribute a full share to your operating economy.

MOLONEY ELECTRIC COMPANY, Main Office and Factories: ST. LOUIS, MO. 
Sales Offices in Principal Cities

Please mention the JOURNAL of the A. I. E. E. when writing to advertisers.
The Stabilized Osciloscope
A Visual Oscillograph

Simple to Operate—An instrument no more difficult to operate than a high grade radio receiving set.

Portable—Weighing but 40 pounds in its beautiful walnut cabinet, it is easily taken from research room to lecture room or to a distant substation.

Linear Time Axis—By the use of a unique scheme, a linear time axis is obtained which is synchronized with the circuit under study, so that a perfectly stationary visual wave is obtained which may be examined with great ease, traced or photographed.

High Frequencies—As there is no damping and the inertia of the electron beam is only 10⁻¹⁸ grams, the response to all frequencies and harmonics is true and accurate.

Small Current—One microampere is sufficient to actuate this small moving element.

Immediate Results—Because it is visual, a class in Electrical Engineering or Radio can watch the effect of changing the constants in any circuit while it is happening. A power engineer can observe the effect on wave form of various loads, field excitations, etc., making a photographic record of the results which it is deemed should be permanent.

Powerful Research Tool—Wherever vibrational phenomena are involved.

The Price is reasonable.

Described by Prof. E. Bedell, A.I.E.E. Journal June 1927.

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