Vol. XLII JUNE, 1923 No. 6

JOURNAL OF THE American Institute of Electrical Engineers

PUBLISHED BY THE INSTITUTE
33 WEST 39TH ST • NEW YORK CITY

ANNUAL CONVENTION NUMBER

American Institute of Electrical Engineers

COMING MEETINGS

Annual Convention, Swampscott, Mass., June 26-29

Pacific Coast Convention, Del Monte, California, October 2-5

MEETINGS OF OTHER SOCIETIES

American Institute of Chemical Engineers, Wilmington, Del., June 20-23

American Society for Testing Materials, Annual Meeting, Atlantic City, N. J., June 25-30

Association of Iron & Steel Electrical Engineers, Buffalo, N. Y., September 24-28

National Electric Light Association, New York, June 4-8

Pacific Coast Electrical Association, San Francisco, Cal., June 19-22

Society for the Promotion of Engineering Education, Ithaca, N. Y., June 20-22

JOURNAL

OF THE

American Institute of Electrical Engineers

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

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

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

Vol. XLII — JUNE, 1923 — Number 6

TABLE OF CONTENTS

Papers, Discussions, Reports, Etc.

Institute and Related Activities

Copyright 1923. By A. I. E. E.
Permission is given to reprint any article after its date of publication, provided proper credit is given

school can accommodate 2000 pupils, while the theatre and Kilbourn Hall have respectively a seating capacity of 3358 and 507. (Fig. 1). Kilbourn Hall is dedicated to Maria Kilbourn Eastman, the mother of George Eastman. The best talent of Europe as well as of America has been secured for the teaching staff and for the musical production both in the theatre and Kilbourn Hall. At the present time the faculty has a membership of about sixty.

In determining the electrical equipment for an undertaking of such magnitude and complexity, the first problem was to decide whether to install electrical generators or to purchase the power from the local electric corporation. The main consideration in deciding in favor of purchasing the power was the diversity factor inherent in equipment of this nature. (The local electric corporation furnishes direct current at 117 and 234 volts, on a 3-wire system; and 60-cycle alternating current on a 234-volt, 3-phase, 3-wire ungrounded system.)

The special features of the installation that introduce matters of general scientific interest have to do for the most part with problems of illumination and the measurements of brightness; in other words, such problems as must be solved in the arrangement and equipment of every motion picture theatre. As will appear in the discussion following, psychological and aesthetic factors must be reckoned with in determining the illumination levels to be adopted.

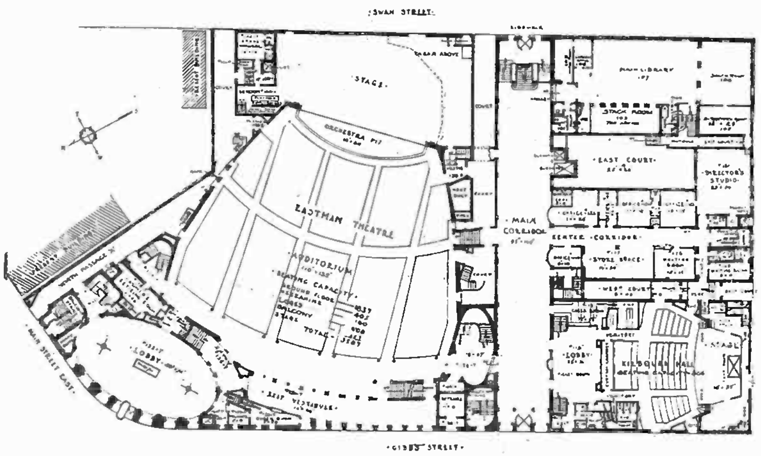


Fig. 1—First Floor Plan of the Eastman Theatre and School of Music

Illumination and Brightness Measurements

Some time before the building of the theatre, the Research Laboratory of the Eastman Kodak Company at the request of Mr. Eastman took up the problem of finding how much general illumination could be tolerated in a motion picture theatre without injuring the quality of the projected picture. Other questions relative to the most suitable conditions of illumination in the motion picture theatre were also considered. The results obtained were published in a paper by one of the authors[1] and it may be well to review briefly the conclusions reached.

An intelligent treatment of the illumination problem involves adequate knowledge of the fundamental visual processes. The relation between the stimulating radiation and the sensation produced when radiant energy falls upon the retina is extremely complicated; even a brief résumé of the subject would require many pages. In this particular problem we shall be concerned chiefly with the way in which the retina responds to brightness and differences of brightness. From the theoretical standpoint, therefore, the treatment of the problem of illuminating this theatre must be based upon the knowledge of the human eye's sensibility to brightness. There are three types of sensibility to brightness: (1) threshold sensibility, which is measured by the least brightness perceptible, (2) contrast sensibility, which is measured by the least brightness difference perceptible, and (3) glare sensibility, which is measured by the brightness just sufficient to produce discomfort or an appreciable lowering of visual acuity.

These visual sensitivity curves have been determined by Nutting[2], Blanchard[3] and others, and for a detailed account of this work and its significance, the reader is referred to the original articles. The eye may be considered as an instrument of var able sensi ivity. The sensibility to brightness, contrast (differences of brightness), and glare depends upon the condition at the particular time the determination is made and that condition in turn depends on previous stimulation. It is necessary, therefore, to specify the condition of the retina at the time the measurement of sensibility is made. This is done by specifying the brightness to which the eye is adapted and is termed "adaptation level" of the retina. For instance, after an observer has looked for ten to thirty minutes at a uniformly illuminated surface large enough to fill the visual field, a condition of equilibrium in the retinal process is reached. The observer's eye is then said to be adapted to the brightness of the field and his adaptation level is specified by stating the brightness of the illuminated surface. This term "adaptation level" will be used later in the discussion of the illumination measurements and it is hoped that this brief definition will make its meaning understood. From the curves (*loc. cit.*) relating the three brightness sensibilities to adaptation level, it is possible to draw many conclusions as to the visual sensations resulting from a specified condition of illumination.

1. Jones, L. A., The Interior Illumination of the Motion Picture Theatre. *Trans. Soc. Mot. Pict. Eng.*, May, 1920, p. 83 and An Improved Method for the Illumination of Motion Picture Theatres. *Trans. Ill. Eng. Soc.* 1920, 15, p. 645.

2. Nutting, P. G., The Fundamental Principles of Good Lighting, *Jour. Frank. Inst.*, 183, 1917, p. 287.

3. Blanchard, Julian, The Brightness Sensibility of the Retina, *Phys. Rev. XI*, No. 2, 1918, p. 81.

The experimental work was done in a small projection room with a screen mounted directly on one of the end walls. The room illumination was obtained by a fixture suspended in such a way as to illuminate the ceiling surfaces. This was so arranged that the ceiling near the rear of the room was illuminated to a fa rly high level while the illumination decreased gradually toward the front of the room. By this arrangement it was found possible to obtain illumination on the table plane (horizontal plane 30 inches from the floor level) varying from 0.1 foot candle near the front of the room up to 0.25 foot candle at the rear without any perceptible injury to the quality of the projected motion picture. The following recommendations for the illumination of motion picture theatres were made. These were based not only upon the results obtained in the experimental work done at that time but also upon a consideration of the fundamental nature of visual processes and the requirements of vision.

1. The il umination on the table plane should vary from 0.1 to 0.2 foot candles, decreasing toward the front of the auditorium.

2. No area (outside of the projected picture) visible from any seat in the theatre should have a brightness of more than 2.5 to 3.0 millilamberts.

3. The attainment of (1) without exceeding the values mentioned in (2) requires the use of a very extended effective source such as illuminated ceilings and walls, and is best accomplished by the use of an indirect system of lighting.

4. All light source fixtures such as diffusing globes and translucent glass ware having a surface brightness of more than 2.5 to 3.0 millilamberts should be concealed from view or so placed as not to fall within the field of vision of the audience.

5. The lighting of the lobbies, vestibules, corridors, and stairways should be so arranged that the transition from the brightness level of the exterior to that of the interior will be as gradual as possible thus eliminating any sudden change in the brightness to which the eye is subjected. Such an arrangement is desirable for the elimination of visual shock which always occurs when one passes from a region of very high to very low illumination or *vice versa.*

Other conclusions relative to the screen, frame, and lighting of the vestibules, lobbies, foyer, etc., were made which will not be reviewed at this time.

The results of these experiments were called to the attention of the architects and electrical engineers concerned in the construction of this theatre, and an effort was made to install a lighting system which would conform as nearly as possible to the recommended requirements.

After the theatre had been in operation for some weeks and the general illumination conditions found to be satisfactory from the practical standpoint, it was thought desirable to make a rather extensive set of measurements to determine just what illumination levels had been actually obtained. Arrangements were therefore made with the management to make this survey in the morning before the opening of the theatre for the daily exhibition.

In Fig. 1 is shown a first floor plan of the entire building. The illumination measurements given in this section, however, relate only to the theatre itself. In Fig. 2 is shown an elevation of the longitudinal section through the theatre. This shows in a general

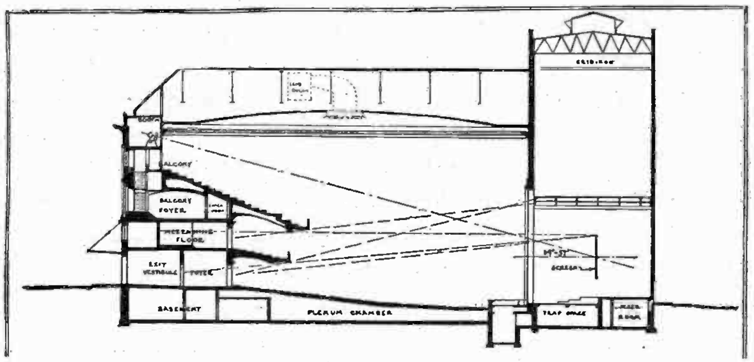


FIG. 2—LONGITUDINAL SECTION OF THE THEATRE AND AUDITORIUM

way the relation between the various elements of interest. In Fig. 8 is a simplified diagram which is more convenient for use in explaining the location of the positions chosen for measurement. It will be noted that this is a simplified drawing taken from Fig. 2. The various locations of interest from the standpoint of this discussion are indicated by letters and may be designated as follows:

L. The main floor of the auditorium.
K. The mezzanine.

FIG. 3—FRONT ELEVATION OF EASTMAN THEATRE AND SCHOOL OF MUSIC

I. The grand balcony.
E. Foyer of the main floor.
F. Mezzanine foyer.
G. Grand balcony foyer.
H. The main entrance lobby.
(As will be noted in Fig. 1, this does not lie on the main axis of the auditorium but for the sake of this discussion it has a position relative to other parts of the theatre as indicated.)

M. Projection room.
S. Projection screen.
A. Large chandelier.
B. Coffered ceiling, shallow dome.

The lighting of the theatre during the projection of pictures is accomplished to a great extent by the large chandelier (Fig. 5). In this are mounted concealed units which throw light upward onto the ceiling. This lighted surface then becomes the effective source of illumination and due to the large area utilized a satisfactory low surface brightness suffices to give the required illumination. Within the chandelier are a few unconcealed lamps of low wattage which are operated at very low voltage. These light the chandelier itself to a very low level just sufficient to prevent the chandelier from being silhouetted as a dark mass against the ceiling. The intrinsic brilliancy of these units is low enough to prevent any possibility of glare.

The mezzanine is lighted chiefly by lamps placed in the cove *D* (Fig. 8). The lamps themselves are entirely concealed, the illumination being obtained by light reflected from the upper portions of the cove surface and from the illuminated ceiling over the mezzanine (Fig. 6). The space beneath the mezzanine is lighted by a similar cove system as indicated at *C* (Fig. 8). All light sources within the region occupied by seats are entirely concealed from the audience, that is, with the exception of the few small units mentioned previously which are operated at a very low intrinsic brilliancy in the main chandelier. Two fixtures for indirect lighting are provided near the rear and at the sides which throw light upon the ceiling above the balcony and serve to provide adequate illumination in these areas. These fixtures are not shown in Fig. 8.

In Figs. 9 and 10, the letters and numbers represent the points, in terms of row letter and seat number, at which measurements were made. At the points indicated, illumination measurements were made on a horizontal plane 30 inches above the floor level, the Macbeth portable illuminometer being used for the purpose. Measurements were made under two different conditions; the one which is designated as "low level" is that lighting which is used when motion pictures are being projected, and the other designated as "high level," is used when all lights are on and operating at normal line voltage. The results obtained at the low level setting are of greatest interest from the standpoint of motion picture projection. In Table I are given the values of table plane illumination for the low level condition. The letters at the left of this table correspond with the rows indicated in Figs. 9 and 10 and the values in each row are of illumination (in foot candles) found at the seat numbers as designated in Figs. 9 and 10. It will be noted that while there is some variation in the illumination at various points of the theatre this variation is not excessive, the minimum being 0.016 foot candles and the maximum 0.066 foot candles. The average value of all readings recorded in Table I is 0.035 foot candles.

As was stated before, these readings apply to the illumination on a horizontal plane 30 inches above the floor level. A few readings were also made at various points on a plane making an angle of 45 deg. with the horizontal plane inclined toward the rear of the auditorium, this being the approximate position in which a printed program would be held by a person occupying one of the seats. It was found that the illumination on this plane was from 40 to 60 per cent greater than that on the horizontal plane. This increase is to be expected since an effort was made in planning the lighting installation to have the higher intensities toward the rear of the auditorium. The illumination on the program for any of the points indicated in Figs. 9 and 10 can, therefore, be obtained by increasing the indicated value in Table I by 50 per cent. The illumination values, it will be noted in actual use in the theatre, are somewhat lower than those recommended in the paper previously mentioned. Further reference will be made to this condition.

TABLE I
LOW LEVEL
Lighting for Motion Pictures
(Values in foot candles on horizontal plane 30-in. above floor)

			Orchestra		
Row B......	0.016		0.024		0.016
" M......	0.027		0.032		0.027
" Q......	0.026	0.035	0.040	0.035	0.026
" W......	0.024	0.034	0.035	0.034	0.024
" F......	0.030	0.047	0.047	0.047	0.030
			Mezzanine		
" A......	0.016	0.018	0.021	0.018	0.016
" D......	0.037	0.045	0.048	0.045	0.037
" F......	0.065		0.066		0.065
			Balcony		
" B......	0.024	0.050	0.081	0.050	0.024
" H......	0.028	0.034	0.044	0.034	0.028
" O......	0.060	0.020	0.015	0.020	0.060

Mean of all = 0.035

In Table II are the measurements showing illumination conditions in the various foyers, lobbies, and entrances. Here again measurements were made on the table plane and in addition to these some brightness measurements were made on walls, vertical surfaces, and fixtures. All measurements of brightness here given are in millilamberts which, for the purposes of this discussion, may be considered as equivalent to apparent foot candles.

In considering the illumination conditions in the motion picture theatre, the chief factor of interest is the brightness of the various objects within the field of the observer's vision. For an observer at almost any point in the auditorium, that is to say, in either the orchestra, mezzanine, or balcony, the central portion of the field of vision is, of course, filled by the picture being observed. The regions immediately surrounding this are occupied by what we may term the "stage setting" which, in the theatre under discussion, is of an architectural type, consisting largely of areas which represent gray stone walls above which may be seen a dark greenish-blue curtain representing the sky. Finally the lateral portions of the field of view are filled by the side walls of the theatre whose lower sections are of buff-colored stone surmounted by large mural paintings.

TABLE II
LOW LEVEL

Orchestra Foyer.		
Illumination on 30 in. plane	Max. 0.52	foot candles
	Min. 0.09	"
	Mean 0.20	"
Brightness of walls and vertical surfaces	Max. 0.40	millilamberts
	Min. 0.18	"
	Mean 0.33	"
Brightness of fixture glass ware	15.0—20.0	"
Mezzanine Foyer.		
Illumination on 30 in. plane	Max. 0.32	foot candles
	Min. 0.02	"
	Mean 0.10	"
Brightness of vertical surfaces	Max. 0.17	millilamberts
	Min. 0.02	"
	Mean 0.05	"
Fixtures	5.0— 1.00	"
Balcony Foyer.		
Illumination on 30 in. plane	Max. 0.66	foot candles
	Min. 0.12	"
	Mean 0.25	"
Brightness of vertical surfaces	Max. 1.6	millilamberts
	Min. 0.1	"
	Mean 0.3	"
Fixture Glassware	40—60	"
Main Lobby.		
Illumination on 30 in. plane	Max. 15.0	foot candles
	Min. 1.0	"
	Mean 4.0	"
Brightness of vertical surface	Max. 8.0	millilamberts
	Min. 0.5	"
	Mean 2.0	"
Subscribers' Entrance.		
Illumination 30 in. plane	Max. 10.0	foot candles
	Min. 0.6	"
	Mean 3.0	"
Brightness on vertical surface	Max. 6.00	millilamberts
	Min. 0.03	"
	Mean 1.00	"

In the case of observers seated in the extreme rear the upper portion of the field of vision may be filled, to a certain extent, by ceiling areas, either the under portion of the mezzanine and balcony or the forward portion of the main dome. Therefore, measurements of brightness were made according to the several elements which may occupy the field of vision. The following values were obtained:

1. Lower portion of the side walls, mean brightness	0.015	millilamberts
2. Upper portion of the side walls (murals) mean brightness	0.010	"
3. Side walls of balcony	0.021	"
4. Ceiling directly over central chandelier	0.51	"
5. Ceiling over small indirect fixtures at rear of balcony	1.21	"
6. Stone railing in front of orchestra	0.01	millilamberts
7. Side walls of stage setting	0.006	"
8. Vertical surface of stage setting directly beneath picture screen	0.04	"
9. Side banister of stage setting	0.03	"

It will be noted that all of these brightness values are relatively very low, especially when compared with the brightness of various elements of the picture which will be mentioned in a later section. None of the areas mentioned within the field of the observer's vision are high enough in brightness to cause glare or to raise the adaptation level of the observer's eyes to such a point as to prevent satisfactory visual appreciation of the picture.

In order to obtain data on the brightness factors of the picture itself, measurements were made at various points on the screen while a picture was being projected. The film used was a portion of the picture then being shown at the theatre and considered a fairly representative picture of the better class of photo plays now being produced. The following items may be mentioned:

Sunlight on the white clothing of one of the actors was represented in the picture by a brightness of 3.0 millilamberts.

A reproduction of a letter written on white paper gave a value of 6.0 millilamberts.

Title background measured 0.06 millilamberts.

Deep shadows in some of the scenes measured as low as 0.05 millilamberts.

With the projection machine running but with no film in the machine, an average screen brightness of 7.0 millilamberts was obtained.

The screen brightness resulting from general house illumination only was found to be 0.01 millilamberts. This represents the illumination on the screen at all times due to light reflected from walls and fixtures in the theatre, and is what may be termed the "stray light" on the screen. This light, of course, is spread uniformly over the picture at all times and the effect is to lower the contrast of the projected picture. This brightness, however, is so small as to be quite negligible in producing loss of contrast.

It has been found in a statistical study of the transmission characteristics of representative motion picture positives[4] that the transmission of the highlight region is on the average 74 per cent, while the transmission of the shadow regions is for an average picture 1.25 per cent thus giving a contrast (that is, ratio of highlight to shadow brightness) of 58. With a screen brightness of 7 millilamberts such as was found in the Eastman theatre, the highlight of the average picture would be represented by a brightness of 5.9 millilamberts. It may be of interest to note that these values are checked fairly well by actual readings taken on the screen.

In order to compute the effect of stray radiation on

4. Jones, L. A., Printing Exposure and Density in Motion Picture Positives. *Trans. Soc. Mot. Pic. Eng.*, Vol. 15, Oct. 1922.

the contrast of the projected picture, it is necessary only to add the brightness due to stray light to both the highlight and shadow brightness and again to take the ratio, an operation that gives a shadow brightness of 0.10 millilamberts and a highlight brightness of 5.3 millilamberts, giving a contrast of 53, which is only about 10 per cent lower than that obtained with no stray illumination on the screen. But a reduction of 10 per cent in contrast under the conditions of visual adaptation existing in the motion picture theatre is barely perceptible and may be considered negligible. As a matter of fact, it is probable that the amount of stray illumination on the screen can be doubled without interfering seriously with the photographic quality of the picture. The computations are all based on values of objective contrast and do not take into account the subjective effect which occurs in the visual processes of the observer when the general adaptation level is raised by increasing the room illumination.[5]

A study of the mechanism of vision shows that the contrast sensibility, that is, the ability to see small differences in brightness, decreases appreciably when the eye is working at very low illumination levels. The presence of an appreciable amount of general room illumination in the motion picture theatre tends to raise the adaptation level of the observer and therefore to increase his sensibility to brightness differences. This effect tends to counterbalance the loss of contrast due to the presence of a certain amount of veiling illumination over the picture. The apparent or subjective contrast, therefore, is not lowered to as great an extent as is indicated by the values based on the objective brightness measurements.

Attention was called earlier in the paper to the illumination on the table plane of this theatre, found to be on the average 0.036 foot candles, and lower than was recommended in the former paper on this subject. Measurements have also shown us that the general illumination can be increased appreciably without giving rise to an amount of stray illumination on the screen capable of interfering seriously with the quality of the projected picture. It may be well, therefore, to consider why higher illumination levels have not been used in this theatre. As a matter of fact, higher levels have been tried. The lighting installation is so flexible that practically any desired illumination can be obtained. When higher illumination levels were tried, there seemed to be a somewhat prevalent feeling that under these conditions the observer's attention was distracted by the higher visibility from the picture to surrounding objects and members of the audience. It has been stated that at higher illumination levels the coming and going of the people is more distracting to the attention than at lower illumination levels and that the higher illumination levels tend to detract from the impression of reality in the appearance of the projected picture. If these opinions represent the truth, it would seem that factors other than the loss of quality by stray light on the screen must limit illumination levels permissible in the motion picture theatre. As these are psychological and aesthetic factors, discussion of them would seem out of place at this time. The illumination levels obtaining, however, are quite adequate for the reading of a program when the type is fairly large and distinct. Moreover, it is not difficult to find one's way into the theatre even when passing from brilliant exterior illumination.

The lighting of the motion picture theatre ought preferably to be so arranged that the eyes of the patron upon entering the theatre may not be subjected to any sudden and great change in the illumination. Moreover, if the change from the exterior to the interior brightness levels can be made gradually, over an appreciable period of time, the processes of adaptation will also have time to operate. Thus the eye will be ready for satisfactory vision at the illumination level existing within the auditorium. From the measurements of illumination and brightness it is possible to trace the decrease in brightness level as the patron passes through the several entrance areas. Some of these values are presented in the following table in a way calculated to illustrate this decrease of brightness as a person enters the theatre through the main lobby, orchestra foyer and on into the central portion of the main floor.

TABLE III

A. In Main Lobby: (Fig. 7).		
Just inside entrance (30 in. plane)	15.0	foot candles
Center of lobby (30 in. plane)	2.0	" "
Near orchestra foyer (30 in. plane)	1.0	" "
Mean wall brightness in lobby	2.0	millilamberts
B. Main Vestibule:		
Just inside door (30 in. plane)	0.23	foot candles
Under main lamps	0.16	" "
Main wall brightness	1.6	millilamberts
C. Orchestra Foyer:		
Just inside door (30 in. plane)	2.1	foot candles
Directly under lamp	0.53	" "
Near entrance to aisle	0.09	" "
Mean illumination (30 in. plane)	0.20	" "
Mean brightness of vertical surface in field of view	0.25	millilamberts
D. Central Portion of Main Floor, Seat Q-107.		
Illumination on 30 in. plane	0.04	foot candles
Illumination on program at 45 deg.	0.06	" "

A consideration of these values will show that the transition from exterior brightness levels is fairly gradual, and experience indicates that at no point is there a feeling of visual shock due to the too rapid decrease in the illumination. A great many other observations have been made from which it is possible to determine the decreasing levels of brightness through which a patron must pass in reaching any particular part of the theatre from either of the entrances. The values in the table are typical; further details will be omitted at this time.

In Table IV are shown the illumination measure-

5. This point was emphasized in a paper previously referred to (*Interior Illumination of the Motion Picture Theatre*).

ments made when all of the lights in the various fixtures are used at the normal line voltage. This, the highest level of light obtainable with the installation, may be used before the motion picture exhibition begins, during an intermission, and at times when the theatre is used for musical entertainments. Under such conditions the illumination produces a pleasing impression of brilliance without the glare and ostentation so characteristic of the interior of many theatres.

Our survey of the conditions of illumination indicates that in general the recommendations made in the earlier paper have been substantially followed. Although the illumination levels adopted are somewhat lower, they seem to be governed more by psychological and artistic factors than by the quality of the projected picture. The illumination through the various entrance areas has been so adjusted that the transition from exterior to interior conditions is gradual. Experience shows that the illumination inside the theatre is sufficient to allow an observer to enter and find his way about without difficulty.

TABLE IV
HIGH LEVEL
All Lights on at Normal Line Voltage

			Orchestra		
Row B.....	0.38		0.60		0.38
" M....	0.75		1.21		0.75
" Q.....	0.60	1.04	1.38	1.04	0.60
" W....	0.44	0.81	1.21	0.81	0.44
" EE...	0.15	0.32	0.28	0.32	0.15
			Mezzanine		
Row A.....	0.15	0.22	0.24	0.22	0.15
" D....	0.30	0.38	0.38	0.38	0.30
" F.....	0.52		0.52		0.52
			Balcony		
Row B.....	0.45	1.43	2.86	1.43	0.45
" H....	0.22	0.50	0.66	0.50	0.22
" O.....	0.11	0.14	0.16	0.14	0.11

Mean = 0.95 foot candles

Some Details of the Electrical Equipment for Light, Power and Communication

It has already been noted that both direct current and alternating current are available from the local corporation. It was decided to put the passenger elevators and motors for the heating equipment, most of which are variable speed, on the direct-current system and the lighting and miscellaneous power motors on the alternating-current system. To adopt the alternating-current system to lighting conditions in such a way that generators could be installed in the future, if desired, the lighting feeders were all run from the main switchboard as 3-wire, single-phase systems, 117-234 volt compensators being used to derive the neutral connection. These compensators are grouped in a fireproof vault with the transformers.

The main switchboard was, therefore, divided into two parts, the direct-current section being fed through a 2000-ampere switch and the alternating-current through a 2500-ampere switch. The feeders from the main switchboard in the engine room extend through a tunnel under a street which separates the power plant from the main building. There are eight of these feeders for the School of Music and eleven for the Eastman Theatre. These feeders terminate in the School of Music at the distribution switchboard in the basement, the stage switchboard in Kilbourn Hall, a switchboard in the booth of Kilbourn Hall and a panel board in the attic for the heating appliances and one for the elevators. In the theatre there is a switchboard in the rear part of the basement, one in the front part of the basement, a stage switchboard, a direct and alternating-current switchboard in the picture booth and a distribution panel board in the front attic and one in the rear attic.

School of Music

As regards the switchboard in the basement of the School of Music, the direct-current power section is fed by two 500,000-cm. cables in each leg and from this section circuits are extended to the direct-current motors, most of which are used in connection with the heating and ventilating system and a sub-feeder to the front attic panel board for the same purpose. An alternating-current, 3-wire feeder consisting of one 500,000-cm. cable per leg feeds the alternating-current power section on this board, and circuits are extended from this section to the alternating-current motors, most of which are used in connection with organ blowers.

A 500,000-cm. direct-current feeder extends to this board and continues to the panel board in the attic, feeding the elevator motors and one of 300,000-cm. extending through this board to the booth of Kilbourn Hall feeds the motion picture projectors. Each of the two lighting sections of this switchboard is fed by 500,000-cm. cables on 3-wire systems, two 15 kv-a. compensators being installed in the transformer vault in the engine room for supplying the neutral current for each of these circuits which are connected to different phases of the alternating-current system.

From these lighting sections of the switchboard, circuits are extended to panel boards on the several floors which feed the individual lighting circuits. Five of these sub-feeders which supply current for the lights on the marquise opposite the school entrance, and the indirect lighting in the main corridor are equipped with contactors. These contactors are controlled by buttons located in a cabinet on the first floor which also houses the switches for controlling all of the stair and corridor lights. The control cables are extended from the buttons controlling the marquise lights to a similar panel board in the theatre so that these marquise lights can be controlled at that point with the other marquise lights which pertain to the theatre and thus make an unbroken system of illumination from one end of the marquise to the other.

Fig. 3 showing an external view of the theatre taken at night, the facade of the building being illuminated by flood lights arranged on top of the marquise, all of these flood lights being controlled from the theatre.

Kilbourn Hall Switchboard and Stage Equipment

Kilbourn Hall located in the Eastman School of Music is a small theatre seating about five hundred.

It is equipped with one of the finest organs in the country and the electrical equipment is very complete. The stage switchboard is of the dead front type, having master levers for each group of switches with preset devices for engaging or disengaging the individual switches when operated by the master levers. The dimmer bank is of the inter-locking type so that each dimmer can be operated individually, in groups on a master lever or on a slow motion wheel either raising or lowering the lights, according to the setting.

The stage equipment consists of foot lights and three borders all in four colors, boomerang lights in four colors and four sets of pockets which are numbered and may be assigned to any color scheme desirable. Each of these four pocket circuits is equipped with two dimmers and selector switches so that they can be arranged for a capacity of 500, 1000 or 1500 watts. Twenty pockets on the four circuits are provided. There are sixteen boomerang lights of 500 watts each.

The footlights and borders are equipped with lamps as follows:

White		Blue	
Foots	26—100 watt	Foots	13—100 watt
Border 1	20—100 "	Border 1	9—100 "
" 2	20—100 "	" 2	9—100 "
" 3	22—100 "	" 3	11—100 "

Red		Green	
Foots	12—100 watt	Foots	13—100 watt
Border 1	9—100 "	Border 1	10—100 "
" 2	9—100 "	" 2	10—100 "
" 3	10—100 "	" 3	11—100 "

The auditorium lights are arranged on three switches which control circuits on six chandeliers. The greatest number of lights is grouped on one switch called the high switch. A smaller number on the low switch and a few lights on a switch called the step switch, the object of this latter system being to supply enough light to make it practicable to use the steps, recognize your neighbor and even read the head lines on the program, and yet not enough to interfere with the best production of the pictures, all as described in another part of this paper.

A switch is provided on the rear of the switchboard for connection to special portable apparatus and controlled from the switch called the company switch. Individual snap switches are provided for stage working lights, orchestra leader, dressing rooms, etc., and the orchestra receptacles are arranged on two dimmers with selector switches so that either 200, 400 or 600 watts may be used as desired and still be within the controlling range of the dimmers.

Illumination of Kilbourn Hall

The illumination is supplied from six bronze fixtures, of a Grecian hanging lamp design, each containing five indirect lighting units. Three of these are arranged on the high circuit, one on the low circuit and one on the step circuit. An ornamental band of eight small lamps, very deeply enameled, breaks the somber appearance of these fixtures. In multiple with the high switch and with the low switch on the switchboard, contactors are arranged with remote control buttons located at the entrance to this theatre and also in the picture booth so that the lights may be conveniently controlled by anyone entering or leaving the hall or by the motion picture operator.

Kilbourn Hall Picture Machine Booth

The Kilbourn Hall picture machine booth is designed for a complete equipment of machines suitable for a large theatre and in fact a duplicate of the equipment for the Eastman Theatre, one reason being that this hall may be used for teaching the musical accompaniment of motion pictures.

School of Music Illumination

The studios, practise rooms and halls in the School of Music are illuminated principally by semi-indirect lighting units, with the exception of one large class room which is equipped with indirect lighting fixtures and stereopticon equipment. In this room as in the case of the theatre, there is a sufficient amount of light used during the showing of stereopticons or moving pictures to find one's seat and even to make notes on the lectures.

The main corridor on the first floor has an arched ceiling and is illuminated by indirect lighting from coves on each side. These lights are controlled alternately on two circuits which are equipped with contactors and have remote control switches located on the panel board on this floor.

Eastman Theatre

Theatre Switchboards and Feeders

In the theatre there is a large switchboard in the rear of the basement, another in the front part of the basement, one in the picture booth, the theatre stage switchboard and a distribution panel board in the front attic and one in the rear attic.

The picture booth switchboard is fed by a 500,000-cm. 234-volt, 2-wire, direct-current circuit and also a 300,000-cm. 234-volt, 3-phase, alternating-current circuit which operates a motor direct connected to a 60-kw. direct-current generator, thus furnishing two sources of direct-current supply for the projectors.

The front basement switchboard consists of five sections, fed by three 500,000-cm., single-phase, 3-wire feeders, each equipped with a 15-kv-a. compensator located in the transformer vault. One of these feeds the electric signs, one supplies the marquise lights and flood lights above the marquise, and the third the public lobbies, corridors and stairs in the front part of the theatre. There is also a No. 2/0 direct-current, 3-wire feeder which supplies the emergency lighting, and a 3-wire feeder of No. 1 cable on the direct-current circuit which feeds the exit lights. This latter circuit is fed from a switch connected back of the main switch and there is no other fuse or switching device on this circuit except at the point of control in accordance with the Underwriters rules. All of the circuits from these five, sections of the switchboard are actuated by remote control contactors with the control buttons located in the panelboard just off of the main lobby on the first floor of the theatre. There are about 900 25-watt lamps on the marquise and 41 250-watt flood lights above the marquise.

The emergency circuit, as stated before, is connected to a direct-current source and feeds alternate lights on the stair as well as lights in the main lobbies, corridors and halls, so arranged that there would be sufficient illumination in case the alternating current was entirely out of commission. This circuit is also very useful at night in case of cleaning and repairs to the building when the main circuits are turned off.

The alternating-current feeder for the inside public lighting and also the emergency and exit feeders pass through the rear basement switchboard, at which point taps are made for the musicians' and hall lights in the rear part of the theatre and also connections for the exit lights in the stairs leading to the dressing rooms. On the rear basement switchboard, there is an alternating-current power section and also a direct-current power section. The alternating-current power section is fed by a 500,000-cm., 3-wire, 234-volt feeder and circuits are extended to two 40-h.p. organ blower motors and vacuum cleaner motor. A sub-feeder extends to the front basement switchboard and feeds ventilating fans and a small elevator. From this latter switchboard a feeder extends to a panel board in the attic which feeds an organ blower motor for use in a studio where the accompaniment of motion pictures is taught.

The direct-current section of the rear basement switchboard is fed by two 500,000-cm. cables in each leg of a 2-wire, 234-volt circuit. This switchboard feeds a number of miscellaneous motors and a sub-feeder to the front basement switchboard feeds a small elevator and a vent fan. A feeder from the rear basement switchboard to the rear part of the attic feeds the main heating and ventilating equipment for the theatre building.

Theatre Switchboard and Stage Equipment

Fig. 4 shows a front view of the stage switchboard and dimmer bank.

This switchboard is fed by two 3-wire, 117 234-volt, single-phase feeders on two different phases of the alternating-current system, each leg of each of these two circuits consisting of two 500,000-cm. cables in multiple. The neutral connection is derived from two 30-kv-a. compensators located in the transformer vault. The switchboard is of the dead front type of dead black finished slate. The individual switches are arranged in groups on master levers with preset devices.

The dimmers, arranged in groups on interlocking master levers, are equipped with preset devices and also a pickup and dropout device, by which any individual dimmer can be picked up at a certain position of the master lever or slow motion device and dropped out at any pre-determined position. The stage lighting is arranged in four colors with footlights and five borders as ordinarily used and also, on a smaller stage, set up upon this stage is a complete set of footlights, three borders and cyclorama footlights. It is also equipped with a white concert strip.

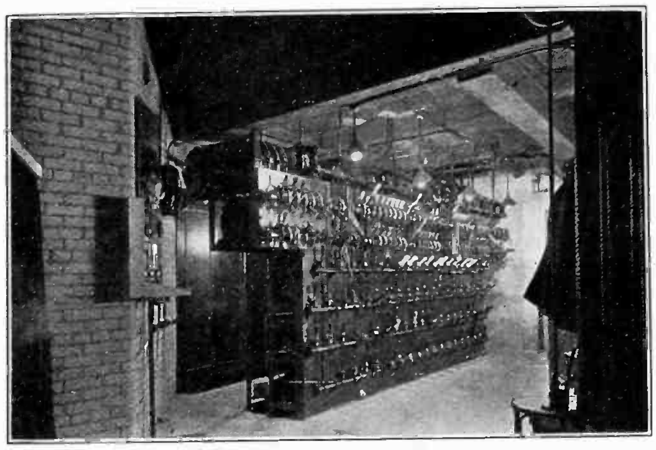


Fig. 4—Stage Switchboard

The footlights and borders are equipped with lamps as follows:

White

Concert	84	100-watt lamps
Orchestra rail	96	25- " "
Foots	43	100- " "
Border 1	52	100- " "
" 2	52	100- " "
" 3	52	100- " "
" 4	60	100- " "
" 5	60	100- " "
Platform foots	20	100- " "
" Border 1	30	150- " "
" " 2	28	100- " "
" " 3	28	100- " "
Cyclorama foots	82	100- " "

Red

Orchestra rail	48	25-watt lamps
Foots	21	100- " "
Border 1	17	100- " "
" 2	17	100- " "
" 3	17	100- " "
" 4	20	100- " "
" 5	20	100- " "
Platform foots	8	100- " "
" Border 1	10	150- " "
" " 2	9	100- " "
" " 3	9	100- " "
Cyclorama foots	27	100- " "

Blue

Orchestra rail	48	25-watt lamps
Foots	21	100- " "
Border 1	17	100- " "
" 2	17	100- " "
" 3	17	100- " "
" 4	20	100- " "
" 5	20	100- " "
Platform foots	8	100- " "
" Border 1	10	150- " "
" " 2	9	100- " "
" " 3	9	100- " "
Cyclorama foots	27	100- " "

Green

Orchestra rail		None
Foots	21	100-watt lamps
Border 1	17	100- " "
" 2	17	100- " "
" 3	17	100- " "
" 4	20	100- " "
" 5	20	100- " "
Platform foots	8	100- " "
" Border 1	10	150- " "
" " 2	9	100- " "
" " 3	9	100- " "
Cyclorama foots	27	100- " "

There are four circuits which run to the bridges and to the boomerang position. These are arranged on a master lever and are numbered one to four consecutively. They may be used for four colors or in any manner desired and each circuit runs to the grid iron where selector switches are installed and connections extended to Bridge No. 1; Bridge No. 2; to a batten and to the boomerang position. At each of these positions pockets are installed and any one or all of these positions may be connected by the selector switches to each one of these four circuits. These four circuits have a capacity of 25 500-watt lamps.

There are 8 100-ampere arc pockets arranged on individual circuits on the stage and 32 color pockets arranged on four circuits. Each of these latter circuits have two dimmers and selector switches for giving a capacity of 1000, 2000 or 3000 watts, so as to bring a varied number of lights within the controlling range of these dimmers. Snap switches are arranged for the stage working lights, orchestra leader, organ console, etc., and the musician's receptacles are arranged on two dimmers with selector switches having a capacity of 500, 1000 or 1500 watts. The dressing rooms are also fed from this board.

Illumination of Theatre Auditorium

Fig. 5 shows the chandelier which is the main source of illumination for the theatre auditorium, and Fig. 6 the cove lighting.

The house section of the switchboard is controlled by eleven switches, two for controlling alternate lights in the cove under the balcony; two for controlling alternate lights in the cove under the mezzannie; seven for controlling the chandelier lights as follows: step lights,

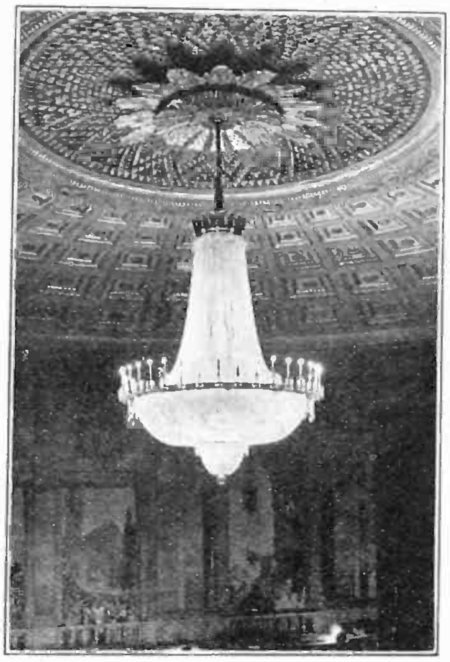


Fig. 5—Crystal Chandelier

low lights, high lights, candles, two for controlling the direct lights and one for the scintillator. The step, low and high lights are indirect. The candles and the direct lights are visible from the floor and the scintillator lights are so arranged within the fixtures as to give scintillation to the crystals of which the fixture is composed. This fixture is about 13 feet in diameter and 18 feet high.

The step lights are so named as they are designed to furnish sufficient illumination to safely use the steps during the showing of the pictures and also to give sufficient illumination to read the head-lines on the programs, as described in another part of this paper.

The low lights have a capacity of about 5 kilowatts, and the high lights of about 15 kilowatts. The direct lights have a capacity of about 8 kilowatts. As their names indicate, they give a low stage or a high stage of illumination for the indirect lighting. The direct lighting is visible and is arranged in symmetrical lines about the lower bowl of the fixture.

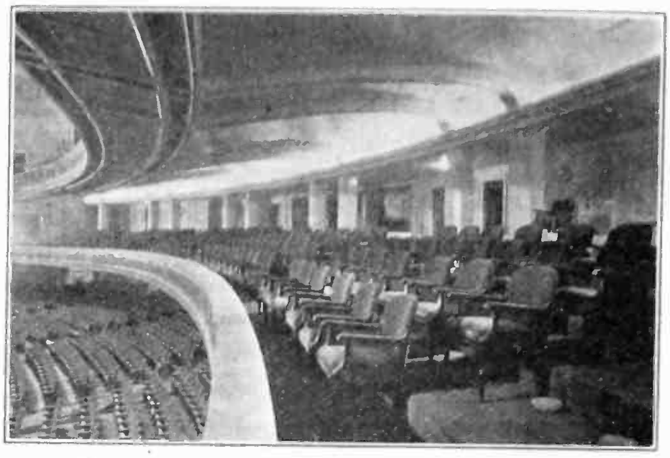


Fig. 6—Cove Lighting of the Mezzanine

Theatre Picture Machine Booth

In the picture machine booth there is a switchboard fed by a 500,000-cm. 3-wire, direct-current 117 and 234-volt circuit and also a 3-wire, 300,000-cm., 234-volt, alternating-current circuit for an induction motor which is direct connected to a 60-kw., 125-volt direct-current generator, thus furnishing two sources of supply for the picture machines. A 4-pole, double-throw switch is used to change from one system to the other, the four poles being required for the purpose of preserving the same polarity as that furnished on the 3-wire, direct-current system from this switch. This switch feeds a dead front switchboard for the control of the equipment in the booth.

This switchboard is of dead black enameled slate and has four switches for the control of the moving picture machines and three circuits for spot lights and dissolvers, besides circuits for exhaust fans, lights and motors for rewind devices. The four circuits feeding the picture machines are arranged with receptacles and plugs in such a manner that any machine can be plugged on any switch with its rheostatic control so that if trouble occurs at that end of the circuit the machines can be switched to another circuit. The rheostats are arranged in a room provided for that purpose and the leads extended from these rheostats in the form of a cable to the rheostat control switches which are located at the front wall of the picture booth adjacent to the picture machines.

Illumination of Lobbies, Halls and Stairs

The main lobby is elliptical in form, the chief source of illumination being two tripods placed at the focusses of this ellipse. These tripods are arranged for indirect lighting, the light being thrown directly against the ceiling. Fig. 7 shows a photograph of this arrangement.

On the table between the two tripods are two aquariums which are illuminated by lights concealed in the bases. Supplementary illumination is obtained from semi-indirect brackets located on the pilasters at the walls of this lobby. The majority of these lights are connected to the alternating-current lighting system, but a few are connected to the direct-current emergency system so that if one system fails there will be sufficient illumination from the other to carry on the production.

The corridors and stairs, of which there are eleven, are illuminated by semi-indirect fixtures, both chandeliers and side wall brackets being used. The alternate lights on the stairs are connected to the emergency direct and alternating-current systems and a few of the corridor and hall fixtures are also connected to the direct-current emergency system.

Panelboards on the different floors supply current for these lights and are all fed by feeders from the front basement switchboard. These feeders are equipped with contactors, the remote control buttons of which are arranged in a control cabinet just off of the lobby on the first floor. The control buttons for the contactors on the outside lights are also located in this same cabinet so that complete control of all of the so-called "public" lighting is obtained from this point.

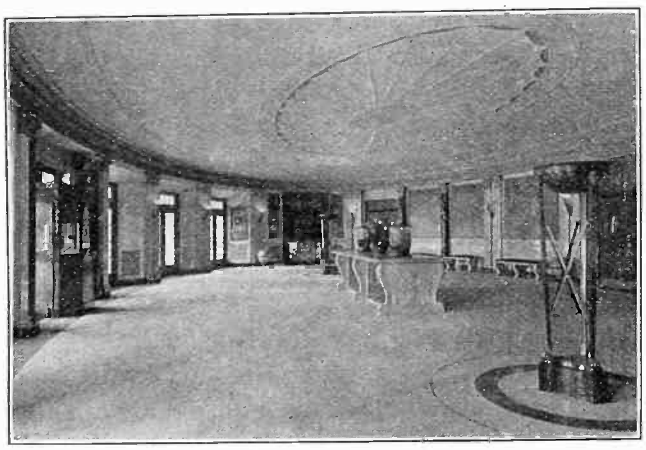


Fig. 7—Elliptical Lobby

Illumination of Business Offices

A separate circuit from the front basement switchboard feeds the business offices, stairs and halls, so that the control is entirely independent of the so-called public lighting.

Electric Signalling Systems

Battery Equipment

The battery equipment operating electric clocks, time systems, chimes, telephone systems and all signaling devices is located in the battery room in the attic of the School of Music. For this service, four separate sets of batteries are installed.

On account of the varied service and the different voltages on which this class of apparatus operates very careful study was given to the problem in order to eliminate any failure of this service both on charge and discharge.

One set of batteries of 24 cells that has a normal discharge rate of 15 amperes with 2 counter cells, controls and operates all automatic telephone equipment in both the Eastman School of Music and Theatre.

The motor generator set charging this battery is automatically controlled by a contact voltmeter and automatic switches so that any variation in battery voltage below a certain predetermined value will automatically cut in and charge the battery to full voltage and after full voltage is reached will cut out the motor generator charging set.

Twelve cells of storage batteries are used for operating secondary clocks. This set of storage batteries is charged from a Tungar rectifier. On account of the uniform discharge rate of this battery on this service the Tungar rectifier charges this battery constantly at a low ampere rate to compensate for the discharge of this battery. The capacity of the battery is such that the clock will continue to operate for one week after the failure of the charging source. As the Tungar rectifier and ammeter indicate at all times whether or not this battery is being charged, there should never be any failure of service.

All programs, buzzers, production, telephones, stage dressing rooms and all other signalling equipment and telephones are operated from two sets of six cells of storage batteries. These storage batteries are charged from a Tungar rectifier which is mounted on a control panel which indicates at all times the charge and discharge rate of this battery.

Electric Clock System

There is a total of 163 secondary clocks of various designs and sizes located in the School of Music and Theatre. Six of those located in the Theatre have illuminated dials and a large number are of special design.

Secondary clocks, program clocks and employees' time recorders are controlled from the master clock located in the Superintendent's office. The master clock is weight driven and wound electrically every 24 hours from the 110-volt direct current. On the failure of the winding current the master clock will continue to operate for eight days.

The secondary clock movements are polarized, that is the current operating these clocks is reversed at every one of the impulses which occur at minute intervals.

There were three reasons for selecting this type of movement: The possibility of the secondary clocks "scattering" on a chattering contact; low battery consumption; and their silent operation, since many are located in studios.

Program Clock

Study periods in the School of Music are closely scheduled and as the studios are soundproof, it was necessary that each instructor should get an indication after each study period to avoid keeping the students waiting. This made it necessary to place some kind of a signal in each studio for this service. This was accomplished by placing a 50-ohm buzzer in an iron box back of the clocks in each studio. These buzzers are controlled and operated from the program clock. With this equipment it is possible to set up six different programs on a two minute schedule every twelve hours. This program clock is located in the executive office.

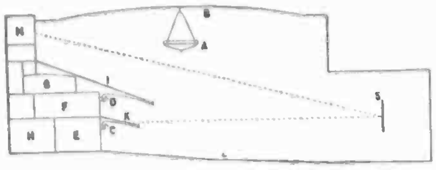


Fig. 8—Simplified Longitudinal Section Through the Auditorium

Employees' Recorders

On account of the large number of employees it was found necessary to install a time keeping system, consisting of "in and out" time recorders in the basement of the theatre, and operating from a secondary clock system.

Time Stamp

In the general office there is a time stamp, operating on a secondary clock circuit, and used to stamp all incoming mail. It indicates the day, hour and minute the mail arrives and also stamps the cards of students who rent practise rooms, thus preventing any misunderstanding as to the length of time they occupy these rooms.

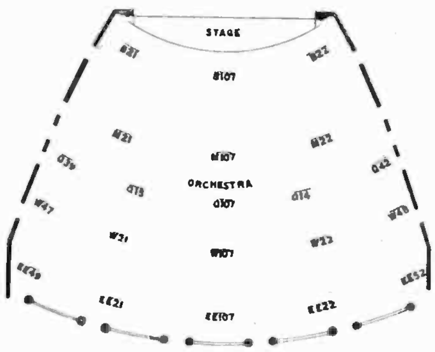


Fig. 9—Seating Plan of Orchestra Section

Watchman's Time Recorders

For this service two watchman's time recorders are installed, one located in the Superintendent's office in the School of Music and one in the telephone booth in the theatre.

The 59 stations connected to them are located in basements, tunnels, smoking and toilet rooms, so as to insure that all people are out of the building at night, and warn against overflow of water and fire hazard; each operates from a 24-volt transformer.

Telephone Systems

For this service it was necessary to install six separate telephone systems.

Manual System. This system is rented from the local Telephone Co. and the switchboard for this service (which is handled by operators) is located on the fifth floor of the Theatre in the telephone room.

Seven trunk lines are connected to this switchboard. All of these trunks are listed in the telephone directory under one number and there are 27 extension telephones connecting to this switchboard. These are located in the executive offices and other necessary places both in the School of Music and Theatre. These 27 extensions are sufficient for both local and long distance communication.

Production Telephones. Two telephone systems are used for this service, one in Kilbourn Hall connecting the stage projection room and the Music Director, and one in Eastman Theatre connecting the stage projection room, the Music Director and the organ console.

Ushers' Telephone System. This system was installed to give the ushers an opportunity to communicate with the ticket booth to advise the ticket seller of the location of vacant seats.

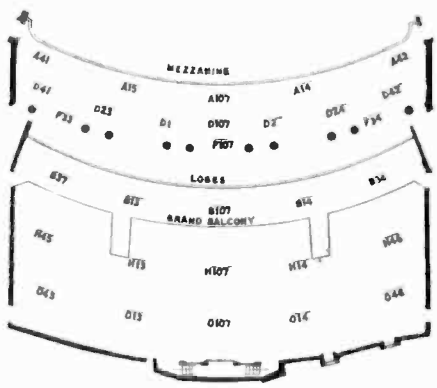


Fig. 10—Seating Plan of Mezzanine and Balcony

Interior Telephone Service

There are 87 telephones used for this service, located in studios, elevators, boiler rooms and executive offices. The activities of the School and Theatre after midnight require very little telephone service, but service is needed for any emergencies that might arise in various parts of the building. Analysis of this situation showed that in order to save rental and operating costs the only economical system to install would be the automatic telephone system.

Automatic Telephone System. The automatic switching equipment is installed in the attic of the School of Music. Connections are made by wires and cables run in conduit. The cables and conduits are of sufficient capacity to allow for future growth. The switching equipment has a capacity for handling approximately 6000 calls every 24 hours.

The switching equipment is fully supervised with signals indicating at all times that the equipment is working properly. Failure of any part of the equipment sets up a signal indicating that part of the equipment which is not operating properly.

Operation. The operation of this system is such that any telephone in the system can call any other telephone by ringing the telephone bell of the called telephone every three seconds until the called telephone answers or the calling telephone is hung up. If the called telephone is busy this will be indicated to the calling telephone by a busy tone.

In the ordinary working of this system, it is impossible to cut in on a busy line, unless supervision is arranged for.

A part of this automatic telephone system parallels the manual system. The primary advantage of two telephones when outside service is used is that it furnishes, as it were, a double track system of telephone communication whereby the outside and the inside requirements do not in any way interfere with or limit each other.

Dressing Room Telephones. This telephone system is arranged so that the stage director and doorman can call all dressing-rooms, but the dressing rooms can call the stage director only. This system is required as the dressing rooms are located on five floors of a separate wing adjoining the stage.

Stage Signals. The stage director has a complete signal system to all dressing rooms, musicians' rest rooms, locker rooms, Musical Director and organ console. The production telephones, automatic telephones, dressing room telephones, fire alarms, film speed indicators from projection machines, city fire alarm box and chime control being all mounted on a control panel at the Stage Director's stand, with volt and ammeter and other indicating devices and lamps that give supervision of all the control apparatus.

Chimes. For notifying the public that the performance is about to start there is installed in the Kilbourn Hall and Theatre corridors a complete set of chimes and altar tones, which are controlled, from the stage of the Theatre and Kilbourn Hall by the stage directors.

Magnetic Douser. This equipment which was designed and built by the electrical contractor, is used to open and close the shutters of the projection machines. Thus, when one machine is operating and coming near the end of the film the operator starts in the other machine carrying the continuation of the film, synchronizing this other machine with the operating machine. When the film in the operating machine is nearly run out he presses the switch and this closes the shutter of the operating machine and opens the shutter of the incoming machine. This operation being instantaneous prevents a double image being thrown on the screen or showing a break in the film while the change is being made.

Fire and Emergency Alarm

School of Music

The State requirements are that all school buildings be equipped with fire alarm systems.

In each corridor of each floor a break glass fire alarm box and 8-inch gong is installed making a total of 12 fire alarm boxes and 12 8-inch gongs. These gongs can be heard in all corridors, offices, mezzanines and in some studios.

As all studios in the School of Music are sound proof but usually filled with a great volume of sound any device placed in the corridors would be inaudible in the studios. This difficulty was solved by installing two large gongs in the heating chambers in the attic, and, as each studio has its own heating flue running direct to the heating chamber, these flues were used to conduct the sound. This proved very satisfactory and the fire alarm signals can be heard in all the studios.

All of this equipment operates from the 117 volt direct-current system.

Film Speed Indicators

At the organ console, stage director's stand, and music director's stand, and at each projection machine, there is located a film speed indicator showing on a scale the feet per minute at which the film is running. These indicators are operated from small generators belted to the shutter shaft and show the operator and musical director whether the film is running at the proper speed to synchronize with the music.

A telegraph indicator similar to that used in marine work is used to notify the operator of the speed desired.

Radio Broadcasting Station

With the idea of carrying out further the purpose of the school which is to educate the public to a greater appreciation of good music and to give them the advantage of the wonderful equipment and talent available a radio broadcasting station was installed.

This is located on the attic floor of the School of Music. The antenna which consists of six wires is supported at one end by a steel tower on the roof of the building and at the other end by the chimney at the power house, making an aerial with very satisfactory characteristics. The transmitter is equipped with two 50-watt oscillator tubes; two 50-watt modulator tubes and one 50-watt amplifier tube supplied with current from a motor generator set at 12 volts for the filaments and 800 volts for the plates.

The speech amplifying system consists of three stages of amplification supplied with filament current from a storage battery of twelve volts and plate current from dry batteries at 135 volts. Double carbon microphones of the duralumin type are located at the stage level and also above the stage in both the theatre and Kilbourn Hall. By means of selector switches and non-inductive variable resistances these microphones may be used either separately or in multiple with the proper balance between the two microphones for the correct blending of soloists and accompanying orchestra.

Other circuits are extended to a studio located on the fourth floor and to the operating room. Supervision is furnished both on the speech and radio sides of this equipment.

CURTAIN OPERATION

In Kilbourn Hall there are four large windows which must be curtained when pictures are shown or the stage lighting equipment used. These curtains are operated by 2 remote control systems consisting of shafts coupled to motors by means of worm gearing.

Drums on these shafts handle the cables for the curtains and counterweights. Limit switches are provided for stopping the curtains at the top and bottom of their travel, and control buttons are located at the switchboard and picture booth. These are electrically interconnected in such a manner that no damage can occur if the control systems are operated from two points at the same time.

Heating a Cotton Weave Shed by Electricity

BY C. T. GUILDFORD
Member, A. I. E. E.
General Engineer, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

Review of the Subject.*—The object of this article is*

(a) To describe an installation of electric heating of a cotton weave shed.

(b) To test the excellency of methods of estimating quantity of heat required for buildings of this kind.

(c) To derive a parity between the cost per kw-hr. and a ton of coal for heating in climates where the average winter temperatures are about 22 deg. and 48 deg. respectively.

(d) To determine under what conditions electric heating in a textile mill may be used.

ELECTRICITY is used for heating a textile mill in two instances known to the writer. One is a 68,000-spindle mill in England, and the other a weave shed at the St. Croix mill of the Canadian Cottons Co. Ltd., Milltown, New Brunswick, Canada. The English mill purchases power at 1.2 cents per kw-hr. during the day, and 0.65 cents at night. The operating results at this mill are not available, but their engineer states them to be satisfactory. The Canadian Co. has its own hydroelectric plant, where surplus power is available for heating. Details of this installation and a report of a test made on the heating plant are the basis of this article.

The St. Croix Mill is one of a group of mills operated by the above company. The others are located at Marysville, N. B., Cornwall and Hamilton, Ontario with main offices at Montreal, Quebec. The company operates a total of 191,584 spindles and 4226 looms, manufacturing ginghams, flannelettes, shirtings, tickings, dress goods, oxfords, yarns and denims. The St. Croix mill operates 56,880 spindles and 1448 looms and comprises a spinning mill, dye house, weave shed, and hydroelectric power plant.

The weave shed (built in 1920) is a one story building (with basement) 480 ft. long by 182 ft. wide of modern mill construction with Monitor roof. The basement walls are of concrete and those of the weave room of brick. The basement floor is of concrete, that of the weave room and the roof are of plank construction with timber and wooden column supports. The south end of the shed butts against the three story main mill while the rest of the building is all exposed and lies north by northwest. The basement is used for storage and the first floor for a weave room.

METHOD OF HEATING

The method of heating adopted is the Sturtevant hot air system with groups of electric heating units instead of steam coils in the fan room. Two such groups are installed in the basement; one at the north and one at the south end.

Each of the two groups is enclosed in a fire proof room with the air distributing fan intake connected therewith, the discharge being connected to the distributing pipes for the weave room. The air from the weave room is drawn down through belt holes in the floor into the basement, and thence into the heating room inlets by the suction of the fans.

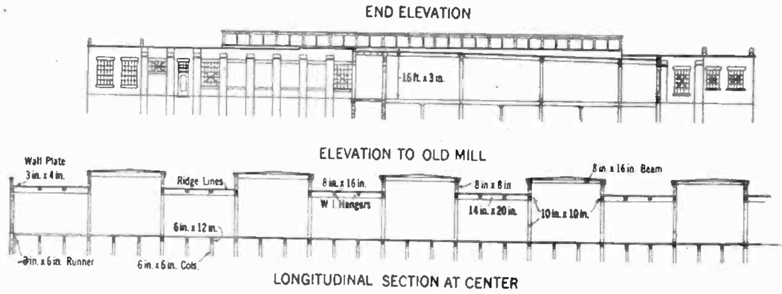


FIG. 1—SECTION OF WEAVE SHED

The heating units and air distributing apparatus installed, also the mill machinery and operating data are as follows:

HEATING APPARATUS INSTALLED

Heaters installed at South End of Weave Shed Basement.

Total number installed 300

Each unit .... 5 ohms.

Controlled as follows:

Switchboard of 5 panels, two sections per panel (called "upper" and "lower").

Panel No.	Section	Total Units	Connections	Grouped	Volts	Kw.	Push Button
1	Upper	45	Delta	M-3:S-5	575	119.025	1
1	Lower	(no heaters)					
2	Upper	(no heaters)					
2	Lower	30	Delta	M-2:S-5	575	79.35	2
3	Upper	45	Delta	M-3:S-5	575	119.025	4
3	Lower	45	Delta	M-3:S-5	575	119.025	3
4	Upper	45	Delta	M-3:S-5	575	119.025	6
4	Lower	45	Delta	M-3:S-5	575	119.025	5
5	Upper	45	Delta	M-3:S-5	575	119.025	6
				Total		793.50	

Presented at the Spring Convention of the A. I. E. E., Pittsburgh, Pa., April 24-26, 1923.

Heaters Installed at North End of Weave Shed Basement.

Total number installed.......................................480

Each Unit..5 ohms.

Controlled as follows:

Switchboard of 6 panels, two sections per panel.

Panel No.	Section	Total Units	Connections	Grouped	Volts	kw.	Push Button
1	Upper	45	Delta	M-3:S-5	575	119.025	1
1	Lower	45	Delta	M-3:S-5	575	119.025	2
2	Upper	45	Dleta	M-3:S-5	575	119.025	1
2	Lower	45	Delta	M-3:S-5	575	119.025	2
3	Upper	45	Delta	M-3:S-5	575	119.025	3
3	Lower	45	Delta	M-3:S-5	575	119.025	4
4	Upper	45	Delta	M-3:S-5	575	119.025	3
4	Lower	45	Delta	M-3:S-5	575	119.025	4
5	Upper	45	Delta	M-3:S-5	575	119.025	6
5	Lower	30	Delta	M-2:S-5	575	79.35	5
6	Upper	45	Delta	M-3:S-5	575	119.025	6
6	Lower	(none)					
				Total..........		1269.60	
				Grand Total........		2063.10	

Note: "M" & "S" indicate Multiple and Series.

Air Circulating Equipment

The circulating equipment furnished by the B. F. Sturtevant Company consists of the following:

1—No. 13 multivane fan at north end with capacity of 63,500 cu. ft. of air per minute at 131 deg. fahr. final temperature and running at 215 rev. per min.

1—No. 12 multivane fan at south end with capacity of 51,000 cu. ft. of air per minute at 134 deg. fahr. final temperature and running at 245 rev. per min.

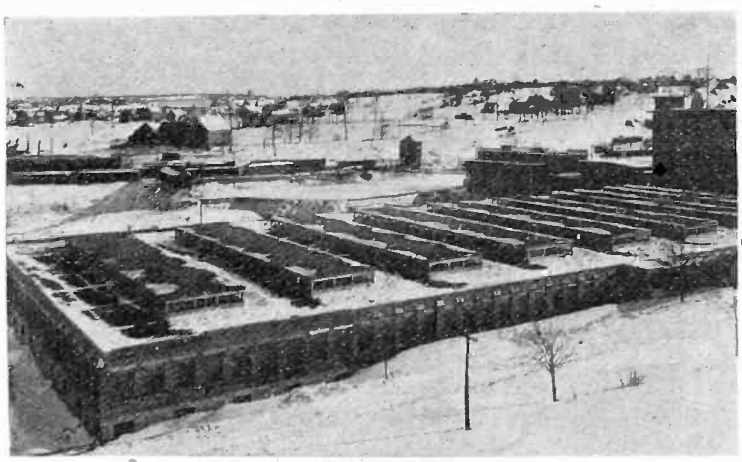


Fig. 2—St. Croix Mill—Weave Shed in Foreground

Air inlet to fans figured at 65 deg. fahr.

At the inlet of the heater there is installed louver dampers with fusible link, set for 160 deg. fahr. and at the outlet of the fan a large single damper with fusible link, set for 250 deg. fahr.

The system of piping consists of a main duct, from each fan discharge, running to about 10 ft. above the floor in the weave room above. This feeds five branches spaced at equal distances across the mill and running lengthwise from the end to near the center. Along these branches are a total of 56 short outlet pipes at the south end and 92 at the north end for the final distribution of air. Each outlet is fitted with a damper to direct or regulate the air discharge.

Each fan is belt driven by a Westinghouse Type CS 30-h. p. 550-volt, 60-cycle, 3-phase, 870 rev. per min. motor.

Mill Machinery

The first floor contained at the time of test 1092 looms, ranging in widths from 34 to 50½ inches, weaving fine ginghams. The looms are driven by belts from line shafting beneath the floor. This shafting is driven by ten 50-h. p., 1150 rev. per min. Westinghouse motors fitted with double flanged pulleys driving in

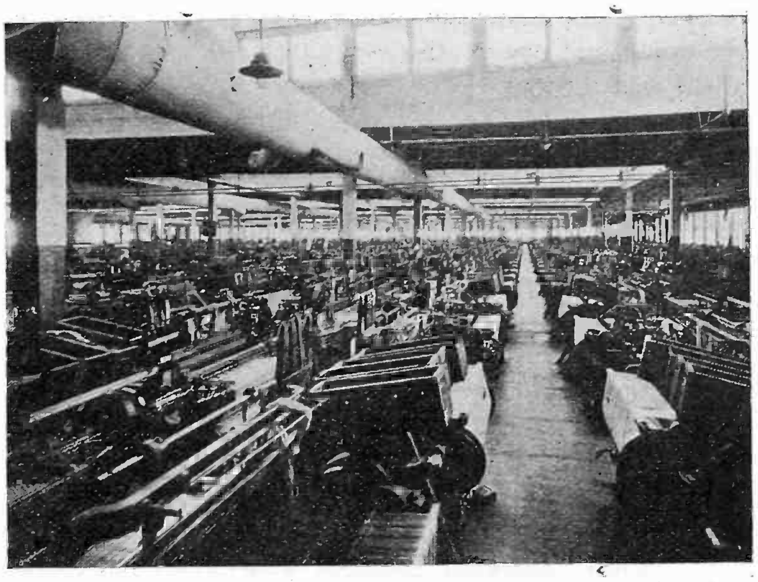


Fig. 3—Interior of Weave Shed. Hot Air Distributing Pipes Shown Overhead

opposite directions to line shafts. The room is equipped with automatic humidifiers made by the American Moistening Co.

Power Recuirements, Operators and Working Schedule

The average power input required to drive the looms is 225 kw. There is an average number of 237 operatives in the room working 10 hours per day, five days per week.

Tests

A continuous record test was made on the heating

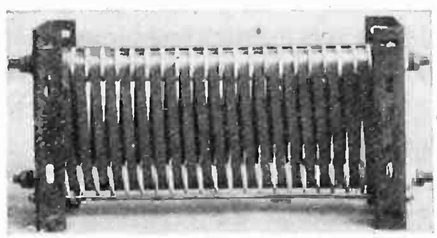


Fig. 4—Type of Heater Unit Used for Heating. Capacity 2.64 Kw. at 110 Volts

system from Mar. 9–April 5, 1922. Recording instruments were used throughout and the heating units were hand operated being cut in and out of service with push buttons by the plant engineer at the engine room where weave room temperature records were shown. The power tests were made with two graphic type Esterline wattmeters connected one in the north and one in the south end heater feeder circuits.

Outdoor temperatures were recorded by a Tycos graphic recording capillary tube type thermometer furnished by the Taylor Instrument Company of Boston. This instrument was located in a small cage placed on top of one of the monitors of the roof on the north end of the main mill and with capillary tube running down into the mill to the recording dial. Inside temperatures were taken with two Tycos graphic recording thermometers, one placed at the center of the north and one at the center of the south section of the weave room.

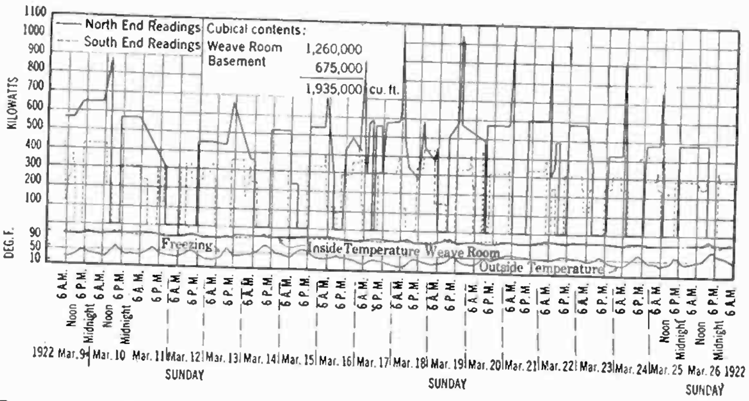


Fig. 5—Chart Showing Kw. and Temperature Changes

Analysis of Test Readings

The test readings though applying to the heating of this particular mill represent definite input records of perhaps the largest electric heating installation made on this type of building and should serve as a practical over-all check on the radiation constants generally used in heating calculations for mill buildings of this kind.

For comparison between the calculated and the observed requirements two cases have been selected from the readings taken:

a. A working day and the night following showing greatest temperature difference during the test.

b. Fifteen working days and nights following, comprising all of the work period during the test.

The calculated requirements below are obtained for each case by using the temperature differences as observed, and these results compared with the actual input readings for that period:

The constants used, B. t. u. per square foot of area per degree difference of temperature per hour, are as follows:

Glass	1.00
Walls weave room	0.31
" Basement	0.30
Roof	0.10
Number of air changes per hr. in weave room	0.75
" " " " " " in basement	0.25

Air equivalent to one B. t. u. 50 cu. ft. raised one degree or 1/50 = multiplier of .02

Building Specifications—Weave Room

Cubical contents	1,260,000 cu. ft.
Total glass area (walls and monitors)	12,255 sq. ft.
Area of roof and monitor walls	84,000 sq. ft.
Area of building walls	9,270 sq. ft.

Basement

Cubical contents	675,000 cu. ft.
Total glass area	2,450 sq. ft.
Exposed area walls	4,120 sq. ft.

In using the above low value for the roof constant it was assumed that, on account of the hot air being drawn down through the floor, the temperature difference between outdoors and indoors, over this surface was considerably less than that observed in the room.

The air changes selected were assumed to take place at all times due to leakage through crevices at windows, doors, etc.

Selecting the temperature difference, of 58.75 deg. for the weave room and 53.75 deg. for the basement, observed on Friday, Mar. 17, when the extreme low temperature for the day was 8 deg. and for the night 6 deg.; the calculated requirements for that day were as follows:

Let H = B. t. u. per hour.

Weave Room:

$H = (0.02 \times 0.75 \times 1{,}260{,}000 + 12{,}255 + 0.31 \times$

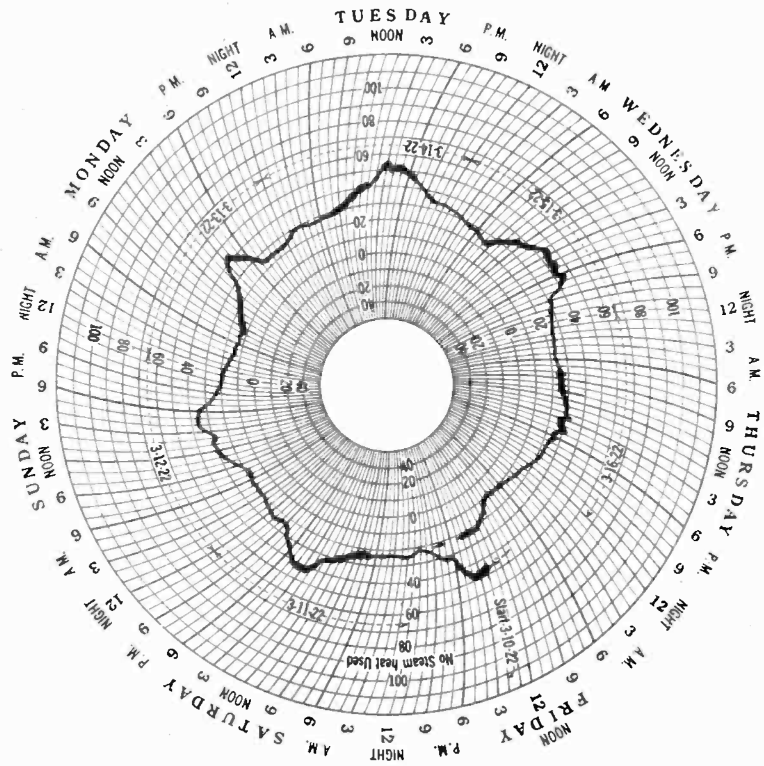


Fig. 6—Sample Weekly Chart Showing Outside Temperatures

$9270 + 0.1 \times 84{,}000)\ 58.75 = 42{,}428 \times 58.75 =$ 2,492,645 B. t. u. per hour.

Basement:

$H = (0.02 \times 0.25 \times 675{,}000 + 2{,}450 + 0.31 \times 4{,}120)\ 53.75 = 7102 \times 53.75 = 381.733$ B. t. u. per hour.

Total heat required = 2,492,645 + 381,733 = 2,874,378 B. t. u. per hour.

Deducting from this the heat developed by the 237 operators at 470 B. t. u. = 111,390 B. t. u. per hour, 225 kw., of power for looms = 768,375 making a total of 879,765 B. t. u. per hr. or $\frac{879{,}765 \times 10}{24}$ = 366,568 B. t. u. per hour on 24 hours basis and 38 kw. of power for heater fans = 129,770 B. t. u. per hour during 24 hours making a grand total of 496,338 B. t. u. per hour, the net calculated heat to be furnished by the heaters = 2,874,378 − 496,338 = 2,378,040 B. t. u. per hour on 24 hours basis.

The actual input to the heaters for this day from 6 a. m. to 6 a. m. the next morning, normal working day and night, was 16,700 kw-hours or 16700/24 = 695.8 kw. or 695.8 × 3415 = 2,376,157 B. t. u. which is within a fraction of one per cent of the calculated value above.

Selecting the fifteen working days and nights following between Mar. 9 and April 4. (See tables).

The calculated heat requirements per hour for this period with the average temperature difference (day and night) of 45.25 and 40.25 for the weave room any basement respectively is:

Weave Room

H = 42428 × 45.25 deg. fahr. = 1,919,867 B. t. u. per hour.

Basement

H = 7102 × 40.25 deg. fahr. = 285,855 B. t. u.

Total = 2,205,722 B. t. u.

Net heat = 2,205,722 − 496338 = 1,709,384.

The actual average daily kw. input for this period was 9150 + 3214 = 12,364 kw-hr. or 12364/24 × 3415 = 1,759,294 which is within 3 per cent of the calculated value above.

Comparison Between Day and Night Heating

The average heat required during the night for this 15-day period is found to be 44 per cent greater than that required during the day even after due allowance is made for the heat supplied by power and the operators. This is accounted for partly by the fact that the average night temperature difference was 3.5 deg. greater than that for the day. This would reduce the excess to 31 per cent; which excess may be explained by the fact that weather conditions during the days for the entire period of the test and also for the fifteen days in question showed an average of 54 per cent of sunshine, many days being 100 per cent.

Heating Costs

A steam heating plant makes available about 70 per cent of the energy in the coal. Electric heating where the power source is steam generated in plants of the highest efficiency would make available about 14 per cent or less of the energy in coal. Parity of prices would, therefore, seem to require the purchase of electricity at about 1/5 of the lowest rates generally available from the larger public service corporations using coal. Two cases are calculated below.

The estimated cost of heating the above weave shed from Nov. 1–May 1 is as follows: Using a mean temperature of 22 deg. obtained from weather reports for the vicinity of Milltown for a period of six years from Nov. 1–May 1, previous to 1920. The temperature difference, with a room temperature of 70 deg., would be 48 deg. for the weave room and 43 deg. for the basement, and the heat required would be:

Weave Room

H = 42,428 × 48 = 2,036,544 B. t. u. per hr.

Basement

H = 7102 × 43 = 305,386 B. t. u. per hr.

Total Heat = 2,036,544 + 305,386 = 2,341,930 B. t. u.

Net Heat = 2,341,930 − 496,338 = 1,845,592 B. t. u. per hr.

Assuming that 10,000 out of the 14,000 B. t. u. per pound of good coal can be delivered into the room. The coal per hour = 1,845,592/10,000 = 184 lb. or for the period Nov. 1–May 1 (181 days) = 184 × 24 × 181 = 799,296 or 400 tons nearly. This at $10.50 the cost of coal at Milltown at the time of the test = $4200.00. Assuming this to be 70 per cent of the cost of heating the remaining 30 per cent for attendance, interest and transmission losses. The total cost for heating = $6,000.00 which would be comparable with electric energy at $0.00255 per kw-hr. This considered as a return on the investment of $16,000. (present prices) on the electrical part of the system (the air distributing system not being included since this would be required if steam units were used instead of electric) would represent over 37 per cent.

In a more moderate climate such as that represented by Atlanta, Ga. and Charlotte, N. C. where the weather records for a number of years show a mean temperature during the months from Nov. to April inclusive of 49 deg. and 48 deg. respectively and where coal costs are lower, the requirements would be about as follows:

Assuming a mean temperature of 48 deg. outside and 70 deg. inside. This would give a difference of 22 deg. and the heat required would be:

Weave Room

H = 42,428 × 22 = 933,416 B. t. u. per hr.

Basement

H = 7102 × 17 = 120,734.

Total Heat = 933,416 + 120,734 = 1,054,150 B. t. u. per hr.

Net Heat = 1,054,150 − 496,338 = 557,812 B. t. u. per hr.

Coal = 557,812/10,000 = 56 lb. per hr. or 56 × 24 × 181 = 243,264 lb. or 121.6 tons.

Coal cost at $5.00 per ton = $608.00. Add to this $500 for attendance (part of one man's time) transmission and interest, the total cost equals $1,108.00 for the season.

The average input required would be 557,812/3415

= 163 kw. or 163 × 24 × 181 = 708,072 kw-hr. which at $0.00156 per kw-hr. would equal $1104 and make it comparable with coal on this basis.

Assuming that surplus hydroelectric power is available at no additional cost for investment or attendance and that the electric installation necessary to provide for minimum temperatures would be about 1000 kw. at a cost of about $6000, the saving of $1104 per year by using the hydroelectric heat would represent a return on the investment of over 18 per cent.

Conclusions

a. The heating plant as installed has proved itself to be adequate for the building. The arrangement of air pipes gives very uniform distribution of heating and the fan capacity is ample. In fact, the fans have been reduced in speed since being installed so as to decrease slightly the quantity of air delivered to the room.

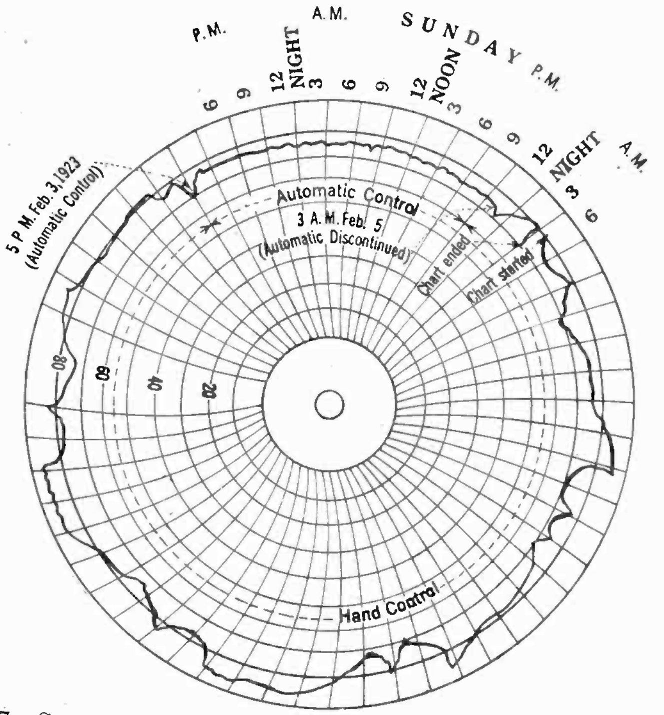


FIG. 7—SAMPLE WEEKLY CHART SHOWING INSIDE TEMPERATURES

The total capacity of the electric heating units is sufficient. The lowest temperature for which readings were taken in 1921 indicated 1600 kw. consumption at fifteen degrees below zero. This leaves a reserve of 463 kw. for further drop in temperature.

The method of enveloping the machines, operators and floor in a blanket of warm air with the proper circulation and air change makes it comfortable and agreeable to the operators and gives a desirable atmosphere for the operation of weaving.

Room temperature change can be quickly brought about by putting into service additional heaters. With temperature at 29 deg. outdoors and 71 deg. inside, the temperature is raised 5 deg. in a half hour, and 9 deg. in an hour by the application of 1519 kw. The heaters are not limited to one temperature as are steam coils, hence the rate of change depends upon the number of heaters in use and the quantity of air passed and both may be increased or decreased at will and almost instantly.

b. The actual heat input checks very closely with the calculated requirements showing the excellence of methods and values of constants generally adopted for heating calculations.

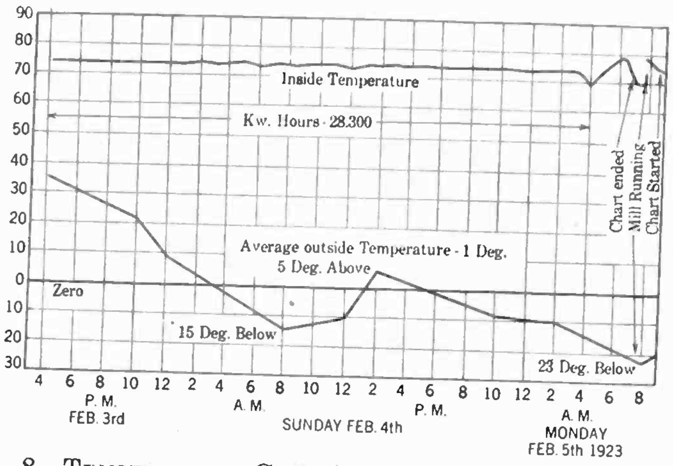


FIG. 8—TEMPERATURE CURVES WITH AUTOMATIC CONTROL TAKEN FEB. 3-5, 1923

c. Electric heat should be purchased at an estimated cost of $0.0025 per kw-hr. to be on a parity with coal at $10.50 per ton as at Milltown where the average temperature is 22 deg. during the heating season.

With coal at $5.00 per ton as in parts of the south and where the average heating season temperature is 48 deg., electric heat it is estimated should be purchased at $0.00156 per kw-hr.

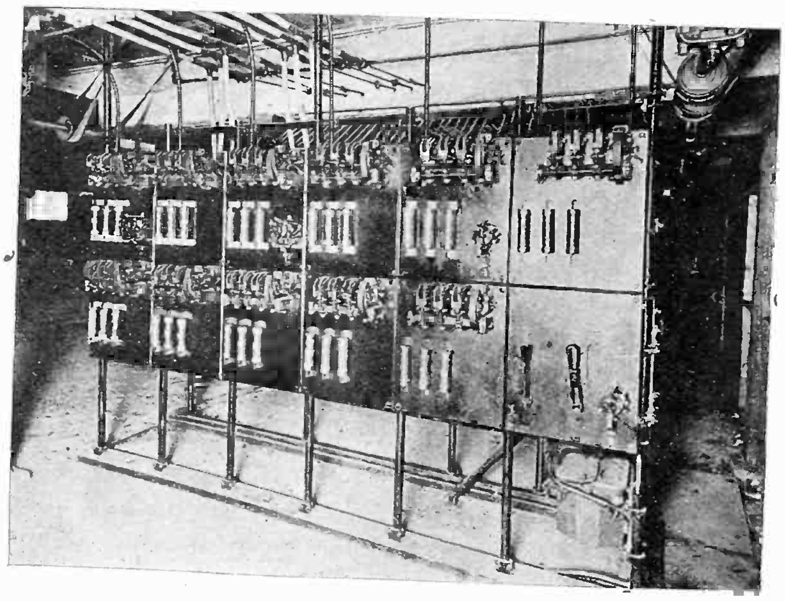


FIG. 9—CONTROL PANEL FOR NORTH END HEATERS

d. Electric heat may be adopted with economy in mills where surplus hydroelectric power is available. In the case of the plant at Milltown, a return of over 37 per cent on the investment for the electrical equipment is shown and in a plant located in Georgia a return of over 18 per cent can be realized. Variations of this will occur depending upon the price of coal and the climatic conditions.

Taples

Building Specifications

Basement

Exposed area (less glass) 4120 sq. ft.
Unexposed area, 2570 sq. ft.
Glass area, 2450 sq. ft.
Total wall area, 9140 sq. ft.
Floor area, 77,200 sq. ft.
Cubical contents, 675,000 cu. ft.

First Floor

Wall area (less glass) 9270 sq. ft.
Glass area, 5055 sq. ft.
Roof area, 75,600 sq. ft.
Monitor roof wall area, 8400 sq. ft.
Monitor roof glass area, 7200 sq. ft.
Cubical contents 1,260,000 cu. ft.

Weather Statistics for Milltown

Milltown is located on the St. Croix River in Charlotte County, N. B., Canada. The winter temperatures

CANADIAN COTTONS CO., LIMITED
TEMPERATURE AND KW-HR. READINGS
Mar. 9–April 5, 1922

Date	Time	Outside Temp.			N. End Inside Temp.			North End Kw-hr.	S. End Inside Temp.			South End Kw-hr.	Total Kw-hr.
		Max.	Min.	Mean	Max.	Min.	Mean		Max.	Min.	Mean		
9	6 a. m.												
9	6 p. m.	38	10	23	76	68	72	2235	83	72	76	2120	4355
10	6 a. m.	35	18	25	80	72	77	7680	79	74	78	5400	13,080
10	6 p. m.	50	13	28	80	76	78	2268	80	74	78	2160	4428
11	6 a. m.	34	21	25	78	76	77	6720	79	74	76	3582	10,302
11	6 p. m.	44	22	33	80	74	77	3711	82	73	77	1485	5196
12	6 a. m.	36	19	24	77	70	73		78	73	74	3000	
12	6 p. m.	37	17	27	79	72	75	Defective Chart	78	73	Defective Chart	3710	
13	6 a. m.	35	12	19	79	70	72		71	69		3456	
13	6 p. m.	44	10	25	75	69	72		77	68	74	785	
14	6 a. m.	33	24	27	77	72	75	5100	77	72	73	4040	9140
14	6 p. m.	56	28	41	78	75	76	1410	79	74	76	720	2130
15	6 a. m.	50	28	35	75	71	74	5130	76	72	75	3240	8370
15	6 p. m.	48	23	37	79	74	77	2070	76	72	74	120	2190
16	6 a. m.	47	22	29	76	72	74	5460	76	71	74	3500	8960
16	6 p. m.	34	22	28	79	70	75	2160	78	73	74	1080	3240
17	6 a. m.	27	12	18	74	69	71	5550	73	69	71	3680	9230
17	6 p. m.	26	8	17	78	68	74	5880	77	68	73	500	6380
18	6 a. m.	20	6	11	76	69	72	6360	75	69	72	3960	10,320
18	6 p. m.	28	4	16	76	67	72	2700	75	67	70	912	3612
19	6 a. m.	25	10	14	69	65	67	4680	72	66	70	5070	9750
19	6 p. m.	37	11	23	78	65	72	4500	81	72	75	2600	7100
20	6 a. m.	36	12	20	72	68	71	5700	75	69	72	3700	9400
20	6 p. m.	34	12	26	78	67	73	5340	77	68	72	1100	6440
21	6 a. m.	42	23	32	77	74	75	6900	78	68	74	3600	10,500
21	6 p. m.	42	33	38	81	71	73	288	81	69	73	234	522
22	6 a. m.	34	30	32	79	70	76	6810	78	69	76	3800	10,610
22	6 p. m.	38	30	34	78	74	77	1008	79	71	76	900	1908
23	6 a. m.	35	28	32	78	72	76	6300	79	72	77	3460	9760
23	6 p. m.	45	24	33	77	72	73	1680	77	72	75	900	2580
24	6 a. m.	37	16	22	78	70	75	3900	77	71	72	3300	7200
24	6 p. m.	49	16	36	77	71	73	1926	77	72	75	1020	2946
25	6 a. m.	45	18	29	77	71	73	4500	77	70	73	3000	7500
25	6 p. m.	42	17	29	75	71	74	1290	74	71	72	850	2140
26	6 a. m.	40	20	28	85	75	77	6300	75	70	74	3460	9760
26	6 p. m.	60	28	45	79	72	76	4500	85	74	80	1950	6450
27	6 a. m.	51	27	40	79	72	76	4320	79	72	76	2950	7270
27	6 p. m.	52	21	40	81	73	77	2700	78	74	76	Defective Chart	
28	6 a. m.	50	30	35	80	72	76		79	71	77		
28	6 p. m.	35	28	31	80	68	74		78	68	73		
29	6 a. m.	34	30	32	78	71	75	5400	75	69	73	2400	7800
29	6 p. m.	53	30	41	79	74	Defective Chart	690	76	71	Defective Chart	854	1544
30	6 a. m.	42	10	19	76	70	72	6300	76	68	70	3500	9800
30	6 p. m.	38	10	20	79	69	76	2880	76	69	72	2000	4880
31	6 a. m.	30	19	24	78	73	74	2850	76	73	74	3500	6350
31	6 p. m.	42	18	31	76	70	74	1650	77	72	74	1500	3150
1	6 a. m.	40	23	34	76	71	74	5250	77	71	75	3300	8550
1	6 p. m.	29	20	26	78	64	72	1800	78	67	73	1830	3630
2	6 a. m.	22	18	20	67	60	63	3660	74	64	71	3230	6890
2	6 p. m.	34	22	28	70	62	66	2550	72	66	69	1700	4250
3	6 a. m.	34	27	29	76	62	67	7200	78	73	74	4750	11,950
3	6 p. m.	44	31	38	79	69	72	870	80	70	73	540	1410
4	6 a. m.	40	29	32	75	69	74	5400	69	77	74	3100	8500
4	6 p. m.	46	28	35	78	71	76	1350	79	72	75	300	1650
5	6 a. m.	45	29	33	77	72	76	4920	78	72	75	3100	8020

Note: Temperature and kw-hr. readings given at 6 a. m. and 6 p. m. are for the preceding twelve hours.

TEMPERATURE DIFFERENCE AND KW-HR., FOR FIFTEEN WORKING DAYS AND NIGHTS FOLLOWING

Date	Temperature difference between out doors and inside Weave Room (fahr.)		Kw-hr.	
	Day	Night	Day 6 a. m. 6 p. m.	Night 6 p. m.-6 a. m.
Thur. Mar. 9	51	52.5	4355	13,080
Fri. " 10	50	51.5	4428	10,302
Tues. " 14	35	39.5	2130	8370
Wed. " 15	38.5	45.	2190	8960
Thur. " 16	46.5	53	3240	9230
Fri. " 17	56.5	61	6380	10,320
Mon. " 20	46.5	42.5	6440	10,500
Tues. " 21	35	44	522	10,610
Wed. " 22	42.5	44.5	1908	9760
Thur. " 23	41	51.5	2580	7200
Fri. " 24	38	44	2946	7500
Thur. " 30	54	50	4880	6350
Fri. " 31	43	40.5	3150	8550
Mon. Apr. 3	34.5	42	1410	8500
Tues. " 4	40.5	42.5	1650	8020
Average............	43.5	47	3214	9150
Average Power Looms during 10 hr. period......			2250	
" " Fans during 12 hr. period........			456	456
" " Operators during 10 hr. period....			328	
Total..................................			6248	9606

according to the U. S. Weather Bureau statistics for a period of six years in the section of Maine adjacent to Milltown, show extreme low of 35 deg. below zero with means of about the following: Nov., 29 deg.; Dec., 20 deg.; Jan., 4 deg.; Feb., 15 deg.; Mar., 27 deg.; April, 38 deg. Considerable precipitation usually in the form of snow occurs during the winter in depths ranging from 11 in. in November, 33 in. in February to about 7 in. in April.

The writer wishes to acknowledge here the very cordial assistance in obtaining the above tests, rendered by the following connected with the mill organization: Mr. J. W. Graham, Mgr. and Mr. F. W. Boyd, Asst. Mgr., through whose courtesy the tests were made possible, Mr. Charles F. Pray, Consulting Engineer, designer of the weave shed and engineer on the equipment, who furnished specifications for the building and assisted in getting complete information on the equipment, and Mr. Windsor L. Dewar, Electrician, who assisted very ably in arranging for the tests and in caring for the instruments during the run.

VIRGINIAN RAILWAY ELECTRIFICATION

In order to increase its traffic capacity and to secure important operating economies, the Virginian Railway has decided to electrify 213 miles of its track lying between Roanoke, Va., and Mullens, West Virginia. The electric locomotives, power house, transformer stations, and other apparatus will be supplied by the Westinghouse Company. The division to be electrified crosses the Allegheny Mountains. The alternating current, single-phase system will be used.

The Virginian is a recognized leader of American railways as regards heavy tonnage operation. Built by the late Henry H. Rogers in accordance with the most modern engineering practise, it has been renowned for the excellence of its construction, the immense size of its trains and its low ton-mile costs, ever since it started operations in 1909. As a matter of consistent policy the Virginian's management has regularly increased the size of the trains with every improvement in railroad equipment, until today this railroad is operating the heaviest trains in the world and hauling them by the most powerful of steam locomotives.

With its present equipment, the Virginian is moving 7,000,000 tons of coal per annum, but this capacity is not enough to take care of the growing demands of the area served. To obtain additional capacity by still further increasing the size of the trains is no longer possible with steam operation, for the simple reason that the limit in the power of the steam locomotive has been reached.

The chief advantage of electric operation is the greater power that can be applied to each train. The largest steam locomotives now in use on the Virginian are the articulated mallet type, with twenty driving wheels and four cylinders. Three of these huge engines are used to move 5500-ton trains over the grades, but their combined power does not exceed 7000 horse power, and their speed on the grades is only 7 miles per hour. The new electric locomotives however, developing 20,000 horse power per train, will haul 9000 ton trains up the grades at the rate of 14 miles per hour, and it will be entirely practical in the future to further increase this power so that 12,000-ton trains can be handled at the same speed.

This electrification is one of the largest railroad improvements undertaken since the world war. It is undoubtedly the forerunner of many other undertakings of the same nature, because it is generally recognized that the traffic-carrying capacity of a number of our leading railroads must be increased in order to take care of the demands upon them, and that electrification is, in general, the most practical method of obtaining the necessary increase for the traffic of the future.

A feature of the electric locomotives will be the use of regenerative braking on the down grades. This method of braking will not only reduce the wear on the brakeshoes and wheels and improve operation, but will also save 15,000,000 kw-hr. of electric energy per year.

Power for operation will be supplied by a 90,000-horse power generating plant to be erected on the New river. This will supply 88,000-volt current to the main transmission line. For use on the trolley wire from which the locomotives will draw their power, this high-voltage current is to be stepped down to 11,000 volts by transformer stations placed at regular intervals along the line. On the locomotives, this is reduced to a low value for the operation of the motors.

General Considerations in Grounding the Neutral of Power Systems

BY H. H. DEWEY
Associate, A. I. E. E.
Asst. Engineer, Lighting Dept. General Electric Co.

***Review of the Subject.**—In the early days of power transmission, there was no consistent practise in respect to operating with neutral isolated or with neutral grounded. The rapid growth of transmission systems with their extensive networks soon began to show disastrous results from arcing grounds on isolated neutral systems and now most power transmissson networks have their neutrals grounded in some manner.*

The discussion of general considerations of neutral grounding is divided into two parts, that of overhead line systems and underground cable systems. He brings out the fact that while most overhead systems are grounded there is some difference in practise as to the extent to which they are grounded, that is as to whether they are grounded solidly or through resistance. Prevailing practise tends toward little or no resistance.

Attention is called to different possible methods of grounding a system and shows by diagrams the flow of short-circuit current with the different methods.

Underground cable systems are consistently operated with neutral grounded but general practise tends toward the use of resistance in neutral. General considerations as to protection from the voltage strains due to arcing grounds on cable systems are similar to overhead line systems and the author analyzes briefly the character of cable breakdowns and general effect of such breakdowns with a view to determining the importance of the extent to which a cable system should be grounded. The conclusion in regard to cable systems indicates about the same limitations as those found for overhead systems and no very good reasons are found for a distinctive difference in practise.

The paper considers the use of grounding resistors of different types and gives some cast figures to show the effect of time and current in the design of metallic resistors.

The general conclusion arrived at is that, on either overhead or underground transmission systems, high-voltage strains are more to be feared than high-current strains and that resistance to limit ground current, if used at all, should be of very low value.

CONTENTS

THE question of grounded neutral has been under discussion for many years and many papers have been written covering various phases of the subject from time to time, each with the purpose in view of presenting data tending to show the logic of the author's conclusions on the particular phase of the subject which has interested him. The general practise of the country has undergone certain changes during the past ten or fifteen years in the methods and extent in which systems have been grounded. These changes of practise have been brought about partly from the influence of individual writers' ideas as presented in the various papers mentioned and partly by an actual change in the problem due to the rapid growth of our transmission systems during that period.

In the early days of power transmission, there was little to base one's judgment upon in determining the advantages or otherwise, of operating the system with the neutral grounded. Such experiences as had been obtained by the pioneers of transmission were complicated by conflicting evidence due largely to the fact that where trouble had occurred, it was often accompanied by the presence of many uncertain factors, and no direct comparison could be made between the isolated neutral and grounded neutral arrangement.

From the beginning of power transmission in 1888 or 1890 to 1910 or 1912, it is safe to state that there was no general practise as regards the question of operating transmission systems either with grounded neutral or with the neutral isolated. During that period, transmission voltages increased at a very rapid rate, the length of individual lines for straight-a-way transmission greatly increased, and the number and length of interconnected lines forming networks handling thousands of kilowatts of power where hundreds had been handled before, presented an entirely new phase of the question.

A glance at the transmission problem of today seems to divide the question into two natural classes, that of overhead lines which have grown in extent and voltage to cover very wide areas handling large blocks of power, and that of underground transmission systems which cover smaller areas but with a much higher density of power per square mile and much lower transmission voltage.

The overhead systems generally speaking, vary in voltage from 13,200 volts to 220,000 volts and involve an aggregate of some 50,000 miles of line. There are several systems having a metallic connection of circuits extending well above 3000 miles at voltages around 44,000 volts and several systems having 1200 or 1500 miles of line at voltages of 110,000 volts or above.

The underground cable systems have an aggregate cable length of perhaps 10,000 miles and handle close to the same amount of power that the overhead lines do. An adequate discussion of grounded neutral versus isolated neutral, requires a careful consideration of the operating characteristics of the two types of systems and an analysis of the results of practical operating conditions from the early days of transmission to the present time.

Presented at the Spring Convention of the A. I. E. E., Pittsburgh, Pa., April 24-26, 1923.

Overhead Transmission Systems

It probably can be truthfully said that in the early stages of transmission practise where the extent of the systems was small and the voltage low, there was no decided difference in the results of operating either with neutral grounded or ungrounded. As they grew in extent, voltage surges began to make themselves felt over wide areas, resulting in breakdown of insulation at various points. In seeking a remedy, many engineers grounded the neutral of their generators or transformers.

So many systems were installed simultaneously and at ever increasing voltage that there was not time to make an analysis of the advantages of either plan and such practise as was shown in the development of our American systems was the result of individual engineer's ideas and experiences during a period when development was too rapid to compare notes thoroughly and to build up a practise based upon weighted judgment and experience.

It has been the natural result then, that during the years from about 1904 to 1912 or 1914, many systems were put into service, some arranged for isolated neutral and some for grounded neutral operation as well as others for what might be called a compromise between the two, that is, neutral grounded through extremely high resistance. During this period, then, it might be said that there were two schools of engineers making an impress on the practise of the country. Neither had very much past experience on which to base its judgment and their conclusions were drawn largely from theoretical considerations.

In the early days of high-voltage overhead line transmission development, certain principles of design and factors of safety of insulation were followed which results seemed later to conclude to be inadequate. Line insulators in particular showed too small a factor of safety and too short a life under operating conditions. The overhead transmission systems during the period mentioned have passed through many vicissitudes and few of the line insulators in use as far back as 1904 are still in service. We have gone to higher insulation and have vastly improved the design of porcelain insulators to make them stand up under operating conditions.

In 1912 or 1914 there were thousands of miles of overhead lines in operation on systems using isolated neutral and grounded neutral as well as some systems with the neutral grounded through high resistance. Sufficient experience had been obtained to enable engineers contemplating the design of new systems to take stock of past experience and the result of this stock taking seemed to indicate that the grounded neutral systems had certain advantages in most cases over the isolated neutral system. The evidence was not conclusive at that time and perhaps is not conclusive today, but there are certain fundamental principles that seem to be reasonably definite and most of them tend to show important advantages in favor of the grounded neutral systems.

The arguments in favor of the isolated neutral system, especially with delta connection, were that a single broken insulator would not cause a short circuit and consequent loss of service over an individual line and that the breakdown of a single transformer did not completely interrupt the service of an entire bank, as it was possible to operate with one line grounded or with two transformers out of three connected in open delta and maintain at least partial service. There was a third theoretical consideration that with delta-connected transformers, any disturbance coming in over one conductor, such as lightning or a steep wave front surge, would have its energy expended over two transformers and be less likely to cause serious damage. In the early days of transmission when the mileage and voltage were low, many systems operated for hours at a time and in some cases days, with one phase grounded and there was considerable use made of open delta connection of transformers on such systems.

It was argued that line insulators were designed to have the necessary factor of safety with full potential to ground and that while the grounding of one phase increased the strain on a given insulator to 73 per cent above normal, it should entail no hardship as the insulator was designed for continuous operation on this basis. Practise, however, showed that most grounds of this nature were not solid grounds but were accompanied by severe arcing which produced oscillations tending to build up high-frequency and high-voltage disturbances which placed the whole system under severe strain and often resulted in breakdown of apparatus at different points on the system.

As the systems grew in extent and increased in voltage, the severity of the disturbances due to these arcing grounds, became a very serious menace to service, not only from the fact that breakdowns often occurred at widely separated points on a network as a result of an arcing ground at a given point, but these disturbances resulted in the breakdown of apparatus such as bushings, transformers, lightning arresters, etc.

As the amount of power transmitted grew, the importance of isolating cases of trouble to the section of line actually in trouble, became apparent. The great exposure to lightning, varying weather conditions, etc. of these extensive systems considerably increased the actual number of unavoidable breakdowns in spite of the greatest vigilance and the question of continuity of service became more and more important as the territory served, increased, and much energy was brought to bear on the study of protection for these systems.

Up to this time, the relay situation was not all that could be hoped for but improvements were going on constantly and there was every hope that if the distribution of current during breakdowns could be predetermined, satisfactory relays for selection of trouble, would be available.

An analysis of the character of breakdowns with this in view, gave some pretty definite indications that on isolated systems the problem was an extremely complicated one. Nearly all transmission line breakdowns occur initially as the failure of some weak insulator from lightning or other cause. The current flowing in the arc caused by this breakdown, is the charging current to ground of the other two conductors of the entire interconnected system. This current may be considerable, depending upon the amount of interconnected line, but is almost entirely wattless and shows up in such an uncertain manner as to be useless for selective relaying. During the time that this arc is playing over the weak insulator, the other two phases of the whole network are subjected to the strains due to this arcing ground until a second breakdown occurs, producing a short circuit from phase to phase and causing sufficient power current to flow to trip the relays.

It is evident that the location of the second breakdown will be uncertain and one that should not have occurred if the line in trouble could have been tripped out by the relay before the arcing ground surge had time to spread the trouble. This second breakdown often occurs on an entirely different line, perhaps miles from the origin of the trouble and it is entirely within the range of experience to have several secondary breakdowns on different lines or different parts of the same line following an arcing ground at a given point. Such occurrences make selective relaying out of the question and a general shut-down of the system may well occur under such conditions.

The frequent occurrence of arcing ground troubles on isolated neutral systems led to the development of the so-called arcing ground suppressor which was brought out and advocated by Mr. Creighton and also by Mr. Nicholson, with the hope that a dead ground immediately placed on the phase in trouble would eliminate the destructive effects of the arcing ground and make it unnecessary to use relays to take the line out of service until inspection and necessary repairs could be made. The arcing ground suppressor however, was an expensive device and only a few were installed.

Another remedy for the elimination of a multiplicity of breakdowns was to ground the neutral of the circuit and thus make all initial breakdowns short circuits, which positively defined the flow of current and made possible the selective action of relays. As most systems feed their important stations by more than one circuit the loss of a line due to trouble is not prohibitive and the system of protection that has grown up on high-voltage networks has been to ground the neutral either solidly or through resistance and to make the maximum use of selective relays to cut off the section of line in trouble in the shortest possible time.

The good results obtained from grounding high-voltage networks and increasing the efficiency of protective relays has been such that the practise has extended to practically all overhead line work and the great majority of transmission line networks at all voltages from 22,000 to 220,000 volts are laid out with some plan of grounding the neutral. The usual practise is to establish a neutral by grounding the transformers at the source of power, that is, the generating station or generating stations as the case may be, employing delta-Y, step-up transformers at these stations. A definite flow of short-circuit current away from the generating stations is thus established and on straight-away transmission lines, particularly, leaves it optional as to the type of transformer connections that may be used at the step-down substations. Grounding at the generating stations and not the substations allows the use of delta-Y, step-down transformers at the substation, thus establishing the neutral point at the source of power for the secondary network emanating from these substations. This general practise may be followed on to the ultimate distribution system in several steps if desirable, each network in itself having its neutral grounded at the source of power.

There has been some difference in opinion as to the desirability of several neutral grounds on an overhead network at distant points, on account of the possibility of interchange current between neutrals which may affect telephone communication. There are, however, in operation, many extensive transmission systems with neutrals grounded at generating stations as well as at many substations with little, if any, telephone interference. The normal interchange of current between neutrals is usually so small as to be negligible and there have been in fact, only a few isolated cases where telephone interference due to circulating current in neutrals, has manifested itself. The conclusion from operating experience to date, indicates that no serious telephone interference under normal operating conditions need be anticipated even though the neutral is grounded at many points.

For the effective application of selective relays on a complicated network, a calculation of the short-circuit current with its distribution as to amount, direction and source, is of great value. Such calculations are comparatively simple with only one neutral grounded but where several are involved, each contributes to the ground current modifying the amount and direction, depending upon the location of these ground points. It is sometimes very difficult to predetermine this ground current with sufficient definiteness as to allow accurate selection and adjustment of relays so that in studying the question of grounding the neutral of a system, it is well to have this point in mind and to attempt a determination in advance as to the complications that may arise from the addition of neutral grounding points.

There is a number of possible combinations both in the connections and kind of transformers that may be used for grounding a system, and the different possible locations of ground points and an analysis of some of these combinations may be of interest.

The simplest arrangement is as shown in Fig. 1, with one generating station transmitting power over a single three-phase line to a substation. In such a case, delta-*Y* transformers would be used at the generating station with the neutral grounded at this point. The substation transformers may be connected in any manner,

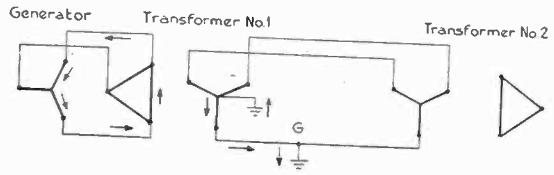


Fig. 1—Transmission System with Neutral of Generating Station Transformer Grounded

Line ground at point "*G*". Arrows indicate flow of current

if there is no generating equipment at this point, without affecting the distribution of current. In such an arrangement with the ground at *G*, the flow of current will be in one conductor only, direct to the ground point and back to the neutral, appearing in one phase only in the transformer and two phases only in the generator. The calculation of this current is simply taking into account the reactance of the generator, transformer and line to the ground point.

Fig. 2, shows a similar arrangement of transmission line but with the substation transformers connected *Y*-delta with the neutral grounded at the substation only. The flow of current in this case is quite different

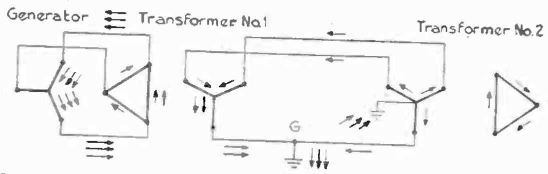


Fig. 2—Same System as Shown in Fig. 1, Except Substation Transformer Neutral Grounded

from that in Fig. 1, and will be as indicated by the arrows on Fig. 2. It will be noted that the current in all three legs of the substation transformer *Y* are equal and so far as the generating station is concerned, there are also heavy currents in all three phases; the current in the grounded phase, however, being double that in the other two phases. The reason for the equal distribution of current in all three legs of the step-down transformer will be apparent, in that, if there is current in the primary of the transformer of the grounded phase it must appear in the secondary and if it appears in the secondary, it must flow, and the only path is around the delta. This puts the same current in the other two legs which must again reappear in the primary giving balanced current in the substation transformer which acts as a grounding transformer for the system.

Fig. 3, shows a case similar to Figs. 1 and 2 with the exception that both the generating station transformer and the substation transformers have their neutrals grounded. In this case the distribution of current will be similar to a combination of Figs. 1 and 2, current flowing as in Fig. 1, directly to the ground *G* from the generating station and appearing on one phase of the transformers and two phases of the generators. There will also be a current back from the substation neutral to the ground *G*, which current will appear in all three phases of the substation transformers. The flow of current to the ground from the generating station direct and the generating station by way of the substation, will depend upon the relative impedance of the various circuits and its calculation is somewhat complicated. For a comprehensive analysis of the calculation of single-phase, short-circuit currents on complicated networks, see article by W. W. Lewis, entitled, "Short-Circuit Currents on Grounded Neutral Systems" in the *General Electric Review* for June 1917.

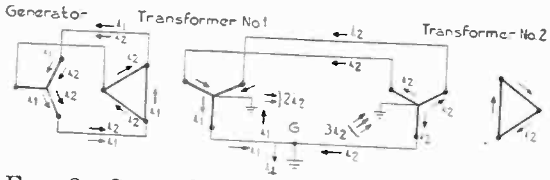


Fig. 3—Same System as Shown in Fig. 1

Neutrals of transformers at both generating station and substation grounded.

Fig. 4, shows a similar arrangement of circuits but with two substations, each having *Y*-delta, step-down transformers with their neutrals grounded as well as the neutral grounded at the generating station. The distribution of current on this system will be similar to that shown in Fig. 3, except that still greater complication due to the division of current among all three neutrals, will follow, the substation transformers having equal current in all three legs but the grounded phase in the generating station carrying the heaviest current. This again will divide up with relation to the impedance of the various circuits.

Fig. 5, shows an arrangement with two generating stations each having the neutral grounded, which introduces a combination of Figs. 1 and 3. The generating station "A" will feed direct to the short circuit. The generating station "B" will feed direct to the short circuit. Generating station "A" has a tendency to feed over the other two lines to the transformers in generating station "B" which will act similarly to the substation transformers in Fig. 3. Generating station "B" has a tendency to feed to the transformers in Station "A" and back to the short circuit in a similar manner. The distribution of current under such circumstances is problematical, depending upon the location of the short circuit with respect to the two stations assuming they are of the same size. If these stations are of different size, the relative impedances of the various paths to the short circuit will influence the division of current. The above examples will serve to call attention to the possible complication in relay equipment that may be encountered in systems grounded promiscuously. There are many other possible combinations that might be mentioned but they are nearly always only variations of the cases cited above.

It will be noted that in the suggestions above, delta-

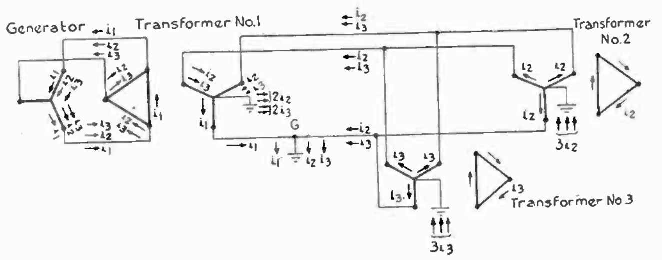


FIG. 4—TRANSMISSION SYSTEM WITH GENERATING STATION AND TWO SUBSTATIONS

Transformer neutrals at all stations grounded

Y or Y-delta transformers have been used in all cases. Transformers connected in this manner are most usually employed for establishing neutral points on a system. There are a few other combinations that have been used occasionally, such as transformers connected Y-Y with a delta tertiary winding. Where this combination is used, a neutral may be established on both primary and secondary networks, the delta tertiary winding acting as a secondary for either high-tension or low-tension Y, depending on which circuit the fault occurs.

A three-phase, core type transformer connected Y-Y

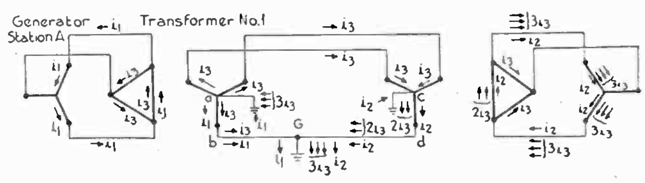


FIG. 5—TRANSMISSION SYSTEM WITH TWO GENERATING STATIONS TRANSFORMER NEUTRALS AT BOTH STATIONS GROUNDED

Current i_3 flows as shown if voltage $c\ d$ is greater than voltage $a\ b$. If $a\ b$ is greater than $c\ d$, then i_3 flows in reverse direction.

will act as a partial grounding transformer, as the interlinked magnetic circuit, allowing the circulation of flux, performs somewhat the same function as the delta which allows circulation of currents. It, however, is a rather inefficient grounding transformer as its reactance with one phase grounded is of the order of 50 per cent. That is, it will allow only about two times full-load current of the transformer to flow.

Another form of transformer that may be used to establish a neutral and allow heavy currents to flow in case of a fault to ground, is the so-called zig-zag or interconnected Y transformer which has no secondary winding as such. The winding on each core leg consists of two equal parts. The upper part of one leg is connected to the lower part of the adjacent; the three phases thus formed, being connected in Y and the neutral grounded. When a ground occurs on the line, this transformer acts similarly to a Y-delta grounding transformer as indicated in Fig. 2, equal currents appearing in all three phases. One-half the winding on each leg acts as a primary and the other half as a secondary winding, the currents in each half being equal and opposite in direction. Such a transformer is equal in efficiency as a grounding transformer, to a Y-delta connected transformer and generally speaking, will cost slightly less to build. Transformers of this type have been used to ground the neutral of systems where no Y-delta connection is available to establish a neutral point for no other purpose than for protection.

The use of the Y-Y transformers is very limited and confined almost exclusively to three-phase core type units as Y-Y connected single-phase transformers invariably have circulating triple harmonic currents between their neutral and the neutral of any other grounded transformers on the system thus tending to cause telephone interference. If there are no other neutrals, the lack of a triple frequency exciting current for these transformers tends to produce triple frequency voltage between line and ground and to put excessive voltage strains on the system. Transformers connected Y-Y or auto transformers Y-connected, perform no function as grounding transformers unless their neutrals are connected to the neutral of a generator or other Y-connected transformer which would in itself, act as a grounding transformer.

The question of the desirability of limiting the current in the neutral on overhead systems is one on which there is a considerable difference of opinion. There is little question that the greatest protection from high-voltage strains comes from the use of a solidly grounded neutral and that in the long run high-voltage disturbances are the most fruitful source of trouble to the lines and apparatus forming a part of a high-tension system. Modern apparatus is designed to withstand the magnetic and thermal effects of absolute short circuits for the time necessary for relays to clear the circuit and from this standpoint, no real disadvantage is derived from grounding solidly. The dead ground allows high enough currents to flow to make the action of the relays definite and a tendency to greater selectivity results. Where the proper relays are used and short time settings employed, the jolt to the system tending to trip synchronous apparatus out of step, is not a serious matter. In any case, many phase to phase and three-phase short circuits are bound to occur and must be provided for.

The main disadvantage claimed by the advocates of limited currents to ground, are almost entirely those of telephone interference. This is a difficult point to pass upon for all cases, as the relative exposure varies as does the relative activity of the engineers of the telephone company in different territories. There is no question that with a short circuit to ground of heavy current, the acoustic shock on an exposed telephone line is considerable and is to be avoided if possible unless there is a probability of introducing other factors that may be more serious in the long run. Any resistance in the neutral tends to increase the voltage to ground on the other two phases and if this resistance is sufficient, it may produce a semblance of arcing ground effects and the resulting operation over a period of time may cause more acoustic shock trouble than would be the case with a solidly grounded neutral system.

There are different methods employed for limiting the ground current, such as neutral resistance, grounding only one transformer of limited capacity or by the use of a small grounding transformer bank. The grounding resistance for high-voltage transformers is an expensive device and requires considerable attention

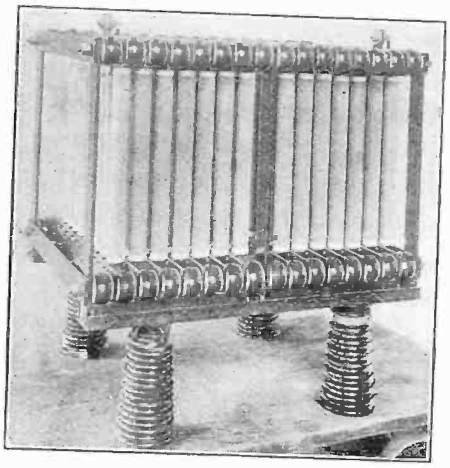


Fig. 6—Neutral Grounding Resistance for 45,000-Volt Service

and maintenance. Various types of resistance have been used such as metallic grid or wound tube resistors, water resistance, concrete and graphite columns, etc. The most satisfactory resistance, however, is either the grid or tube type. Fig. 6 shows a 45,000-volt neutral grounding resistance of the tube type designed for two-minute duty. The individual resistance tubes are insulated by porcelain between sections and post type porcelain insulators to ground. This completed resistor is insulated for line to neutral voltage and is not only very costly to build but requires considerable installation expense from the fact that it takes up a large amount of room and must be housed.

At the present time, the greater number of high-voltage systems are operating with the neutral solidly grounded at their important generating stations. As an example of such systems, the following may be mentioned:

Alabama Power Company, Georgia Power Company, Southern Power Company, Mississippi River Power Company, Montana Power Company and the Utah Power & Light Company and many others. There are a few high-voltage systems operating with neutral resistance such as the Hydro-Electric Power Commission of Ontario, Niagara Falls Power Company, Niagara & Lockport Power Company and Public Service Company of New Jersey and a few others. The Pennsylvania Power & Light Company, Shawinigan Water & Power Company and the Georgia Power Company operated for several years with a neutral resistance but have since taken them out of service.

The effect on methods of relaying high-voltage systems with limited ground current for the selection and isolation of faults, varies with the extent to which the current is limited.

A ground resistance is often selected of such value as to allow sufficient current to flow to trip overload relays on any feeder and in such cases the current amounts to two or three times full-load current of the largest one. There are no complications with such an arrangement and any type of relay that could be used with solidly grounded neutral, will give equally good results with such a neutral resistance. Systems using high resistance in the neutral and consequent low ground current must resort to special methods of relaying for selective action and there is usually a narrow margin of error allowable in these special cases. The overload relay has no function in clearing a fault on such a system except to back up the special selective relays in case a phase-to-phase short circuit ensues. In case of a ground on a line, the small amount of current, where a high resistance in the neutral is employed, may be indefinite in its action, due to the fact that it is a small percentage of the normal load current on the various circuits and this action is complicated by the action of charging current to ground, and it is doubtful if as positive results can be obtained as in the case where comparatively heavy currents flow and their amount and direction can be reasonably closely determined.

We have today, high-voltage systems operating up to 110,000 volts with the neutral grounded solidly in many cases and in a few cases with the neutral grounded through varying values of resistance.

It is difficult to make a comparison of the operation of any two systems with respect to the effect of any one feature. Generally, results are influenced by so many factors that equivalent continuity of service on two dissimilar systems would give little proof of the advantages of one protective scheme, over another. It is, therefore, difficult to say from the experience to date that the system with the solidly grounded neutral or with the neutral grounded through comparatively low resistance shows distinct advantages over a system grounded through high resistance in all respects. Our experience under both schemes of operation covers a wide range of voltage over a considerable period of time, but during this period of time both types of systems have been constantly increasing in capacity, in length of line and complication of network, and have been under the handicap of passing through a transition period in insulation, relaying, maintenance methods, etc., all of which upset the conclusions which might otherwise be drawn.

The generally accepted primary object in grounding the neutral of high-voltage systems is to avoid the possibility of trouble due to arcing grounds. An arcing ground produces a resonant condition, building up voltages of high value that subjects the entire system to abnormal strains likely to cause serious damage. These strains bear a relation to the character of the current in the arc, that is, whether it is lagging, leading or of high power factor. The current in the arc of an isolated system is almost entirely leading current and produces oscillations giving much more severe disturbances than will a lagging current arc of the same value. Where solidly grounded neutral systems are involved, the current in the arc is usually of comparatively high value and of very low power factor lagging. The power factor of the current in the arc is influenced by the voltage and extent of the system, the power factor being a combination of the low power factor lagging current due to the short circuit and the leading current flowing to ground from the entire system and this leading current is of practically the same value that it would be on an isolated system of the same extent. In all ordinary cases of dead grounded neutral, the short-circuit current will easily predominate. The oscillatory character of the arc will, therefore, be small in such a case.

With an extensive high-voltage system grounded through a comparatively high resistance, it is easily within the bounds of reason to expect the charging current to ground to be as high or higher than the short-circuit current when limited by resistance. Under such circumstances the arc will tend to be oscillatory and the strain on the system will approach arcing ground strains on an isolated system. We have 110,000-volt systems operating with an interconnected network of more than 1500 miles. The charging current on such a system to ground would be in the neighborhood of 750 amperes. It will be evident that a high resistance in the neutral of this system which limited the current to 100 amperes or so, would have little effect in the way of stabilizing the arc and keeping down the high-voltage strains. In addition to this, the 750-ampere charging current goes back into the system in an uncertain and variable manner and makes selective action of relays most difficult.

Above 110,000 volts we have no systems operating as yet with neutrals grounded through resistance. At higher voltage the charging current feature becomes more important for the same mileage of interconnected lines. The Japanese power systems have adopted 154,000 volts as their standard transmission voltage and several extensive networks are under construction at this voltage. It is their plan to ground the neutral through high resistance limiting the current to low value and in some cases the extent of the system will be such as to make the charging current to ground predominate. The relay problem of such a system is complicated and expensive and the safety of operation under these conditions is yet to be proved.

There are other methods of limiting the current to ground as mentioned before, such as only grounding one generating station or only part of the transformers in one generating station. With such an arrangement the power factor of the current in the arc would be of lower lagging value from the short circuit itself than in the case where the current is limited by grounding resistance. It is doubtful if a materially different result would be obtained, however. Many systems originally laid out with delta-connected transformers have since been grounded by the use of what is commonly called a grounding transformer, such as a *Y*-delta transformer or a zig-zag transformer, discussed previously. In selecting the size of such a transformer bank the amount of current required for the kind of protection decided upon, determines the bank capacity. If sufficient current to trip overload relays on any part of the system is required, the bank capacity must be such that under short-circuit conditions it allows this current to flow through its own reactance and through the reactance of lines to the grounding transformer and away from the grounding transformer to the farthest point on the system. As an example, a grounding transformer on a 110,000-volt network, would be required to furnish sufficient current to trip an overload relay on any 110,000-volt line. As an average value the normal line capacity may be taken as 25,000 kv-a. Under abnormal conditions this line might be required to carry as high as 50,000 kv-a. The overload relay settings should be something above this value, say 60,000 kv-a. The grounding transformer then should be able to pass 60,000 kv-a. equivalent current over the grounded phase. Assuming no reactance in the circuit to the grounding transformer, a *Y*-delta bank of 6000 kv-a. having 10 per cent reactance would be required, or a 4800 kv-a. bank having 8 per cent reactance. If the longest line from the substation should have a reactance based upon this 60,000 kv-a. of 10 per cent a transformer bank 10 per cent larger of the same reactance would be required.

Such a grounding transformer would give protection equivalent to a system grounded through a neutral resistance of low enough value to allow the same current to flow. If more effective grounding is desired, such as afforded by the solidly grounded neutral system through a large percentage of its generating capacity, a still larger bank must be used or a bank of lower reactance, thus allowing more current to flow.

The advantage in a high-current flowing would seem to be the assurance of a minimum increase in the voltage strain of any part of the system to ground above its normal value. A heavy current flowing from the generator tends by armature reaction to not only reduce the voltage in the grounded phase but also in the other two phases. Full-load current on the generating station flowing to ground through a circuit consisting of step-up transformer, transmission line and grounding transformer would have a fairly low lagging power factor which would have a tendency to drop the voltage of the entire system and in consequence the voltage to ground from the two ungrounded phases to a value little in excess of normal and insure no excessive voltage strains on any part of the system in case of trouble.

It has seemed to the writer that a rule to the effect that ground current at least equal to the full-load current of all the generators should flow. This would give adequate grounding protection to the system and would be a surer rule to follow than merely to allow sufficient current to flow to trip the relays. In some cases this rule would give about the same results as the method of arriving at the size of grounding transformer by a determination of the short-circuit current necessary to trip all the overload relays taking into account multiple circuits, etc.

In case the engineer determines that he wishes to create the same conditions by use of a grounding transformer as he would on a new system by the use of high resistance in the neutral, the grounding transformer would be, of course, correspondingly smaller in capacity as the requirements would be much less.

It will be evident from the foregoing discussion that the extent to which a system is grounded is usually dependent upon the relation of ground current during a short-circuit to the full-load current of the total generating capacity and not necessarily on whether resistance is used in the neutral or not. We normally speak of a system as grounded solidly if no resistance is used, but many so-called dead grounded neutral systems are grounded through such a small part of their total generating station transformer capacity as to allow less current in terms of a percentage of their total generating capacity to flow, than in some other systems grounded through resistance. The impedance from the generators to the point of short circuit is really the measure of the extent of the grounding.

Adequate grounding for the maximum voltage protection of a system will always be obtained by grounding all the generating station transformers and usually by only one half or less. The grounding of any system at its source of power through all the transformers feeding that system will give ample assurance of no arcing ground effects tending to produce high-voltage strains. There is not as a rule, much object in grounding the receiving stations, practically the only advantage being to insure a neutral point on a station normally acting as both a receiving station and generating station should this be split apart from the main system. There is in fact, some disadvantage in grounding the neutral of several substations fed from the same line or network as a ground at any point on the system draws short-circuit current from every one of these as illustrated in Fig. 4, tending to trip their overload relays or blow their fuses as the case may be, while there is no reason why these stations should be involved in the short circuit at all except for a slight dip in voltage on one phase.

Another method of neutral grounding is by use of a reactance coil between neutral and ground. Such a reactor when designed with an ohmic value such as to allow a current to flow equal and opposite in phase to the charging current to ground of the entire line on which it is connected, is called a Petersen Coil. Papers are being presented at this meeting by Mr. W. W. Lewis and Messrs. J. M. Oliver and W. W. Eberhardt, discussing the action of such a reactor and some operating results from its use. It is probable that such a coil has a very limited field of application and that on comparatively small low-voltage systems or very short lines up to perhaps 110,000 volts where the charging current is of low value and a reasonable percentage of error in tuning will not be likely to allow sufficient current to flow over the insulator to maintain an arc.

Cable Systems

The practise in grounding underground cable systems which are usually supplied direct from the generators without the interposition of transformers has in the main, been somewhat different from the practise on overload transmission systems. The greater number of such systems are operating with the neutral grounded as is the case on overhead lines but a much smaller proportion are operating solidly grounded. It has been quite common practise on such systems to use a small amount of grounding resistance designed to limit the fault current to a value calculated to trip overload relays. A few are operating with solid grounds and a few with comparatively high resistance but the latter are so few in number as to require little comment. No difficulty from telephone interference need be provided for and the object of extremely low fault current being absent accounts for the difference in practise in this respect as the same difficulties are met in selective relaying from the low short-circuit current complicated by high ground charging current.

The most usual method of grounding the neutral of an underground system is to ground one generator through a resistor at each generating station, provision being made to ground any one unit at a time for the sake of flexibility. This practise grew from the fact that in the early days generator wave shapes differed widely and large third harmonic currents were likely to circulate between neutrals if more than one unit were grounded at a time. Modern generators have only a slight third harmonic and such circulating currents will be negligible in most cases. There is, however, no great object in grounding all the generators in a station where a resistor is used as in most cases one unit can provide all the short-circuit current that can pass through the resistor.

Underground cable systems have grown in extent and amount of power handled at a rate that is comparable with the growth of overhead systems and there is a marked tendency just at this time for even more rapid growth. The generating stations being constructed by the larger companies are making the distribution of this power more and more difficult to handle and the voltage of cable distribution is increasing at a rapid rate. At this time, there is a considerable amount of 22,000 to 24,000-volt cable in operation and some at 26,400 volts and one or two installations in the United States of 33,000-volt, 3-conductor cable. There are also one or two installations of 66,000-volt, single-conductor cable being seriously considered. Abroad they have been operating 33,000-volt, 3-conductor cable for sometime, have a 50,000-volt, 3-conductor system about to go in operation and two or three 60,000-volt, single conductor cable systems working. In all of the higher voltage cable installations the neutral has been grounded and up to date, everything above 26,000 volts, has had this neutral solidly grounded. Grounding in this manner definitely insures a limitation of the voltage strain to ground, during faults, not exceeding the leg voltage, which in the present state of the art at least would seem to be extremely desirable.

There seems to be a preponderance of evidence from operation of underground cable systems to indicate that practically all cable faults occur initially as breakdowns from one conductor to the sheath rather than from conductor to conductor. The limitation of the ground current thus caused to flow by means of resistance in the neutral of the generator or transformer feeding the system and the use of selective relays with extremely short time setting gives a good chance of clearing the trouble before the fault can develop into a phase-to-phase short circuit. Of course the greater proportion of underground cable troubles have developed in the the cable joints rather than the cable itself and there is probably considerably greater tendency for such breakdowns to go from conductor to conductor in the joint than in the cable itself, so that we are probably getting a large number of short circuits on our cable system that are not limited by the neutral resistance.

In higher voltage cable such as 26,400 or 33,000 volts, it is problematical as to whether cable breakdowns from conductor to sheath may not develop so rapidly as to produce phase-to-phase short circuits before the switches can open on both ends of the cable even with the minimum time of operation possible with relays. If this proves to be the case the advantage of neutral resistance for limiting the current will be lost and it is probable that better operation will follow from dead grounding of such systems.

Many of the systems now in operation have been laid out for radial distribution and there is a marked tendency toward the use of reactors to limit the current that can be fed into a short circuit on any cable. With such an arrangement it is common practise to use reactors of about 3 per cent reactance based on the rating of the table. Generating stations of the large capacity now becoming general are not seriously jolted by a short circuit of even 33 times the capacity of a given feeder, especially as the use of bus reactors to partially segregate the station are in quite common use. This again probably precludes the necessity of neutral resistance to limit the short-circuit current.

Several recent large generating stations have been built with a radically new bus arrangement generally referred to as "isolated phase" construction. The main object in such an arrangement is to preclude the possibility of a bus short circuit as all parts of each phase are isolated from the other two phases. The only way in which a short circuit can occur will be to ground and here we obtain a definite advantage from the use of neutral resistance which will limit the possible short circuit in the station to the value of current that will pass through the resistor. In such stations it is common practise to use reactors on all feeders, and in many cases reactors in the generator leads, omitting the use of bus reactors for partial isolation of sections of the station. The only manner in which a station short circuit can occur is through two simultaneous breakdowns to ground which should be an extremely rare occurrence. If neutral resistance is used with such an arrangement of a value sufficient to limit the current to that necessary to trip overload relays or to a value from 1000 to 1500 amperes, it is probable that the heaviest arc that could be expected would be of this value. If neutral resistance were not used, and the practise maintained of grounding one generator at a time, the current in this arc might be as high as 25,000 or 30,000 amperes to ground in some of the larger stations.

At the present time there seems to be little agreement among engineers as to the best method of grounding the neutral on cable systems. There is some tendency toward reducing the resistance in the neutral to a very low value or to leaving it out altogether. The writer hesitates to give an opinion as to which is the better method, but is inclined to think that the omission of resistance is not out of the question, from an operating standpoint, and to feel that lower voltage strains on the complete system would ensue from such a practise, for reasons similar to those discussed for overhead line practise.

Underground cable systems may be grounded in similar ways as discussed for overhead lines and the different methods have a similar influence on the amount and distribution of short-circuit current. The only distinctive difference lies in the tendency for circulating currents between neutrals of generators where it is usually of less importance than between the neutrals of transformers. It is quite general practise to wind high-voltage generators for Y connection and a ready means of grounding is thus provided.

It was shown in Fig. 5, that a delta-Y transformer at a generating station not only furnishes current direct to a fault to ground from its own generators but in addition may furnish extra current from its function as a grounding transformer from other generating stations. A generator with a grounded neutral will act in a similar manner furnishing current generated internally in the ground phase and also extra current coming from other ungrounded neutral generators. This current flows from the ungrounded neutral generators to ground on the phase in trouble and returns through the neutral of the grounded neutral generator and thence back over the other two phases to the ungrounded neutral generators. (See Fig. 7).

Should it be impracticable or undesirable to obtain a neutral ground by the direct grounding of generator neutrals, the system may be grounded through *Y*-delta transformers *Y*-*Y* transformers with tertiary delta, zigzag connected transformers, etc., as in the case of overhead systems and the calculation of the rating of such transformers would follow the same general method as outlined.

The effect of different methods of grounding the neutral of a cable system on the function of various types of relays is similar to that on overhead lines although

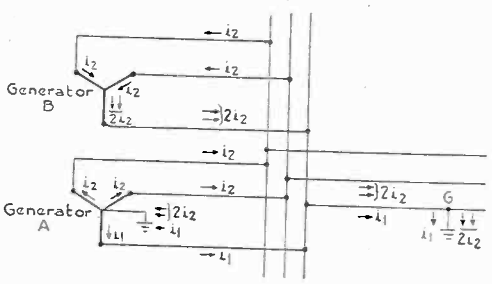


FIG. 7—TWO GENERATORS IN MULTIPLE, NEUTRAL OF ONE ONLY GROUNDED

Line ground at "*G*". Current flows to line ground from both generators, as illustrated.

there are in use in some cases certain relay schemes on underground networks not generally considered applicable to overhead line use.

Overload relays on radial feeders are used very extensively and are only affected by the method of grounding to the extent that sufficient current must be available to cause them to trip with a fault to ground. For this purpose provision is usually made in grounding for a current of two or three times the rating of the feeder. As an alternative scheme for radial feeders residual current relays are sometimes used in which case lower ground current is possible as residual current relays may be made more sensitive and set to trip at a lower current.

Relay schemes such as the Merz-Hunter or Cole scheme using split conductor cable for differential protection or using pilot wires, are peculiarly applicable to cable systems and are only affected by the method of grounding by the relation of the sensitiveness of their setting to the current available in case of a fault to ground. While it would seem that lighter ground currents would be possible with these relay schemes, it is probable that more accurate and consistent results would be obtained by working with heavier currents with more available energy for the relays.

Relay schemes such as the case of balanced current relays at the source of power and directional relays at substations require practically as much current as overload relays for selective action.

It has sometimes been argued that higher resistance could be used to ground the neutral of a cable system than a high-voltage overhead line system for the same protection against voltage strains, on the basis that a large amount of energy is stored in the electrostatic capacity of the latter system which tends to produce an oscillatory arc when discharged to ground. Such an argument can hardly be substantiated as the electrostatic capacity of a cable system is much greater at the same voltage than an overhead line system. A 13,200-volt, three-conductor cable at 60 cycles has a charging current per mile to ground of about one and eight tenths amperes, while a mile of 110,000-volt line at 60 cycles has a charging current of only about one half an ampere. It is evident that a 60-cycle system consisting of 13,200-volt cable of the same total mileage as a 110,000-volt overhead line system discharged to ground, would have more than three times the amount of leading current in the arc and a consequent greater destructive tendency.

The presence of the high charging current in an arc from conductor to sheath in an extensive cable system tends to nullify the effect of an unduly high resistance in the neutral for the purpose of limiting the current to a low value, as the charging current does not return through the neutral and hence is not limited by it. A 13,200-volt, 60-cycle cable system with 600 miles of cable would have a charging current to the sheath of over 1000 amperes and on account of the indefiniteness of its path in the system tends to make relaying unreliable. Such a large leading current is almost sure to produce a destructive oscillatory arc unless the short-circuit current combined with it, is of high enough value to stabilize it.

The relay protection of generators is influenced to some extent by the method of grounding the neutral of the system. As units are becoming so large and represent such a heavy investment, it is important that an adequate relay scheme be employed to preserve them from excessive damage resulting from electrical breakdown. It is necessary to open the oil circuit breakers, disconnecting them from the bus and to open their field switches, as well, in the minimum possible time after a breakdown to prevent excessive burning. The relay scheme almost universally employed is to use sensitive quick acting relays, differentially connected to current transformers in the neutral and line end of each phase. A breakdown to ground causes current to flow back through the neutral current transformer and not through the line current transformer, thus producing differential current to operate the relays. Should such a ground develop close to the neutral end of the winding, this unbalance will be small and if limited by a neutral resistance of high value may delay the action of the relays and extend the damage to the generators.

The most usual type of neutral resistor used for grounding generator neutrals consists of the grid type

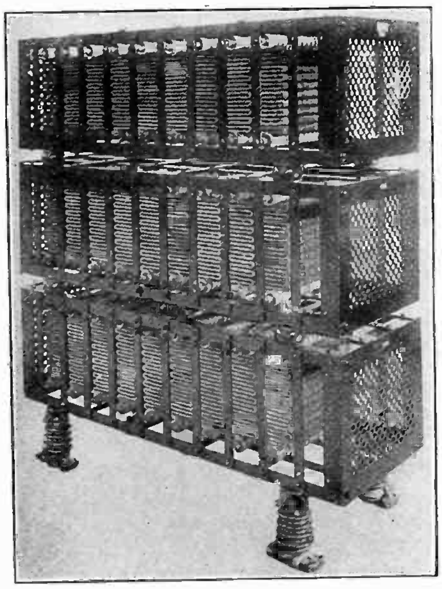


Fig. 8—Neutral Grounding Resistance for 13,200-Volt Service

similar to Fig. 8. All parts are of standard construction in general use for starting resistors for induction motors and show a high efficiency as to space, first cost, reliability and minimum of maintenance cost. Such resistors can be safely operated for short time duty at temperatures up to 400 degrees cent. and thus absorb a great amount of energy for the space taken up. When

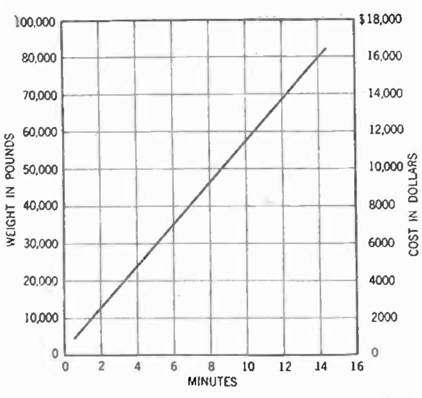


Fig. 9—Relation of Weight and Cost to Duty in Time of a 1200-Ampere, 5-Ohms, 13,200-Volt Resistor

t is realized that a 1200-ampere, 6.3-ohm resistor in the neutral of a 13,200-volt generator must absorb 9100 kw., the importance of working materials to their limit, will be apparent.

A factor of great importance in selecting a neutral resistor is the length of time to be specified for safe operation. The size, weight and cost of such a resistor increases very rapidly with increase in the time for which it is designed. Curve Fig. 9, shows the relation of cost and weight to duty in time of a 5-ohm, 1200-ampere resistor.

Practise varies widely in respect to the time specified for such resistors but the tendency is to make it as short as possible on account of the great saving in first cost. There are many resistors in operation designed for 30-second duty and they range from that all the way up to 10 minutes.

The principles on which the rating should be based are not entirely clear and the issue is usually decided on more or less a compromise basis. The primary function of such a resistor is for the purpose of limiting the current flow to ground for the time necessary to clear the short circuit. Most relay schemes are laid out with the expectation of tripping the oil circuit breakers in a few seconds at most and if they work properly a resistor designed for 30-second duty should have ample margin of safety. If the circuit breaker or relay fails to operate, either due to being out of order or unforeseen distribution of current over several feeders, time must be allowed for the operator to act and 30 seconds is an insufficient time for him to locate the trouble and clear it. The assumption may be made that failure of relay operation is very remote and that in such a case the loss of a resistor may not be serious. This of course, will depend on the damage that might be expected outside of the loss of the resistor itself.

Conclusion

The author has attempted to outline the major problems that present themselves for consideration in laying out a large power system, having in mind the maximum protection feasible for good continuity of service. It is evident that future practise in the design and operation of power systems, both overhead and underground, will be with some form of neutral ground.

There are various methods of grounding in use, such as grounding Y-connected generators direct on through resistance, grounding step-up transformers direct or through resistance, the use of step-down transformers grounded direct or through resistance as well as the use of special types of transformers arranged especially for grounding purposes such as Y-Y transformers with delta tertiary, zig-zag connected transformers, three-phase core type transformers connected Y-Y, etc. all of which were discussed with the purpose of calling attention to the variations in the methods of grounding, which the author has tried to make, leads to the conclusion that effective grounding for desired results can be obtained by any of the methods outlined. The choice of method, then becomes one of convenience and economics.

The one important consideration that the author has laid the most stress on, is the question of the extent to which a system should be grounded for best all around protection to equipment and service. Systems have been loosely spoken of generally as being grounded solidly or grounded through resistance, irrespective of the fact that a system grounded solidly through a relatively small part of its total step-up transformer capacity may show less effective grounding than another system where low resistance in the neutral is used. The real measure of the extent to which a system neutral is grounded depends upon the relation of ground current flowing to the full-load current of the system.

The important function of the grounded neutral is to limit voltage strains on the system at the time of faults to ground, as experience has shown that such strains are the most fruitful source of extended interruption to service. Modern apparatus is designed to withstand the magnetic and thermal stresses of high current and modern relays will protect service under short-circuit conditions. Voltage strains, however, are difficult to predetermine and expensive to protect against and the neutral ground should be selected with this in mind.

The author has attempted to show that effective grounding for limitation of voltage strains can best be obtained by allowing comparatively heavy currents to flow which means either solid grounding of an appreciable part of the system capacity or a larger part through fairly low resistance.

It has been brought out that from the standpoint of continuity of service, which involves the protection of apparatus and equipment, the successful functioning of relays, etc., that the system with heavy ground current, has many advantages.

Development of the Large Electric Melting Furnace

BY FRANK HODSON

President, Electric Furnace Construction Co., Philadelphia, Pa.

Review of the Subject.—*The paper describes the development of the large electric melting furnace; the limitations of large electrode furnaces; the design and construction of the largest electric melting furnace ever built; the advantages of correct heat application in the large furnaces; the influence of the new Soderberg Continuous Electrode on furnace design; and possibility of using large electric furnaces as an intermediate process for the manufacture of cheap steel.*

IN speaking of "large" electric furnaces, the term must be understood to mean the size as compared to the average existing electric furnace. What was considered a very large open hearth furnace ten years ago might well be classed as small today, and in the same way what is now considered a large electric furnace may be small a few years hence.

One of the reasons hitherto against the development of large electric furnaces has been that the older system of three top electrodes does not, for very good electrical and metallurgical reasons, lend itself to multiples of three electrodes. Thus the size of such a furnace is pretty well limited by the current-carrying capacity of the three largest commercial sized electrodes that can be bought and used in steel furnaces. This limit has just about been reached at 40 tons of hot metal and three 24-in. electrodes.

Mechanically, there is no reason why electric furnaces cannot be built just as large as open hearth furnaces, and if we remove this three-electrode limitation in size, we open up a new field of design and utility for the large electric furnace.

The size of a finishing electric furnace for tool steels is somewhat restricted by the necessity of casting small ingots—as compared to say gun or armor ingots—and by the need for accurate control of pouring temperatures. This condition does not, however, apply to furnaces for cheaper grades of steel or for furnaces used as an intermediate process, say between the blast furnace and the finishing furnaces. Provided power can be obtained at a reasonable rate, electric furnaces of very large capacity can be usefully and economically employed as a feeder to smaller finishing furnaces.

The modern metallurgical tendency is toward increased size of melting furnace; this is particularly noticeable in recent open hearth plants and it is now generally recognized that handling large quantities of metal is much more economical than small—refining is quicker, metal is more homogeneous and heat losses are less.

The "Greaves-Etchells" furnace, first introduced in 1915, enables the furnace builder to double up on the number of electrodes he can use without disturbing either the electrical or the metallurgical efficiency of the furnace. Two, four, six or eight electrodes can be used, or any multiples of these numbers, so the size of the furnace is limited only by practical design and requirements. At the same time, the supply station is given a well balanced load and high power factor. Large three-electrode furnaces are subject to much greater fluctuations than the four, six or eight electrode "Greaves-Etchells" furnace and the latter furnace also meets the metallurgists objections to entire source of heat being over the charge. When all the heat is over the bath, the top layers of metal must be heated too hot in order to get the metal lying nearer the fur-

Presented at the Spring Convention of the A. I. E. E., Pittsburgh, Pa., April 24-26, 1923.

ace bottom to correct temperature. The temperature of the bath will always grade from the hottest part of the furnace under the arcs to the coldest near the lining. During melting down, when the arcs can be buried in the charge and the heat absorbed, or in small furnaces, this change of temperature is not of great importance but in large furnaces, or during refining operations, a cold furnace bottom is one of the things the melter most dislikes. Considerable money has had to be spent on such furnaces in heating up the hearths with oil or gas before putting in even a molten charge; otherwise, the metal tends to solidify and segregate out contained alloys on the cold part of the furnace hearth.

In the large "Greaves-Etchells" furnace heat is applied in three ways, entirely over the furnace—but with more electrodes—giving better heat distribution, by change of switch, through top electrodes, by the heat generated in the charge by its resistance, and underneath the charge by the resistance of the lining to the flow of current. The lining is just a solid thick magnesite or magnesite-dolomite hearth rammed and baked in over a flat copper plate lying on the shell of the furnace. There are no studs of carbon or steel coming through and it is just as solid and durable as any other basic furnace lining. The heat generated by its resistance to current is always immediately taken up by the charge. This small amount of heat generated under the charge is sufficient to prevent skulling or sticking on the furnace hearth and also gives rise to convection currents, ensuring thorough mechanical mixing of the charge, uniform temperature throughout the bath and generally overcomes one of the most serious objections to the large electric furnace. Operation of two 20 to 25 furnaces over several years has shown that these are facts, not theories.

In working out the design and system of the "Greaves-Etchells" furnace, careful consideration was given to the fact that the ideal way of heating any material is by induced currents in the metal to be heated, and following that of heat underneath rather than on top of the charge.

Data on all existing induction types of furnace were thoroughly examined and practical tests made, but it was decided on many grounds—electrical complications, difficulty of charging and changing slags, trouble with refractory linings, high cost, expert attention need on such furnaces,—that the induction furnace could not be put forward as a rugged, strong, workshop job, to compare in general utility even with the top electrode furnace. Subsequent costly failures of many types of induction furnace have verified the assumptions then made and although considerable improvements have been made recently, the induction furnace is not likely to ever be a serious competitor for standard melting.

The induction furnace not being feasible, and keeping in mind the main requirements of a new furnace, *viz.*, a balanced electrical load, higher power factor, better control of electrode arcs, less reactance, heating in the charge itself and underneath, the inventors after several years of experiment were able to put forward the "Greaves-Etchells" furnace. One of the most difficult problems was to get heat in and under the charge instead of merely over the metal to be melted. Experience with previous furnaces, notably the French "Girod" and the Swedish "Gronwall Elektrometall" furnaces, showed grave objections. The Girod furnace had a number of water-cooled steel studs projecting through the furnace hearth, and although this four-electrode furnace, in which the electrodes are all connected in parallel to the same pole of the electric supply with steel studs in the hearth, making electrical contact with the molten steel, gave better electrical conditions

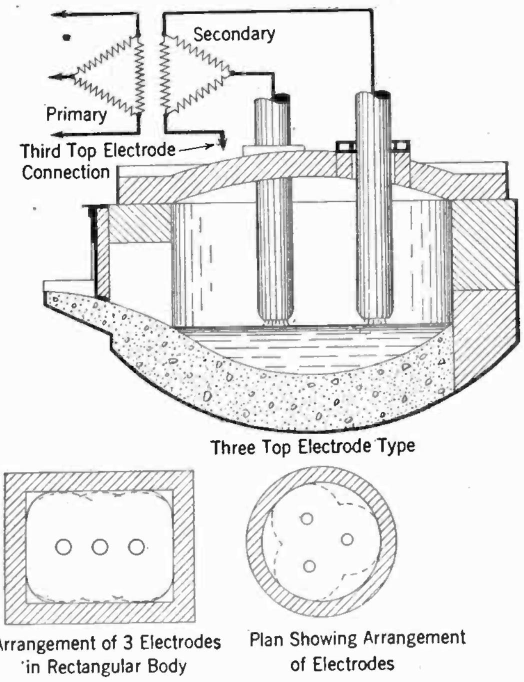


Fig. 1

than a series-arc furnace like the Heroult, yet there were serious objections in induction losses and also the fact that all the bottom heat was concentrated to four steel points in the lining. The intense local heat caused expansion and contraction of refractories around the water-cooled studs and trouble invariably followed. It was therefore decided that the Greaves-Etchells lining must be solid and not pierced by studs of any kind.

One of the objections to the "Elektrometall" furnace with bottom conducting hearth was that the furnace is really a two and not a three-phase furnace, and although by means of a Scott-connection a better balanced load might be obtained than on a three-electrode series-arc furnace, it was felt this was an unnecessary complication. Another grave objection was that the furnace bottom was bound to be thin and highly conductive, as it was not connected to any leg of the power but only to the neutral point.

The "Greaves-Etchells" furnace was designed with a thick resistive lining, and generated heat over the charge, in it by its resistance, and under it by resistance of the lining. This was achieved by attaching one of

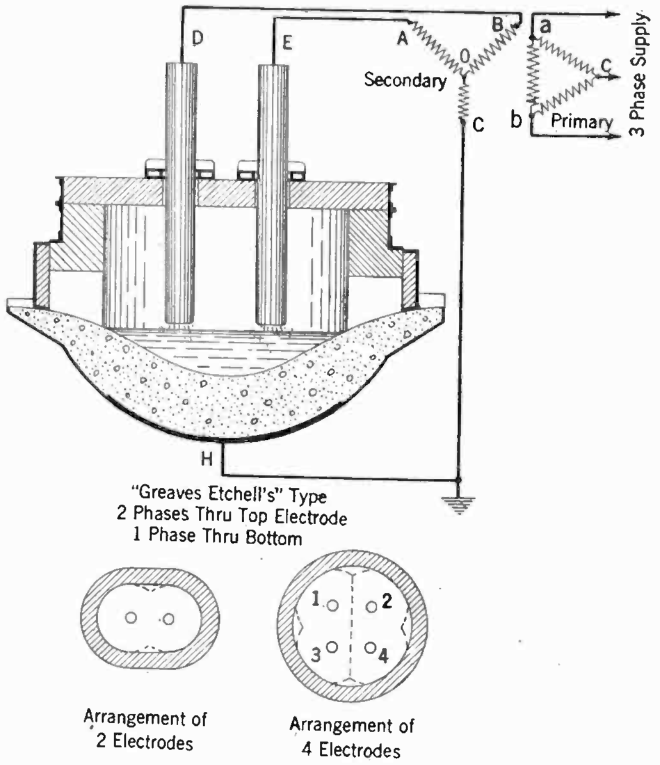


FIG. 2

the three phases to the whole of the furnace hearth. This gave the power to force current through almost any thickness of solid lining and the lining could be made highly resistive where it was in contact with the charge. At the same time, to achieve a balance in all three legs, the secondary winding of the leg connected to the furnace hearth differs from that of the upper electrodes. The metal and hearth resistance is decidedly less than the resistance of the top arcs and so by suitably designing the bottom voltages and windings a balanced load is obtained for any hearth resistance. This can be mathematically proved by vector diagrams and oscillograph curves. The designs and arrangement also permits of independent control of each of four or more electrodes and render possible the multiplication of the number of electrodes and consequently of the size of the furnace.

In starting up a "Greaves-Etchells" furnace with a cold charge of scrap iron, the electric current first arcs over the metal, then passes through the whole mass of material and heats this by small arcs at all the poor contacts throughout the mass. The electric current passes right through the steel instead of merely skimming the surface as it would be expected to do in a series-arc furnace.

The furnace as finally developed may be described as an arc-resistance furnace, which on normal operation introduces two phases of the three-phase power supply line through two or more top electrodes and the third phase through the whole of the furnace hearth. On all recently installed "Greaves-Etchells" furnaces with four or more electrodes, the system and design permit of the whole of the power being put through top electrodes or by change of position of an oil switch through top electrodes and the furnace hearth, a balanced load being obtained with either method. This arrangement gives the furnace considerable flexibility of operation, as top electrodes and high voltage can be used when melting down or when starting up cold furnace, and the top and bottom contacts when molten bath is obtained or for refining and superheating.

The general arrangement of this furnace is shown in Fig. 2, on which D and E are the electrodes and H is

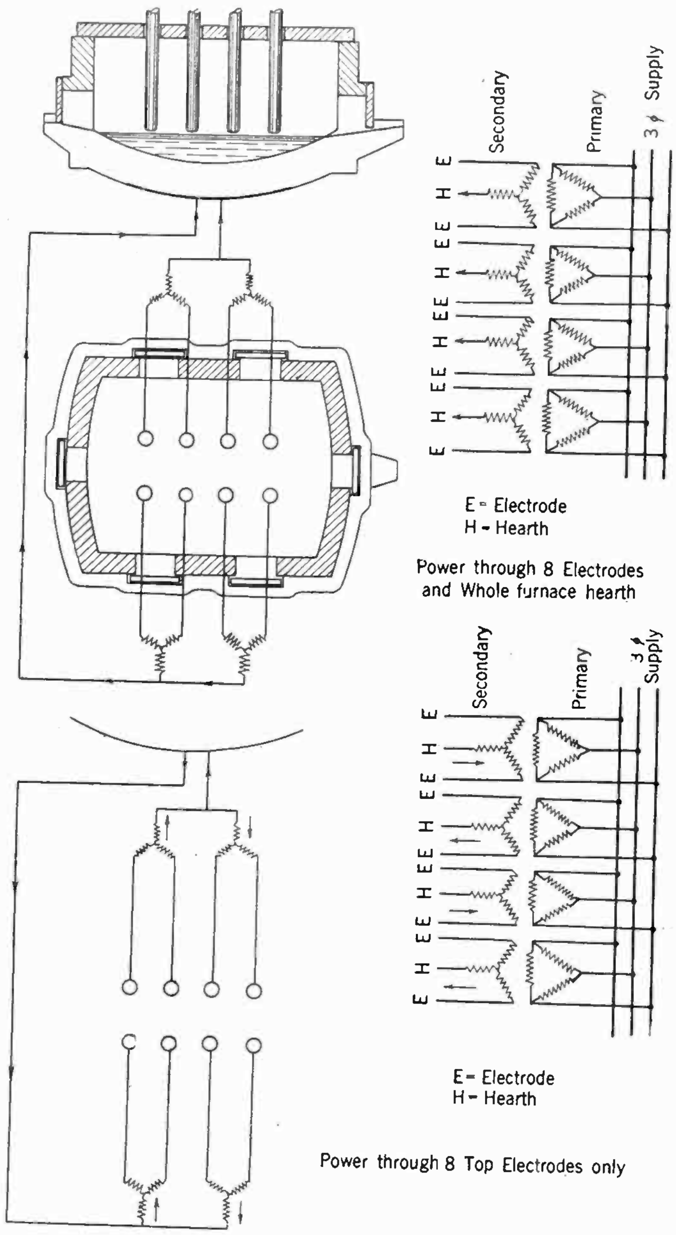


FIG. 3

a sheet of copper beneath the lining of the hearth. The three terminals, D, E and H are connected to the legs, A, B and C of a star-connected transformer system, the primary windings being in delta. If the electrical resistance of the hearth were equal to the resistance of each of the electric arcs, the terminals D, E and H could be supplied from an ordinary three-phase source of supply, the voltages between D and E, E and H, H and D, would all be equal and the molten metal F would be the neutral point of this system. As, however, the hearth-resistance is in practise decidedly less than the resistance of an arc, an ordinary three-phase supply cannot be used, and in order to obtain a balanced load on the supply lines the secondary winding, $O\,C$, must have a smaller voltage than $A\,O$ or $O\,B$. Comparing the "Elektrometall" and the "Greaves-Etchells" furnaces, to obtain a balanced load with the former the hearth resistance must be very small, while with the "Greaves-Etchells" furnace a balanced load can be obtained with any reasonable hearth resistance if the voltage $O\,C$ is suitably chosen.

It will be seen from diagrams that the "Greaves-Etchells" furnace is not limited in size or in number of electrodes, as each group of two or four, with or without hearth connection, constitute electrically a separate furnace unit, and any multiples of two or four electrodes are quite feasible. The 60 to 80 ton furnace under construction for the Ford Motor Co. has four banks of transformers each of 3000 kv-a. These are just as satisfactory and safe as four separate furnaces would be, and the power input will be so introduced that a stoppage of one, two, three or even four electrodes will not necessarily mean a furnace shut down. Each electrode will operate independently, so stoppage of arc on one electrode will not break the other arcs. The four, six and eight electrode furnaces offer more scope for correct mechanical design of large furnaces than three electrodes in a circular shell and the heat distribution from the top arcs is much better.

The fact that the number of electrodes can be increased indefinitely on the "Greaves-Etchells" furnace without electrical or electrode complications is removing some of the previously accepted ideas as to limit in size of electric furnace, and if the reader is earnestly informed that it is not safe or desirable to build electric furnaces larger than say 30 to 40 tons, it may be depended upon, it is because the design and system that would be employed is limited.

The advent of the Soderberg continuous electrode, now operating on a number of electric steel furnaces, may also have considerable bearing on future design of large electric furnaces. For the benefit of readers not acquainted with this device, it may be desirable to say that it consists of a thin metallic casing the size of the electrode to be used, into which the electrode paste or mix is dropped. This can be made up either over the furnace, or as is now done on most steel melting furnaces fitted with the Soderberg, by jointing up outside the furnace from 12 to 18 feet of casing, filling with the mix and putting into existing electrode holders, the actual baking of the electrode being done in the furnace. The cost is the mix, plus thin metallic casing, against finished extruded baked electrodes. Actual electrode consumption is considerably less, as the electrodes are protected by metallic casing and there are no broken electrodes, butt ends, etc. The significant point, however, is that the size of this electrode is not limited by the size of the largest extruding press and electrodes either solid or hollow can be built far larger than called for in any existing furnace. By use of such electrode, the design of holding capacity of the large 3-top-electrode furnace can be more than doubled, although it would still have some of the inherent electrical and metallurgical defects of such furnaces.

Fig. 3 shows a diagrammatic plan and elevation of the 60 to 80 ton furnace designed for the Ford Motor Co., River Rouge Plant, Detroit, and now under construction. It will be equipped with eight electrodes and transformers of 12,000 kv-a. capacity. The electrodes are arranged in two rows of four, and each pair and contact plate under the hearth of the furnace—which is common to all—form an electrical unit and is supplied by a 3000 kv-a., 3-phase transformer with the connections shown in Fig. 1. By means of switch, power can, if desired, be put entirely through the top electrodes. When this is done, the bottom connections are thrown in series and consequently no current can

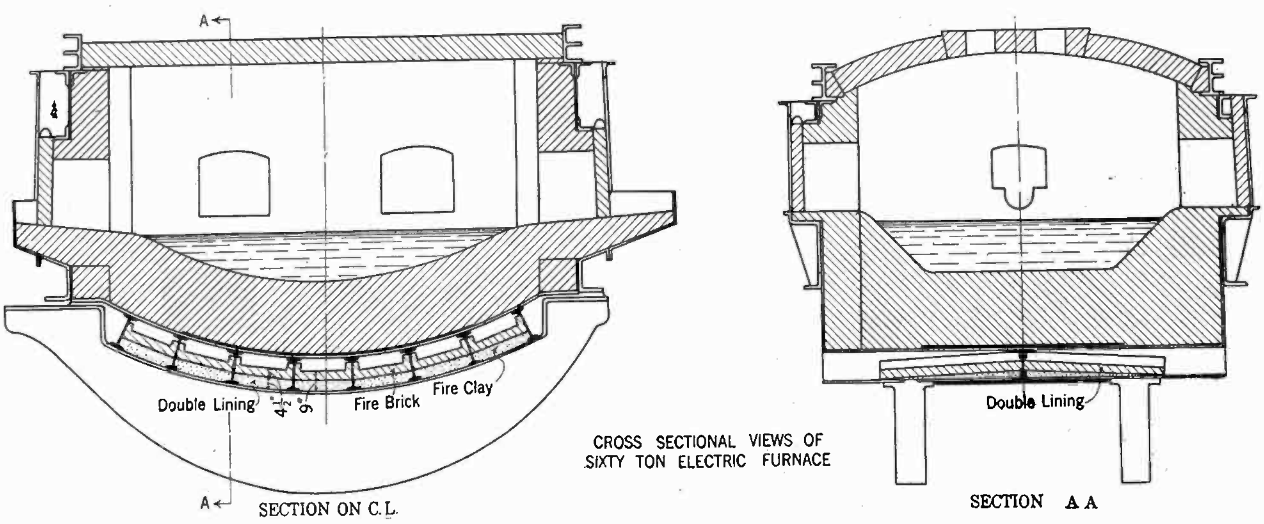


Fig. 4

flow through the hearth. As the additional current which would ordinarily flow through the hearth is distributed over the transformers and thence to the electrodes, the efficiency of the furnace is not altered and a balanced load is still maintained.

The two diagrams illustrate the relations obtained in the primaries of the transformers when operating with top electrodes only, or with top and bottom connected.

This furnace therefore has a much greater flexibility of operation than any existing furnace of large size—the top operation can be used in starting up a heat and by change of a switch heat applied underneath for getting the circulation in the bath necessary for quick refining.

The furnace has inside dimensions of 20 ft. 6 in. by 16 ft., built up of one-inch plate. Two rockers of heavy cast iron section form the main supports and these are assisted by 12 inch I-beams placed 27 inch centers. The rockers are so placed that the two upright channel columns in the rear rest directly on the rocker bearings. The furnace has a double lining with air space between. Fig. 4 illustrates general design and lining. The furnace is designed on open hearth lines, has five doors, giving access to all parts of furnace, and tilts endwise. All doors are operated by air cylinders, having a definite stroke to prevent overtravel. Side walls of furnace are 18 inches thick and the rear wall is given a slight arch. Roof bricks are 12 inches thick, but are thickened somewhat around the ports.

The special electrode economizers developed by the Electric Furnace Construction Co. and fitted on the existing "Greaves-Etchells" furnaces at the Ford Motor Co. will again be used on the large furnace and on the two 10-ton furnaces.

For tilting the furnace a 65-h. p. motor is used. A double spur gear reduction operates a horizontal screw, which is placed under centre of the furnace. The screw moves a nut to which are fastened two connecting rods, in turn fastened to a heavy casting bolted to beams under furnace. Screw and nut are enclosed in an oil tight housing and operate in an oil bath. Limit switches are provided to prevent overtravel.

The whole of the tilting mechanism and under part of furnace is protected in case of a run out by a double lining consisting of plate work covered with firebrick, lying under the proper furnace shell. This lining slopes from the center outwards.

The electrodes and motors are carried on a top platform above the furnace, supported by six vertical channel columns with horizontal supporting beams. These main supports are suitably tied together, braced by structural members, and covered with steel plate, on which electrode motors and gearing are placed. The electrode holders are hung by two steel chains passing over sheaves to winding drum and have insulated guide rods. This top arrangement of gearing, motors, etc., leaves the furnace body clear for metallurgical operations and enables the actual furnace shell to be designed solely for holding metal.

The furnace is designed to operate on a variety of voltages and with such heavy currents it has been necessary to pay special attention to interlacing the copper bus bars from transformers. Flexible copper strips carry current from the interlaced terminals to electrodes.

The whole of the switchboard, control equipment automatic regulators, oil switches, transformers, etc., are located under the furnace stage level and the only electrical equipment showing above furnace stage will be two control pillars fitted with vari-colored lights. The electrical layout and installation is quite unique and reflects great credit on the engineers of the Ford Motor Co. who were responsible for this.

The new plant at the Ford Motor Co. also includes two 10-ton "Greaves-Etchells" furnaces, each with four electrodes and 3000-kv-a. transformers, but no description of these will be attempted in this article beyond saying that these, like the 60-ton furnace, are so designed that they can operate either as acid or basic, with power either entirely through top electrodes or merely by change of position of oil switch with power through top electrodes and the whole of the furnace hearth.

The furnace hearths are quite solid, with no studs, water cooling or embedded electrodes; the whole of the hearth acts as a huge electrode if power is put through it by the switch arrangement previously mentioned.

The operation of the Ford furnaces will, in the writer's opinion, mark a new advance in the science of steel making and prove that the scope of the electric furnace is not confined to small melting furnaces for high grade steels but can economically be an essential part of the process of making all steel.

TESTS OF RADIO RECEIVING SETS

During the past two years, the Bureau of Standards has been developing methods for testing radio receiving sets, and has tested a number of different types. The results of this work are given in a series of letter circulars most of which are still in preparation.

The first of this series, designated as Letter Circular 90, "Tests of Radio Receiving Sets, I" has recently been issued. This circular describes tests of regenerative sets using electron tube detectors of the type intended for the reception of continuous wave signals from arc transmitting stations on wave frequencies down to 60 kilocycles, wave lengths up to 5000 meters.

Because of its interest in the reception of crop, market, and weather reports by radio, the Bureau of Agricultural Economics of the Department of Agriculture has assisted in this investigation.

A limited number of copies of these circulars are available and will be sent to those directly interested in this subject on application to the Bureau of Standards.

Experimental Determination of Short-Circuit Currents in Electric Power Networks

BY O. R. SCHURIG
Member A. I. E. E.
General Electric Co., Schenectady, N. Y.

Review of the Subject.—*No means has yet been discovered whereby the abnormal rise of current occurring during short circuits is avoided. Protection against its destructive effects remains, therefore, a subject of major importance. Among the problems requiring short-circuit current determinations, the following are the chief ones:*

(1) Selection of oil circuit breakers of the required interrupting capacity.

(2) Determination of the size of current-limiting reactors.

(3) Determination of relay settings in relay systems depending on selective action from over-current and directional relays.

(4) Calculation of mechanical stresses in the structural elements of apparatus subject to short-circuit electromagnetic forces.

Each of these problems requires the knowledge of the magnitude of short-circuit currents; relay problems frequently require, in addition, the relative phases of currents and voltages at different points of the system during short circuits; in item (4) above the wave-form of the short-circuit current sometimes has to be considered. The available information on the latter subjects, i. e. on phase relations and on wave form during short circuits is relatively meager, probably because it has been required in special cases only. Nevertheless, the demands for these data are increasing—on account of both the tendency towards increased sensitiveness of protective devices and the rapid increase in the magnitude of the short-circuit currents to be handled—and it will be worth while, therefore, if this added information is obtained. This paper is confined to the problems of the determination of the magnitude of short-circuit currents.

The magnitude of short-circuit currents depends on a multiplicity of factors which have been enumerated and dealt with in other publications.[1] *When the impedances of all the circuit elements affected by the short-circuit are known together with the current-time decrement characteristics of all machinery capable of supplying current to the short circuit,*[2] *the problem of short-circuit-current determination resolves itself into one of current division in a given network of electrical conductors under given electromotive forces.*

In the following paper, the comparative merits of three methods—calculation, a-c. test, and d-c. test—of determining short-circuit currents in networks are briefly discussed. Two d-c. experimental methods applicable to the "short-circuit calculating table" are analyzed in detail. The accuracy of its results, by both methods, is obtained for a variety of circuit conditions. The proper field of use of the short-circuit calculating table, and the best method of its application are determined.

1. See Bibliography No. 1, 2.
2. See Bibliography No. 1, 2, 3.

Introduction

SHORT-CIRCUIT currents in networks may be determined by calculation from the circuit constants and the connection diagram, or by tests with an experimental circuit equivalent to the system under consideration. The calculations for complicated networks by the elementary procedure using Kirchhoff's law without employing simplifications or mathematical shortcuts are extremely lengthy and not practical. Although the complications are reduced by the use of circuit transformations and by mathematical methods,[3] test methods in many cases give quicker results of sufficient accuracy for routine short-circuit-current determinations.

The most obvious test method is that in which all the essential elements in the system under consideration are reproduced in a miniature system in true proportion. This kind of test calls for a miniature a-c. system. The chief disadvantages of this type of a-c. test system are due to the necessity of both resistor and reactor units and to the limitations of the low-range a-c. meters: the miniature apparatus has to be either of relatively large current rating to accommodate the available a-c. instruments and thus becomes quite expensive, or delicate low-range instruments are required. These conditions have brought about the d-c. miniature line in the form of the short-circuit calculating table. Its use is based on an approximation whereby the complete a-c. system under short-circuit conditions is reduced to an approximately equivalent d-c. network. The magnitudes of the currents in the various circuit branches of this equivalent d-c. system under short-circuit are determined by test, and converted by the use of the proper factor of proportionality into the corresponding a-c. currents of the original system.

One method of employing this short-circuit calculating table is to make the ohmic resistance values in the equivalent d-c. system proportional to the reactances of the various circuit elements, *i. e.* of generators, reactors, transformers, lines, etc. This method may be called the *reactance method.*

The second method of applying the short-circuit calculating table is the *impedance method,* in which the impedances in all the system elements are assumed to be in phase and set up as resistances on the calculating table. This method is not in general use.

The details of construction of this apparatus and the customary method of its application have been fully described in several publications.[4]

Object

It is the object of this paper to determine the merits and limitations of the short-circuit calculating table,

3. See Bibliography No. 4, 5, 6.

Presented at the Midwinter Convention of the A. I. E. E., New York, N. Y., February 14-17, 1923.

4. Descriptions of several forms of short-circuit calculating table are found in the following articles: Bibliography No. 7, 10, 11. 12 and 13. For reference to the reactance method of short-circuit-current determination, see Bibliography No. 8, 9 and 13.

by a consideration of its proper field of use, its accuracy and the methods of its application.

Characteristics of Short-Circuit Calculating Table

The use of the short-circuit calculating table depends on the following features:

(1) Substitution of single-phase circuit for polyphase circuit.

(2) Neglect of capacity current.

(3) Neglect of phase differences arising from the inequality of the impedance angles of the various circuit elements represented.

(1) *Substitution of Single-Phase for Polyphase Circuit.* When three-phase short-circuits in a three-phase circuit are considered, the reactance values represented on the calculating table are the values per phase; the conversion of the three-phase circuit to a single-phase circuit is thus quite simple. This simple procedure is not generally applicable to problems of line-to-ground short-circuits on grounded-neutral systems, or to single-phase, line-to-line short-circuits on polyphase circuits because the short-circuit currents are not equally divided among all the phases. In such cases it is necessary first to determine the paths taken by the components of short-circuit current. Then the equivalent reactance (or impedance) of the current paths may, in some cases, be found experimentally by the calculating table.[5] In other cases, complete solution by calculation or by a-c. miniature test is necessary. An a-c. miniature polyphase testing equipment having resistance, reactance and capacity units is described by Gray, Bibliography No. 15. The circuit constants of this system are substantially fixed, since it is intended for application to one power system only.

A miniature 3-phase a-c. generating and transmission system with adjustable resistance, reactance and capacity units has been constructed and operated in the General Engineering Laboratory of the General Electric Company for the solution of network problems. It is hoped that the author will be permitted to present the details of this miniature system in a later paper.

To summarize: the chief application of the short-circuit calculating table is for the solution of balanced short circuits, such as three-phase short circuits in a three-phase circuit; other short circuits, *i. e.* those with unequal currents in the various phases, require either a solution combining theoretical analysis with calculating-table tests, or complete solution by calculation, or solution by a-c. miniature test.

In this connection attention should be called to the fact that three-phase short-circuit currents are generally used as the basis for selecting circuit breakers for three-phase systems, because three-phase short circuits impose, as a rule a heavier duty on the circuit breakers than other short circuits.[6]

(2) *Consideration of Capacity Currents.* Capacity charging currents require consideration in short-circuit-current determinations in the following cases:

(a) for short circuits far remote from generating station on long lines.

(b) for line-to-ground short circuits on grounded-neutral systems when the short-circuit current is limited such as by neutral resistors or reactors, to a value comparable to the capacity charging current.

The following example will serve to illustrate item (a) applied to a three-phase short circuit on a 200-kv. line 200 miles long having aerial conductors of 350,000 circular-mil copper at 20 ft. spacing. For a distant-end short circuit, omitting the capacity current, the computed short-circuit current at the generator is about 6 per cent higher than the correct short-circuit current including consideration of distributed line capacity. For short circuits, occurring at points less than 200 miles remote from the generator,—excepting line-to-ground short circuits—the capacity current may, therefore, be neglected.[7]

For line-to-ground short circuits, the capacity current[8] is readily calculated from the physical data for the circuits involved.

To summarize: the neglect of capacity charging currents introduces errors smaller than 10 per cent for three-phase short circuits occurring less than 200 miles remote from the generator. For line-to-ground short circuits the capacity current is sometimes a considerable part of the total short-circuit current, and is determined by calculation or by a-c. miniature test.

(3) *Consideration of Phase Differences.* When a system having circuit elements of dissimilar impedance angles is represented on the short-circuit calculating table errors are encountered, because scalar quantities only can be used on the table. The error due to this approximation will be considered first with the aid of several examples taken from typical circuits. In addition to these examples, calculated data are presented. The latter data cover a wide range of circuit constants, including not only those of the more common types of circuits but also those of special and extreme cases. In all the cases considered, the accuracy of the reactance method and of the impedance method for short-circuit calculations was determined—either by test or by calculation.

In the following examples, three types of systems may be considered:

Systems of aerial conductors

5. See W. W. Lewis, Bibliography No. 14.

6. See discussion by E. G. Merrick, A. I. E. E. Trans. 1918, pp. 153-154.

7. Short-circuit-current data on long aerial lines, up to 3000 miles in length, are given by Lewis, Bibliography No. 17.

8. See Gray Bibliography No. 15; and Lewis, Bibliography No. 16, p. 638.

Underground cable systems

Systems having both aerial conductors and underground cables.

Sytems of Aerial Conductors. The error most readily determined is that due to the impedance angles of generators and of distribution lines. When all the principal lines affected by a short circuit have equal impedance angles, these lines may for this purpose be consolidated into one equivalent impedance of the same angle. When, furthermore, in such circuits all sources of short-circuit current may be replaced by one equivalent generator, all short-circuit currents will have the same error. Circuits of this type will be considered first. The resistance of generators, when of the order of 1/20 of their reactance, will be neglected.

The examples given apply to three-phase systems, and the resistance and reactance data are the values per conductor. Three-phase short-circuits are considered.

Example 1

Series circuit consisting of generating station, transformer bank and aerial conductors, all in series; reference kv-a. = 11,000.[9]

	Resist.[9] per cent	React.[9] per cent	Imped. per cent
Generators, total capacity 11,000 kv-a.; 6600 volts, 60 cycles, 3-phase........	..	28.0	28.0
Transformer bank 6.6/44 kv..........	0.9	4.8	4.9
Lines 44 kv., of 116,000 cir. mil copper and of 179,000 cir. mil aluminum; total resistance and reactance of lines to point of short circuit 124 miles from generating station, all lines having practically the same impedance angle..............................	16.5	31.0	35.1/62

Total impedance of all circuit elements = 17.4 + j 63.8 = 66.1 per cent.

Scalar sum of all impedances = 68.0 per cent.

Hence the error of the short-circuit current by the reactance method is indicated by the ratio $u_x = \frac{66.1}{63.8} = 1.04$, meaning that the result is 4 per cent high.

The corresponding error of the impedance method, obtained from the impedance accuracy factor $u_z = \frac{66.1}{68.0} = 0.97$, is 3 per cent low.

9. It is often convenient to express resistance and reactance in terms of the per cent voltage drop through them; *i. e.* the percentage reactance drop—frequently called briefly the "per cent reactance"— is the voltage drop, expressed as a percentage of normal voltage, across the reactance when traversed by a current due to a specified balanced kv-a. load on the circuit. If x is the reactance in ohms, kv-a. the reference kv-a., and kv. the line voltage in kv. in a 3-phase circuit, the "per cent reactance" is per cent $x = \frac{x\ (\text{kv-a.})}{10\ (\text{kv.})^2}$ (see Bibliography No. 9).

NOTE: The accuracy factor u_x is the ratio of short-circuit current by reactance method to the correct short-circuit current; u_z is the corresponding ratio applied to the impedance method.

It is seen that the error of the short-circuit current by the reactance method is not excessive and is on the safe side. The chief source of error is the resistance of the lines. It should be noted that the impedance angle of the lines is 62 deg., while that of generators and transformers is substantially 90 deg.

Example 2

A three-phase generating station with transformers supplies a 110-kv. 60-cycle aerial line. Reference kv-a. = 60,000.

	Resist. per cent	React. per cent	Imped. per cent
Generators, 60,000 kv-a. aggregate rating, total combined reactance..		12.0	12.0
Transformer unit, 13.2/110 kv., 20,000 kv-a. rating..............	1.5	19.4	19.4
Line, 110 kv., 250,000 cir. mils copper short-circuited 88 miles from station..........................	10.0	35.9	37.2/74.4

Total impedance of all circuit elements up to point of short circuit = 11.5 + j 67.3 = 68.3 per cent.

Scalar sum of all impedances = 68.6 per cent.

For the short-circuit current by reactance method,

$$u_x = 68.3/67.3 = 1.015$$

which means that the short-circuit current is 1.5 per cent high. Likewise, for the impedance method

$$u_z = 68.3/68.6 = 0.996$$

which means an error of 0.4 per cent low. The errors of the short-circuit current are seen to be negligible.

Example 3

One 60-cycle, 3-phase generating station with transformer bank; circuits affected by short-circuit: two series-connected aerial lines fed from the generating station; reference kv-a. = 25,000.

	Resist. per cent	React. per cent	Imped. per cent
Generators with transformers 13.2/88 kv. aggregate rating 43,750 kv-a., impedance components of entire station..................	0.5	13.3	13.3
Line 88 kv. No. 1/0 B & S copper, 29 miles.....................	4.8	8.1	9.5/59.4
Line 88 kv. No. 1/0 B & S aluminum, 51 miles.......................	13.9	13.3	19.3/43.8

Both lines in series, point of short-circuit 80 miles from generating station.

Total impedance of all circuit elements up to point of short-circuit = 19.2 + j 34.7 = 39.7/61.0.

Scalar sum of all impedances = 42.1 per cent.

For the short-circuit current, by reactance method

$$u_x = 39.7/34.7 = 1.14$$

which means that the short-circuit current is 14 per cent high. Likewise for the impedance method

$$u_z = 39.7/42.1 = 0.94$$

which means that the error is 6 per cent low. The somewhat greater errors in this case are caused by the following factors: The impedance of the distribution lines between the generating station and the point of short-circuit has a fairly low angle (49 deg.) and a relatively large magnitude (more than twice that of the generating station impedance); in other words, the circuit elements of low impedance angle constitute the larger part of the total system impedance. This example illustrates the accuracy of the short-circuit current by the calculating table for a fairly remote short-circuit on a system having distribution lines of an impedance angle in the vicinity of 45 deg.

Example 4

Occasionally the distribution lines of a system have dissimilar impedance angles. This condition may arise from the use of unequal wire sizes, or of dissimilar metals, or of reactors. In the example chosen, a generating station with step-up transformers feeds two aerial lines, of unequal wire sizes, connected in parallel and terminating in a common bus. The data are as follows: Reference kv-a. 15,000, frequency 60 cycles.

	Resist. per cent	React. per cent	Imped. per cent
Generators with step-up transformers total generating capacity 26,000 kv-a.	0.60	9.20	9.21
Line No. 1, 38 miles long, No. 2 B & S copper, 60 kv.	13.70	13.10	$18.95/\underline{44}$
Line No. 2, 38 miles long, No. 4/0 B & S copper, 60 kv., connected in multiple with line 1	4.25	11.80	$12.55/\underline{70}$

Short-circuit at terminal of lines.

By calculation from these data, by the customary method, the errors of the total short-circuit current and of the branch currents in lines No. 1 and No. 2 are as follows:

	Reactance Method	Impedance Method
Total short-circuit current	7 per cent high	1 per cent low
Branch current 1	24 per cent high	4 per cent low
Branch current 2	9 per cent low	4 per cent low

It is seen that the total current by the reactance method is not badly in error and is on the safe side, while the branch current No. 1, is 24 per cent high. It will be observed that the reactance method gives a high result for the branch of low impedance angle, (44 deg.), and a low result for the branch of higher impedance angle, (70 deg.), while the impedance method gives equal errors (only 4 per cent low) in the two parallel branch lines.

The results of the preceding four examples may be summarized as follows: In examples 1, 2 and 3, systems having distribution circuits of the same impedance angle were considered. The errors of the reactance method were on the safe side in all cases (*i. e.* high results); in the first two cases the error was below 5 per cent, but in the third case the error was 14 per cent because the distribution lines had impedance angles of the order of 45 deg. and impedance magnitudes amounting to as much as two thirds of the total system impedance. In the fourth example, one of occasional occurrence, parallel circuits of widely dissimilar impedance angles gave by the reactance method a permissible error for the total short-circuit current, but an error of slightly over 20 per cent for one of the branch currents. The impedance method gave low values in this case, but none more than 4 per cent in error. The conditions illustrated by examples 3 and 4 are considered in detail in the more general analysis presented later.

Systems of Underground Cables. Cables generally have lower impedance angles than aerial lines. When short circuits occur near a generating station, the impedance limiting the short-circuit current is largely due to the generators and station reactors and therefore has a large angle. The total short-circuit current, as determined by the calculating table, will then not be badly in error. The minor components of short-circuit current in the longer cable lines may however have greater errors. Similarly for remote short circuits the impedance angle of the cables may materially lower the accuracy of the total short-circuit current.

The case of a near short circuit on a cable system having No. 4/0 B & S 3-phase, 3-conductor, 15,000-volt cables, at 60 cycles, will be illustrated by the following example:

Example 5

Reference kv-a. = 40,000

	Resist. per cent	React. per cent	Imped. per cent
Generating station	0.50	16.5	16.5
Combined data for cable circuits between generating station and point of short circuit; this impedance is equivalent to that of two parallel No. 4/0 B & S 15,000 volt 3-phase cables, each one mile long	3.06	1.55	$3.43/\underline{27\text{ deg.}}$

The total circuit impedance to the point of short circuit is

$$3.56 + j\,18.05 = 18.4 \text{ per cent}$$

The scalar sum of the circuit impedances is 19.9 per cent. Hence, we have by the reactance method

$$u_x = 18.4/18.05 = 1.02$$

or an error of 2 per cent (high). Likewise, by the impedance method,

$$u_z = 18.4/19.9 = 0.92$$

representing an error of 8 per cent (low).

Example 6

In this example, the system of example 5 will be considered, but the short circuit will be located remote from the generating station, such that the combined impedance of the cable circuits between generating station and point of short circuit is equivalent to 2.5 miles of No. 4/0 B & S copper 3-conductor cable. Using 40,000 kv-a. as the reference kv-a. the data are,

	Resist. per cent	React. per cent	Imped. per cent
Generating station	0.50	16.5	16.5
Combined data for cable circuits between generating station and point of short circuit	15.3	7.75	17.15/27 deg.

The total impedance to the point of short circuit is

$$15.8 + j\,24.3 = 29.0 \text{ per cent}$$

The scalar sum of the circuit impedances is 33.7 per cent.

Hence, by the reactance method,

$$u_x = 29.0/24.3 = 1.19$$

representing an error of 19 per cent high. Likewise by the impedance method:

$$u_z = 29.0/33.7 = 0.86$$

representing an error of 14 per cent low.

Example 7

In this example, the network shown in Fig. 1 will be considered. The data given in this diagram and in Table I are miniature test data representing an 11,000-volt, 60-cycle underground 3-conductor cable system, having current-limiting reactors (giving a 3 per cent voltage drop in the cables when carrying full-load cable current) in each of the lines *A*, *B*, *C*, *D*, *E*. The cables are of No. 4/0 B & S and 250,000 cir. mil copper. Those in lines *F*, *G*, *H*, and *I* have no reactors, and therefore have low impedance angles, of the order of 26 to 31 deg. The results by a-c. test, by reactance and by impedance methods, are given in Table I, for a 3-phase short circuit at *b*. The tota short-circuit current by reactance method is 5 per cent high, that by impedance method is 4 per cent low. These errors are small because the impedance angle of the cable network from generator bus to the point of short-circuit is 56 deg. The three principal components, *B*, *C* and *F* of current fed into the short circuit have errors, by the reactance method, from 7 per cent low to 16 per cent high, the negative error occurring in *B*, *i. e.* in the path of highest impedance

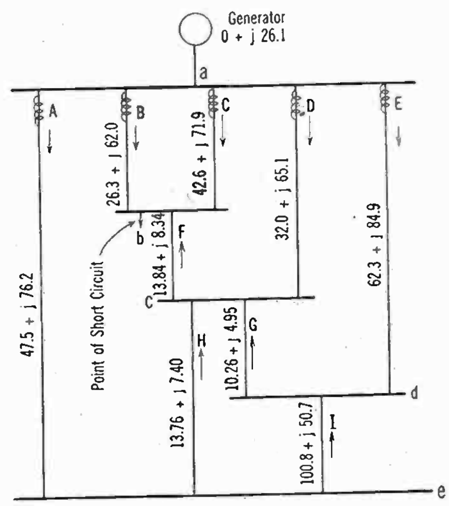


FIG. 1—CIRCUIT DIAGRAM FOR EXAMPLE 7

Short-circuit current determination. Arrows indicate direction of short-circuit current. Note: Figures opposite lines and generator represent resistance and reactance values, expressed as complex numbers; line-to-neutral values in ohms per phase. Reactance of reactors included with line impedances for lines *A*, *B*, *C*, *D*, *E*.

angle (67 deg.). The current in line *F* (error 16 per cent high) is partly dependent on reactances of lines having low impedance angles (as low as 26 deg.). Errors of over 20 per cent high, by reactance method, occur in three lines more remote from the point of short circuit. However, these lines have the lowest currents, each carrying less than 15 per cent of the total short-circuit current, and two of them are over four miles long.

The short-circuit currents by the impedance method have a maximum error of 6 per cent low. In this

TABLE I

Circuit constants and miniature test data for short-circuit current determination in cable network of Fig. 1. The data given represent in true proportion the conditions of the actual network. The ohmic values given are 56 times the actual system values.

	Length miles	Miniature circuit data			Miniature a-c. test short-cir't. current amperes	Reactance Method		Impedance Method	
		Resist. ohms.	React. ohms	Impedance ohms		Short-circuit current	accuracy factor	Short-circuit current	Accuracy factor
gen.		——	26.1	26.1 /90	9.70	10.13	1.05	9.27	0.96
A	3.1	47.5	76.2	89.8 /58.1	1.30	1.550	1.19	1.218	0.94
B	2.1	26.3	62.0	67.3 /67.0	2.96	2.765	0.93	2.875	0.97
C	3.3	42.6	71.9	83.5 /59.3	2.37	2.385	1.01	2.320	0.98
D	2.4	32.0	65.1	72.5 /63.8	1.88	1.99	1.06	1.761	0.94
E	4.1	62.3	84.9	105.3 /53.7	1.17	1.438	1.23	1.098	0.94
F	1.1	13.84	8.34	16.20 /31.1	4.28	4.98	1.16	4.075	0.95
G	0.7	10.26	4.95	11.4 /25.7	1.21	1.507	1.24	1.145	0.95
H	1.0	13.76	7.40	15.6 /28.3	1.25	1.480	1.18	1.172	0.94
I	5.9	100.8	50.7	112.8 /26.7	0.05	0.069	1.4	0.047	0.94

NOTE: The reactance and impedance values for lines *A*, *B*, *C*, *D* and *E* include the reactances of cables and of the reactors in series with the cables.

example cables with reactors in series were considered jointly as a single circuit element. By this procedure the magnitude of the errors of the impedance method is reduced slightly. The results of the reactance method are, of course, not affected by this combination.

The results of the examples on cable circuits may be summarized as follows: In cable systems having cables of the same impedance angle (without current-limiting reactors), a cable impedance angle of the order of 30 deg. does not cause serious errors by the reactance method in the near short-circuit of example 5, but the error becomes nearly 20 per cent when, for a more remote short-circuit, in the same system, the cable circuit impedance is larger than the station impedance. Reactors inserted in some of the cables (example 7) cause series-parallel combinations of lines of dissimilar impedance angles giving, by the reactance method, a wider range of errors, exceeding 20 per cent in some of the longer cable lines carrying minor components of short-circuit current. The impedance method under these conditions (example 7) gives better accuracy, the errors being 6 per cent low or better. The use of reactors in all cables will, of course, tend to equalize the impedance angles of the cable circuit elements and improve the accuracy of the reactance method. More general data on the errors due to parallel-connected circuit elements of dissimilar impedance angles are given in a later paragraph.

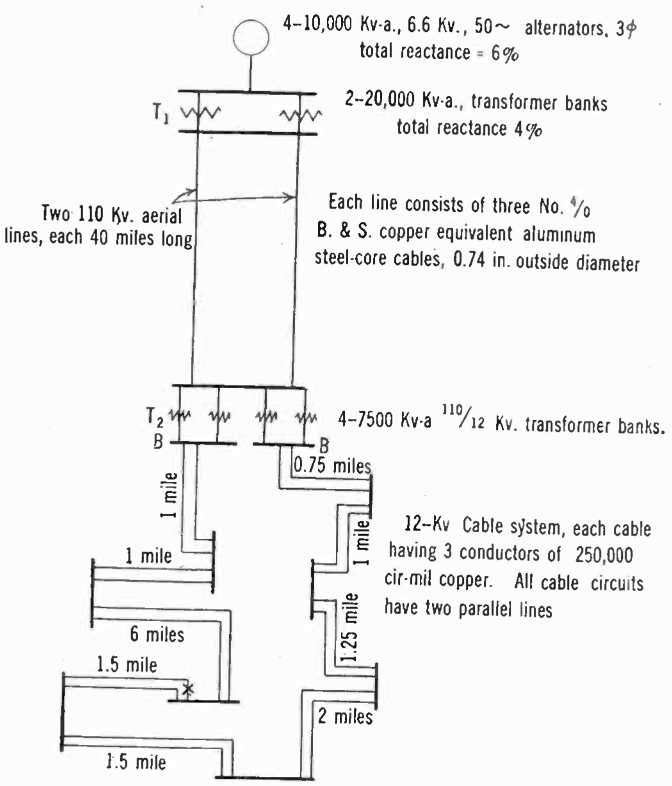


FIG. 2

Reference kv-a. for all impedance data = 20,000

Systems having both Aerial Conductors and Underground Cables: In some transmission systems energy is transmitted over aerial circuits for a number of miles and then distributed underground in cables. Such a system is that shown in Fig. 2, for example 8.

Example 8

For a reference basis of 20,000 kv-a., the system data are as follows, from Fig. 2.

	Resist. per cent	React. per cent	Imped. per cent
Generating station		6.0	6.0 $/90$ deg.
Transformers at T_1, total equivalent	0.4	4.0	4.02 $/84$ deg.
110 kv. lines, total equivalent	0.9	1.9	2.10 $/65$ deg.
Transformers at T_2, total equivalent	0.6	5.3	5.33 $/84$ deg.
12 kv. cable system from busses B B to point of short circuit x, total equivalent	6.3	3.1	7.02 $/26$ deg.

By vector addition, the total system impedance is

$$8.2 + j\,20.3 = 21.9 \,/68 \text{ deg.}$$

The scalar sum of all impedances is 24.5 per cent. Then the error of the reactance method is determined by

$$u_x = 21.9/20.3 = 1.08$$

which means an error of 8 per cent (high). Likewise the error of the impedance method is found from

$$u_z = 21.9/24.5 = 0.89$$

giving an error of 11 per cent (low). Although the cable portion of this system has an impedance angle as low as 26 deg., the total system impedance angle is 68 deg., since the circuit elements of high impedance angle prevail; accordingly, the error of the reactance method is not excessive. In this type of circuit the elements of dissimilar impedance angle occur in series connection only. A series-parallel combination of circuit elements of dissimilar impedance angles, due to cables and aerial lines, is illustrated in the next example.

Example 9

In the system under consideration, shown in Fig. 3, a three-phase short-circuit is located at a. The principal current path to the short-circuit is over line A. All the other lines may be considered as being consolidated into a single circuit K representing B, C, D, E, F, G, H, J, in combination. The impedance of K then is

$$z_k = 8.03 + j\,1.65 = 8.19 \,/11.6 \text{ ohms}$$

The combination of this impedance, together with that of A, namely

$$z_A = 1.11 + j\,2.48 = 2.72 \,/65.9 \text{ ohms}$$

is equivalent to the distribution network of Fig. 3, for a three-phase short-circuit at a. Circuits A and K are in multiple. The accuracy of the short-circuit currents in generator, branch A and branch K are as follows:

	Per cent error react. method	Per cent error imped. method
Total short-circuit current, in generator	95 per cent high	6 per cent high
Short-circuit current in line A	5 per cent low	2 per cent low
Short-circuit current in K representing B, C, D, E, F, G, H, J in combination	330 per cent high	2 per cent low

This circuit condition, while somewhat unusual, serves to illustrate the magnitude of the errors that may arise from the use of the reactance method in systems having parallel connected circuit elements of widely dissimilar impedance angles. The circuit construction of Fig. 3 has the disadvantage of giving large interchange currents in normal system operation and is, therefore, not common.

Analysis of Circuits

From the preceding examples it is seen that, for the determination of the accuracy of the short-circuit calculating table, electric power systems may be divided into two classes:

(a) those systems in which the circuit elements of dissimilar impedance angles occur in series connection only; *i. e.* all parallel connected circuit elements are of the same impedance angle; systems of this class are illustrated by examples 1, 2, 3, 5, 6, and 8.

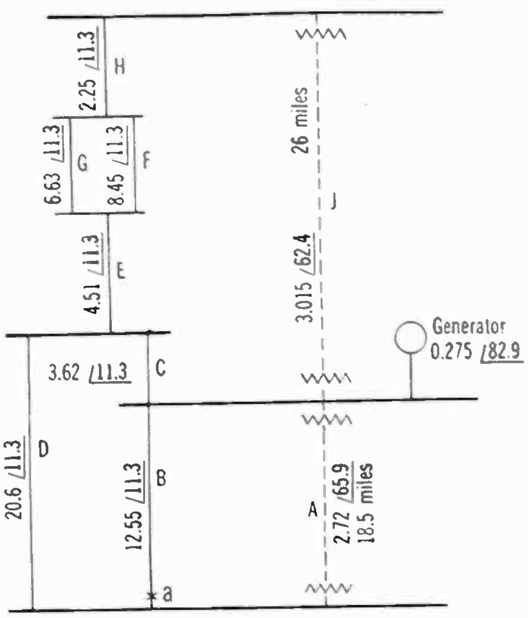


Fig. 3

Full vertical lines indicate 10,000-volt 3-conductor cables. Dotted lines indicate 50,000-volt aerial 3-phase circuits. All impedances are expressed in ohms with their impedance angles. Impedances of circuits *A* and *J* include transformer impedances.

(b) those systems in which the circuit elements of dissimilar impedance angles occur in multiple as well as in series. Such circuits are represented by examples 4, 7 and 9.

The following analysis of circuits is made on the basis of this classification.

Systems in which the circuit elements of dissimilar impedance angles occur in series connection only. The simplest circuit of this type is that of Fig. 4, in which z_G represents the impedance of the generating station and z_1 represents the impedance of the distribution network to the point of short-circuit, all distribution lines having the same impedance angle. The accuracy of the reactance and impedance methods was determined by calculation of the accuracy factors, as explained in example 1. These factors for the reactance method are plotted in Fig. 5 for a wide variety of circuit constants covering a range of variation of z_G from 0.2 z_1 to 2.0 z_1 and a wide range of variation of impedance angle of z_1 from 90 deg. (pure reactance) to 0 deg. (pure resistance). The application of these curves will be illustrated by the following case employing the system of example 6:

z_G = impedance of generating station = $0.5 + j\,16.5$ = $16.5\,/\underline{88}$ deg.

z_1 = impedance of distribution system to point of short-circuit = $15.3 + j\,7.75$ = $17.15\,/\underline{27}$ deg.

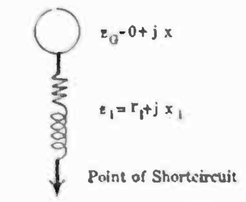


Fig. 4—Series Circuit Diagram

With practically no error, the angle of z_G may be taken as 90 deg. The ratio of z_G/z_1 = 0.96. In sheet 5, for an abscissa of 27 deg. the ordinate for $z_G = 0.96\,z_1$ is, by approximate interpolation, 1.19 (*i. e.* slightly greater than the ordinate for the curve $z_G = z_1$). The error by reactance method is, therefore, 19 per cent high and agrees with the result previously given.

When a system of this type has more than two series-connected portions, all having different impedance

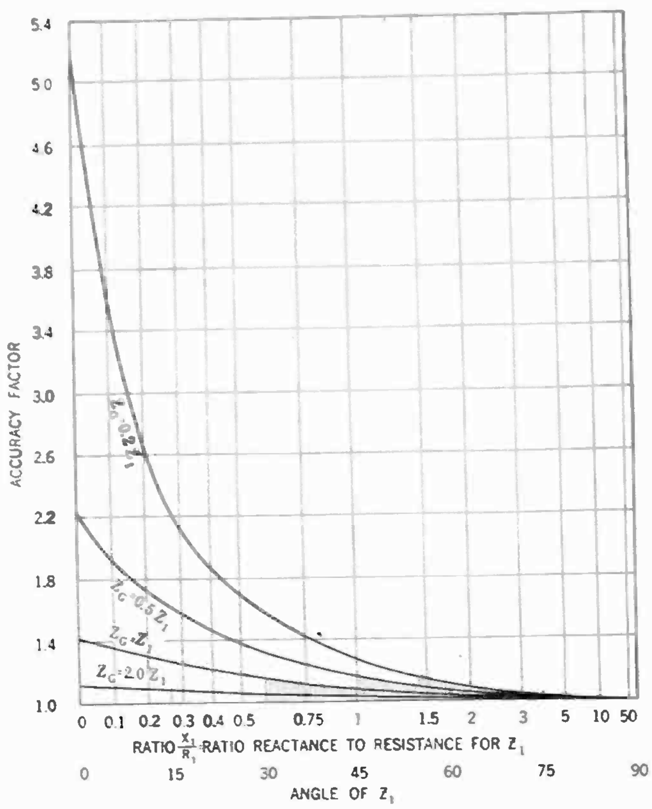


Fig. 5—Accuracy Factor

Total current, reactance method. Circuit: A generator supplying a single circuit. Variation of magnitude of Z_G and of angle of Z_1; $/Z_G/ = 0.2, 0.5, 1.0$ and 2.0 times $/Z_1/$; Z_G angle, 90 deg. constant; Z_1 angles, 0 deg. to 90 deg.

angles, the data of Fig. 5 may be applied as long as all parallel-connected circuit elements have the same impedance angle. Example 8 is of this type. This system of five major portions may be reduced to two series-connected impedances, namely:

z_G = generating station and $T_1 = 0.4 + j\,10.0 = 10.0$

z_1 = series combination of 110 kv. lines, T_2 and 12 kv. cables = $7.8 + j\,10.3 = 12.9\,/\underline{53}$ deg.

It follows that $z_G = (10.0/12.9) \times z_1 = 0.78\, z_1$

Correspondingly, the accuracy factor of the short-circuit current by reactance method is, from Fig. 5, for an abscissa of 53 deg. approximately 1.08, a value identical with that found by previous calculations.

The shaded parts of Fig. 5 indicate circuit conditions for which errors safely below 20 per cent are obtained by the reactance method in this type of system. Typical circuit conditions resulting in errors within this limit are the following:

Generating station reactance not lower than distribution system impedance and angle of the latter not lower than 30 deg.

Generating station reactance not lower than one half the distribution system impedance and angle of the latter not less than 45 deg.

Generating station reactance not lower than one fifth the distribution system impedance and angle of the latter not less than 55 deg.

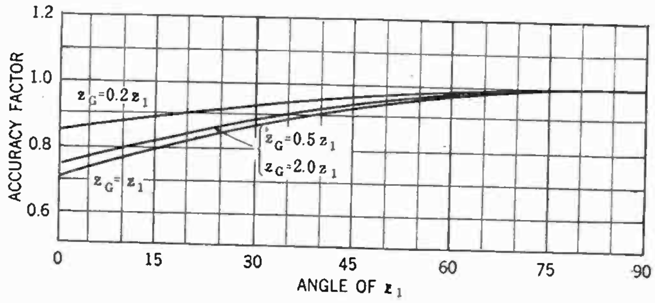


FIG. 6—ACCURACY FACTOR

Total current, impedance method. Circuit: A generator supplying a single circuit. Variation of magnitude of Z_G and of angle of Z_1; $/Z_G/ = 0.2$, 0.5, 1.0 and 2.0 times $/Z_1/$; Z_G angle, 90 deg. constant; Z_1 angles, 0 deg. to 90 deg.

These circuit conditions include the majority of aerial systems and a large number of cable systems.

The results of the impedance method for the same range of series circuit conditions covered by Fig. 5 are given in Fig. 6. The accuracy factors shown indicate low values of short-circuit current. It is seen that the errors for the customary circuit conditions are not consistently smaller than those obtained with the reactance method.

It follows from these considerations that the reactance method is preferable to the impedance method under the circuit conditions stated above (as covered by the shaded portions of Fig. 5), the former method giving values of short-circuit current slightly high, and not necessitating impedance determinations.

Application of Results for Series Type of Circuits. The determination of the error for systems within this class requires the knowledge of the impedance angle of the distribution system (62 deg. in the case of example 1) and of the ratio of generating-station reactance to distribution-system impedance. The latter ratio is approximately equal to the product of the sine of the distribution system impedance angle times the ratio of generating station reactance to distribution system reactance, the latter being obtained from the test data by the calculating table when completely connected up for short-circuit tests.

Systems in which parallel-connected circuit elements have impedance angles less than 15 deg. apart may be considered as belonging to the class of systems under consideration. It should be pointed out here that a reactor placed between a distribution line and the bus from which it is fed must be considered as a separate circuit element for a short circuit occurring in the line near its junction to the reactor. The reactor will then be in multiple with other impedances, generally of lower impedance angle, if there are other lines feeding short-circuit current from the bus towards the fault. In such cases, the results derived above for series circuits do not apply.

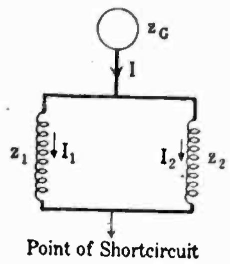


FIG. 7—PARALLEL CIRCUIT DIAGRAM

Systems having Multiple-Connected Impedances of Dissimilar Angles. The simple circuit chosen for the consideration of multiple circuits is that of Fig. 7, where z_G represents a generating station (of substantially pure reactance) supplying two parallel impedances z_1 and z_2. It frequently occurs that part of a network under short circuit consists of a number of impedances of substantially the same angle θ_1, the remaining portion having impedances of another angle, θ_2. Networks of this type may be reduced to the circuit of Fig. 7. The accuracy factors were deter-

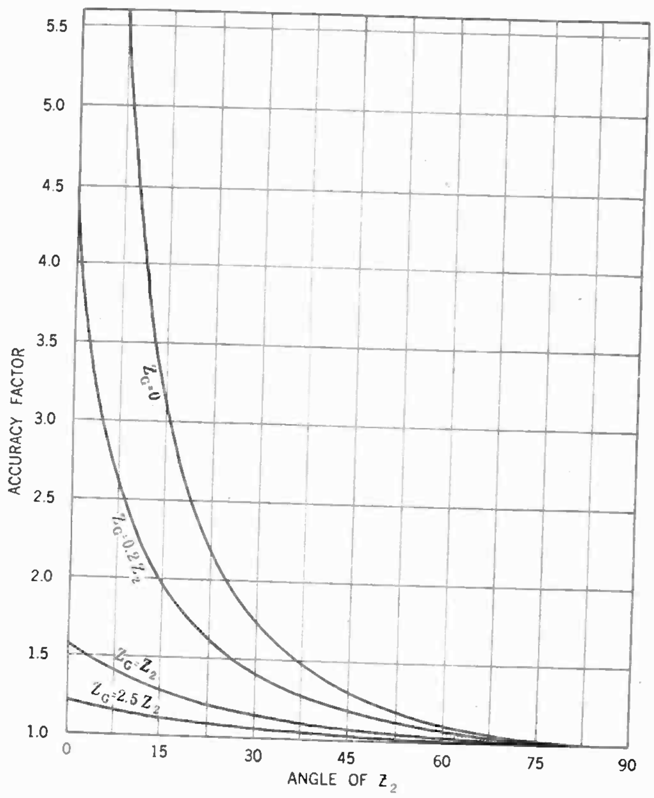


FIG. 8A—ACCURACY FACTOR

Total Current—Reactance Method. Circuit: A generator supplying two parallel branch lines. Variation of magnitude of Z_G and of angle of Z_2: $/Z_1/ = /Z_2/$; $/Z_G/ = 0$, 0.2 and 2.5 times $/Z_2/$; Z_G angle, 90 deg. constant; Z_1 angle, 90 deg. constant; Z_2 angles, 0 deg. to 90 deg.

TABLE II

Circuit Conditions Covered by Accuracy Data in Figs. 8, 9 and 10. The Data Apply to Circuits of the Type Shown in Fig. 7.

Fig. No.	Method of short-circuit-current determination	Constants of Generator and of Branch Circuits (Fig. 7)					
		z_g		z_1		z_2	
		Magnitude	Angle	Magnitude	Angle	Magnitude	Angle
8A, B, C........ 8D, E..........	React. method Imped. method	from 0 to 2.5 times z_1	90 deg.	$= z_2$	90 deg.	$= z_1$	from 0 deg. to 90 deg.
9A, B, C........ 9 D, E..........	React. method Imped. method	$= z_1$	90 deg.	$= z_2$	from 15 deg. to 90 deg.	$= z_1$	from 0 deg. to 90 deg.
10 A, B, C...... 10 D, E.........	React. method Imped. method	$= z_1$	90 deg.	$= 0.2\, z_2$	from 15 deg. to 90 deg.	$= 5\, z_1$	from 0 deg. to 90 deg.

mined by the customary calculations and plotted for the total current I and for each of the branch currents I_1 and I_2. The circuit conditions covered by the curves so obtained are tabulated in Table II. These circuit conditions include variations of magnitude of generator and branch-circuit impedances as well as variations of impedance angle for each of the branch circuits.

Reactance Method. From an examination of the curves in Figs. 8A, B, C, 9A, B, C and 10A, B, C it is seen that in a number of cases one of the branch currents is low, the current in the other branch and the total current being high. If on account of this fact the error is limited to 10 per cent above or below the correct value, meaning a maximum discrepancy of 20 per cent between branch currents, the reactance method is limited to systems with impedance angles not materially lower than 60 deg., *i. e.* systems having impedance angles ranging from 60 deg. to 90 deg. in parallel-connected circuit elements. The shaded areas in the curves for the reactance method cover this range.

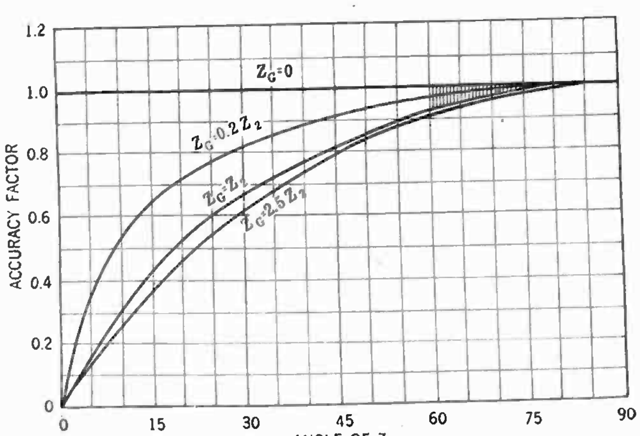


FIG. 8B—ACCURACY FACTOR

Branch current I_1—Reactance method. Circuit: A generator supplying two parallel branch lines. Variation of magnitude of Z_G and of angle of Z_2; $/Z_1/ = /Z_2/$; $/Z_G/ = 0$, 0.2, 1.0 and 2.5 times $/Z_2/$; Z_G angle, 90 deg. constant; Z_1 angle, 90 deg. constant; Z_2 angles, 0 deg. to 90 deg.

When the error limit is 20 per cent, the permissible range of impedance angles under these conditions is from 90 deg. down to about 50 deg. For wider ranges of impedance angle in parallel-connected circuit elements, the errors of the reactance method increase rapidly.

Impedance Method. The curves in Figs. 8D, E, 9D, E and 10D, E indicate that some types of systems

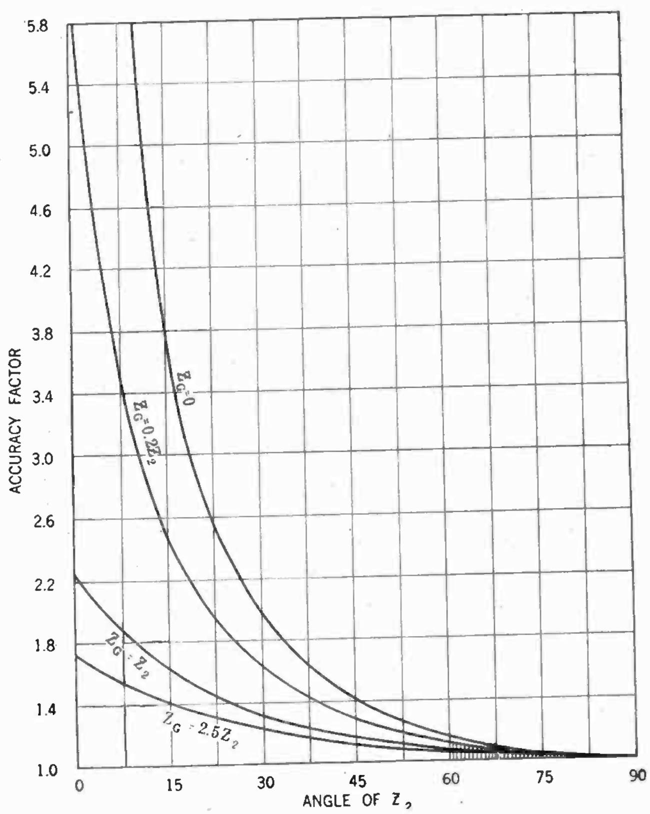


FIG. 8C—ACCURACY FACTOR

Branch current I_2—Reactance method. Circuit: A generator supplying two parallel branch lines. Variation of magnitude of Z_G and of angle of Z_2; $/Z_1/ = /Z_2/$; $/Z_G/ = 0$, 0.2, 1.0 and 2.5 times $/Z_2/$; Z_G angle, 90 deg. constant; Z_1 angle, 90 deg. constant; Z_2 angles, 0 deg. to 90 deg.

for which the reactance method gives excessive errors may be solved by the impedance method with better accuracy. The prevailing tendency of the impedance method is to give low values of short-circuit current. High values occur occasionally but these are only slightly large for impedance angles as low as 30 deg. For an error limit of 15 per cent, indicated by the shading in Figs. 8D, E, 9D, E and 10D, E, the impedance method is applicable to systems with parallel-connected circuit elements of widely dissimilar impedance angles including angles as low as 30 deg. The following example will illustrate a case of this kind in a circuit similar to Fig. 7. Let the percentage values of impedance be as follows:

$$z_G = 10 \angle 90 \text{ deg.}$$
$$z_1 = 10 \angle 90 \text{ deg.}$$
$$z_2 = 10 \angle 40 \text{ deg.}$$

where z_1 represents a feeder reactor (the short circuit

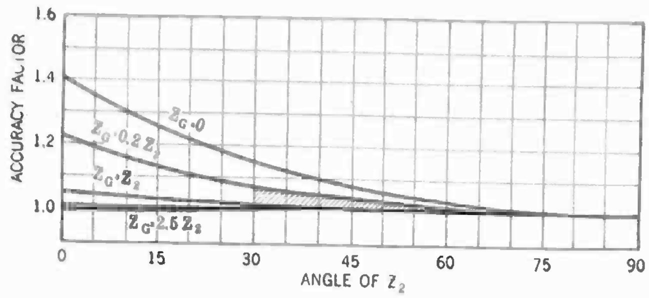


FIG. 8D—ACCURACY FACTOR

Total current—Impedance method. Circuit: A generator supplying two parallel branch lines. Variation of magnitude of Z_G and of angle of Z_2; $/Z_1/ = /Z_2/$; $/Z_G/ = 0$, 0.2, 1.0 and 2.5 times $/Z_2/$; Z_G angle, 90 deg. constant; Z_1 angle, 90 deg. constant; Z_2 angles, 0 deg. to 90 deg.

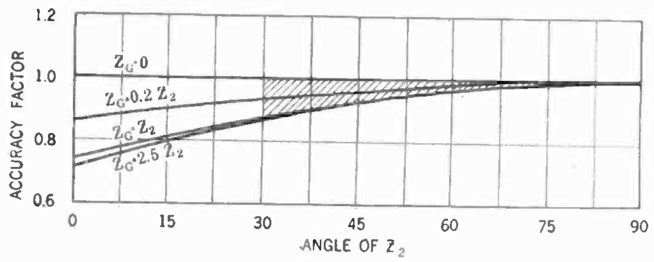


FIG. 8E—ACCURACY FACTOR

Branch currents—Impedance Method. Circuit: A generator supplying two parallel branch lines. Variation of magnitude of Z_G and of angle of Z_2; $/Z_1/ = /Z_2/$; $/Z_G/ = 0$, 0.2, 1.0 and 2.5 times $/Z_2/$; Z_G angle, 90 deg. constant; Z_1 angle, 90 deg. constant; Z_2 angles, 0 deg. to 90 deg.

being just beyond the reactor in a cable), and z_2 the impedance of the other cable paths feeding into the short circuit from the generator. By the impedance method, the accuracy factor for the total short-circuit current is 1.01 from Fig. 9D. This represents an error

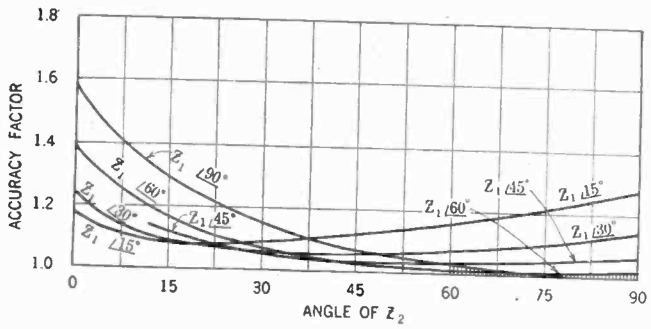


FIG. 9A—ACCURACY FACTOR

Total current—Reactance method. Circuit: A generator supplying two parallel branch lines. Variation of angles of Z_1 and Z_2; $/Z_1/ = /Z_2/ = /Z_G/$; Z_G angle, 90 deg. constant; Z_1 angles, 15 deg, 30 deg., 60 deg., 90 deg.; Z_2 angles, 0 deg. to 90 deg.

of 1 per cent high. For each of the two branch currents, the error is 8 per cent low, obtained from Fig. 9E from the accuracy factor 0.92 measured as the ordinate to the curve for an angle of z_1 equal to 90 deg. for an abscissa of 40 deg.

This discussion leads to the conclusion that for systems not covered by the reactance method but having impedance angles not materially below 30 deg. the impedance method gives errors well below 20 per

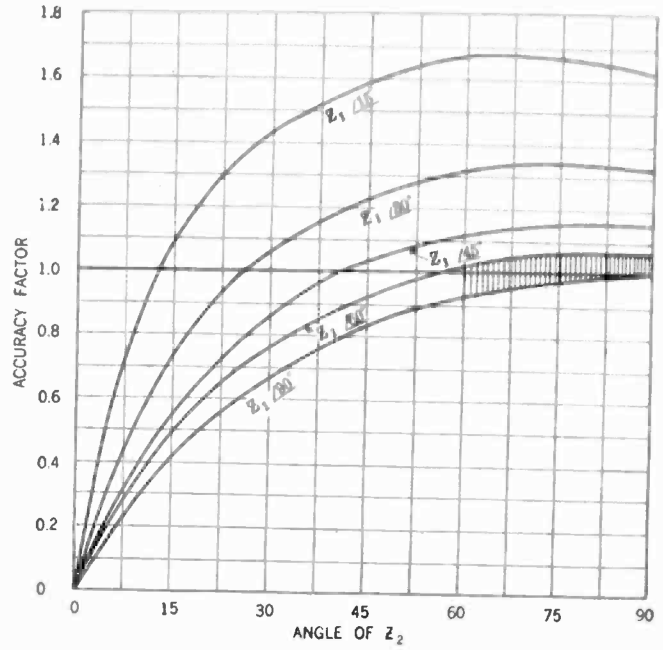


FIG. 9B—ACCURACY FACTOR

Branch current I_1—Reactance method. Circuit: A generator supplying two parallel branch lines. Variation of angles of Z_1 and Z_2; $/Z_1/ = /Z_2/ = /Z_G/$; Z_G angle, 90 deg. constant; Z_1 angles, 15 deg., 30 deg., 60 deg., 90 deg.; Z_2 angles, 0 deg. to 90 deg.

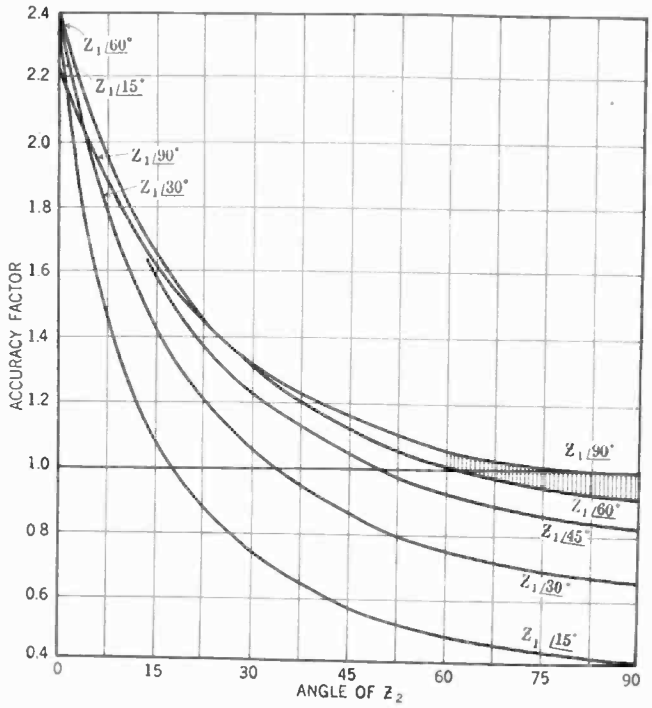


FIG. 9C—ACCURACY FACTOR

Branch current I_2—Reactance method. Circuit: A generator supplying two parallel branch lines. Variation of angles of Z_1 and Z_2; $/Z_1/ = /Z_2/ = /Z_G/$; Z_G angle, 90 deg. constant; Z_1 angles, 90 deg. constant; Z_1 angles, 15 deg., 30 deg., 60 deg., and 90 deg.; Z_2 angles, 0 deg. to 90 deg.

cent and commonly below 10 per cent. The short-circuit current values are generally low. When parallel-connected circuit elements have dissimilar impedance angles ranging from 90 deg. to angles materially below 30 deg., excessive errors may occur.

Additional Factors. While the results given above were derived from an analysis of the two simple types of circuit shown in Figs. 4 and 7, they do not apply exclusively to the simpler circuits, as will be indicated in the following.

In the discussion of series-connected circuits it was shown that the accuracy data given for the reactance

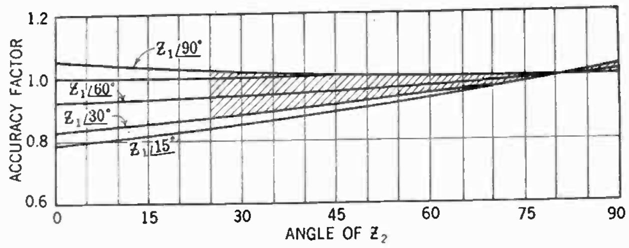


Fig. 9d—Accuracy Factor

Total current—Impedance method. Circuit: A generator supplying two parallel branch lines. Variation of angles of Z_1 and Z_2; $/Z_1/ = /Z_2/ = /Z_G/$; Z_G angle, 90 deg. constant; Z_1 angles, 15 deg., 30 deg., 60 deg., 90 deg.; Z_2 angles, 0 deg. to 90 deg.

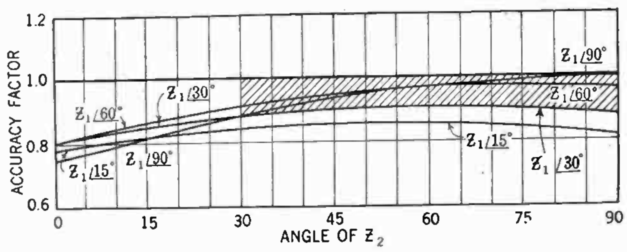


Fig. 9e—Accuracy Factor

Branch currents—Impedance method. Circuit: A generator supplying two parallel branch lines. Variation of angles of Z_1 and Z_2; $/Z_1/ = /Z_2/ = /Z_G/$; Z_G angle, 90 deg. constant, Z_1 angles, 15 deg., 30 deg., 60 deg., 90 deg.; Z_2 angles, 0 deg. to 90 deg.

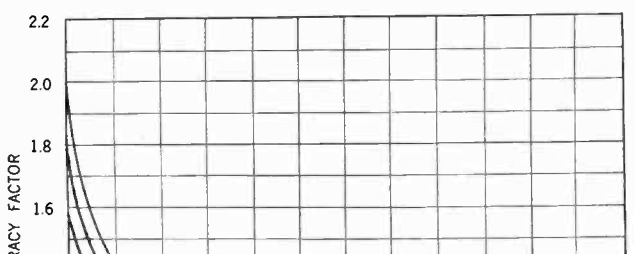


Fig. 10a—Accuracy Factor

Total current—Reactance method. Circuit: A generator supplying two parallel branch lines. Variation of angles of Z_1 and Z_2; $/Z_1/ = /Z_G/$; $/Z_2/ = 5 /Z_G/$; Z_G angle, 90 deg. constant; Z_1 angles, 15 deg. 30 deg., 60 deg., 90 deg.; Z_2 angle, 0 deg. to 90 deg.

method is applicable to any number of series-connected circuit elements as long as all parallel-connected circuit elements have substantially the same impedance angle.

Likewise, for parallel circuits of three or more multiple impedances ranging from pure reactance to pure resistance, the maximum errors for the impedance method cannot exceed those determined for two multiple impedances in accordance with the preceding analysis. This is due to the fact that the sum of the magnitudes of any number of inductive admittances

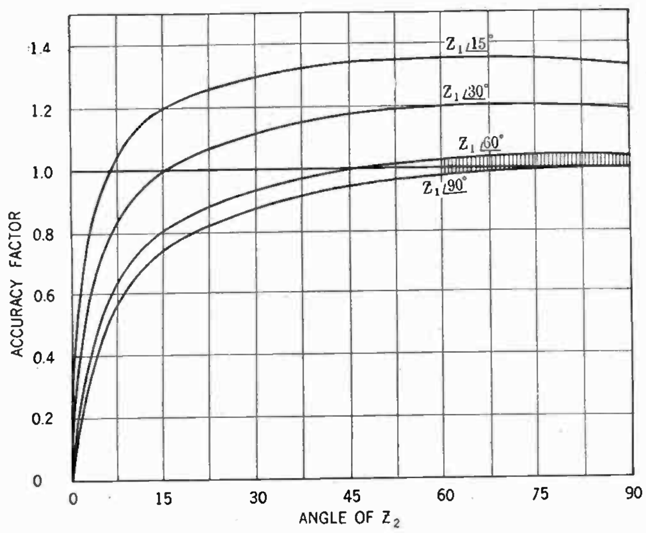


Fig. 10b—Accuracy Factor

Branch current I_1—Reactance method. Circuit: A generator supplying two parallel branch lines. Variation of angles of Z_1 and Z_2; $/Z_1/ = /Z_G/$ $/Z_2/ = 5 /Z_G/$; Z_G angle, 90 deg. constant, Z_1 angles, 15 deg., 30 deg., 60 deg., 90 deg.; Z_2 angles, 0 deg. to 90 deg.

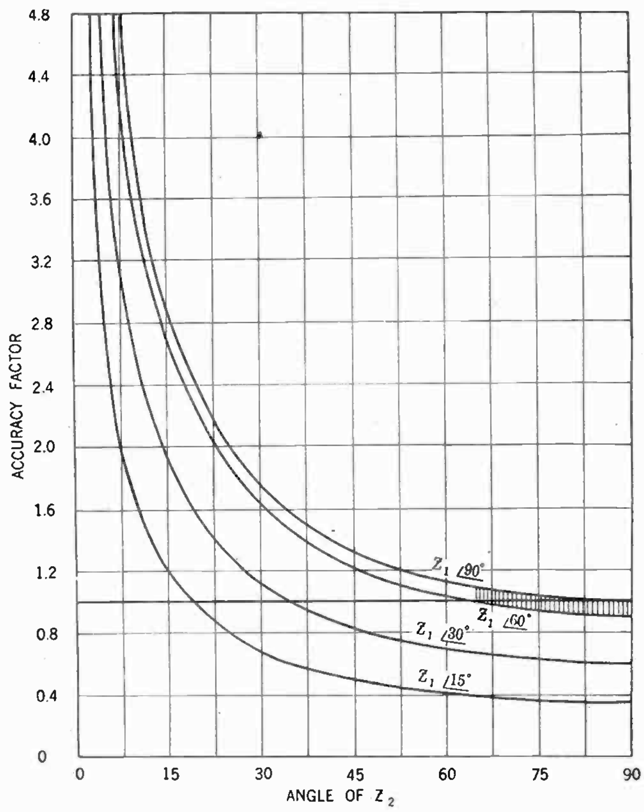


Fig. 10c—Accuracy Factor

Branch current I_2—Reactance method. Circuit: A generator supplying two parallel lines. Variation of angles of Z_1 and Z_2; $/Z_1/ = /Z_G/$; $/Z_2/ = 5 /Z_G/$; Z_G angle, 90 deg. constant; Z_1 angles, 15 deg., 30 deg., 60 deg., 90 deg.; Z_2 angles, 0 deg. to 90 deg.

can never be more than 1.414 times their vector sum. Furthermore, the likelihood of obtaining maximum errors diminishes as the number of parallel connected impedances in Fig. 7 increases beyond two.

The error of currents in low-impedance tie lines interconnecting substations in systems having elements of widely dissimilar impedance angles is likely to be greater than that in the feeders supplying these stations on account of distorted voltage drops (such lines are *F*, *G*, and *H* in Fig. 1).

The currents supplied to a short-circuit from different generating stations may be mutually out of phase. This condition may cause an increase or a decrease of error.

In view of these considerations, it is to be concluded that the error limits established for the circuit constants specified apply primarily to the principal current components from the generating stations, and only approximately to tie-line currents or to minor short-circuit-current components.

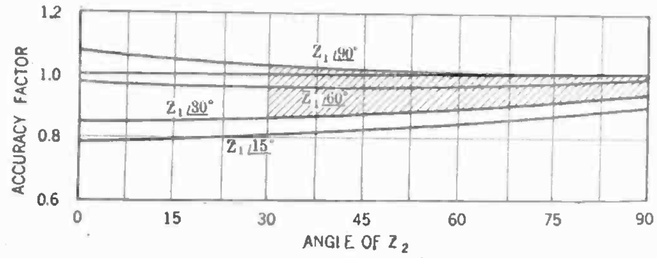


Fig. 10D—Accuracy Factor

Total current—Impedance method. Circuit: A generator supplying two parallel branch lines. Variation of angles of Z_1 and Z_2; $/Z_1/ = /Z_G/$; $/Z_2/ = 5\ /Z_G/$; Z_G angle, 90 deg. constant; Z_2 angles, 0 deg. to 90 deg.

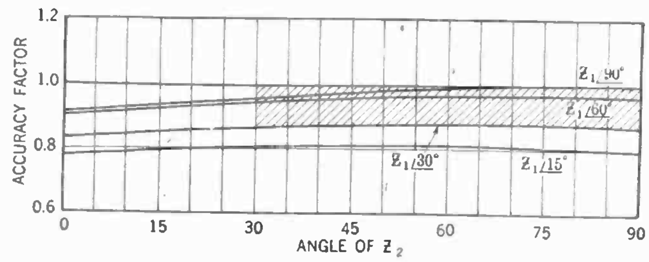


Fig. 10E—Accuracy Factor

Branch currents—Impedance method. Circuit: A generator supplying two parallel branch lines. Variation of angles of Z_1 and Z_2; $/Z_1/ = /Z_G/$; $/Z_2/ = 5\ /Z_G/$; Z_G angle, 90 deg. constant; Z_1 angles, 15 deg. 30 deg., 60 deg., 90 deg.; Z_2 angle, 0 deg. to 90 deg.

Conclusions

The short-circuit calculating table is a simple practical means of making approximate short-circuit-current determinations in networks. It is applicable to a large variety of electric-power networks.

Its chief field of application is that of polyphase short-circuit-current calculations as employed for the selection of oil circuit breakers, for the determination of relay settings, and for the layout of distribution systems.

It is not generally applicable to phase-to-phase short-circuits or to phase-to-ground short-circuits on account of the unbalanced current division among the phases. These latter problems may be solved by calculation or by a-c. test.

The errors of the short-circuit calculating table are due to the neglect of capacity charging currents and due to dissimilar impedance angles occurring in the various elements of a network. The former error is almost always negligible for polyphase short-circuits, being smaller than 10 per cent for a three-phase short-circuit occurring in an aerial line 200 miles from the generator.

In the following, accuracy data are given. The error limits established for the circuit conditions specified apply primarily to the principal current components from the generating stations, and only approximately to tie-line currents.

In a great many systems the resistance component of all the impedances in the network may be entirely neglected for short-circuit-current determinations. This method, the reactance method, generally gives erroneously high current values. The errors are safely below 20 per cent, and commonly under 10 per cent,

(a) in systems in which circuit elements of dissimilar impedance angles occur in series connection only, (*i. e.* parallel-connected circuit elements have impedance angles less than 15 deg. apart), provided the circuit constants are within a definite range of the following character:

Generating-station reactance not lower than distribution system impedance, and angle of the latter not lower than 30 deg.

Generating-station reactance not lower than one-half the distribution system impedance and angle of the latter not less than 45 deg.

Generating-station reactance not lower than one-fifth of distribution system impedance and angle of the latter not less than 55 deg.

(b) in systems not covered by (a), provided all impedance angles are larger than 55 deg.

The systems covered by (a) and (b) above include the majority of aerial systems and a variety of cable systems.

For systems not covered by the range of circuit conditions defined in (a) and (b) above, but having impedance angles not materially below 30 deg., the impedance method is preferable and gives errors well below 20 per cent and commonly below 10 per cent. The short-circuit current values are generally low. Cable systems with current-limiting reactors in some of the lines come within this class. While the impedance method is particularly suited to systems having parallel-connected circuit elements of widely dissimilar impedance angles within the limits stated, it is not a substitute for the reactance method in systems of type (a) and (b) above.

Acknowledgments are due to Mr. G. B. Phillips and to Mr. A. R. Miller for their assistance in the preparation of the data.

A number of the publications bearing on this subject are listed below.

Bibliography

1. E. M. Hewlett, J. N. Mahoney, G. A. Burnham. Rating and Selection of Oil Circuit Breakers. TRANS. A. I. E. E. 1918, p. 123, Vol. 37.
2. R. E. Doherty and O. E. Shirley. Reactance of Synchronous Machines and its Application. TRANS. A. I. E. E. 1918, p. 1209, Vol. 37, part 2.
3. R. E. Doherty and E. T. Williamson. Short-circuit Current of Induction Motors and Generators. TRANS. A. I. E. E. 1921, p. 509, Vol. 40.
4. R. D. Evans. Analytical Solutions. *Elec. Jour.*, August 1919, p. 345.
5. Charles Fortescue. Development of Analytical Solutions. *Elec. Jour.*, Aug. 1919, p. 350.
6. A. E. Kennelly. The Equivalence of Triangles and Three-Pointed Stars in Conducting Networks. *Elec. Wld. & Eng.*, Sept. 16, 1899, p. 413, Vol. 34, No. 12; also A. E. Kennelly, The Application of Hyperbolic Functions to Electrical Engineering Problems. *University of London Press*, 1912, p. 222.
7. A Device for Calculating Currents in Complete Networks of Lines. *G. E. Rev.*, October 1916, p. 901.
8. E. G. Merrick. Approximate Solution of Short-circuit Problems. *G. E. Rev.*, June 1916, p. 470.
9. H. R. Wilson. An Approximate Method of Calculating Short-circuit Current in an A-C. System. *G. E. Rev.*, June 1916, p. 475.
10. W. W. Lewis. Calculation of Short-circuit Currents in Alternating-Current Systems. *G. E. Rev.*, Feb. 1919, p. 140.
11. W. R. Woodward., Calculating Short-circuit Currents in Networks. *Elec. Jour.* Aug. 1919, p. 344.
12. W. W. Lewis. A New Short-circuit Calculating Table. *G. E. Rev.*, Aug. 1920, p. 669.
13. E. A. Hester, O. C. Traver, R. N. Conwell, L. N. Crichton. Transmission-Line Relays, II. A. I. E. E. JOUR., Nov. 1922, p. 839.
14. W. W. Lewis. Short-circuit Currents on Grounded-Neutral Systems. *G. E. Rev.*, June 1917, p. 524.
15. G. H. Gray. Design, Construction and Tests of an Artificial Power-Transmission Line for the Telluride Power Co. of Provo, Utah. TRANS. A. I. E. E. 1917, p. 789, Vol. 36.
16. W. W. Lewis. Present Status of High-Voltage Transmission of Power. Part I. *Gen. Elec. Rev.*, Oct. 1922, p. 628.
17. W. W. Lewis. Present Status of High-Voltage Transmission of Power. Part II. *G. E. Rev.*, Nov. 1922, p. 674.

FEDERAL WATER POWER LICENSES

The number of applications for permit or license under the Federal water power act has now passed the 400 mark. These applications have been received at the average rate of three per week since the Commission was organized in the summer of 1920. They aggregate the enormous total of 13,375,000 primary horse power and involve an estimated installed capacity of 22,154,000 horse power, or approximately two-thirds of the total capacity of both water wheels and steam engines used for public-utility and industrial purposes in the United States at the present time. These applications embrace water-power enterprises of all sizes, from individual plants of less than 100 horse power to great interconnected systems involving hundreds of thousands of horse power.

DECIMAL CLASSIFICATION OF RADIO SUBJECTS

In many organizations actively engaged in radio work, there is an urgent demand for a convenient and comprehensive method of classifying the large amount of printed matter and other radio material which is constantly accumulating. A good method of classifications by subjects in which the grouping of like material together instead of simply in the order in which it was received results in the saving of a great deal of time and money. Knowledge to be of any value must be available for use. It is often easier to look up a fact anew than to search through a large amount of poorly classified material.

Several years ago the staff of the radio laboratory of the Bureau of Standards felt the need for a suitable classification in connection with its own work, and after some trials, it was decided that the decimal system of classification would be very useful for this purpose. A detailed decimal classification of radio subjects has, therefore, been prepared at the Bureau. Persons connected with library work are familiar with the Dewey decimal classification which assigns a classification number according to subject to every book in a library. The entire field of human knowledge is divided into nine main classes and each main class is subdivided as minutely as may be required.

The decimal classification adopted by the Bureau has been worked out so that it will fit conveniently into a library where the Dewey classification is already in use. In the Dewey classification, the number 621,384 represents radio communication, and the classification prepared at the Bureau of Standards is really a subdivision of this number. For the radio classification, the abbreviation "R" is suggested to represent the number 621,384.

Circular 138 of the Bureau of Standards, which has recently been issued, is entitled "Decimal Classification of Radio Subjects—An Extension of the Dewey System," and it can be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C., at 10c. a copy. In the classification given in this publication, the general field of radio communication is divided in nine main classes each of which may be subdivided as minutely as required. This system is used in classifying the references to current radio periodical literature which are published in each issue of the Radio Service Bulletin, and readers of this publication will find it worth while to purchase a copy of the classification since it will explain the significance of the numbers appearing before each reference in the monthly list. With a copy of the classification and a file of the Radio Service Bulletin, the literature on a given radio subject can be quickly located. The number of classes used by any organization will depend upon how detailed a classification it is desired to make. The system can be carried as far as it appears necessary.

The Problem of Insulation

REPORT OF THE COMMITTEE ON ELECTRICAL INSULATION DIVISION OF ENGINEERING, NATIONAL RESEARCH COUNCIL

COMMUNICATED TO THE AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS THROUGH THE A. I. E. E. RESEARCH COMMITTEE

THE Committee on Electrical Insulation of the Division of Engineering, National Research Council, has as its principal purpose the coordination and stimulation of research in this important field. Its ultimate aim is the laying of a foundation of fundamental knowledge of the nature of the phenomena of insulation, on which the solutions of practical problems can be safely erected in a rational scientific fashion.

It is not, therefore, the immediate purpose of the committee to attempt the solutions of specific industrial problems, nor to develop new insulating materials, but rather to study the general nature of the processes involved in insulation in its various forms. It is recognized, however, that the behavior of insulation under the variety of conditions obtaining in modern practise has shown the inadequacy of existing theory and knowledge, and that a study of insulating materials under the conditions of practise is of the greatest importance and second only to the more fundamental problem mentioned.

It is a chief purpose of this report to suggest that the best and only sure way to reach a position in which the properties of insulation may be predicted and controlled, is through a clearer knowledge of the ultimate nature of the several functions of insulation, and the laws by which these functions vary in composite materials, and under the various conditions of service. Further it is felt that much valuable time and effort have been wasted in the past, on the complex materials met in practise, by reason of the non-separation of all the factors entering, the absence of coordination with other results in the same field, and the impossibility of reliable application of the results to other conditions. Coordination and the sifting of the results of past work are emphasized, therefore, as important preliminaries to the further investigations now proposed.

The present aims of the committee are, first, to formulate a statement of general and specific problems of insulation requiring attack through experimental research. Second, the development of a plan for organized effort in attacking these problems. Third, the assignment of specific problems to particular laboratories and individual experimenters, and the stimulation of the work by conference or otherwise. Fourth, the coordination and publication of the results of experimental work under the committee's plan.

This report is the committee's first statement of the general problems of insulation requiring experimental attack. It is recognized, however, that the field of usage of insulation is so wide and complex that an authoritative statement or even a single phase of it would appear to demand the united thought of as many scientists and experts as it is possible to consult. Suggestion, comment, and criticism are, therefore, cordially invited and may be addressed to the Chairman, Dr. J. B. Whitehead, Johns Hopkins University, Baltimore, Md.

THE NORMAL FUNCTIONS OF INSULATION

There are three simple properties of insulation which are commonly utilized in practise. They are

1. Dielectric constant, or, specific inductive capacity. High values are desirable for condensers, but are in general objectionable in other usages.
2. Resistivity, or, specific resistance. High values of resistivity are invariably desired. In the utilization of this property it is sought to prevent leakage rather than breakdown; as for example, in telegraph and telephone equipment, in precision measuring apparatus, and the like.
3. High electric or dielectric strength. In this case protection against complete breakdown is sought; resistivity to prevent leakage is of secondary importance although as a rule, it is high in insulators having high electric strength.

Usually the various applications of insulation call for one or more of these three properties, and so they may be designated the "normal" functions of insulation. It is not often the case, however, that these normal functions operate in their simplest forms. For example, the dielectric constant of a given material may vary widely under such varying conditions as temperature and alternating frequency. Resistivity, as preventing leakage, in many cases involves surface resistance as well as the better known resistivity pertaining to unit volume. Closely related to the dielectric strength of an insulator is the question of flashover voltage, and it is not unlikely that this in its turn is related to the surface resistance.

THE NORMAL FUNCTIONS UNDER CONTINUOUS POTENTIAL

While the normal functions of insulation, as utilized in practise, are sometimes complicated by the simultaneous presence of two or more of them, it is nevertheless possible to devise experimental arrangements in which the individual functions may be made to operate singly, and through definite ranges of value. Such arrangements will usually be limited to the case of continuous electric stress.

It would appear, therefore, that the obvious plan of experimental attack would be a straightforward investigation of these simple functions under continuous potentials; first, from the standpoint of the nature of the underlying processes, and then expanding the study to the properties of both simple and complex materials. In fact, a great mass of data has already been produced by work of this character. If sifted and collected it will do much to bring about a better understanding. Experiments of this character will yield results pertaining only to the use of the insulation under continuous potentials. Insulation selected for use under continuous potentials, and on the basis of one of the simple functions mentioned, will rarely cause trouble by reason of the presence of the other functions. There is, therefore, sound reason, from the standpoints of both theory and practise, why these fundamental studies should be made.

However, it is to be noted at once that when the applied potential varies, the normal functions mentioned above are immediately complicated by the appearance of several new or "abnormal" properties of insulation.

The Abnormal Properties of Insulation

When the electric intensity to which insulation is subjected is alternating, or otherwise variable within short intervals of time, it is not often possible to take advantage of one desirable property or function, without at the same time introducing serious objectionable phenomena due to the presence of the others;—for example, high specific resistance may be accompanied by an objectionable charging current due to high specific inductive capacity. Moreover, under alternating stress, the simple constants of insulation as determined for continuous potentials, appear no longer to hold their values, but to vary in value, under variation of temperature, frequency and stress, in ways as yet quite beyond our knowledge.

Further, under alternating stress the dielectric or insulator becomes the seat of losses, the nature of which presents perhaps the most baffling, and at the same time the most important question in any attempt to place the theory of insulation on a rational basis. We should expect to find in insulation a dielectric loss, analogous to the hysteresis loss in magnetic materials, and arising in some form of intermolecular or perhaps subatomic friction; and there is good evidence of a loss of this character. Further, if an insulator has conductivity, even though small, it must contribute to the loss under alternating stress. However, these two types of loss fail to account for those that are observed, and at the same time the phase angle of the alternating current takes values quite unaccounted for by the value of dielectric constant as based on continuous potentials.

The apparently anomalous behavior in the matter of dielectric loss and phase angle are intimately related to the phenomenon of absorption, most readily observed as the slow decay of current after the application of continuous potential. The nature of absorption is quite unknown.

Still another factor of great importance is the influence of moisture, especially in composite and fibrous dielectrics. In these it is almost impossible to completely eliminate moisture, yet even in small quantities it has great influence on resistance, loss, and phase angle. The laws, however, of this influence are also as yet unknown.

It has been suspected for some time that the complete failure of insulation under electric stress is not a sudden phenomenon but that it is associated with temperature rise and conductivity. Important indications have been announced recently that breakdown is gradual or relatively slow in time, and that in its last stages it partakes of the nature of pure conductivity, so that ultimate breakdown is merely overheating and combustion, leading to short circuit through a relatively low resistance. However, the study of the processes by which this conductivity begins, in a material originally of high resistance and high electric strength, has as yet scarcely been touched.

In addition to these strictly electrical peculiarities of insulation it is obvious that there are numbers of other physical properties which are of the highest importance in practise, as for example, tensile strength, ductility, porosity, heat conductivity, and the like. It is highly probable that, in many cases, particularly in complex materials, there is intimate relations between the electrical, the mechanical, and the thermal characteristics.

Plan of Experimental Attack

It is obvious, therefore, that the investigation of the simpler functions of insulation under continuous potentials, is quite inadequate for a complete understanding of the phenomena which occur in practise. In addition we must study the mutual relations of these functions under varying stress, and various extraneous conditions, such as temperature, moisture, and mechanical stress.

The problems suggested in the following lists, therefore, are chosen as those most likely to lead to better knowledge of the fundamental processes involved in insulation under varying stress. Dielectric absorption and phase angle are placed first, as being the most obscure of all insulation phenomena. Electric strength or breakdown appears as next in importance, and the other functions follow in close sequence. The great influence of moisture on the functions of insulation is well known, and the study of this influence is suggested under the various headings. None of the theories so far proposed for insulation phenomena are satisfactory. The study of these theories is of the first importance, and it is placed last in the classification of problems, only because it appears to depend upon the results of experimental research under the earlier headings.

As a plan for further procedure the committee invites suggestions and modifications of the lists of problems. Following general agreement as to the value of the problems for the purpose in view, effort will be made to secure reviews and compendia of work already done on the respective problems, to recommend specific methods of experimental attack, to ascertain the laboratories and workers best suited for the prosecution of the work, and to collect, coordinate and publish the results.

Industrial Problems

The committee has collected a large number of suggestions for the investigation of the properties of complex types of insulation under the conditions arising in practise. These problems have not been included in the lists below, partly because many of them fall within the more general problems given. It is proposed to classify these industrial problems and present them as a separate group.

Insulation—Fundamental Problems

I. Reviews and Compendia of Work Already Done. A first essential to attacking any of the following problems is a comprehensive review of all past literature on the subject. A concise summary of the literature of any one of the subjects may be considered a research of the first value in itself. An excellent list of publications on dielectric research up to the date of publication is given in the paper by E. H. Rayner, JOURNAL of the Institution of Electrical Engineers, Vol. 49, 1912, p. 53. This list has been brought up to recent date, in the field of engineering research, by D. M. Simons, A. I. E. E. JOURNAL, August 1922, p. 617. The Committee also has in hand several lists bearing on specific materials and topics, and will be glad to furnish them on request.

II. The Nature of Dielectric Absorption. Dielectric absorption or viscosity has been recognized for a long time. It was noted by Faraday, and theories to account for it have been discussed by Maxwell, Fleming, Von Sceweidler and many others. It is most readily observed as the slow absorption of electric charge by the body of the dielectric, when continuous potential is applied. This absorption of charge decreases, so that on applying the potential the charging current rises to a maximum value which slowly decays to the steady value pertaining to the resistivity of the material. The time interval of this decay of current is very short in some substances, and in others the slow change may still be detected after periods as long as an hour or more. The shapes of the charge and discharge curves are not the same. Various efforts have been made to state the law by which the charging current decreases with the time. Its form is not exponential. This question has been discussed by Maxwell, Hopkinson, Fleming and recently K. W. Wagner. However, important as these discussions are, no one of them meets more than a few isolated facts of observation.

Absorption is usually attributed to the presence of two or more dielectrics either in the form of compounds or mixtures, and each possessing some conductivity. However, there is still some question as to whether or not absorption is present in pure dielectrics of simple chemical form. This would appear to be a question of fundamental importance. It is obvious that both temperature and alternating frequency must have an important bearing on absorption.

The following problems are directed principally to the problem of the nature of absorption in the light of existing theories. The importance of a satisfactory method of quantitative expression is also indicated.

(a) Are there any dielectrics entirely free from absorption?

(b) Do mixtures of such dielectrics show absorption, and what are the relations of the absorptions of the mixtures to those of the component substances.

(c) The absorption of dielectrics formed of alternate layers of different dielectrics of simple chemical composition and known properties.

(d) Determination of the amounts of absorbed charge and energy which are recoverable.

(e) Nature and amounts of impurities which cause absorption to set in?

(f) What is the effect of moisture in small amounts on the absorption of simple dielectrics?

(g) Do compound dielectrics, made up in successive samples, show the same values of absorption? What are the factors which cause differences in successive samples?

(h) The influence of temperature in the above.

(i) The influence of frequency in the above.

(j) Any relation between resistivity and absorption?

(k) A quantitative method for defining absorption.

(l) Determination of an analytical formula representing the absorption current as a function of the time.

(m) Absorption in liquid dielectrics—effect of impurities and moisture.

III. Phase Difference in Dielectrics. The phase difference of a dielectric, or the departure of the charging current from the 90 deg. relation to the impressed alternating voltage may not be predicted from the dielectric constant, insulation resistance, and dielectric hysteresis, as determined by continuous potential methods. Our knowledge here is very meagre. It is certain that absorption plays an important part in the apparent changes in the values of dielectric constant and one promising method of attack is a study of the influence of frequency beginning at very low values, as in the work of Granier, *Rev. Gen. de l'Electricite*, August 13, 1921, and September 30, 1922.

(a) The relation between absorption and phase difference, in dielectrics free from leakage.

(b) A convenient way of separating the influence of absorption and leakage on the angle of phase difference.

(c) The phase differences of mixtures of simple dielectrics as related to those of the components.

(d) The effect of placing different known simple materials in layers.

(e) The influence of impurities, and of moisture on the phase difference.

(f) An analytical expression connecting phase angle with absorption, resistivity, or other properties, or constants, of a dielectric.

IV. Elctric Strength. The nature of the processes active when insulation fails are practically unknown. Further knowledge in this direction is one of the most important problems arising in the applications of insulation. For a long time there has been suggestion that the breakdown of insulation is not a sharp disruptive failure, but that there is a considerable time element involved. In the operation of high-voltage cables, for example, the occurrence of hot spots has long been noticed, and it has been known that if the cable continues in operation it is likely to fail at such a hot spot. Recently K. W. Wagner has crystalized thought in this direction by suggesting a progressive accumulation of temperature, with corresponding lowering of resistance, in limited regions of dielectrics, under stress. The theory proposed here is that the failure of insulation is a direct result of the lowering of insulation resistance by the elevation of temperature, and that the insulation finally fails as the result of cumulative overheating due to increasing conductivity. While there is much evidence in support of this view as related to the final stages, it is by no means certain that the initial stages, or the approach to the final condition, may be so explained.

Increasing attention is also being directed to the question of the movement and freedom of ions in dielectrics as bearing on the question of breakdown. The free motion of ions, and the possibility that they may accumulate ionization velocities, are problems which appear susceptible of experimental attack. We have a fairly satisfactory theory of breakdown in gases. Liquids offer the best field for the further study of the influence of the motion of ions in insulators and solids for the study of temperature-conductivity relations.

(a) The breakdown of chemically pure liquid dielectrics, with special reference to current before breakdown, stress distribution, temperature at electrodes, and the formation of corona.

(b) The same as influenced by temperature and pressure.

(c) The same for mixtures of known simple liquids.

(d) The question of the motion of charged and uncharged particles, and the effect of circulation, in liquids under electric stress.

(e) The breakdown of pure solid dielectrics.

Current voltage curves for small areas up to breakdown.

The proper type of electrode for studying breakdown strength (see Wagner, A. I. E. E. JOURNAL, December 19, '22.)

Voltage gradient in uniform and divergent fields.

Law connecting thickness and dielectric strength.

The influence of temperature on the thermal and electrical conductivities of simple dielectrics.

The variation of breakdown voltage with ambient temperature.

(f) The influence of X-rays or other agencies affecting molecular stability on the conductivity and breakdown of liquid and solid dielectrics.

(g) Voltage gradient between coaxial cylindrical electrodes, for liquid, solid, and impregnated fibrous dielectrics.

V. Dielectric Constant. The specific inductive capacity of a material is constant only in a comparatively narrow range of conditions, as for example, under constant temperature and continuous potential. Under alternating potentials in many instances this constant practically loses itself by reason of our ignorance of the processes within the insulation. In insulation showing absorption, the apparent capacity, and the loss components of the charging current, vary with frequency, voltage, and moisture content, in ways which we have not yet been able to follow.

(a) Dielectric constant of composite materials as related to values of constituents.

(b) Dielectric constant of simple and composite materials as influenced by temperature.

(c) Dielectric constant of simple and composite materials as influenced by electric stress.

(d) Dielectric constant of simple and composite materials as influenced by frequency—compare with zero and radio frequencies.

(e) Dielectric constant of materials free from absorption and of high resistivity as affected by temperature, electric stress and frequency.

(f) The nature of electric displacement, as regards the relation of the shifting of the electron to the structure of the atom or molecule. The influence of the magnetic field and of X-rays, on the dielectric constant. The dielectric constant of crystals in various directions.

(g) The correlation of dielectric constant and the index of refraction.

(h) The explanation of the increase of power factor with voltage, especially in the case of impregnated paper.

VI. Resistivity. The resitivities of simple dielectrics under continuous potentials show variations in value even when conditions are carefully controlled. The problems here are as to the nature of such low conductivity as occurs in good dielectrics. Is it due to impurities, or do we actually have some form of ionic conduction or passage of current through pure dielectrics? Absorbed moisture is known to have a very great influence on resistivity, and since such a large proportion of the insulating materials of practise are more or less absorbent, the questions of the absorption of moisture, and the surrounding humidity, become immediately of the first importance.

(a) The resistivity of pure dielectrics, liquid and solid.
(b) The resistivities of compound dielectrics as related to those of their constituents.
(c) The influence of impurities, particularly water in small amounts.
(d) The influence of humidity (*i. e.* water vapor) on resistivity and surface resistance.
(e) The relation between resistivity and electric gradient, in pure and impure substances and in mixtures—up to values met in alternating-current practise.
(f) The relation between the resistivities or effective resistances, at continuous and alternating potentials.
(g) The separation of the resistance and absorption components of the angle of phase difference.
(h) The influence of temperature and pressure on volume resistivity.
(i) Study of electrolytic and chemical effects of conduction.
(j) Study of absorption and conduction in jellies.

VII. Flashover Voltage. The problem of the cause of flashover of insulators requires the separation of several obvious factors, and a statement of their relative importance. It is not certain that any fundamental phenomena, other than those already discussed, appear in this problem. The following problems bear on the relative importance of these phenomena in flashover.

(a) The relation of surface resistance to sparkover voltage, in vacuum, in air, and in oil.
(b) The influence of gaseous ionization on flashover.
(c) The possible presence of gaseous ionization arising in the surface film of the insulator.
(d) The influence of roughness and of radius of curvature on the insulator.
(e) The relative importance of insulator surface resistance, and the shape and size of the electrodes, in sparkover.
(f) The influence of humidity (*i. e.* water vapor) on flashover.

VIII. Theories. Theories as to the nature of insulation processes have, for the most part, been confined to the phenomena of absorption. The first of many important contributions in this direction was that of Maxwell. Notable discussions of Maxwell's theory have been made by Fleming and Dyke, C. Lubben, K. W. Wagner, and others. Maxwell explains dielectric absorption in the relationship between resistivity and dielectric constant, without speculation as to the ultimate nature of these properties. Pellat, von Scweidler and others, on the other hand, explain absorption as arising in frictional forces due to the motions and vibrations of the ions in the body of the molecule and the atom. These two points of view are radically different, and so present an important question for investigation.

(a) Suggestions of experimental methods for testing the relative validities of the Maxwell and the Pellat-von Scweidler theories of absorption.
(b) The use of X-rays or radium rays in studying the insulating properties of very thin layers.
(c) To study the crystals of solid insulators, the action of one part of a crystal on a neighboring part, and the mutual action between crystals of the same or different types.
(d) Extension of the study of the theory of Evershed as to the influence of moisture.
(e) Theoretical analysis of the conditions of thermal and electrical equilibrium in a medium having dielectric absorption, dielectric constant and low electrical and thermal conductivities, under continuous and alternating stresses.

An excellent summary of all the theories proposed up to 1911 is found in the paper by Frederick W. Grover, *Bulletin of the Bureau of Standards*, Vol. 7, No. 4, December 15th, 1911. Since then engineering discussion has been contributed by Fleming and Dyke, JOURNAL of the Institute of Electrical Engineers, Vol. 49, 1912, p. 323; K. W. Wagner, *Archiv fur Elektrotechnik* II–9–1914, p. 371; Del Mar and Hanson, A. I. E. E. JOURNAL, June 1922, p. 439, and others. A review of the work of physicists in this field is much needed.

J. B. WHITEHEAD,
Chairman.

AUXILIARY CONDENSERS AND LOADING COIL

The operation of radio receiving sets can be improved by the use of a very simple and cheap condenser connected across the telephone receivers and a similar one connected in series with the antenna, according to the Bureau of Standards of the Department of Commerce. Longer waves can be received by the use of a very simple type of loading coil. The coil is particularly useful in connection with the single-circuit receiving set.

The auxiliary condenser which is used in series with the antenna, and the loading coil, may also be used when the crystal detector is replaced by an electron tube detector unit, or when an amplifier is added to the receiving set.

The condenser used in series with the antenna makes it convenient to tune to wave lengths less than 300 meters. The condenser used across the telephone receivers increases the intensity of signals which are received from some radio stations. The loading coil enables the equipment to respond to wave lengths above 600 meters, up to about 3000 meters. Time signals from high power stations can thus be received.

The Effect of Transient Voltages on Dielectrics—III

(An Investigation with very High Lightning Voltages.)

F. W. PEEK, Jr.
Member, A. I. E. E.
General Electric Company, Pittsfield, Mass.

Review of the Subject.—*During a thunder storm lightning voltages that reach the transmission line appear across insulators, transformers and other apparatus at the extremely rapid rate of millions of volts per second. With this rapid rate of application the voltage may reach a very high value in a microsecond (millionth of a second). Hence, since there is always a delay or lag in the breakdown of insulation, quite peculiar effects result from these voltages. For instance, some remarkable phenomena that take place are: Much higher lightning voltages are usually required to jump a given distance than voltages at normal operating frequency; conductors at normal frequency voltages are often good insulators for lightning voltages; water may be punctured like oil; the wet and dry spark-over voltage of insulators are equal; the lightning discharge has a decidedly explosive effect, etc. In addition to the characteristics just mentioned, a study has also been made of the change in voltage and shape of a lightning wave as it travels over a transmission line at the velocity of light.*

In order that a laboratory study may be of a practical as well as a theoretical interest, it is necessary to be able to reproduce lightning voltages in the laboratory on a large scale and of known characteristics. This investigation was started some years ago with a 200-kv. generator. The generator has been added to from time to time until now, 2,000,000 volts are available and single lightning strokes can be obtained that increase at the rate of 50 million million volts per second. The power is of the order of millions of kilowatts. It is believed that this generator closely approximates voltage and other conditions that usually occur on transmission lines. The lightning voltages used in this investigation were far in excess of any heretofore produced in a laboratory. This impulse generator discharge must not be confused with that produced by an oscillator. The lightning generator, unlike the ocillator, discharges with a loud sharp report or crack.

The photographic study shows the lightning spark-over of insulator strings that are of such a length as rarely to spark-over in practise even in bad lightning country. The photographs of the flashes show all the characteristics of lightning such as a zig-zag path, side flashes, etc.

The study of the travel of the lightning wave on transmission lines is of interest. It indicates for instance, a certain protective effect of corona and shows that under certain conditions inductance coils may increase the lightning voltage four fold. Certain phases of the ground wire have also been studied.

Former Investigation—The Lightning Generator

The first paper of this series, published in 1915, described a generator for producing lightning impulses of a predetermined shape and voltage.[1] The maximum voltage of this generator was about 200 kv. Quite complete data were given at that time on the time lag and lightning spark-over voltages of various gaps, line insulators, etc. Data were also given on the lightning breakdown voltage of oil, air and solid insulation, corona produced by lightning, etc. It was found convenient to term the ratio of the lightning spark-over voltage to the continuously applied or 60-cycle voltage the "impulse ratio." This term has since come into general use.

The second paper dealt more particularly with lightning arrester gaps.[2]

The voltage and capacity of the impulse generator has been increased from time to time as higher exciting voltages have become available. During the past year the voltage has been increased to about two million maximum, while the power may be millions of kilowatts. Two million volts is higher than most lightning voltages that are induced on transmission lines. Tests can now be made in the laboratory at voltages and energy approximating operating conditions. It seems desirable, therefore, to report progress at this time.

The methods of making the tests and predetermining the characteristics of the impulse have already been adequately described in the first paper of this series. For convenience, a very brief description will be given

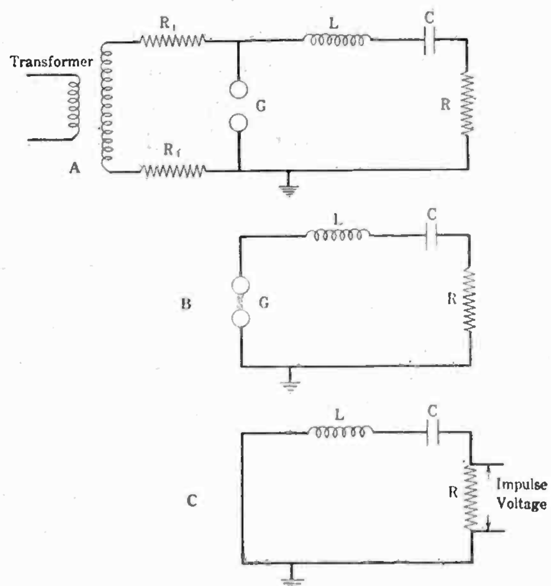


Fig. 1—Impulse Generator Circuit

here. The circuit is as shown in Fig. 1A. The gap G is set at some desired voltage. The transformer voltage is increased until discharge occurs. At that instant the condenser C is charged up to a voltage corresponding to the gap setting. A dynamic arc forms at G and holds. This acts as a switch and the condenser discharges through the known inductance L

1. Peek, Jr., F. W.—"The Effect of Transient Voltages on Dielectrics,—I." Transactions, A. I. E. E. 1915.

2. Peek, Jr., F. W.—"The Effect of Transient Voltages on Dielectrics,—II." Transactions, A. I. E. E. 1919.

To be presented at the Annual Convention of the A. I. E. E., Swampscott, Mass., June 26-29, 1923.

and resistance R. The circuit that produces the impulse is shown in Fig. 1B or is, in effect, that shown in Fig. 1C. The condenser discharging through the known resistance and inductance causes a transient current that can be readily calculated. This current

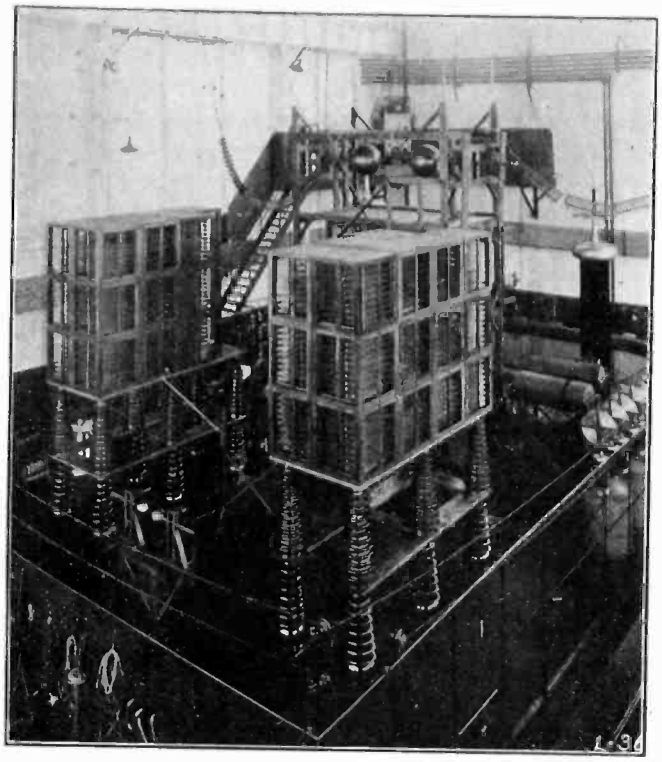


FIG. 2—2,000,000 VOLT IMPULSE OR LIGHTNING GENERATOR

produces a transient voltage drop across R. This is the impulse voltage used in the test.

The lightning generator in its present form in the "High-Voltage Engineering Laboratory" at Pittsfield is shown in Fig. 2. The condenser C of Fig. 1 is shown supported on post insulators. It will be noted that C

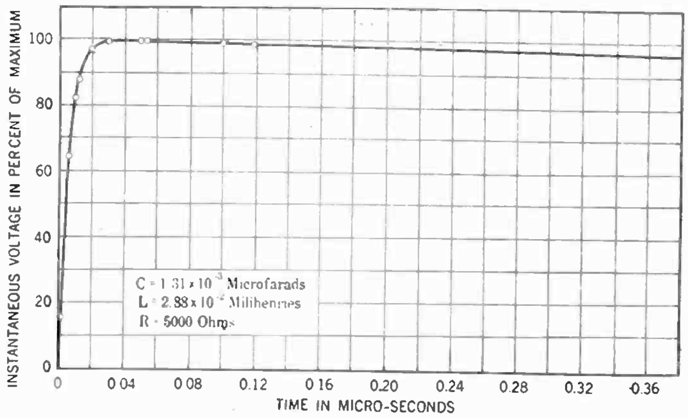


FIG. 3—WAVE SHAPE OF LIGHTNING USED IN THE TESTS
Wave shape No. 1. Two million-volt impulse generator.

is made up of a number of cells or frames with ten plates in series in each frame. The plates are made of glass coated on both sides with tin foil. The insulated stands as shown will hold fortyeight frames or cells or four hundred and eighty plates. More cells can be added at will. In fact, it is planned to increase the number of plates to one thousand.

The capacity per plate is 0.0112 microfarads; per cell, 0.00112 microfarads. The cells are readily arranged in multiple and series combinations as required. Three cells in series on each side operate satisfactorily at a million and a half volts maximum to ground. In the "set-up" shown, a series of tests were made up to 1500 kv. max. The energy available for the discharge is proportional to $\frac{E^2 C}{2}$. The inductance L is that formed by the rectangular circuit. The resistance R is a water tube of 5000 ohms. This particular arrangement gives the wave shown in Fig. 3.

FIG. 4—1,500,000-VOLT LIGHTNING STROKE BETWEEN POINTS

FIG. 5—1,500,000-VOLT LIGHTNING STROKE BETWEEN POINTS
Note zig-zag path and characteristic side flashes of lightning.

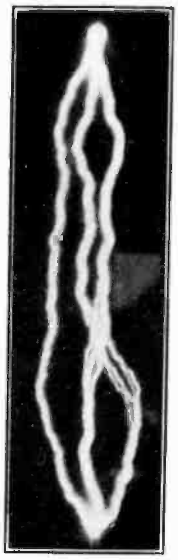


FIG. 6—THREE 1,500,000-VOLT LIGHTNING STROKES BETWEEN POINTS
Note that successive strokes do not follow the same path.

NEEDLE GAPS—DISCHARGE HAS ZIG-ZAG PATH AND CHARACTERISTIC SIDE FLASHES OF LIGHTNING—SAME LAWS FOLLOWED AS AT LOWER VOLTAGES

Fig. 4 shows a discharge of 1500 kv. max. between points. This type of discharge must not be confused with the high-frequency discharge produced by an oscillator. This discharge takes place with a loud explosive report. It will be noted that the general appearance of the spark resembles a lightning flash. In addition to the "zig-zag" path a close examination of Fig. 5 will show characteristic side flashes. In Fig. 6 three discharges are produced on the same plate. It will be noted that no two occur in the same place. The lightning spark-over curve for needles is given in

Fig. 7. Confirming data given in the previously mentioned papers the impulse ratio is high for points.

SPHERES—SAME LAWS FOLLOWED AS AT LOWER VOLTAGES. SERIES RESISTANCE INTRODUCES TIME LAG

Figs. 8 and 9 show the discharge between spheres. The great thickness of the spark (over 3 in. in diameter)

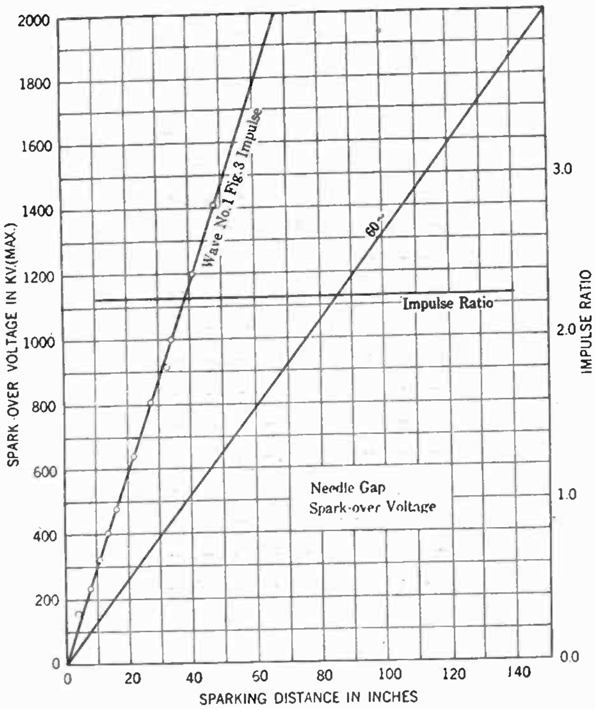


FIG. 7—LIGHTNING SPARK-OVER CURVE BETWEEN POINTS

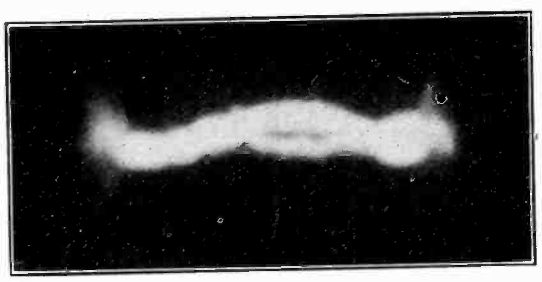


FIG. 8—LIGHTNING DISCHARGE BETWEEN SPHERES
Note thickness of the discharge.

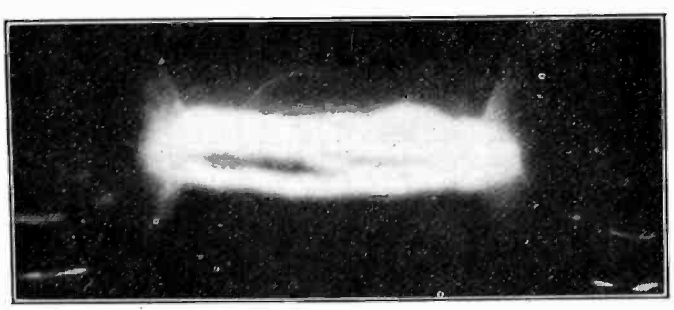


FIG. 9—LIGHTNING DISCHARGE BETWEEN SPHERES
Note thickness of discharge.

shows the large current (approximately 10,000 amperes) in this discharge. In measuring the maximum lightning voltage with sphere gaps it is important to have no appreciable series resistance. Series resistance will give the sphere the characteristic of the needle gap. It takes time to charge the capacity of the sphere through the high resistance.

This is illustrated by the following data:

Applied lightning voltage kv. (max.)	Series resistance ohms	12.5 cm. spheres gap cm. setting	60-cycle spark-over kv. (max.)
106	0	3.95	106
106	2,500	3.60	98.5
106	5,000	3.30	92.0
106	10,000	2.80	80.0
106	20,000	2.30	66.0
106	30,000	2.05	59.1

Constant lightning voltages were applied to the sphere and series resistance. As the series resistance was increased it was necessary to reduce the gap as indicated in order to obtain spark-over with the same applied impulse. The effect of the series resistance

FIG. 10—DRY 60-CYCLE SPARK-OVER OF A SHIELDED STRING OF INSULATORS
Arc clears the string

increases with increasing wave front. This arrangement may be used, therefore, to indicate the duration and wave front of a transient.

LINE INSULATORS—EFFECT OF 1,200,000 VOLT LIGHTNING STROKE—LIGHTNING DOES NOT FOLLOW DRIP DURING RAIN ON SHIELDED STRING

Previous tests showed that the wet and dry lightning spark-over voltages of insulators were equal. Tests made at the higher voltages further confirm these data. These tests are, however, particularly important from the practical standpoint since they give the lightning spark-over characteristics of very long strings of insulators. Laboratory tests have been made at higher lightning voltages than usually occur on operating lines. Fig. 10 shows the characteristic dry 60-cycle arc-over on a shielded string; the corresponding lightning spark-over is shown in Fig. 11. Fig. 12 is of great practical importance. It shows that the lightning spark-over clears the string during a very heavy storm. The great display is due to the illumination of the drops. The drops appear stationary in space because the photograph was taken by the light of the spark lasting less than a millionth of a second. It was found that the wet and dry lightning spark-over voltages were not reduced by the shield. Fig. 13 shows a non-shielded string struck by lightning.

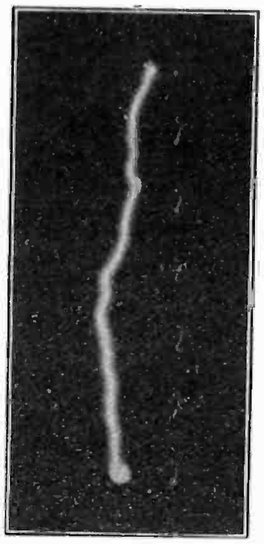


FIG. 11—1,200,000-VOLT LIGHTNING SPARK-OVER OF A SHIELDED STRING OF INSULATORS—DRY
Spark clears the string

A few years ago the author's attention was called to some suspension insulator units of the cemented type that had been punctured through the head, apparently the result of a direct stroke. In these insulators, not only was the porcelain in the head shattered, but the metal cap had the appearance of having been punctured by a bullet shot through from the inside. Recently, in puncturing a glass plate in the laboratory a heavy foil coating was punctured in the same manner. This seems to be due to an "explosion" between the insulation and the foil. The foil is shown in Fig. 14.

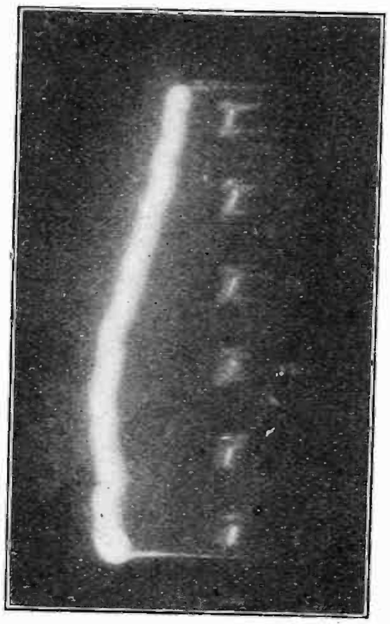


FIG. 12—1,200,000-VOLT LIGHTNING SPARK-OVER OF A SHIELDED STRING OF INSULATORS
During a heavy rain. Note rain drops illuminated by the flash. The illumination differs from that in Fig. 11. The spark clears the string.

As in the case of spheres, if a resistance is placed in series with an insulator the lightning voltage necessary to cause spark-over is greatly increased. The following insulator spark-over data are given as an example.

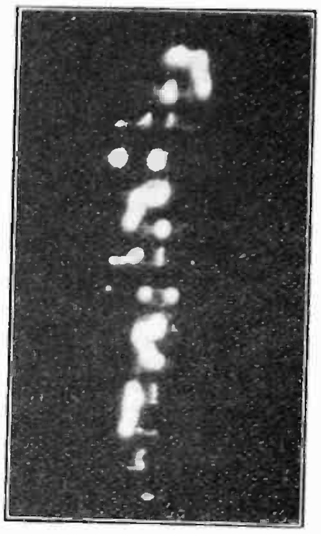


FIG. 13—1,200,000-VOLT LIGHTNING SPARK-OVER OF A NON-SHIELDED STRING OF INSULATORS—DRY

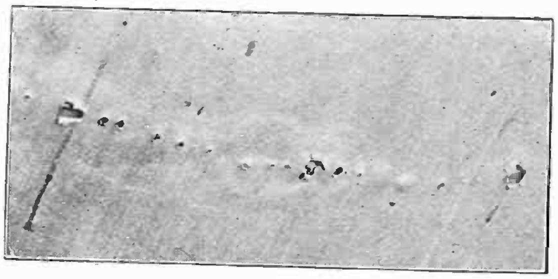


FIG. 14—METAL "PUNCTURED" BY LIGHTNING

LIGHTNING SPARK-OVER VOLTAGE—INSULATOR IN SERIES WITH RESISTANCE

Series resistance ohms	60-cycle spark-over voltage kv. (Max.)	Lightning spark-over voltage kv. (Max.)
0	119.0	127.0
5,000	119.0	190.0
10,000	119.0	235.0
20,000	119.0	320.0
30,000	119.0	420.0
50,000	119.0	600.0

The resistance has the effect of increasing the time lag. In these tests the gap (insulator) was kept constant and the impulse spark-over voltage measured with increasing resistance. In the sphere gap tests above, the impulse was kept constant and the gap varied.

Incidentally, these tests show how useless a high-resistance arrester is.

Propagation of Lightning on Transmission Lines Decrease in Voltage due to Corona and Other Losses. Choke Coils Cause Dangerous Voltages—Ground Wire—Reflections

A study is being made of the propagation of lightning on transmission lines. It is possible at this time to report only the preliminary study which seems to be of considerable practical interest. In these preliminary tests an impulse with a front equivalent to that of a 5,600,000 cycle sine wave was applied to a short transmission line. The length of the front of this wave from zero to maximum was approximately 36 feet (12 meters). The maximum length of line used was made up of two parallel wires each 280 feet (85 meters) long and spaced 3 ft. (0.92 meters) apart. The diameter of the wire was 0.04 in. (0.102 cm.). The object of the small wire was to cause a high corona loss, and thus get the attenuation effects of a much longer line. Corona produced by these transients could readily be seen and the eye could differentiate between the positive and negative wire.

The general connections used in studying wave propagation are shown in Fig. 15. The data will be found in Table I. Fig. 15 shows the arrangement for test 3 of Table I. The impulse was applied to the line and the voltage measured at the start, in the center of the line,

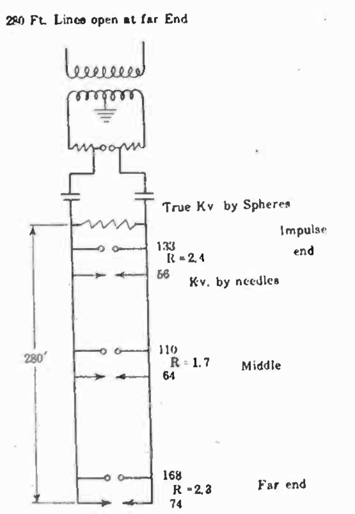


Fig. 15—General Connections Used in Studying Propagation on Transmission Lines

Figures give voltage as measured by spheres, impulse ratio and voltage as measured by needles.

and at the end. Both needles and spheres were used to measure the voltage. The sphere measures the correct maximum voltage, while the needle always indicates a lower voltage. The steeper the wave the lower the voltage that is indicated by the needle. The ratio of the sphere and needle voltages, or the impulse ratio, is thus a measure of the steepness of the wave. The higher the ratio the greater the steepness. Referring to Fig. 15, test 3, a 133-kv. impulse was applied. The needle gap indicated 56 kv. or an impulse ratio of 2.4. At the center of the line the maximum voltage of the wave was reduced 18 per cent while the wave front was flattened out as shown by the impulse ratio of 1.7. It is interesting that the needle gap indicated a higher voltage in the center than at the start. If the voltage decreased at the above rate it would have a value of 80 kv. at the end. Actually, approximately

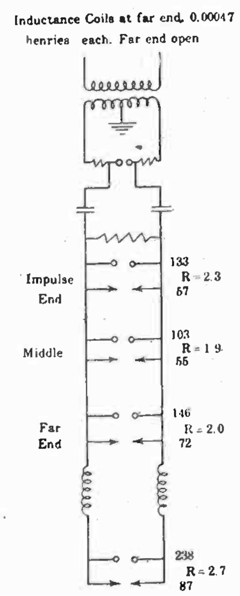


Fig. 16—Lightning Propagation on Transmission Lines Inductance at End of Line

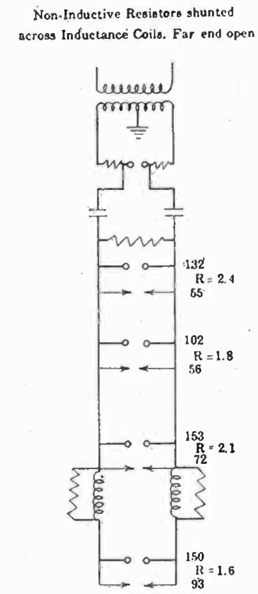


Fig. 17—Lightning Propagation on Transmission Lines Inductance at End of Line Shunted by Resistance

double this value was measured; in striking the end the voltage doubled in value as would be expected. The wave front was also steepened at the open end as shown by the impulse ratio.

In test 4, the line was short-circuited at the far end, while in test 5 the far end was closed by a resistance approximately equal to the surge impedance. In both cases, the voltage and impulse ratio at the start and in the center of the line were approximately the same as for the open line.

Of great practical interest is test 7, shown diagrammatically in Fig. 16 where inductance coils were placed at the end of the line. In this case the wave almost doubled up on reaching the start of the reactor. At the far side of the reactor a very high voltage appeared. This voltage, 238 kv. was almost double the impulse applied to the line and probably three times the voltage that reached the start of the reactor. Under these conditions the reactor would be dangerous. By shunting the reactor by a resistance, test 9, Fig. 17, the voltage was greatly reduced. A greater reduction in voltage is found when the far end is shunted by a capacity.

Tests made by applying the impulse between one wire and the ground are given in Table II. A comparison of tests 12 and 13 is of interest. Test 13 is similar to test 12 except that the wave was split at the start

TABLE I

PROPAGATION OF LIGHTNING ON TRANSMISSION LINES

Test number	Arrangement Parallel wires	Start			Middle			Start of Inductances or Resistances			Far End		
		Voltage (Max.)		Impulse ratio	Voltage (Max.)		Impulse ratio	Voltage (Max.)		Impulse ratio	Voltage (Max.)		Impulse ratio
		Sphere	Needle		Sphere	Needle		Sphere	Needle		Sphere	Needle	
1	Line 6′ (1.84 meters) long—open at far end	..	..	..	..	..	..		None		191	71	2.7
2	Line 140′ (43 meters) long—open at far end	137	56	2.4	..	..	..		None		194	78	2.5
3	Line 280′ (86 meters) long—open at far end	133	56	2.4	110	64	1.7		None		168	74	2.3
4	Line 280′ (86 meters) long short circuited at far end	139	57	2.4	100	51	2.0		None		0	0	0
											Short circuited		
5	Line 280′ (86 meters) line short circuited at far end by resistance = approximate surge imped. = (850 ohms)	132	54	2.4	99	48	2.1	Resistance = surge impedance 85	47	1.8	End closed		
6	Line 280′ (86 meters) line open with 425 ohm resistance in series on each line	133	54	2.5	104	59	1.8	163	71	2.3	160	71	2.3
7	Line 280′ (86 meters) line open at far end with an inductance coil in series in each line	133	57	2.3	103	55	1.9	146	72	2.0	238	87	2.7
8	Line 280′ (86 meters) closed at far end with an inductance coil in series in each line	134	55	2.4	103	54	1.8	148	64	2.3	0	0	0
								L = .47 mile henries			End closed		
9	Line 280′ (86 meters) open at far end. Inductance shunted by resistance	132	55	2.4	102	56	1.8	153	72	2.1	150	93	1.6
10	Line 280′ (86 meters) end closed by a condenser	136	60	2.3	102	54	1.9	...	..	..	92	44	2.1
11	Single 280′ (86 meters) line ground return-end open	116	51	2.3	..	..	..	..	..	..	158	61	2.6

Size of conductor 0.04″ (0.102 cm.) Spacing 3′ (91.5 cm.). 5600 Kc. Wave.

TABLE II

PROPAGATION OF LIGHTNING ON TRANSMISSION LINES

Test number	Arrangement	Start			Far End		
		Voltage (Max.) to ground		Impulse ratio	Voltage (Max.) to ground		Impulse ratio
		Sphere	Needle		Sphere	Needle	
12	Single wire 280′ (86 meters) long-open at far end. Impulse between line and ground	133	56	2.4	151	65	2.3
13	Two wires connected at start 280′ (86 meters). Volts between wire and ground	133	56	2.4	113	62	1.7
14	Single wire 280′ (86 meters) single ground wire 3′ (.91 meters) distance grounded at far end	133	56	2.4	146	64	2.3
15	Same as (14) ground wire grounded at start and end	133	56	2.4	148	66	2.2
16	Two parallel wires each 280′ (86 meters) connected together at far end. Impulse sent out on one and back on other at total of 560′ (172 meters)	133	56	2.4	136	61	1.9

Size of conductor 0.04″ (0.102 cm.). Distance to ground 25′. 5600 Kc. Wave.

and sent over two wires. The result was a considerable reduction in voltage at the far end.

When the impulse was applied between one wire and ground it was observed that the attenuation was greater when the wire was positive than when it was negative. That is, the voltage was always higher at the end of the line when the wire was negative.

The effect of a ground wire in absorbing energy and thus reducing the lightning voltage is indicated by comparing tests 12, 14 and 15, Table II. This effect is quite small. However, this is only one phase of the ground wire question; it is in no way a measure of the value of the ground wire in reducing induced voltages or of protecting from direct strokes.

That phase of the problem is being investigated.

The Dielectric Strength of "Conductors"

Conductors at Operating Frequencies may be Insulators for Lightning. Importance of Low Resistance Arrester

When voltage is gradually applied between metallic terminals separated by an insulating material, there is no appreciable flow of conduction current. If this voltage is increased so that the stress is of the order of 30 to 200 kv. per cm. of insulation, puncture suddenly occurs at some point; the insulation breaks down and conducts through the arc. If the insulation is replaced by conducting material the current increases with increasing voltage, and the conductor either melts or boils away before a small portion of a stress of 30 kv. per cm. can be placed across it. By suddenly applying the voltage very high stress can be obtained across conductors without appreciable heating. Certain conductors can thus be subjected to the same voltage stresses as insulations. By means of the impulse generator it was found possible to puncture water.

In this test the voltage of the impulse applied to the water was increased until disruptive discharge or spark

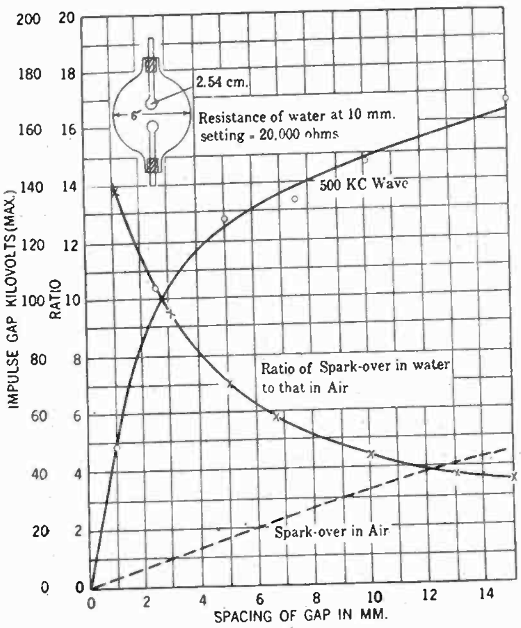


FIG. 18—DISRUPTIVE STRENGTH OF WATER BETWEEN 2.54 CM. BRASS SPHERES

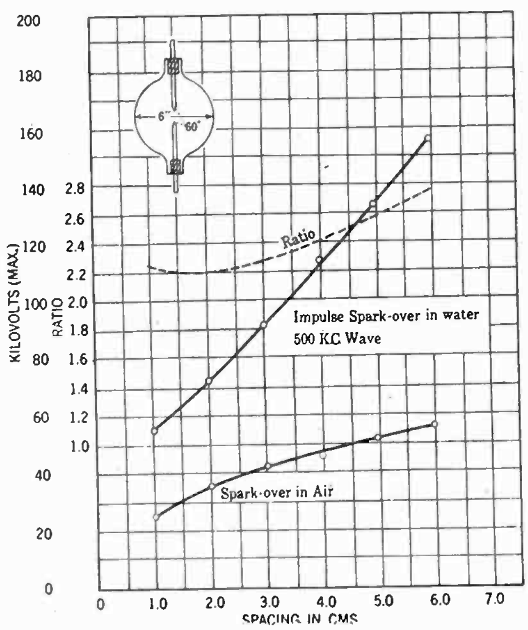


FIG. 19—DISRUPTIVE STRENGTH OF WATER BETWEEN 60-DEGREE POINTS

took place. The water was actually "punctured." The appearance of the spark was very much like a disruptive discharge in air or oil and was quite violent. Tests were made with both point and sphere electrodes. It was possible to cause voltages as high as 165 kv. across 1.50 cm. (0.6 in.) of water. Since the time of application was about one micro-second (10^{-6} seconds) there was no heating. Applied in the usual way over a few seconds not 1 per cent of these voltages would be possible without causing the water to boil out.

The results of the tests are given in Table III and plotted in Figs. 18 and 19. The spark-over voltages for the same electrodes with the globe filled with air were also measured and are given on the curves. It will be noted that the disruptive strength of water is much greater than that of air.

TABLE III
TRANSIENT DISRUPTIVE STRENGTH OF WATER
2.54 cm. Spheres

Gap cm.	Impulse kv. (Max.) water	Impulse kv. (Max.) air	Ratio
0.1	49.5	3.5	14.1
0.2	86.0	7.0	12.3
0.3	105.5	11.0	9.6
0.5	126.0	17.5	7.2
0.7	137.0	24.0	5.7
1.0	149.0	33.0	4.5
1.3	159.0	42.0	3.8
1.5	165.0	46.0	3.6
	Resistance 20,000 ohms		
	60 deg. Points 1/8 in. Rod		
1.0	56.5	25.0	2.25
2.0	72.0	35.3	2.15
3.0	92.0	41.0	2.25
4.0	113.0	46.5	2.42
5.0	134.0	51.5	2.61
6.0	156.0	56.5	2.76
	Resistance 40,000 ohms		

NOTE. Tests made with single half cycle of a 500-kilocycle wave. This wave was, therefore, not as steep as waves used in some of the other tests.

The results of this test are in agreement with the tests above which showed the wet and dry spark-over voltages of insulators to be equal. The test also shows that "insulation" that is not good or is, in fact, a conductor at operating voltages may be very good insulation at lightning voltages. This again emphasizes the importance of low-resistance lightning arresters.

CONCLUSIONS

Lightning voltages are now available in the laboratory which exceed those usually induced on transmission lines. This conclusion is based on the fact that insulator strings of the length flashed over in this investigation rarely spark-over in practise due to lightning. An investigation on lines in Colorado also showed that lightning voltages in excess of 400 kv. were rarely induced on lines. This, of course, is not a direct measure of the voltage of the lightning bolt. The lightning voltages used in the investigation were far in excess of any heretofore produced in a laboratory.

The lightning spark-over of various gaps follow the same laws at these extremely high voltages as at the lower voltages.

It usually takes a higher lightning voltage to "jump" a given gap than a low-frequency voltage. When it is considered that two million volts bridge only a few feet, the voltage of the lightning bolt from cloud to cloud or cloud to ground must be exceedingly high.

A photographic study shows that the laboratory lightning has the characteristic zig-zag path and side flashes of cloud lightning. The discharge also takes place with an explosive report.

The lightning spark-over of insulators is not greatly affected by rain or weather conditions. On a shielded string of insulators the spark may be made to clear in both fair and rainy weather. The lightning spark-over voltage is not reduced by the shield.

Certain materials that are conductors of moderate resistance at normal frequency voltages may be good insulators for lightning voltages. Tests in this direction indicate at once how useless a high-resistance lightning arrester is.

In measuring lightning voltages resistance must not be used in series with the sphere gap. Resistances so placed give the sphere gap all of the time lag characteristics of the needle gap and the spark-over voltage varies with the wave front.

The investigation of the change in characteristics of lightning waves as they travel along a transmission line shows a decrease in voltage and flattening of the wave front due to corona and other losses. The waves tend to double up or increase on striking an open line or an inductance. An inductance may be a real source of danger. Under certain conditions the voltage on the *far* side of an inductance may be increased to three or four times the voltage that reaches the inductance. In general, inductance to be safe should be shunted by resistance.

With these high lightning voltages and currents it is possible to investigate the protective value of ground wires and also of lightning rods. This investigation is under way.

I acknowledge the assistance of Mr. W. L. Lloyd in conducting the laboratory work.

TECHNICAL MEETINGS AT THE BUREAU OF STANDARDS

The American Physical Society and the Association of Scientific Apparatus Makers of the United States held their regular annual meetings at the Bureau of Standards at Washington on April 20 and 21. In connection with the meeting of the Scientific Apparatus Makers, an interesting exhibit was arranged in the Industrial Building.

Among the papers presented at the sessions of the American Physical Society was one by H. D. Arnold and G. W. Elman on "Permalloy," a new alloy having valuable magnetic properties. It is composed of iron and nickel and was developed in the research laboratories of the American Telephone and Telegraph Company and the Western Electric Company.

The permeability of this new alloy, it was stated, is very much greater than that of the best magnet iron. It is being tried in a new submarine cable and is expected to increase the speed of sending with the cable about four times. It also has valuable uses in telephone and radio transformers and induction coils. In addition to its high permeability, it has a very small hysteresis loss.

The electrical resistance is found to vary with the strength of the magnetic field in which the alloy is placed, so that a difference amounting to three-tenths of a per cent is caused by the earth's magnetic field, the resistance being different in the east and west position from what it is in the north and south. Its electric and magnetic properties are also changed by the application of a load.

Among the other papers presented at this meeting was a description of a high-temperature high-vacuum furnace developed at the Westinghouse laboratories and used for tantalum and other metals which have high melting points and are very susceptible to oxidation at these high temperatures.

Dr. P. W. Bridgman of Harvard gave an account of some of his measurements of the thermal conductivity of liquids at high pressures. Dr. Bridgman's apparatus is capable of attaining pressures up to 20,000 atmospheres, or 300,000 lb. per sq. in. In the present paper the values of the conductivity were given at 6000 atmospheres and at 12,000 atmospheres. It was shown that the amount of heat conducted increases about 15 per cent between these two pressures. The increase varies somewhat for the different liquids.

W. E. Forsythe of the Nela Research Laboratories described the results of comparisons of the standard high temperature scale in use at the Nela Laboratories with those used at the Bureau of Standards and at the National Physical Laboratory of England.

Other papers dealt with problems of accoustics, electricity, the determination of spectral lines, the quantum theory, and other problems of interest to physicists. A number of new and interesting types of apparatus were described. In all about 60 papers were presented.

Among the exhibits was an automatic daylight recorder which makes a record of the intensity and duration of the light throughout the day. It is possible to use color screens with this apparatus thus obtaining a record for light of any particular wave length.

A compound microscope, shown by another exhibitor, is designed so as to fold up and go in the pocket. When folded and placed in its case, it occupies about the same space and weighs about as much as a vest pocket kodak. Its magnifying power is as good as many of the smaller types of stationary compound microscopes.

A vacuum pump was shown which was conveniently arranged for lecture table use; and another, almost as compact, consisted of a combination of a rotary pump and a mercury vapor pump of the type used for producing the highest vacuum.

Another exhibit showed the various stages in the making of standard cells, and still others illustrated the latest developments in many types of instruments.

The Production of Porcelain for Electrical Insulation--III

BY FRANK H. RIDDLE
Associate, A. I. E. E.
Champion Porcelain Company, Jeffery-Dewitt Insulator Company

Review of the Subject.—*The raw materials should be carefully tested before using. China and ball clays should be tested for fired color, porosity at the regular burning temperature, fineness of grain, etc. Ball clays should be tested for raw physical strength.*

The grain size of quartz is of particular importance and the fine grain sizes should be determined by elutriation or water separation.

Feldspar should fuse to a glass with the fusion of pyrometric cone No. 8, 1280 deg. cent. (2336 deg. fahr.), and its color, degree of glassiness, amount of deformation, etc. noted.

The composition and formation of porcelain in firing are briefly described. The limits of composition are wide but the quality of the final product will vary with the composition. Special porcelains for use as spark plug cores are made by eliminating feldspar and quartz and substituting synthetic calcines.

During firing the mechanical water is first expelled. Chemically combined water is driven off at 500 deg. cent. (932 deg. fahr.). Alpha quartz assumes the beta form at 575 deg. cent. (1067 deg. fahr.) with a similar expansion in volume. Shrinkage and condensation of the volume of the clay substance takes place at 900 deg. cent. (1652 deg. fahr.). Continued firing contracts the porcelain and decreases the porosity, the feldspar finally melting and gradually taking the more refractory clay and quartz into solution or assisting in converting it into other materials, particularly the clay which breaks up into sillimanite and free silica. The solution of the quartz depends upon grain size and heat treatment. On account of volume change of the quartz grains, it is evident that the fired porcelain, in which the quartz grains are in intimate contact with the glassy groundmass will be placed in a condition of stress after cooling down as the quartz contracts more rapidly than the rest of the porcelain. Naturally the greatest strain occurs around the largest quartz grains and clearly demonstrates the necessity for fine grinding.

The properties and testing of porcelain are described. Ordinary porcelain has a tensile strength of from 3000 to 6000 pounds per square inch and a coefficient of lineal thermal expansion of from 4 to 9 $\times 10^{-6}$ per degrees centigrade, while special porcelains have a strength as high as 12,000 pounds and an expansion as low as 2.7 $\times 10^{-6}$.

Tests of Raw Materials

In the manufacture of porcelain it is necessary that the raw materials used be subjected to tests in order to check up their properties. Of these chemical analysis is one of the most important as it assures constancy of composition.

The china clays or kaolins are tested for color upon firing, for porosity at the kiln temperature employed and for fineness by passing the material through a 200-mesh sieve. In the latter test the amount of residue is determined and its color upon firing noted. The presence of impurities in the clay thus becomes readily apparent.

The ball clays are likewise tested for firing color, for porosity at the kiln temperature to note the occurrence of overfiring, for their residue on the 200-mesh sieve and for their strength in the dried state. The last test usually expresses also in an indirect way the plasticity of the material. The strength is expressed by the modulus of rupture of bars made from 50 per cent of the sample and 50 per cent of flint, which are dried up to 110 deg. cent., and kept in desiccators over sulphuric acid to keep them dry until ready for the test. The bars are usually 6 inches long with a cross-section of 1 inch by 1 inch. The load is applied at the center of the specimen which is supported by movable bearings, a fixed distance apart. From the breaking load, the length, depth and width of the bars, the modulus of rupture is computed. For good ball clays, under the conditions of the test, the modulus may vary from 300 to 450 pounds per square inch.

The ground quartz, or flint as it is commonly called, is tested for fineness by determining the residue left on the 200-mesh sieve and the color upon firing. For the more accurate determination of the fineness the so-called elutriation test is applied in which a weighed sample of flint, usually 50 grams, is placed in a cylindrical vessel, conical at the bottom, through which a current of water is caused to ascend and which carries away all finer particles, below a given size. The latter value

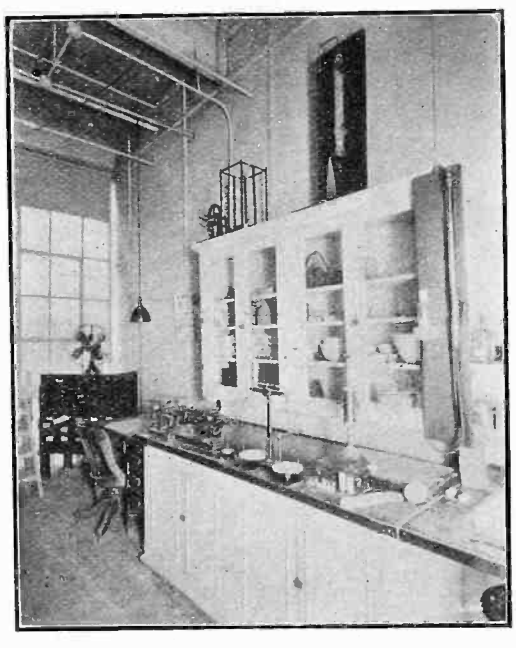


Fig. 6—Materials Testing Laboratory

depends upon the velocity of the water current, which must be kept constant. The velocities employed range from 0.8 to 1.5 mm. per second according to the kind of porcelain which is to be made. The elutriation is continued until the water runs off clear, showing that the washing separation is completed. The residue left in the conical part of the apparatus is then dried and weighed. It is evident that such a separation is much to be preferred to the sieve test, especially in the case of high grade porcelains where it is imperative that the flint be as fine as possible and its content of flour-like material as high as can be obtained. The importance of the fineness of flint for this industry cannot be emphasized too much and every precaution must be taken to insure the constancy of this factor.

Feldspar is tested for fineness in the same way as flint and in addition its degree of fusion at the temperature of pyrometric cone No. 8, about 1280 deg. cent. (2336 deg. fahr.), is noted, by observing the degree of glassiness which has been reached, the color and the degree of deformation. In addition the composition is obtained by chemical analysis. The accessory raw materials used are subjected to analytical tests.

The Composition and the Formation of Porcelain in Firing

It has been shown that the composition of porcelain may vary between wide limits. According to the proportions of the constituents, clay, feldspar and ground quartz (flint), the required firing temperature and the resulting properties of the product will vary decidedly. This is well illustrated in the triaxial diagram of Fig. 7, according to Klinefelter of the Westinghouse Electric Company, in which the relation between the composition and the physical properties is shown very clearly.

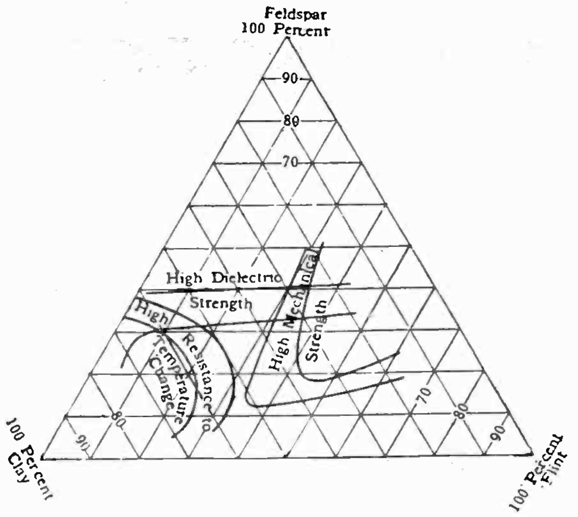


Fig. 7—Triaxial Diagram Showing Various Compositions of Electrical Porcelain and the Physical Properties of the Resultant Products

Graphs of this character are used extensively in the study of ceramic problems as they are convenient for judging areas of compositions. In studying the triaxial diagram it is evident that if a composition was made up of two of the three ingredients used it would lie on the line or leg of the triangle somewhere between the two angles which represent 100 per cent of the two particular ingredients. A mixture of 50 per cent clay and 50 per cent flint would be represented by a dot on the leg and half way between 100 per cent clay and 100 per cent flint. It is also evident that a dot right in the center of the triaxial would represent a body containing 33.3 per cent of each of the three ingredients, flint, feldspar and clay.

Again, take a body of the composition, 25 per cent feldspar, 25 per cent flint and 50 per cent clay. Make a dot on this point on the triaxial and it will be noted that it lies in the field between bodies having the best high dielectric strength, mechanical strength and resistance to temperature change. This brings out the point

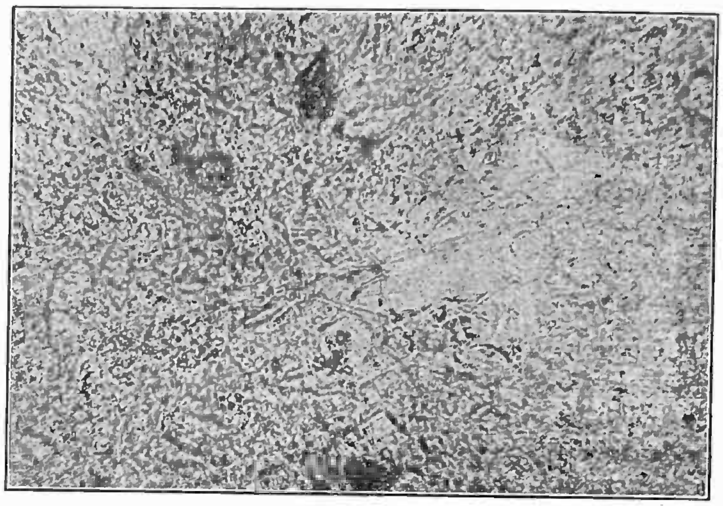


Fig. 8—The Solution of Quartz Grains and the Development of Sillimanite

that it is very difficult to get a body composition having all three properties at their best, it usually being necessary to sacrifice some of each making a body of about 85 per cent perfect in all respects or perhaps 100 per cent perfect in two respects and less perfect in the third respect. The firing, grinding, kinds of raw materials used and other variables also have an effect on these characteristics; however, the example is given to illustrate the general method of study.

While roughly speaking many high-tension porcelains contain about 50 per cent of clay substance, 27 to 30 per cent of feldspar and 20 to 23 per cent of flint, there are some in which the feldspar is as high as 45 per cent, the clay 40 to 45 per cent and the flint only 10 to 15 per cent. In some European porcelains which are matured at about cone 15 (approximately 1400 deg. cent., 2552 deg. fahr.), the clay content is 50 per cent, that of feldspar 25 per cent and of flint 25 per cent.

As has already been indicated above there are being produced for special and severe service as in spark plugs, special porcelains in which both feldspar and quartz have been practically eliminated and replaced by synthetic calcines. Thus feldspar has been replaced by a flux, corresponding to the formula, $MgO \cdot Al_2O_3 \cdot 4SiO_2$, composed of 56 per cent of kaolin, 18.2 per cent of magnesite and 25.8 per cent of flint. Again, the flint is replaced by another calcine, sintered at a high temperature, composed of 70.2 per cent of kaolin, 27.8 per cent of anhydrous alumina and 2 per cent of boric acid. The whole spark plug composition would then be, kaolin 30 per cent, ball clay 10 per cent, fluxing calcine (as given above) 20 per cent, and refractory or sillimanite calcine (as above) 40 per cent. In this case the refractory calcine may, of course, be replaced by one of the natural minerals which yields sillimanite.

It is evident that the important stage in the production of porcelain is the firing and what happens there determines once and for all its physical properties. It is also not difficult to see that different kinds of heat treatment may produce different structures from exactly the same composition. It might be well to consider briefly the changes in structure which occur during the firing process, as told us by the petrographic microscope.

During the earliest part of the firing the mechanical and hygroscopic water is expelled and at above 500

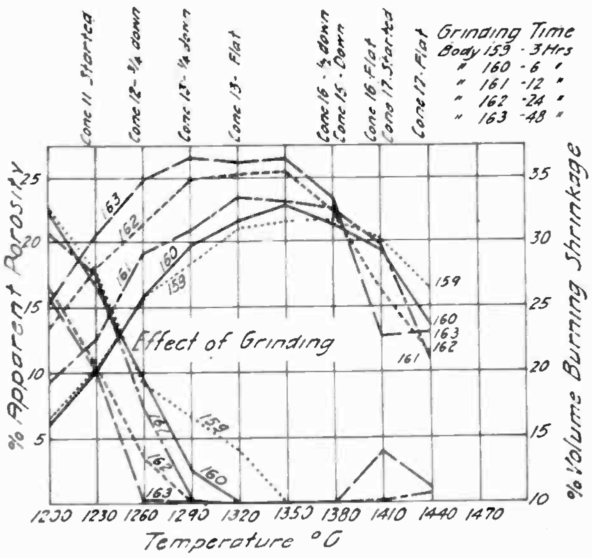


FIG. 9—DIAGRAM SHOWING PROGRESS OF VITRIFICATION OF OF FIVE PORCELAINS, THROUGH THE DROP IN POROSITY AND INCREASE IN VOLUME SHRINKAGE

Note increased porosity after vitrification had been reached through overfiring. These five porcelains all have the same composition but their differences are caused by different grain sizes due to grinding the mixtures for different periods of time.

(From *Journal* Amer. Ceramic Society, Vol. 2, No. 10, 1919.)

deg. cent. (932 deg. fahr.) chemically combined water is lost. The clay substance shows a drop in density from 2.55 to 2.47, approximately, between 500 deg. cent. and 600 deg. cent. (932 deg. to 1112 deg. fahr.) and hence an increase in molecular volume. The average expansion for different clays at this point is about 6 per cent, at 575 deg. cent. (1067 deg. fahr.) the alpha quartz assumes the beta form with a similar expansion in volume. At about 900 deg. cent. (1652 deg. fahr.) a condensation in the volume of the clay substance takes place coincident with an exothermic change. With further rise in temperature the porcelain begins to contract in volume and to decrease in porosity, slowly at first and then faster as the temperature increases commensurate with the amount of fluxes present. With the progress of vitrification the true density of the porcelain decreases, in spite of the contraction in external volume, and in fact, the progress of the molecular changes due to vitrification is admirably shown by the drop in true density with temperature. The increase in molecular volume with progressive vitrification and fusion is characteristic of most silicates. As the temperature rises the most fusible eutectics of the porcelain soften,

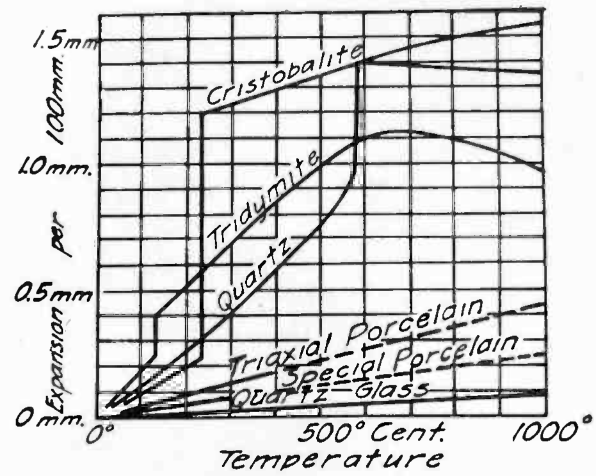


FIG. 10—CURVES SHOWING TOTAL LINEAR EXPANSION OF VARIOUS FORMS OF QUARTZ, QUARTZ GLASS AND TRIAXIAL AND SPECIAL PORCELAINS

followed later by the fusion of feldspar. The fluidity of the feldspar increases rapidly and with it its solvent effect upon the more refractory constituents, clay and quartz. The latter is attacked vigorously, the fine particles being dissolved entirely and the edges of the larger ones being rounded off. If the quartz is sufficiently fine grained all of it will be brought into solution ultimately, provided the heat treatment is continued long enough. On the other hand if the quartz is coarse the large particles remain as such suspended in the glassy matrix, thus causing the structure of the porcelain to remain heterogeneous. That such coarser

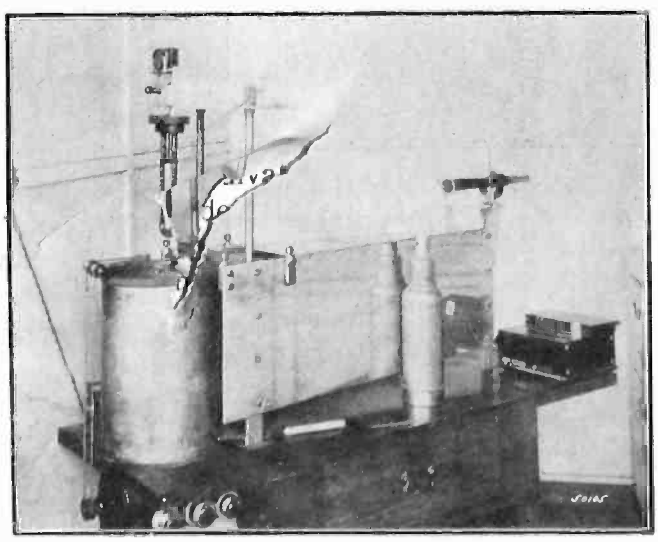


FIG. 11—APPARATUS FOR THE DETERMINATION OF THE THERMAL EXPANSION OF PORCELAIN

The expansion is measured optically on the principle of the optical lever.

quartz grains are detrimental to the best development of the porcelain cannot be doubted. Since they are subject to the crystalline inversions of quartz and the accompanying expansion and contraction in volume it is evident that upon cooling these grains which in intimate contact with the glassy groundmass must necessarily cause a condition of stress to be produced. On passing through 575 deg. cent. (1067 deg. fahr.) the contraction in volume from the beta to the alpha quartz is certain to react upon the surrounding material in causing a strained state. The larger the quartz grains the greater must be the stress produced. The importance of having the quartz as finely ground as possible is hence obvious.

It is a curious fact that the quartz remains largely as such and is not converted to cristobalite. It has been suggested by Klein that the solution of the quartz

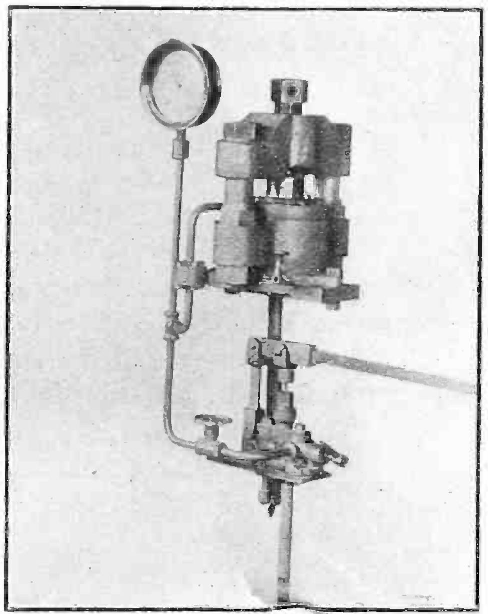


FIG. 12—PRESSURE APPARATUS FOR THE TESTING OF PORCELAIN WITH REFERENCE TO ITS IMPERVIOUSNESS TO THE ABSORPTION OF FUCHSINE SOLUTION

Tests can be made with this apparatus up to 20,000 lb. and have been run at 5000 lb. for seven days.

progresses faster than its inversion to cristobalite. However, some European investigators report the presence of some cristobalite in hard fired porcelains.

With the complete vitrification of the porcelain and the enrichment of the feldspathic glass with dissolved quartz and some of the clay substance, the bulk of the latter undergoes dissociation into sillimanite. This mineral constituent at first assumes the amorphous and crypto-crystalline form and later develops as needlelike crystals. According to the length and final temperature of the heat treatment this crystallization is more or less pronounced. In the presence of small amounts of fluxes like magnesia the crystal development becomes very marked and may become excessive, due to the growth of coarse crystals which actually reduce the mechanical strength of the porcelain. The solution of the quartz grains and the development of sillimanite are shown in the microphotograph of a porcelain in Fig. 8.

If the temperature continues to rise after complete

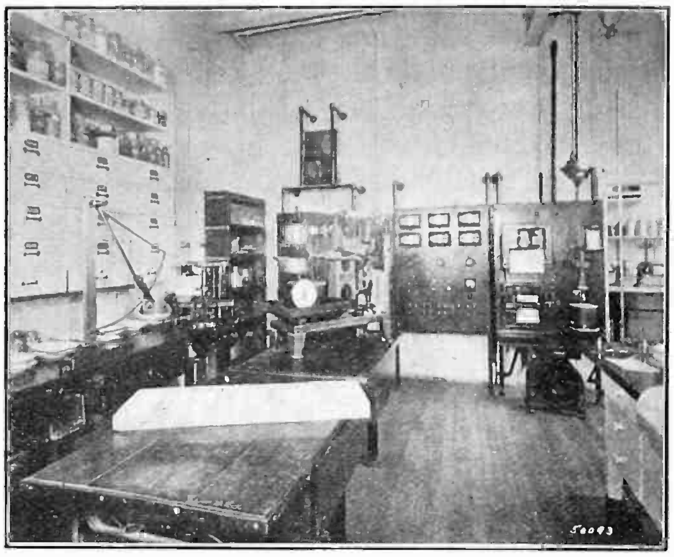


FIG. 13—VIEW OF PHYSICAL LABORATORY FOR THE TESTING OF SPECIAL PORCELAIN

vitrification has been reached the porcelain may become overfired, that is, the fluidity of the mass may become increased to such an extent that an evolution of gases takes place. This results in the formation of a vesicular structure which is worthless for the purposes of electrical insulation.

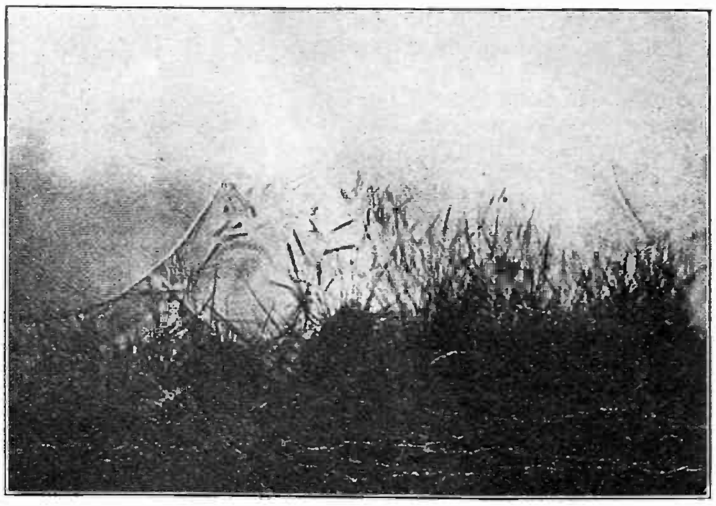


FIG. 14—CONTACT SURFACE BETWEEN BODY AND GLASS IN HIGH FIRE PORCELAIN

Note growth of sillimanite crystals with the glaze. (After Klein Tech. Paper No. 80, Bureau of Standards).

The progress of the vitrification of a porcelain and its subsequent overfiring are shown in the diagram of Fig. 9, in which both the porosity and the shrinkage of a number of porcelains are plotted against temperature.

From what has been said it is evident that there is a wide latitude in the production of widely different porcelain structures and that the heat treatment must be carefully regulated for each special type. The translucency of porcelain increases with vitrification since more light is transmitted in the presence of a larger volume of glassy matrix.

The Properties and the Testing of Electrical Porcelain

The chief properties of the porcelain with which we are concerned are their imperviousness to the absorption of liquids, their dielectric resistance and their mechanical strength.

It is evident that the first characteristic must be developed to the highest extent since any absorption of water by high-voltage porcelain must be fatal. The test commonly employed for this purpose is the immersion of the porcelain in fuchsine dye dissolved in alcohol under a pressure of 200 pounds per square inch. The appearance of the dye penetration is a measure of the thoroughness of the vitrification.

The dielectric resistance of these porcelains has been the subject of many discussions and need not be gone into at this time. This test is carried out at every plant making high-tension porcelain. In the case of special porcelains such as for spark plugs, still other severe requirements must be met. The porcelain must not only be a good insulator at atmospheric temperatures but must resist moderate voltages at temperatures around 815 deg. cent. (1500 deg. fahr.) at which the average feldspathic porcelain breaks down completely. This electro-thermic resistance is expressed by the so-called Te value, which represents the temperature at which a cubic centimeter of the material still shows a resistance of one megohm. While for the usual type of porcelain this value is approximately 400 deg. cent. (752 deg. fahr.) some of the special porcelains reach figures varying from 650 deg. to 800 deg. cent. (1202 deg. to 1472 deg. fahr.)

The mechanical strength of porcelains differ widely. The resistance to compression may vary from 45,000 to 65,000 pounds per square inch and the tensile strength from 3000 to 12,000 pounds per square inch.

The feldspathic porcelains show a resistance to tensile stress of from 3000 to 6000 pounds per square inch and some of the modern special porcelains from 9000 to 12,000 pounds per square inch. The latter values cannot be reached with feldspathic porcelains containing much undissolved quartz.

Of the less obvious properties of porcelain the thermal expansion deserves some consideration. It is easy to see that this property is likewise the result of the internal structure of the material. In this connection it is interesting to compare the total expansion of different silica materials with those of porcelain and quartz glass which are shown in the diagram of Fig. 10. The thermal expansion of porcelains as a rule decreases with the firing temperature. The coefficient of thermal expansion of some special porcelains between 16 deg. and 250 deg. cent. (59 deg. and 482 deg. fahr.) is as low as 0.00000269 to 0.000004, while clay-feldspar-quartz porcelains of ordinary low fire type are as high as 0.000009. The more homogeneous the structure of the porcelain and the lower the content of the alkalies the lower should we expect the thermal expansion to be.

It has been noted that the importance of a properly developed porcelain structure is of paramount importance and the realization of this fact will lead ultimately to the use of petrographic inspection as a criterion of the quality of porcelain. Just as in the metallurgical arts the microstructure of metals has been studied so successfully, so for electrical porcelain the petrographic microscope will aid in the detection of inferior structures.

Glaze

The subject of porcelain cannot be dismissed without some reference to the glazes which are applied to the surface. These are invariably alkali-lime-alumina silicates and form typical glasses. These must be adjusted to the body, particularly with reference to the coefficient of thermal expansion. When properly fitted the glazes increase the mechanical strength of the porcelain decidedly. On the other hand, poorly adjusted glazes weaken the product markedly. The composition of porcelain glazes may be expressed by means of empirical chemical formulas according to which it may vary from—1 RO, 0.5 Al_2O_3 4 SiO_2 to 1 RO, 1.2 Al_2O_3, 12 SiO_2, depending upon the maturing temperature of the porcelain. In these expressions RO represents the sum of the molecular equivalents of the alkalies and lime. The alkalies may fluctuate between 0.2 to 0.3 and the lime between 0.8 to 0.7 molecular equivalents. In the case of colored glazes metallic oxides such as those of iron, maganese and chromium may be introduced. The first is usually brought in by means of iron carrying, fusible clays, called slip clays.

There is usually an intimate contact produced between the glaze and the body which is shown very strikingly in the photomicrograph of Fig. 14 where crystals of sillimanite have grown out of the body into the glaze. If for some reason the contact between the glaze and the porcelain body should be lacking in intersolution surface defects are quite likely to arise.

NEW ELECTRICITY SUPPLY PLAN FOR LONDON

Centralization of London's electricity supply is provided for in a bill to come before the next session of Parliament. It is proposed that power shall be supplied through a body composed of various local authorities by acquiring the generating centers of any supplying body. Profits made are to be applied toward a reduction in the charges for electricity.

The Wave Antenna

A New Type of Highly Directive Antenna

BY HAROLD H. BEVERAGE, CHESTER W. RICE, and EDWARD W. KELLOGG

(*Continued from page 519*)

Determination of Constants from Input Impedance. Fig. 61 shows a generator (or oscillator) supplying alternating current to a line. This results in waves which travel from A to B. Assuming for the time being that there is no reflection at B and no return waves, the relation of voltage to current is $\mathbf{E}/\mathbf{I} = \mathbf{Z}$ in which $\mathbf{Z}$ is the surge impedance of the line. When the generator makes the point A positive with respect to ground it supplies a current in the direction $A - B$. Let us now imagine the generator and the absorbing terminal circuit interchanged so that the generator supplies current to the end B and the waves travel from B to A. The impedance measured at the terminals of the generator will be the same as before, but when the line is positive with respect to ground the current will be flowing in the direction $B - A$. Therefore if we define the voltage as positive when the line is positive with respect to ground, and the current as positive when in the direction $A - B$, then for waves traveling in the direction $A - B$ the voltage is $\mathbf{E} = +\mathbf{Z}\,\mathbf{I}$, but for waves traveling in the direction $B - A$ the relation is $\mathbf{E} = -\mathbf{Z}\,\mathbf{I}$.

If the forward wave leaves the end A with a magnitude and phase represented by $\mathbf{I}_0$ it will reach B with the magnitude and phase $\mathbf{I}_0\,\epsilon^{-(\alpha+j\beta)l}$ or $\mathbf{I}_0\,\epsilon^{-\gamma l}$ in which $\gamma = \alpha + j\beta$. We shall represent the forward wave as it reaches B by the symbol $\mathbf{I}_1$. Then since $\mathbf{I}_1 = \mathbf{I}_0\,\epsilon^{-\gamma l}$, $\mathbf{I}_0 = \mathbf{I}_1/\epsilon^{-\gamma l} = \mathbf{I}_1\,\epsilon^{\gamma l}$. Likewise at any point X, Fig. 61, x kilometers from B measured toward A, the current of the forward wave is $\mathbf{I}_1\,\epsilon^{\gamma x}$. And the voltage of the forward wave at X is $\mathbf{Z}\,\mathbf{I}_1\,\epsilon^{\gamma x}$.

If the reflected wave leaves B with a magnitude and phase represented by $\mathbf{I}_2$, it will be $\mathbf{I}_2\,\epsilon^{-\gamma x}$ when it reaches X, and $\mathbf{I}_2\,\epsilon^{-\gamma l}$ when it reaches A. And the voltage of the return wave is $-\mathbf{Z}\,\mathbf{I}_2$ at B, $-\mathbf{Z}\,\mathbf{I}_2\,\epsilon^{-\gamma x}$ at X and $-\mathbf{Z}\,\mathbf{I}_2\,\epsilon^{-\gamma l}$ at A.

When waves traveling in both directions are present, the total current in the line at any point X will be the vector sum of the currents due to the two trains of waves or

$$\mathbf{I}_x = \mathbf{I}_1\,\epsilon^{\gamma x} + \mathbf{I}_2\,\epsilon^{-\gamma x} \tag{36}$$

And the total voltage will be the vector sum of the voltages $\mathbf{Z}\,\mathbf{I}_1\,\epsilon^{\gamma x}$ and $-\mathbf{Z}\,\mathbf{I}_2\,\epsilon^{-\gamma x}$, or

$$\mathbf{E}_x = \mathbf{Z}\,\mathbf{I}_1\,\epsilon^{\gamma x} - \mathbf{Z}\,\mathbf{I}_2\,\epsilon^{-\gamma x} \tag{37}$$

The ratio of voltage to current, or the impedance at X is

$$\mathbf{E}_x/\mathbf{I}_x = \mathbf{Z}\,\frac{\mathbf{I}_1\,\epsilon^{\gamma x} - \mathbf{I}_2\,\epsilon^{-\gamma x}}{\mathbf{I}_1\,\epsilon^{\gamma x} + \mathbf{I}_2\,\epsilon^{-\gamma x}} \tag{38}$$

or at A the impedance is

$$\mathbf{Z}_A = \mathbf{Z}\,\frac{\mathbf{I}_1\,\epsilon^{\gamma l} - \mathbf{I}_2\,\epsilon^{-\gamma l}}{\mathbf{I}_1\,\epsilon^{\gamma l} + \mathbf{I}_2\,\epsilon^{-\gamma l}} \tag{39}$$

This becomes equal to Z if $I_2 = 0$, and becomes $-Z$ if $I_1 = 0$. The negative sign means that power is being supplied from the line to the terminal circuit by waves which travel in the direction $B - A$, instead of from the terminal circuit to the line as is the case for waves leaving A. If the waves leaving A are larger than those arriving at A (*i. e.* if $\mathbf{I}_1\,\epsilon^{\gamma l} > \mathbf{I}_2\,\epsilon^{-\gamma l}$) there is a net power supply to the line.

If the line is made very short $\mathbf{Z}_A$, the impedance at A, of the line plus the terminal circuit, must eventually become equal to that of the terminal circuit alone or equal to Z_t. Setting $l = 0$ in (**39**) and equating to $\mathbf{Z}_t$, we have

$$\mathbf{Z}_{A\ (\text{for } l=0)} = \mathbf{Z}\,\frac{\mathbf{I}_1 - \mathbf{I}_2}{\mathbf{I}_1 + \mathbf{I}_2} = \mathbf{Z}_t \tag{40}$$

The value of $\mathbf{Z}_t$ relative to $\mathbf{Z}$ determines the relation of the reflected wave $\mathbf{I}_2$ to the oncoming wave $\mathbf{I}_1$ at the reflection point B. From (**40**)

$$\frac{\mathbf{I}_1 - \mathbf{I}_2}{\mathbf{I}_1 + \mathbf{I}_2} = \mathbf{Z}_t/\mathbf{Z} \tag{41}$$

Adding 1 to each side of this equation,

$$\frac{2\,\mathbf{I}_1}{\mathbf{I}_1 + \mathbf{I}_2} = 1 + \mathbf{Z}_t/\mathbf{Z} \tag{42}$$

Subtracting 1 from each side of (**41**)

$$\frac{-2\,\mathbf{I}_2}{\mathbf{I}_1 + \mathbf{I}_2} = \mathbf{Z}_t/\mathbf{Z} - 1 \quad\text{or}\quad \frac{2\,\mathbf{I}_2}{I_1 + \mathbf{I}_2} = 1 - \mathbf{Z}_t/\mathbf{Z} \tag{43}$$

From **42** and **43**

$$\mathbf{I}_2/\mathbf{I}_1 = \frac{1 - \mathbf{Z}_t/\mathbf{Z}}{1 + \mathbf{Z}_t/\mathbf{Z}} \tag{44}$$

This is the general vector expression for reflection, which was given on page 56, where an illustrative problem was worked. We have used the term "reflection coefficient" for the ratio $\mathbf{I}_2/\mathbf{I}_1$.

If the line is short circuited at the end, $Z_t = 0$ and (**44**) becomes $\mathbf{I}_2/\mathbf{I}_1 = 1$ or $\mathbf{I}_2 = \mathbf{I}_1$. The total current $\mathbf{I}_1 + \mathbf{I}_2$ then becomes $2\,\mathbf{I}_1$ which is the familiar case of the current doubling at a short-circuit reflection.

If $Z_t = Z$, $\mathbf{I}_2/\mathbf{I}_1 = 0$, or $\mathbf{I}_2 = 0$ or there is no reflection.

With an open circuit at the end $Z_t = \infty$, $\mathbf{I}_2/\mathbf{I}_1$ becomes -1, or $\mathbf{I}_2 = -\mathbf{I}_1$, the total current at the reflection point being $\mathbf{I}_1 + \mathbf{I}_2 = \mathbf{I}_1 - \mathbf{I}_1 = 0$. The total voltage at the reflection point becomes $\mathbf{Z}\,(\mathbf{I}_1 - \mathbf{I}_2) = Z\,(\mathbf{I}_1 + \mathbf{I}_1) = 2\,\mathbf{Z}\,\mathbf{I}_1$ or twice that due to the oncoming wave alone. This is the case of doubling of voltage at an open circuit reflection.

Fig. 62 shows the current and voltage vectors at 0, 1, 2, 3, 4, 5 and 6 kilometers from a short-circuit reflection, the attenuation constant being taken as 0.05 per kilometer, the wave length 15 kilometers and the velocity ratio $n = 0.8$ so that the length of a wave on the wire is 12 kilometers. Since in the case of a short circuit reflection $I_2 = I_1$, their vectors coincide at the reflection point. The vector $\mathbf{I}_1\, \epsilon^{\gamma x}$ of the forward wave, is advanced in phase and increased in magnitude as we proceed toward the source, or away from the reflection point, while the vector of the reflected wave, $\mathbf{I}_2\, \epsilon^{-\gamma x}$, becomes smaller and retarded in phase. At 3 kilometers from the reflection end, the current vectors have rotated 90 deg. each, in opposite directions, and are therefore 180 deg. apart, and the resultant current is seen to have a minimum value equal to the difference in the lengths of the two vectors. Referring next to the voltage diagram, the

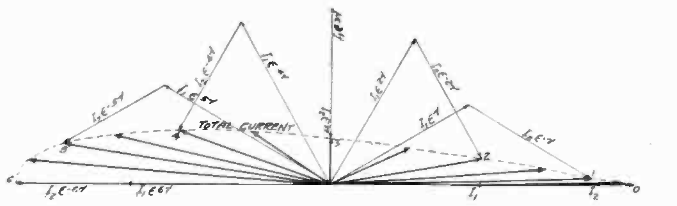


Fig. 62A—Currents at Various Distances from Short Circuit (Heavy Arrows are Vectors of Total Current)

vectors $\mathbf{Z}\, \mathbf{I}_1$ and $-\mathbf{Z}\, \mathbf{I}_2$ at the reflection point are equal and opposite giving zero resultant, for there is no voltage across the line at the short circuit. At 3 kilometers from the short circuit the voltage vectors have rotated into coincidence, giving a maximum resultant equal to the sum of the lengths of the two vectors. Since the current reaches a minimum and the voltage a maximum value at this point, the impedance or ratio of voltage to current will be a maximum. Fig. 63 shows the total current and voltage at various distances from the short-circuited end, calculated by vectors as indicated in Fig. 62. The impedance and phase angle are also shown. The general form of the current distribution curve should be compared with the experimental curves shown in Figs. 7 to 9.

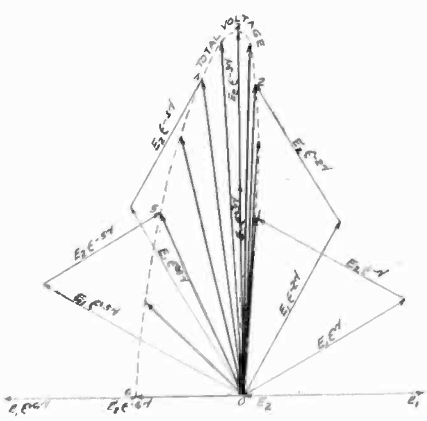


Fig. 62B—Voltage at Various Distances from Short Circuit (Heavy Arrows are Vectors of Total Voltage)

The three kilometers, or distance at which the impedance minimum was reached in Fig. 62, is a quarter of the length of a wave on the wire. Let us compare this result with that given by equation (**38**). Restating the equation.

$$\mathbf{E}_x / \mathbf{I}_x = \mathbf{Z}\, \frac{\mathbf{I}_1\, \epsilon^{\gamma x} - \mathbf{I}_2\, \epsilon^{-\gamma x}}{\mathbf{I}_1\, \epsilon^{\gamma x} + \mathbf{I}_2\, \epsilon^{-\gamma x}} \qquad (38)$$

In the case of a short-circuit reflection $I_2 = I_1$. Making this substitution in (**38**) and multiplying numerator and denominator by $\epsilon^{-\gamma x}$, which simplifies the expression, we get

$$\mathbf{E}_x / \mathbf{I}_x = \mathbf{Z}\, \frac{\mathbf{I}_1 - \mathbf{I}_1\, \epsilon^{-2\gamma x}}{\mathbf{I}_1 + \mathbf{I}_1\, \epsilon^{-2\gamma x}} = \mathbf{Z}\, \frac{1 - \epsilon^{-2\gamma x}}{1 + \epsilon^{-2\gamma x}}$$

$$= \mathbf{Z}\, \frac{1 - \epsilon^{-2\alpha x}\, \epsilon^{-j 2 \beta x}}{1 + \epsilon^{-2\alpha x}\, \epsilon^{-j 2 \beta x}} \qquad (45)$$

which is the impedance of the line x kilometers from a short circuit reflection

In the case we have been considering $x = 3$ kilometers and the wire wave length $= n\,\lambda = 12$ kilometers, so that $x = \frac{1}{4}\, n\,\lambda$. Since $\beta = \frac{2\pi}{n\,\lambda}$, $\beta\, x = \frac{2\pi}{n\,\lambda} \times \frac{n\,\lambda}{4} = \pi/2$, and $2\,\beta\, x = \pi$. The factor

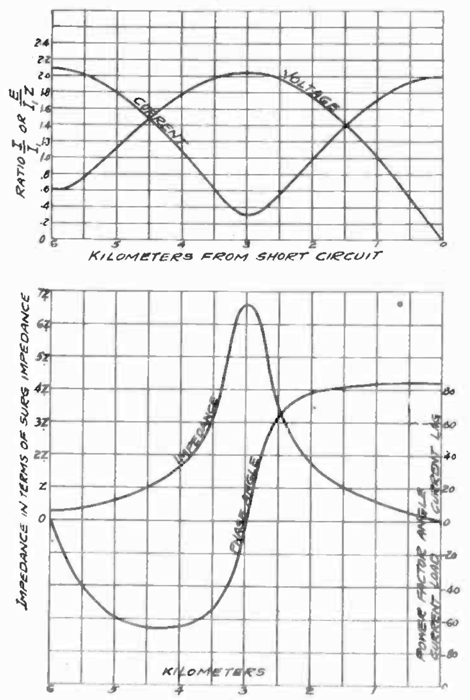


Fig. 63—Current, Voltage, Impedance and Power Factor Angle on Short-Circuited Line. (Current and Voltage Expressed as Ratio to Those of Wave Reaching Reflection Point)

$\epsilon^{-j 2 \beta x}$ in (**45**) then becomes $\epsilon^{-j\pi} = \cos \pi - j \sin \pi = -1$ so that the impedance a quarter of a wire wave length from a short-circuit reflection is

$$\mathbf{Z}_{max} = \mathbf{Z}\, \frac{1 + \epsilon^{-2\alpha x}}{1 - \epsilon^{-2\alpha x}} \qquad (46)$$

At six kilometers or a half wire wave length from the short-circuit reflection, we find in Fig. 62 that the total voltage is a minimum and the total current a maximum, so that the line impedance is at a minimum value. Here $x = \frac{1}{2}\, n\,\lambda$, $\beta\, x = \frac{2\pi}{n\,\lambda} \times \frac{n\,\lambda}{2} = \pi$, and $2\,\beta\, x = 2\,\pi$. Therefore $\epsilon^{-j 2 \beta x} = \epsilon^{-j 2 \pi} = +1$. Using this in (45) we find that the impedance a half wire wave length from a short-circuit reflection is

$$Z_{min} = Z \frac{1 - \epsilon^{-2\alpha x}}{1 + \epsilon^{-2\alpha x}} \qquad (47)$$

The factor $\epsilon^{-j2\beta x}$ again reaches the value -1, when $2\beta x$ becomes 3π, 5π, 7π, 9π, ..., or when the distance x is equal to any odd number of quarter wave lengths, and it becomes $+1$ when $2\beta x$ equals 2π, 4π, 6π, 8π, ..., or when x is an even number of quarter wave lengths. Therefore the impedance of a short-circuited line is expressed by (46) if x is an odd number of quarter wave lengths and by (47) if x is an even number of quarter wave lengths. (It being understood that "wave length" in this connection refers to the wire wave length, $n\lambda$)

In the case of an open-circuit reflection $I_2 = -I_1$, and the general expression (38) for impedance becomes

$$E_x/I_x = Z \frac{I_1 \epsilon^{\gamma x} - I_2 \epsilon^{-\gamma x}}{I_1 \epsilon^{\gamma x} + I_2 \epsilon^{-\gamma x}} = Z \frac{I_1 \epsilon^{\gamma x} + I_1 \epsilon^{-\gamma x}}{I_1 \epsilon^{\gamma x} - I_1 \epsilon^{-\gamma x}}$$

$$= Z \frac{1 + \epsilon^{-2\gamma x}}{1 - \epsilon^{-2\gamma x}} = Z \frac{1 + \epsilon^{-2\alpha x}\,\epsilon^{-j2\beta x}}{1 - \epsilon^{-2\alpha x}\,\epsilon^{-j2\beta x}} \qquad (48)$$

In Fig. 62 the minimum current or voltage is seen to be the difference between the lengths of the vectors of the forward and return waves. If these are very nearly equal, the impedance becomes very high at a

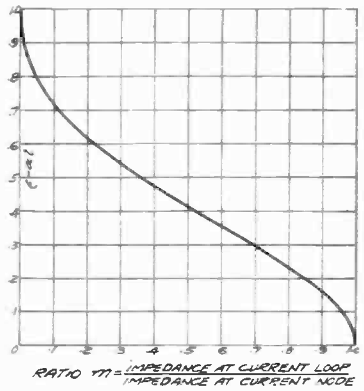


FIG. 64—CURVE FOR DETERMINING LINE ATTENUATION FROM IMPEDANCE RATIO

current node, and very low at a voltage node. On the other hand if the return wave is small compared with the forward wave, the impedance varies through a much smaller range. Thus the ratio of minimum to maximum impedance shows the magnitude of the return

TABLE VIII

CONDITIONS FOR MAXIMUM OR MINIMUM IMPEDANCE OF LINE

Distance from point of reflection, wave lengths	1/4	2/4	3/4	4/4	5/4	6/4	7/4	8/4	9/4
Impedance, with short-circuit reflection	max.	min.	max.	min.	max.	min.	max.	min.	max.
Impedance, with open circuit reflection	min.	max.	min.	max.	min.	max.	min.	max.	min.

When $\epsilon^{-j2\beta x} = -1$, or when x is an odd number of quarter wave lengths, the impedance (48) takes the minimum value shown in (47), and when $\epsilon^{-j2\beta x} = +1$ or x is an even number of quarter wave lengths the impedance x kilometers from the end of the open-circuited line has the maximum value given by (46).

Summarizing, the impedance of the line takes the minimum value (47) or the maximum value (46), depending on the type of reflection and the distance from the reflection point, as shown in Table VIII. Since in the present case the impedance is to be measured at the end of the line we substitute l for x in (46) and (47) giving for the line input impedance.

$$Z_{max} = Z \frac{1 + \epsilon^{-2\alpha l}}{1 - \epsilon^{-2\alpha l}} \qquad (46a)$$

$$Z_{min} = Z \frac{1 - \epsilon^{-2\alpha l}}{1 + \epsilon^{-2\alpha l}} \qquad (47a)$$

In the foregoing discussion we have thought of the wave length as constant and the distance from the point of reflection as being varied, but a series of maxima and minima as indicated in Table VIII is also obtained if the length of the line is constant and the wave length, or frequency is changed. This is what is done when we take the measurements for plotting the input impedance curve like that shown in Fig. 60.

wave as compared with the forward wave, or in other words it shows the attenuation which the waves undergo in traveling to the end of the line and back.

If the frequency of the current being supplied to the line, (in Fig. 61) is such that there are a whole number of quarter waves on the line, and we take measurements of the input impedance, with the far end open, and also with it short-circuited, we obtain a maximum impedance (46a) and a minimum impedance (47a) for the same frequency. Letting m stand for the ratio of the minimum to maximum impedance, we may calculate the attenuation as follows:

$$m = Z_{min}/Z_{max} = \frac{Z \dfrac{1 - \epsilon^{-2\alpha l}}{1 + \epsilon^{-2\alpha l}}}{Z \dfrac{1 + \epsilon^{-2\alpha l}}{1 - \epsilon^{-2\alpha l}}}$$

$$= \left(\frac{1 - \epsilon^{-2\alpha l}}{1 + \epsilon^{-2\alpha l}} \right)^2$$

$$\sqrt{m} = \frac{1 - \epsilon^{-2\alpha l}}{1 + \epsilon^{-2\alpha l}} \qquad (49)$$

$$\sqrt{m} + 1 = \frac{2}{1 + \epsilon^{-2\alpha l}}$$

$$\sqrt{m} - 1 = \frac{2\,\epsilon^{-2\alpha l}}{1 + \epsilon^{-2\alpha l}} \text{ or}$$

$$1 - \sqrt{m} = \frac{2\,\epsilon^{-2\alpha l}}{1 + \epsilon^{-2\alpha l}}$$

$$\frac{1 - \sqrt{m}}{1 + \sqrt{m}} = \epsilon^{-2\alpha l}$$

$$\sqrt{\frac{1 - \sqrt{m}}{1 + \sqrt{m}}} = \epsilon^{-\alpha l} \qquad (50)$$

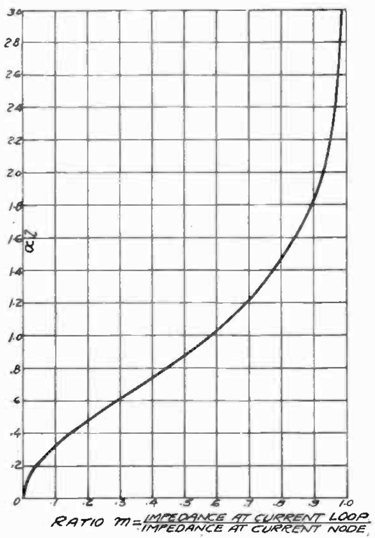


FIG. 65—CURVE FOR DETERMINING ATTENUATION CONSTANT

Fig. 64 shows $\epsilon^{\alpha l}$ as a function of the impedance ratio m, and Fig. 65 shows $\alpha\, l$ as a function of m.

If the frequency at which it is desired to determine the attenuation, is not such as to make the line an exact number of quarter waves long, the values of maximum and minimum impedance may be found by interpolation, using the envelopes of the curves as shown in Fig. 60. For example, in Fig. 60 the imped-

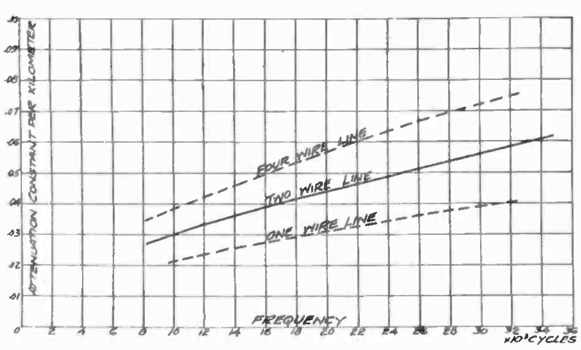


FIG. 66—ATTENUATION CONSTANTS OF ANTENNAS

ance ratio at 25,000 cycles is $m = 220/740 = 0.297$. Using this in Fig. 64 we find $\epsilon^{-\alpha l} = 0.54$.

Then $-\alpha\, l = \log_\epsilon 0.54$ and $+\alpha\, l = \log_\epsilon \dfrac{1}{.54} = \log_\epsilon$ $1.85 = 2.3 \log_{10} 1.85 = 2.3 \times 0.2672 = 0.617$ which may also be found directly from Fig. 65.

In this case $l = 12$ kilometers so that $\alpha = 0.617/12$ $= 0.0513$ Fig. 66 shows the values of the attenuation constant α, corresponding to the input impedance curves shown in Fig. 60.

Referring again to equations (**46**) and (**47**) we see that if we multiply the two together we have (**Z** max.) (**Z** min.) $=$ $\mathbf{Z}^2$ or

$$\mathbf{Z} = \sqrt{(\mathbf{Z}\text{ max.})\,(\mathbf{Z}\text{ min.})} \qquad \mathbf{(51)}$$

Using the values of impedance for 25,000 cycles obtained from Fig. 60 we find that the surge impedance of the line at this frequency is $\mathbf{Z} = \sqrt{740 \times 220}$ $= 435$ ohms. The surge impedance or geometrical mean of the maximum and minimum impedance values is indicated in curve C of Fig. 60.

For finding the line velocity it is necessary to know the mode of oscillation (or number of quarter waves on the line) for each frequency at which a maximum or minimum impedance occurs. A curve like the one marked A in Fig. 67 can then be plotted showing the number of quarter waves on the line, as a function of frequency. A similar curve B is plotted on the same sheet for a light velocity line of the same length. Thus if the length of the line is 12 kilometers and its wave

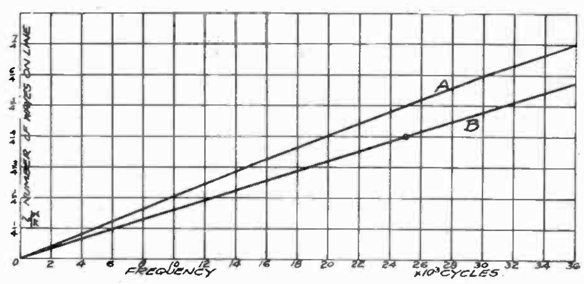


FIG. 67—MODE OF OSCILLATION OF TWELVE KILOMETER ANTENNA. A—ACTUAL LINE. B—IDEAL LINE

velocity were equal to that of light, it would show a 4/4 wave oscillation at $\lambda = 12$, or $f = \dfrac{3 \times 10^5}{12} =$ 25,000 cycles. Since the line B is straight and passes through the origin, it may be drawn by calculating and plotting a single point. The ordinate to the line B is l/λ and the ordinate to curve A is $l/n\,\lambda$, whence the velocity ratio for any frequency is

$$n = \frac{\text{Ordinate to } B}{\text{Ordinate to } A}$$

Fig. 68 shows the velocity ratio u/v or n corresponding to the input impedance curves of Fig. 60. The values shown represent a fair average of those so far observed on antennas consisting of two bare 0.102 inch (0.26 cm.) diameter wires in multiple, seven to nine meters above ground. Curves are also shown which give an idea of the effect of using a different number of wires. The line constants depend not only on the type of construction but on the character and moisture of the soil and therefore will vary from place to place and change somewhat with the season.

Fig. 69 shows the apparatus which the writers have used for measuring line input impedance. At either a voltage or current node the line is substantially a unity power factor load and its impedance may be determined by finding the non-inductive resistance which will give the same current. The pick-up coil should preferably have a low reactance compared with the impedance to be measured. When a current maximum is observed, the resistance is substituted for the line and the condenser C_2 adjusted to tune out the reactance of the pick-up coil. The circuit is then switched back to the line and the oscillator frequency readjusted to give current maximum. If the change of oscillator frequency has been considerable a repetition of the process will be needed. In the case of a low loss line it is desirable to use a relatively high-reactance pick up coil and high sensitivity meter for measuring the impedance maxima and a lower impedance coil

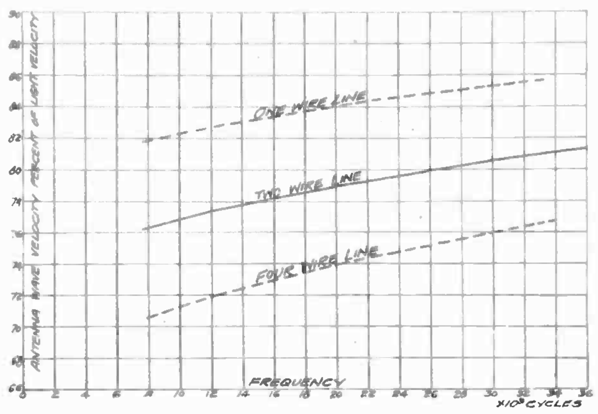


Fig. 68—Wave Velocities of Antennas

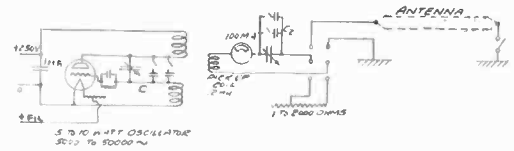


Fig. 69—Circuit for Measuring Antenna Input Impedance for Long Waves

and less sensitive meter for measuring the low values of line impedance. Fig. 70 shows such an arrangement, indicating coil values which have been found suitable for a 10,000 to 20,000 meter range of wave lengths. Current transformers are permissible. Owing to the rapid change from low to high-current values precautions should be taken to avoid meter burn outs. Oscillator harmonics should be minimized by using large capacity C, and high-efficiency, low-inductance coils in the oscillator circuit, with loose coupling to the pick up coil.

It is not in all cases necessary to take the impedance characteristics of the line, both open and short-circuited. With a good set of readings for either condition, the envelope of the curves can be drawn in and the surge impedance and attenuation determined approximately.

It is not necessary to use a damping resistance at the oscillator end of the line with a view to preventing reflection. For a given frequency the line presents a definite impedance at its terminals, and adding resistance in the supply circuit merely reduces the current and voltage supplied to the line without altering the ratio of voltage to current at the line terminals.

It is desirable in some cases to check the values of line constants as determined from the input impedance, by direct measurement. Arrangement is made for telephone communication over the line as shown in Fig. 71 the circuits being designed to have negligible effect on the radio frequency currents. Various resistances are tried at the far end of the line, until a value is found which gives constant impedance at the oscillator end,

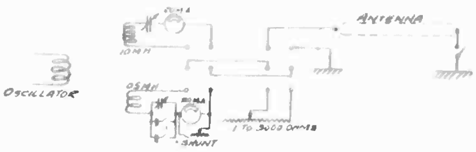


Fig. 70—Circuit for Measuring Input Impedance of Low Loss Lines

over a considerable range of frequency. A small amount of reactance in addition to the resistance may be required to give perfectly constant impedance at the oscillator end, since the surge impedance is not necessarily a pure resistance. If the surge impedance changes with frequency a new resistance setting will be required for a different frequency range. Leaving the surge impedance as found in this way, in the far end of the line, simultaneous readings of the currents at the two ends are taken at a number of different frequencies, and the average ratio of received to supplied current gives the attenuation, $\epsilon^{-\alpha l}$. Measurements at different frequencies of the impedance of the line at the oscillator end give a check on the surge impedance as found by trial at the far end. The presence of partial reflections

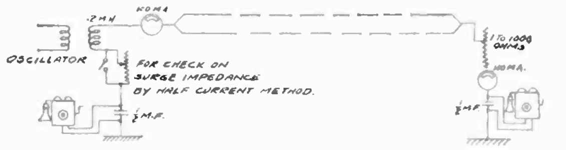


Fig. 71—Circuit for Direct Measurement of Attenuation

on the line, which may result from changes in ground conditions, may cause considerable error in the values of the constants as found by this method.

More complete and reliable information on the behavior of the line is obtained by supplying one end with current of constant frequency and amplitude, and measuring the current at intervals along the line, with different circuit conditions at the far end. If the end is damped with the true surge impedance, and there are no points of partial reflection on the line itself, the current will show a continuous decrease, following the exponential law. If the current is plotted as a function of distance on "semi log" paper, the points will fall on a straight line and the slope of the line will show the attenuation constant. If reflections occur either at the end or at any other point on the line there will be humps or hollows in the curve. With the end open-circuited or grounded, this method of study shows the standing waves on the line, from which the velocity and attenuation can be calculated. Curves of this kind are shown in Figs. 3, 4, 5, 7, 8 and 9.

Interpretation of Observed Line Constants. The explanation of the manner in which velocity and attenuation are affected by frequency, is to be found in the varying depth of penetration of the return currents into the ground. Fig. 72 shows the general shape of the path of the ground current. There is a "skin effect" which tends to concentrate the earth currents near the surface. If it were not for this skin effect the mean depth of the earth currents in ground of uniform conductivity would be a considerable fraction of a wave length, probably between one and two thousand meters with a twelve thousand meter wave. As it is, most of the earth current is within one hundred meters of the surface, with waves of this length and soil of moderate conductivity. Zenneck's[19] analysis gives the depths of penetration of earth currents for the case of space waves of plane wave front from which we can obtain a rough idea of the order of magnitude for the case of waves on a wire supported a short distance above earth.

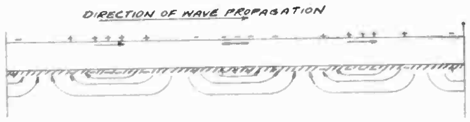


FIG. 72—DISTRIBUTION OF GROUND CURRENTS UNDER WIRE CARRYING WAVES

If the earth carries current almost entirely by conduction rather than by capacity, which is true for all except short wave lengths or extremely high-resistance ground, Zenneck's formula for penetration may be stated in the following form.

$$D = 50\sqrt{\rho/f}$$

in which D is the depth in meters at which the earth current density is reduced to $1/\epsilon = 0.368$ of its value at the surface.

ρ = specific resistance of the earth in ohms per centimeter cube.

f = frequency

This gives for a 12,000 meter wave ($f = 25{,}000$) and a specific resistance $\rho = 10^5$ ohms, a penetration $D = 100$ meters.

In Fig. 72 it is seen that there are both vertical and horizontal earth currents, but for the vertical currents the distance is relatively small and the cross section great. If the drawing were more nearly to scale this difference between the vertical and horizontal earth currents would be still more apparent. The conditions may be approximately represented by Fig. 73 in which a small resistance is shown in series with the line to ground capacity and a higher resistance in the horizontal return conductor, which is at a depth corresponding to the mean depth of the earth currents. The capacity of such a line would be substantially the same as for a wire of the same height, over a perfectly conducting earth. The inductance would be that corresponding to a wire $H + D$ meters above a conducting plane which forms the return conductor. There would be a small added charging current loss due to the resistance in series with the capacity and a much larger loss due to the resistance of the horizontal return conductor. Since the depth of penetration increases with wave length we should expect greater inductance and therefore lower velocities on long waves. The greater the penetration the lower the resistance to the earth currents. Therefore the losses are less and the attenuation less on long waves. High-ground resistance increases the penetration and loss at the same time, and therefore reduces the velocity and increases the attenuation.

Beverage found for the sandy soil near Eastport, L. I. a specific resistance of about 2×10^6 ohms per centimeter cube. Since ground water occurs at a depth of something less than 100 feet (30 meters) the excess resistance and inductance of the Riverhead antenna are materially less than those corresponding to this value of soil resistance.

Table IX shows the calculated inductance and capacity of a one, two, and a four wire line based on perfectly conducting ground. The wire spacing is taken as 4 feet (1.3 meters) each way with 20 feet (6.6 meters) clear above ground.

TABLE IX.
CONSTANTS OF LINE OVER PERFECT GROUND

	1 wire	2 wires	4 wires
L_0 inductance, $\frac{m\,h}{k\,m}$, perfect ground	1.86	1.14	0.8
C_0 capacity, $\frac{m\,f}{k\,m}$, perfect ground	0.006	0.0098	0.0139
D-C. resistance of wires, $\frac{\text{ohms}}{km.}$	3.3	1.64	0.82
R_w = A-C.[20] resistance of wires at f = 12,000 ~	4.44	2.22	1.11
20,000	5.50	2.75	1.38
30,000	6.6	3.3	1.64

The observed attenuation and velocity shown in Figs. 66 and 68, give a basis for calculating the effective inductance and resistance provided the capacity is known. The actual capacity is somewhat greater than C_0 as given above owing to insulators, poles, and the proximity of trees. An audio-frequency bridge measurement showed 0.011 microfarads per kilometer for two wires at a height of thirty feet. As this value seems high and the accuracy of the bridge was not checked, we shall assume the capacity to be 10 per cent greater

19. Translation given in Fleming "Principles of Electric Wave Telegraphy and Telephony" Third Edition P. 812.

20. Calculated by formula for skin effect given on page 135 of Principles of Electric Wave Telegraphy and Telephony, J. A. Fleming, 1916.

than the calculated value C_0. This gives the constants shown in Table X for a two wire line.

TABLE X.

	Two Wire Line		
Frequency	12,000	20,000	30,000
u = observed velocity, km. per sec.	2.33×10^5	2.37×10^5	2.42×10^5
$n = \frac{u}{3 \times 10^5}$ = velocity ratio	77.4	79	80.6
$L = \frac{1}{u^2 (1.1\, c_0)}$ = effective inductance	1.73	1.66	1.59
$L_g = L - L_0$ = added inductance for ground, mh. per km.	0.59	0.52	0.45
D = mean depth of earth currents (meters)	118	82	56
$Z = \sqrt{\frac{L}{1.1\, C_0}}$ surge impedance	400	393	384
α = observed attenuation per kilometer	0.033	0.044	0.056
$R = 2\, \alpha\, Z$ = resistance to give observed attenuation, ohms per k. m.	26.5	34.5	43
$R_j = R - R_w$ = equivalent resistance of ground	24.3	31.75	39.7
$\omega\ L$ = Inductive reactance per kilometer	131	208	300

The ground losses and penetration would not be materially different for the one and four wire lines. Taking the values of R_g and L_g for the two wire line as applicable to the one and four wire lines, we may calculate the attenuation and velocity to be expected on the latter as follows:

The formulas $Z = \sqrt{L/C}$, $\alpha = \frac{R}{2\ Z}$, and $u = \frac{1}{\sqrt{L\ C}}$ are approximations applicable when the resistance is small compared with the inductive reactance. In this

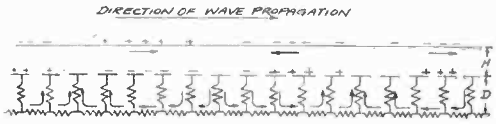


FIG. 73—CIRCUIT APPROXIMATELY EQUIVALENT TO GROUND

instance $\omega\ L$ is more than four times R for all the cases calculated and the errors in the magnitudes of α, u, and Z, due to the use of these abbreviated formulas are small. There is however an appreciable phase angle to the vector of the surge impedance Z, which it is of interest to estimate. If the losses were equally divided between dielectric and vertical ground current losses on the one hand and wire resistance and horizontal ground current losses on the other, or to put it differently if a short section of line with ground return had the same power factor, considered as an inductance as it has when treated as a condenser, then the surge impedance, would have zero phase angle or be equivalent to a pure resistance. In the present case the ground losses are for the most part equivalent to the effect of an added resistance in the line. If we assume all the losses to be the result of line resistance we shall obtain a maximum value for the phase angle of the surge impedance. The full expression for surge impedance in vector terms is

$$Z = \sqrt{\frac{R + j\,\omega\,L}{G + j\,\omega\,C}}$$

in which G represents a shunt conductance of such value as to give the equivalent of all the dielectric loss.

The phase angle of Z is $1/2 \left(\tan^{-1} \frac{\omega\ L}{R} - \tan^{-1} \frac{\omega\ C}{G} \right)$ which becomes $-\ 1/2 \tan^{-1} \frac{R}{\omega\ L}$ when $G = 0$. From the values of L, C, and R given in the above tables we find the values for the surge impedance shown in Table XII. The figures preceded by $-j$ are ohms of capacity reactance. The actual amount of reactance would be slightly less than this, since G is not actually zero.

DIRECTIVE RECEPTION AND STRAY RATIO

Direction of Static. The general opinion that, on the average, summer static comes from a definite direction, for example from a southwesterly direction on our North Atlantic coast, seems to have been brought to a focus by Pickard's classical paper[21] on "Static Elimination by Directional Reception." In the discussion Pickard cites an interesting note made by Marconi in 1906, giving the results of his observation on the directivity of static.

The remarks by Austin, Blatterman, Hoxie and Beverage are of particular interest in showing the trend of opinion as based on observation. The early work of Taylor[22] is also of considerable interest in this connection. Taylor found that atmospherics were very strong on the high vertical antennas contemplated for European reception. After describing tests of various heights and lengths of antenna with the result that the signal to static ratio remained constant, he goes on to say—"One of the first questions that naturally arises in connection with these sturbs is, 'where do they come from?' and it was considered that if their office of origin could be located this might help solve the problem of their elimination. For this purpose an investigation has been conducted at the Belmar Station, where a directive antenna of the Bellini-Tosi type was erected." The conclusions from his observations are that static at Belmar has an average direction of south to southwest, as later observations have shown. Alexanderson[23] had also observed the marked directivity of static with his Barrage Receiver. More recently a great deal of very valuable systematic experimental work has been done by Austin[24] on this subject.

Austin's conclusions on the directivity of static for the wave length range of 8000 to 18,000 meters are briefly as follows:

1. *U. S. Atlantic Coast* static mainly southwest.
2. *Gulf Coast* roughly southwest.

21. Institute of Radio Engineers 1920 Vol. 8, P. 397.
22. C. H. Taylor, Direction of Maximum Atmospheric Disturbances on Wave Range 6000 to 12000 Meters "Belmar," N. J. Sept., Oct. 1915 and Nov., Jan. 1916, Yearbook of Wireless Telegraphy and Telephony 1917 P. 726-743.
23. E. F. W. Alexanderson, I. R. E. Aug. 1919.
24. Louis Austin Jour. Franklin Inst. May 1921, page 619.

TABLE XI

	One Wire Line			Four Wire Line		
Frequency	12,000	20,000	30,000	12,000	20,000	30,000
L_0 – inductance, perfect ground, mh. per km	1.86	1.86	1.86	0.8	0.8	0.8
L_g – inductance due to penetration	0.59	0.52	0.45	0.59	0.52	0.45
$L = L_0 + L_g$ = total inductance	2.45	2.38	2.31	1.39	1.32	1.25
$C = 1.1\ C_0$ = Capacity	0.0066	0.0066	0.0066	0.0153	0.0153	0.0153
$u = \frac{1}{\sqrt{LC}}$ = velocity	2.48×10^5	2.52×10^5	2.56×10^5	2.16×10^5	2.22×10^5	2.28×10^5
$n = \frac{u}{3 \times 10^5}$ = velocity ratio	0.827	0.84	0.853	0.72	0.74	0.76
R_g = ground resistance, $\frac{\text{ohms}}{k\ m}$	24.3	31.75	39.7	24.3	31.75	39.7
R_w = wire resistance $\frac{\text{ohms}}{k\ m}$	4.4	5.5	6.6	1.1	1.4	1.6
$R = R_g + R_w$ = total resistance	28.7	37.25	46.3	25.4	33.15	41.3
$\alpha = \frac{R}{2Z}$ = attentuation constant	0.0235	0.031	0.039	0.042	0.0565	0.072
$Z = \sqrt{L/C}$ = surge impedance	610	602	592	301	294	286
$\omega\ L$ = inductive reactance per km	185	299	435	105	166	236

TABLE XII

Surge Impedance

	1 Wire Line			2 Wire Line			4 Wire Line		
Frequency	12,000	20,000	30,000	12,000	20,000	30,000	12,000	20,000	30,000
$\omega\ L$	185	299	435	131	208	300	105	166	236
R	28.7	37.2	46.3	26.5	34.5	43	25.4	33.1	41.3
$\text{Tan}^{-1} \frac{R}{\omega L}$	8.8°	7.0°	6.0°	11.4°	9.4°	8.2°	13.6°	11.3°	10°
Angle of $Z = -1/2\ \text{Tan}^{-1} \frac{R}{\omega L}$	−4.4°	−3.5°	−3.0°	−5.7°	−4.7°	−4.1°	−6.8°	−5.65°	−5°
Z = Total Impedance	610	602	592	400	393	384	301	294	286
Components, R	608	601	591	398	392	383	299	292	285
X	−47j	−37j	−31j	−40j	−32j	−27j	−36j	−29j	−25j

3. *Seattle* (vicinity) roughly east.
4. *San Francisco and San Diego* sharply east.
5. *Porto Rico* two marked directions, namely, west and south.

Gain from Directive Receivers. Even at times when static shows no marked predominating direction, a directive receiving system will obviously reduce or eliminate that fraction of the static which comes from directions to which the receiving system is insensitive. When static is sharply directional the possibilities of improving the stray ratio through the use of a suitable directive receiving system are still greater.

An important step in the improvement of stray ratios was taken when loops superseded static antennas for long wave reception. A further improvement resulted from combining a loop with a static antenna to give a unidirectional antenna system. The loop is more directive than the static antenna. Fig. 74 shows the directive curve of a loop, the large circle being drawn to show the relative sensitiveness of a static antenna for various directions as compared with the loop. The area of the directive curve of the loop is one-half that of the static antenna when both have the same sensitiveness for signal. This means that if disturbances come equally from all directions, the loop will receive just half the energy from the disturbing waves which the static antenna receives.

The combination of loop and static antenna while no more sharply directive than the simple loop from the standpoint of the area of its directive curve, can be adjusted so that reception from certain directions is prevented. Fig. 75 shows the directive curve of the combination of loop and static antenna when the intensities of the two are adjusted to equality for signal. By using less energy from the static antenna than from the loop the directive curve can be made to assume any form such as Fig. 76, intermediate between the cardioid of Fig. 75 and the lemniscate of Fig. 74. This is an exceedingly useful property, particularly if static or other disturbances comes largely from a certain direction.

At times static has a predominating direction, while at other times it appears to be widely distributed, so that both features are important—directive curve of small area, and ability to prevent reception entirely from certain directions. If static, while not confined to a specific direction, comes largely from a certain quarter, it is important to have an antenna system whose directive curve has a small area within the angle from which the heaviest static comes.

A number of antenna arrangements have been used which are considerably more directive than the loop and vertical. The calculated directive curves of some of these are very similar to that of the one-wave-length, full-velocity wave antenna. Fig. 77 shows the directive curve of a pair of loops spaced apart in the direction of signal propagation, the currents from the two loops being combined in the receiving circuit in such phase as to neutralize for disturbances coming from a direction

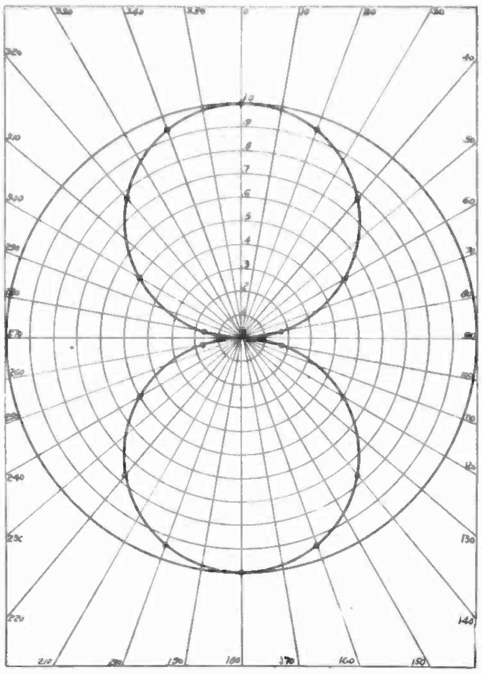


Fig. 74—Directive Curve of Loop

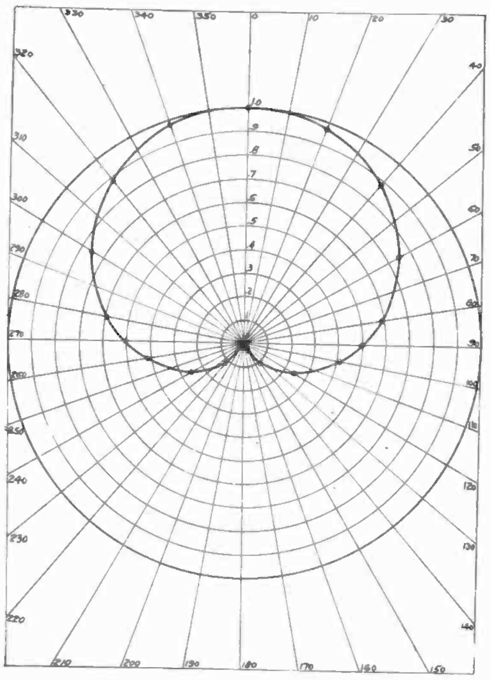


Fig. 75—Directive Curve of Combined Loop and Vertical Antenna (Equal Intensities)

opposite to the desired signal. The spacing of the loops is preferably between an eighth and a quarter wave length. Compared with systems which obtain their directivity in a small space, the full length wave antenna has the advantage mentioned in connection with the discussion of short wave antennas, namely, that the signal currents developed are strong in comparison with residuals, and therefore there is a better chance fo realizing in practise the directive properties predicted by calculation.

Reference to Figs. 35 to 41 and 44 shows that the areas of the directive curves of wave antennas are small, that the areas of the back and lobes of the curves are very small so that disturbances coming from any direction more than 90 deg. from the signal have relatively small effect, and we have shown in the discussion of the reflection balance, that a blind spot can be produced for any direction more than 90 deg. from that of the signal.

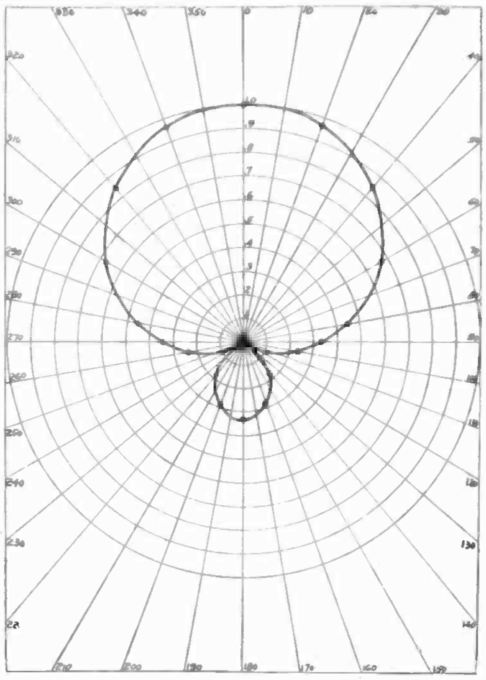


Fig. 76—Directive Curve for Loop and Vertical (Vertical Giving Half Intensity of Loop)

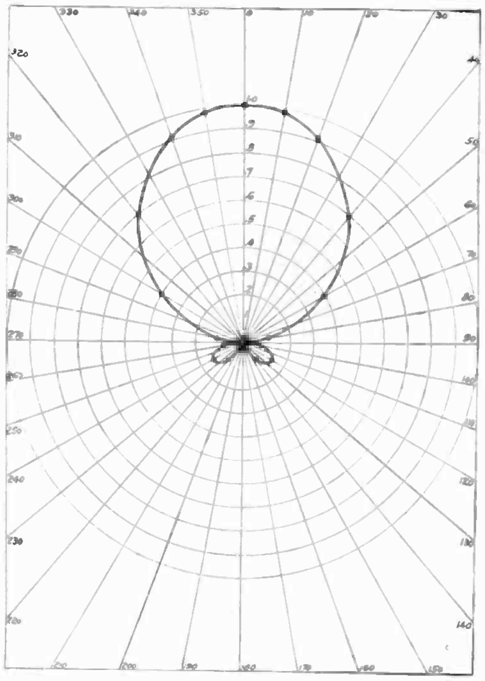


Fig. 77—Directive Curve for Two Loops an Eighth Wave Length Apart

The benefit resulting from reduction in directive curve area is illustrated by the fact that in a number of comparisons the full wave antenna has always shown noticeably better stray ratios than an antenna half the length, although the difference in calculated area is comparatively slight.

Superpower—A National Resource

At the Spring Convention of the Institute, in Pittsburgh, the subject of superpower in its various aspects was discussed by the after-dinner speakers at the banquet. While the engineering details of superpower systems have been discussed at considerable length in previous A. I. E. E. papers, the following addresses depict the sociological and political aspects of the subject which have received less attention. The relation between power and social progress was discussed by Mr. Paul T. Brady, Special Representative, Westinghouse Electric & Mfg. Co., the engineering features in their broadest sense were described by Mr. R. F. Schuchardt, Electrical Engineer, Commonwealth Edison Co., and the political aspects of the subject were discussed by Mr. M. H. Aylesworth, Executive Manager, National Electric Light Association.

Power and Social Progress

BY PAUL T. BRADY

THE earliest form of power was the labor of slaves. This was, of course, deplorable; it was highly inefficient; and it possessed the great drawback that the engineers were liable at any time and without notice to become the machinery. Nevertheless, had not men been enslaved, Thebes, Babylon, Athens and Rome would never have existed, and we would still be living in camps and caves.

The use of draught animals was a great advance over slavery, and gave us the Europe of Shakespeare, Montaigne and Goethe. Then came Watt with his steam engine, and Fourneyron with his hydraulic turbine, and Edison with his central electric power station; and with each improvement in the methods of generating and distributing power, society made immense strides forward. Today we are living in the age of Westinghouse, the age of the long-distance transmission of alternating-current electricity, the age of modern miracles.

But were the great inventor alive today, he would be the first to warn us that we must not stop here. He was always a generation ahead of his time, and it would be clear to his far-sighted vision that the work he did forty years ago has reached fruition and that we must now plan anew for the benefit of our children's children.

Fortunately, we know what the next step should be, and we are fully equipped to take it. We must now give everyone in the United States and Canada an abundant supply of electricity; and we must do this by putting our water power to work and, pouring all of this energy into a single great international network, distribute it to practically every inhabited portion of the continent. This plan, which is known as the "superpower" plan, represents the consensus of the opinion of all competent engineers who have studied the subject; and though gigantic as the task may be, we can rest assured that it will eventually be carried out.

But as man cannot live by bread alone; neither can a power system live on water alone. With few exceptions, all rivers vary greatly in their seasonal flow. The upper waters of the Hudson, for example, are able to generate 500,000 horse power at high water, but in dry seasons, the flow may not be sufficient to produce 5000 horse power. Similar conditions obtain with the rivers of Pennsylvania—the Clarion, Cheat, Susquehanna, Delaware, Allegheny, Monongahela and all the others. It is recognized, therefore, that the most economical and reliable method of generating power is by means of a system using both water power and steam power. When water is abundant, the water-power plants carry the main load of the system, and only enough steam power is used to take care of demands in excess of the capacity of the water-power plants. In this way, the consumption of fuel is reduced to a minimum. But in dry seasons, operation is reversed. The steam plants now supply the main load, while the water-power plants are shut down for the greater part of each 24 hours so that they can accumulate enough water in their storage reservoirs to take care of peak and emergency demands. In this way, a continuous supply of power to meet all requirements, is provided.

Hence, to take the next step in social progress, not only must we utilize our water-power resources to the fullest extent, but we must also use huge steam plants which will supplement the water powers. The ideal location for these steam plants is beside the rivers of the coal regions, where fuel can be delivered to the boilers with a minimum of transportation and where ample supplies of condensing water can be obtained. But there is a tendency on the part of certain power engineers connected with plants thus favorably located to take a short-sighted view of the power situation. "Why should our plants cooperate with water-power plants?" they ask. "Here we have abundant supplies of cheap fuel for generations to come. We can gain nothing by becoming part of a larger system, and are therefore not interested in the project."

These people forget that outside the narrow limits of their own systems there are millions of people who are either paying high prices for electricity or are unable to get it at any price. They forget that their properties form an essential element in any plan to supply the country as a whole with power at the lowest cost. They forget that, if their plants become a part of such a system, they will have the widest possible market for their excess power and their surplus coal. They forget that after all their systems are not absolutely self-sufficient, and that, unless connected with other sources of power, they may fail to give service in event of serious accidents. And finally, they forget that it is precisely this attitude of self interest that forms one of the strongest arguments for the Governmental ownership of the unified power system.

They must see the larger picture. Up North in Canada, there are 18 millions of horse power of the finest water power in the world; down here in Pennsylvania, West Virginia, and Ohio there are billions of tons of coal. Employed separately, each will indeed benefit many people; but used together to the best advantage, they will bring ever increasing prosperity to all of the people in northeastern North America—in other words they will usher in the next age in the history of civilization.

I must not be understood to be criticising our central stations. Their splendid work has alone made possible life as we know it today and has opened the way to the even fuller life that we can confidently expect the next generation to enjoy. Furthermore, no one can be censured for acting in the best interests of his own people. But good work is no excuse for not doing better work. The welfare of all people transcends the welfare of a few. It is just as wrong to confine to a small area the power generated directly from Pennsylvania's coal as it would be for a state to monopolize its water power and refuse to permit the citizens of other states to benefit by it.

The spirit of the times calls for cooperation in order to secure the greatest good for the greatest number. Nothing better can be given to the people of the United States and Canada than a single international power system that will permit the utilization of our water power and coal to the best advantage and will provide everyone with an abundant supply of electricity. It will mean increased prosperity, happiness, and health for everyone; and I believe that on the principle of noblesse oblige it is the duty of every engineer to contribute what he can towards the creation of this system.

It cannot be too strongly emphasized that a general power system covering a wide area can only be formed by the coordinate use of water power and coal. Those districts which are favored by the possession of an abundance of either of these resources cannot selfishly monopolize them but must share with the less fortunate neighbors.

To speak frankly, the present New York State administration is advocating a policy which if persevered in will prevent the export of power outside of the State's boundaries. Inasmuch as New York possesses a considerable amount of water power of her own and is endeavoring to gain control of the much greater amount provided by the Niagara and St. Lawrence Rivers, and especially since because of her geographical location, the interstate lines of the great system must run across her territory, her success in establishing this policy will prevent the formation of the system and will make it impossible for Pennsylvania and other southern states to obtain any power from Niagara or the St. Lawrence.

And of exactly the same character would be the attitude of power interests in the coal field, should they refuse to become a part of the unified system and furnish it with the necessary steam power. I would say to them as I have said to the New York Administration "You are selfish, short-sighted, un-American. Your good is tied up with the good of the nation and your interest is identical with the interest of the people as a whole. Though you do not appear to realize it, to become a part of the larger system will be the best step you could take from your own selfish standpoint. It will assure you a continuous market for excess power; and it will secure you against the failure of your service because it will enable you in emergencies to draw upon an ample supply of power from outside sources."

I am not surprised to find politicians ignorant of the proper methods of distributing power, and I realize that there is a long task ahead of us before they—or rather their constituents behind them—are educated to the point when they will understand the advantages of a superpower system; but I am surprised to discover any central station interests that are not thoroughly in sympathy with the project. However, when a given plan is scientifically practical, economically right, and advantageous to the public, it will in time become a reality, hence, opposition from any motive is futile but it can cause delay and I am firmly of the opinion we cannot start too soon, for the good of the nation, to formulate this great undertaking.

The Engineering of Superpower

By R. F. Schuchardt

In addressing myself to the subject assigned to me as defined by the title, I shall interpret the term "engineering" in its very broadest sense. In the narrower sense "the engineering of superpower" resolves itself into the determination of the factors that fix the location of power plants, the study of stream flow, of super-voltage (if I may use the term) transmission line design, etc. These are no proper subjects for a banquet after a day's faithful devotion to the details of engineering technique, so I shall take the time-honored liberty of after-dinner speakers and roam all around the subject.

First of all, what is "superpower?" I believe the term was born in Europe during or right after the war. As far as I could learn, everything that was planned in Europe on a scale as done in America was called "super," and so power stations designed to have an ultimate capacity of about 200,000 kw. or more or employing units of 15,000 to 20,000 kw. or greater were called "superpower stations." The term seems to have caught the fancy and appeals to the imagination so that when our fellow member, Mr. W. S. Murray, carried his message to the governmental officials he adopted it for his great vision of an interconnected system covering the North Atlantic states and it has stuck ever since. While a simple system like that of the West Penn Company here in your vicinity or the Central Illinois Company in my state would be a great superpower system in Arizona or in New Mexico the term undoubtedly to most of us brings a picture of systems like those just mentioned as parts of a greater system with extra high-voltage trunk lines connecting the mammoth power houses of the separate systems and tying in with all available water powers. The California systems come nearest to matching up with our picture.

Let us go back just a bit and try to get a perspective of our subject—this power industry. The industrial era which transformed civilization in a few brief decades was, as you all know, ushered in by the steam engine slightly more than a century ago. Previous to that, except for a few inefficient water wheels entire dependence was had on man power and animal power. But early in the nineteenth century coal was found in comparative abundance and a means had been developed of using this stored solar energy to do man's work. The steam engine brought emancipation from drudgery and man had time for some leisure and for self-improvement. This speeded invention and new developments followed fast. The reign of steam as the ultimate power lasted little more than half a century but its use was limited to within a small radius of its point of production. Then science gave us that wonder-servant, electricity. By its use factories need no longer be tied to their engines through shafting and belts but can be located close to their market and miles from the source of the power that drives the wheels. A new industry was created—the Electricity Supply industry, and the economical manufacture of energy and its efficient use received intensive study. The cheap power that resulted has caused a rapid growth in industrial centers and every community that had this cheap power prospered. Because of the flexibility of this form of energy and its comparative ease of transmission, industries spread out and even the wide stretches between settled communities now enjoy its benefits. Through its factories thrive and convenience and comfort are brought to practically everyman's door wherever this industry has built its lines.

How important to a nation is an abundance of cheap power is evidenced by the action of the European countries. Most of these appointed commissions, during or soon after the war, to study means of obtaining most economically power to offset the great loss of man power. Naturally these all reported recommendations to develop so-called superpower systems designed to use all economic sources of power and particularly the water falls. All eyes were turned to our great systems in America and they were studied by the European commissions.

We in America are not resting on our oars. The electricity supply industry appreciates its obligation to supply power most economically so that the industrial supremacy of our country will be maintained, so that, among other things, American labor and American investments will get their fair share of the world's trade. Efforts to reduce cost of production are unceasing and this leads logically to inter-connection.

Inter-connection and still more inter-connection, with power developed only at the most economical points, all things considered and with every available source that can be economically developed put into use,—to that we are directing our thoughts at this moment and we call it superpower. Self-interest of the industry leads in this direction but it is manifestly also conserving the best interests of the nation.

What elements of the problem are of greatest interest? I think there are two and they relate to two resources, coal and dollars, and inter-connection spells conservation for both of these. Take coal first. No need to tell this audience how the building of giant stations with their efficient units and the economic development of water power will conserve coal, but let us see how important this is to the nation. With our present population we are consuming about 6 tons of coal per capita per year. Compare this with 3.67 tons for England, 1.24 for France, and 0.18 for Russia. (Incidentally the energy liberated by combustion of our 600,000 tons is roughly the equivalent of a year's labor of 4,000,000,000 healthy men.) Make your own estimates of our coal resources and of the growth in our population and reach your own conclusions as to the need for conserving coal. The central power stations of the country, by constantly improving efficiency, have already saved the nation hundreds of millions of tons. It is by combining the load of an extensive area through inter-connections that the most economical large stations are made possible in addition to those in the metropolitan areas, and in this manner still further improvements in efficiency are obtained. Inter-connections, including water power developments, also permit the highest use of hydro-power with resultant coal saving.

But where does the conservation of the dollar come in? I am, of course, using the dollar as a figure for the labor and the materials of the nation. In addition to the many dollars saved by lesser coal consumption the service is rendered with a smaller investment, and incidentally with greater reliability. There is a great diversity in the time of use of energy in large areas, *i. e.*, the coincident maximum demand is much less than the summation of the maxima of various portions of an area. By supplying the larger area therefore, a smaller total generating capacity is required because of this diversity and also because the total system can carry common reserve capacity. The diversity between a city like Pittsburgh, for example, and the area surrounding it may well be on the order of 10,000 kw. or more. Estimates made for the Chicago district indicate that, in spite of the very extensive development in that area, the complete electrification of all industries and their supply from the central system, including the electrification of the steam railroads within the Chicago switching district would save an investment of about $20,000,000 due to diversity alone. Added to this are the many, many dollars to be saved in operation, which capitalized represent many millions more. Dollars saved from waste are available for the creation of wealth and surely that nation profits most that uses its resources most wisely.

It may be worth while in passing to express the thought that the economic affairs of the various sections of our country are pretty much interwoven. The prosperity of one aids the prosperity of the adjoining and intelligent cooperation prospers all. The natural industrial or power areas in which, for the greatest good of all the people, power systems should be interconnected are not defined by accidental state lines but by economic considerations; by industries and markets, national resources, such as coal, metals, water ways, agricultural areas, etc. A development on any other basis would not be in the best interests of the nation and would, therefore, not be of permanent profit to anyone or any section.

As stated earlier, the electricity supply industry in its onward march is bringing about many extensive inter-connections. Is this development following a definite, logical engineering plan? No such plan has as yet been developed except that for the north Atlantic coast area. What assurance have we that when the grouping of groups, which is on the horizon, arrives the systems will be found readily adaptable to economical inter-connection? Is the frequency common and how about the voltages? Who should set up the standards and see that investments made for present extensions will have their proper value in the coming years? Who will see to it that the industry lives up to its obligation, to its trust? Naturally, the industry itself, for it is keenly alive to its obligation to the nation. Already there are committees of the industry's organization, the National Electric Light Association, studying the problem in various parts of the country, and more will undoubtedly be formed. The society of the profession most interested, that is the American Institute of Electrical Engineers, will of course, also aid. Cooperation between all these will assure uniformity at least in the fundamentals of such studies.

In his "Outline of History" H. G. Wells says that "the great republic of the United States would have been impossible before the printing press and the railway." Had this gifted author a profound knowledge of our industrial situation he might have added, and with equal truth,—the great republic will endure because the organizations that are supplying the life blood of industry to the nation are, from self-interest, building in harmony with the great economic law and by so doing are speeding civilization and giving a tremendous impetus to the forward movement of man in his quest for happiness.

Superpower as a National Policy

BY M. H. AYLESWORTH

As professional engineers have good reason to know, the installation of superpower stations and systems is not hindered by questions of engineering but by weightier matters of finance, law, economics, politics and policy. These handicaps still beset us, and when they are once disposed of superpower stations will spring up with remarkable rapidity. The whole trend of economics in the electrical industry is toward larger stations and systems, and notable examples of these are to be found here in the Pittsburgh district and in numerous other sections of the country. Eventually the United States will be studded with large superpower stations, for the ultimate destiny of the country is to be covered with a network of inter-connected transmission lines fed from such stations and reaching every city, town and village.

The idea of bulk supply is not new. It is as old as the electric lighting industry itself. From the very beginning it was recognized that the economics of the situation demand that the supply of electricity for the home, for the store, for the factory, and for transportation come from one central source. Samuel Insull has for years spoken at length on this subject and shown to what extent concentration of electric production makes for economies of capital, labor and material and the conservation of fuel and water supply. Superpower is merely an elaboration of the central station principle making for the greatest possible economies and conservation and enabling the electric light and power industry to keep the price of its service constant in the face of enormous increases in the cost of labor, fuel, equipment and supplies.

Considering the numerous and marked advantages which accrue from superpower stations and systems, and the desire of the electric light and power industry to engage in a progressive and far-reaching program of expansion, one is naturally surprised that the number of superpower stations in existence is not larger. Certainly it is not for want of vision on the part of the industry; nor yet for want of load. The electric light and power companies of the country are in no danger of over-expansion—the regulatory commissions will see to that. Our companies have great difficulties even in normal times to keep abreast of demands for service and are erecting and will erect superpower stations just as fast as financial and economic conditions warrant and handicaps are brushed aside. It is a matter of great national interest whether the billions of horse power hours produced in this country shall be produced at an expenditure of six pounds of coal per horse power hour in a small plant or one pound of coal in a superpower station. It is also a matter of public concern whether we shall continue to be prodigal in the utilization of our fuel resources and at the same time permit our water-powers to run to waste.

LEGAL DIFFICULTIES

According to the second annual report of the Federal Power Commission, applications have been made for licenses for the development of an aggregate of 20,000,-

000 horse power on lands over which the Federal Government has jurisdiction. This is twice the water-power which has been developed in the United States to date and is from five to six times greater than the aggregate of all applications filed with the Federal Government since hydroelectric development became an art. In other words, no sooner was favorable legislation enacted than the electrical industry set about to make developments exceeding the combined water-power resources of Norway, Sweden, Finland, and the Artic and Baltic drainages of Russia. Obviously the inclination and desire to develop water-power in this country has not been lacking; the right to do so under reasonable legislation has only just been granted.

Now, the source of half of the power represented by the applications in the hands of the Federal Power Commission is found in three rivers, the St. Lawrence, the Colorado, and the Columbia, and every one of these streams is at present involved in legal entanglements. The St. Lawrence, for instance, is an international boundary stream, and until a treaty with reference to its greater canalization and control is negotiated between the United States and Canada, no American water-power projects of any magnitude can be undertaken.

The Colorado River, also an international stream, is further involved by a compact signed in Sante Fe, New Mexico, last November. This compact must be ratified by the seven interested states, all but one—Arizona—having already signed, and then by the National Government. The treaty between the states allocates the water of the Colorado between the geographical divisions and provides for flood control, irrigation, and power development. It is apparent that in any national system of superpower, the Colorado River will be an important factor because of the great potential force bound up in that river with its drop of 8000 feet compared with other streams of the country. Thus far, however, the Federal Power Commission has taken no final action on the applications involving this stream and it is not likely to do so until some unity of action is agreed on by the States of California, New Mexico, Nevada, Utah, Wyoming, Colorado and Arizona. The effect of the seven-state treaty will be to handicap to some extent power companies seeking to develop in the Colorado watershed, since not only must these companies secure a license from the Federal Power Commission but they must in addition satisfy the Commission that the terms of the treaty are complied with.

The Columbia River has been under investigation by a special board to determine the relation between water-power, irrigation, and navigation, and for these reasons action on almost all of the projects on the Columbia River has been suspended for the time being.

To cap the climax the State of New York has brought suit in the United States Supreme Court to have the Federal Water Power Act of 1920 and the activities of the Federal Power Commission thereunder, declared unconstitutional. Already Pennsylvania and seven Western states have announced that they will fight the suit and it is not unlikely that in the end as many as forty states may appear against New York. Annulment of the Federal Water Power Act would produce a chaotic situation in Western states where much hydroelectric development has begun under it, and would open the way to further selfish state discrimination, such as now obtains in the State of Maine. Until, therefore, the Federal Law is upheld by the United States Supreme Court, all permits issued by the Federal Power Commission are under a cloud and because of that fact, very little money will be available for water-power development. It is just as difficult to sell bonds on a hydroelectric property thus encumbered as it is to raise a mortgage on real estate the title to which is not clear. Other superpower streams, like the Delaware, are also involved in legal controversies, and until these are settled many hydroelectric superpower projects will be effectually checked.

It will be recalled that the United States Geological Survey made an exhaustive study of the Boston to Washington power zone and brought to light the enormous economies procurable through a proper coordination of steam and water-power resources in the district. Were it merely a matter of engineering, the recommendations of Mr. W. S. Murray and the other engineers who made the survey would now be carried out; but legal and financial difficulties are not easily disposed of. As it is, the plans laid down in that report are already being carried out in part through the natural evolution of the business.

I would not have you feel from what I have said that the electric light and power companies are pessimistic over the outlook. On the contrary, we are not at all apprehensive and are going right ahead with characteristic enthusiasm and optimism, building huge stations here and extending transmission lines there in spite of handicaps. We have a mission to perform and intend to live up to our obligations, and difficulties which seem from a distance to be insurmountable somehow disappear as we come up to them. The road is not strewn with roses, however, nor do the handicaps always go down before a frontal attack. More often, they necessitate quite a long siege.

National Aspects of Super Power Supply

Manifestly, if we are to maintain the high standard of living which is characteristic of America, the per capita earnings of the country must also be high. With the competitive markets of the world, it would be impossible to bring this about without the aid of machinery and therefore, in this country, use is made of every trade facility, invention and appliance. The United States, through its great use of machinery and electricity is able to maintain a higher standard of living than any other country because its labor produces more and earns more. During the twenty years prior to the war, the annual national per capita earnings in the United States increased 116 per cent, those of Germany 52 per cent, France 27 per cent, and Great Britain 21 per cent.

These percentages reveal much. They show what an enormous influence cheap power, which means electricity, has on the productive capacity of a nation and people and it is chiefly because they are such great users of electricity that Americans excell in so many directions. But if we are to continue to enjoy an abundant and cheap supply of power, we must concentrate more and more in its production; we must erect fewer but larger stations; we must develop our water-powers, conserve our fuel resources, and through inter-connected networks of transmission lines, make power available in every market.

Thus the water-power of the Sierras will be the mainstay of industry on the Pacific Coast; the Rockies will provide sufficient power for local needs and large blocks of energy ought to find their way into the prairie states far to the east; the Middle Atlantic and New England States must look for hydroelectric developments on the Niagara and St. Lawrence Rivers to augment their supply of energy, and the watersheds of the Southern Appalachian range ought to provide additional power for the states bordering on the Ohio River in addition to meeting the fast growing needs of the South.

Economic Advantages of Water Power

There are in existence numerous examples of electric superpower stations and systems which have not only justified the faith which the electrical industry has in them but have also proved their value to the nation and to its industrial development. A romance could be written around the use of hydroelectric energy by the electrochemical industry at Niagara Falls, and one of the most interesting chapters could be devote pot tracing the use of those electrochemical products manufactured through the instrumentality of cheap electricity in the thousand and one essential industries scattered throughout the country. It would be vain to dilate on the application of electricity in California and what hydroelectric development means to that state. It is an open book and the story can best be told by a citizen of that State.

Let me give you some striking examples of what a great asset cheap hydroelectric power is to the nation and also why hydroelectric development is essentially monopolistic in its character. The Montana Power Company furnishes 85 per cent or more of all the electricity used in the State of Montana. This energy is derived from numerous hydroelectric stations which are interconnected and which feed high-tension transmission lines traversing the greater part of the State. The mining and production of copper is the chief industry of Montana. Before the present hydroelectric stations on the Missouri River were built, the mines of Butte and the smelters at Anaconda were depending on steam power to the extent of 35,000 h. p. and it was costing them on an average $85 a horse power year. Hydroelectric energy was transmitted into the district from Great Falls, 130 miles away, and sold to the mines at $30 a horse power year. In other words, the mining companies were enabled to carry on their operations for $2,000,000 less money a year than it cost before. But the most significant fact of all is that this cheap electric power made it commercially profitable to refine and reclaim tens of millions of tons of low grade copper ore that otherwise would have had to be passed by—and the United States is the largest producer of copper in the world.

Two much emphasis cannot be placed upon the large public service that is being rendered in power development by bringing down the price of power, not only to the copper mines, but to the gold, zinc, lead, coal, and other mines with which the country abounds. In making power cheaper, the possible return per ton of ore or of coal is not only increased but a larger body of ore than otherwise could be mined and brought to the surface is opened up. Thus the available metallic and other resources of the country are increased enormously. Can you not see why the interest in cheap power extends far beyond the limits of the electric light and power industry and becomes national in importance?

Railroad Electrification

The question of transportation is one of the most active in the national mind today and in its solution the electric light and power companies will play a most prominent part. Here again we are brought face to face with the national aspects of electric superpower supply and with the policy that must dominate our industry.

The steam locomotive is notoriously wasteful in the use of coal and inasmuch as there is approximately 50,000,000 h. p. in locomotives in the country and a large part of the rolling stock and equipment of the railroads are used for hauling coal for these locomotives, it needs no stretch of imagination to picture what large savings can be effected through the electrification of the steam railroads. Obviously such a change cannot be brought about in a night. Passenger terminals would normally be electrified first, then the freight terminals, and after that would come more general electrification. When, however, the great arteries of travel are electrified, as they eventually must be, the officials of the railroads will find abundant power available in superpower plants which, by that time, will have spread their circuits all over the states.

Transportation is the life blood of industry and the greatest factor in the upbuilding of the nation. Given transportation and power, industry may settle at strategic and economic points and contribute toward better sociological and living conditions. The electric light and power industry recognizes the advantages of supplying all the energy required in any community and is more than willing to cooperate with the railroads in order that when the time comes the railroads may receive an adequate supply of low-priced power and not be called upon to generate it for themselves.

As indicative of the savings which electrification makes possible, the case of the Chicago, Milwaukee and St. Paul Railroad, which receives electricity for operating its trans-continental line from central station sources, may be cited. At the time the Milwaukee road was electrified, a long term contract was made with the Montana Power Company for power to be delivered over 450 miles of the road. The cost of the electricity was something like $550,000 a year, whereas, although the Milwaukee Railroad furnished its own coal from its own mines and one-third of its equipment was used in hauling the coal, the cost of the coal to operate the steam trains over the same section that was afterward electrified, was approximately $1,750,000 a year. The same power company provides electricity for the Butte, Anaconda & Pacific Railroad Company at the same price and practically under the same conditions as it does to the Chicago, Milwaukee & St. Paul Railway Company. The cost of electrical energy for the Butte, Anaconda & Pacific Railroad Company a year after its electrification was $8000 a month whereas it formerly cost the railroad $22,500 a month for coal alone.

Aside from the advantage which accrues to every shipper over these railroads due to the more dependable and cheaper electric power, such an arrangement possesses other marked advantages. It saves coal in the ground and utilizes an absolutely waste product—water-power—which, until recently, was permitted to flow unmolested to the sea. It also contributes not a little to the growth of the State because it enables industry to locate in the territory and assures it of low price power anywhere along the line of the railroad. Now if there is anything that people dislike, it is increases in transportation rates. Manufacturers would rather that the rates be not disturbed at all unless they are reduced, and although the savings of electrification, great as they are, may not have a very appreciable effect on the ultimate rate, they certainly tend to keep the rates stable and to contribute perceptibly to their possible reduction.

The acquisition of a large amount of railroad load is especially beneficial to electric public utilities in that it makes for cheaper operation in direct proportion to the volume and diversity of the business and this in turn means cheaper money and lower consumer rates. It is the experience of every public utility operator that under regulation the only way to be successful is to follow the modern plan of big volume and small margin. For purely economic reasons little plants and distributing systems and little companies in the electric public utility field are passing out of the modern picture along with local thought and restriction. Even in the case of the great steam railroad systems of the country, traversing as they do many states, it has been found that the best interests of the public as well as the railroads lies in still greater consolidation of railroad groups under a single management. It is refreshing to know that this policy, which has been followed for at least ten years by operators of electric public utilities, is at last recognized as an economic necessity by the Interstate Commerce Commission. Thus it will be observed that questions of concentration, whether it be of transportation or of electric power, are not local or even of state-wide interest but involve the entire nation, and in preparing to supply the steam railroads with the necessary electricity when they ultimately become electrified, the electric light and power industry is performing a farsighted national and public service.

Civilization and Super Power

Superpower is a measure of advancing civilization. It is machinery raised to the *n*th degree, superseding municipal and state boundaries and becoming national and continental in its character. It can find no abiding place in countries where life is primitive and labor cheap. A superpower system in China or India, for instance, would manifestly be a wild extravagance. The simpler manufacturing processes, the only ones that are performed in primitive countries, are in those lands more economically carried on by man power than they could be through the use of electrical energy, even at a rate that will barely pay interest on the cost of setting up the generators and building the transmission lines. But, as civilization grows in backward nations, as the wants of their people increase, as laborers begin to refuse to work for wages that barely keep soul and body together, as ambitious natives or foreign settlers spread the idea among the richer classes of manufacturing comforts and luxuries at home instead of importing them from abroad, the demand for machinery will grow and a time may come when progress will not only bring with it the multiplication of steam and hydroelectric stations, but will cause their energy to be carried for scores or hundreds of miles to supply light, heat and power to every district and to turn the wheels of innumerable factories.

In America, that day has already come. Electricity is demanded in ever-increasing quantity. Kilowatt hour output grows by leaps and bounds. It is becoming a matter of common knowledge that to build a central station in every little town is as wasteful as it was to install a plant in every building. The individual plants once so numerous will soon be almost things of the past. So, too, will the small central stations, disadvantageously situated, disappear as the economy of service from greater stations, built near mines or on water-power sites becomes more and more apparent. Inter-connection, already a proved boon to consumers in economy of rates and reliability of service, will extend until the isolated system becomes a rarity and over all parts of the land networks will be built offering to every user of power the strength of a hundred horses or a thousand brawny laborers, or such fraction of it as they may need, at a rate relatively far less than he would otherwise pay.

The advance of machinery and of unified operation has had in past generations to combat two fears—the fear of the hand workman that his displacement means his destruction, and the fear of the people at large that monopolies for their exploitation and oppression will spring up. The march of events in America has shown that—aside from such temporary individual hardships, regrettable but inevitable, as every great change must bring—both fears are illusory. Nowhere else is machinery so firmly installed and nowhere else is the workman half so prosperous. Nowhere else are public service companies so large and so tied together and nowhere else are their rates and their service more firmly under the control of governmental agencies for the protection of their customers and the public at large. Superpower is a further extension of the principles of machinery and cooperation. Government regulation and customer ownership will travel with it. Cheaper energy, better service, progress, prosperity, profit and plenty will follow in its train.

Discussion at Midwinter Convention

DISCUSSION ON "EXPERIMENTAL DETERMINATION OF SHORT-CIRCUIT CURRENTS IN ELECTRIC POWER NETWORKS"*

(SCHURIG), New York, N. Y., February 14, 1923

R. E. Doherty: I wish to discuss two points bearing upon this paper: One regarding accuracy; the other, regarding the extension of the use of miniature models to determine, in addition to the short-circuit current distribution under steady state, as covered by the present paper, the most desirable feeder connections for normal load transfer; and further, the behavior of stations and generating units under transient state.

Although the impedances of lines, cables, reactance coils, etc., can be calculated with a fair degree of accuracy, the calculated value of *transient reactance*[1] of the generators is not so accurate. It can, of course, be determined with fair accuracy by actual short-circuit tests; but in calculations an error as great as 15 or 20 per cent may be expected in some cases. The principal reason for relatively large errors in the calculated values is the effect of abnormal saturation of local flux paths under short circuit. The phenomenon of saturation is extremely complicated and different types of machine construction involve different degrees of saturation. Hence it becomes very difficult to calculate the result. Therefore, in the calculated, or rather estimated, values of *transient reactance*, such errors as I have mentioned must be expected.

This, of course, is no reason, as may be suggested, why the accuracy of the "calculating table" itself should not be better than 20 per cent. The former source of error is necessary, unless tested results are available; but that is no reason why another *known* error of 20 per cent should be superposed, perhaps in the same direction. I therefore agree with the author that by the proper use of the various curves given in the paper, together with a study of the examples, excessive error from the table itself can be avoided. However, the possible error in generator reactance should be kept in mind, especially in those cases where the external reactance is relatively low.

Another source of error is the set of decrement curves usually applied in this connection. I refer to the Hewlett, Mahoney and Burnham curves. The calculating table gives the "initial" or the "sustained" current, as the case may be. In selecting oil circuit breakers, the time element enters; and if such curves are applied to determine the effect of the time element, that is, the decrease in current due to the transient, the possible error in such curves should be kept in mind. As everyone knows, who has read the Hewlett, Mahoney and Burnham paper, these curves represent the first step in the direction of giving some basis for selection of switches, and combining into a single set of curves, as they do in the interest of simplicity, numerical values covering such wide limits, they must necessarily contain sources of considerable error. These errors, however, are, I believe, usually on the safe side, thus giving current values too high. The point is, that having obtained the "initial" value, perhaps by the calculating table, there is possible further error in applying the decrement curves.

Hence, from the foregoing discussion, error may arise from three sources, namely: The generator reactance, the calculating table, as the author brings out, and the application of the Hewlett, Mahoney and Burnham curves. It has, therefore, seemed advisable to offer the suggestion that, in the use of the calculating table, these additional sources of error be kept in mind.

What appears to be a promising extension of the application of miniature models is the representation of certain isolated sections of a network, including receiving circuit impedances as well as the feeder impedances, for the purpose of determining the most desirable connections of the feeders. This is usually a compromise between the connection which is the most favorable for copper on the one hand and simplicity, relay settings, etc., on the other. Such an extension would obviously involve the case of both resistance and reactance units and to this extent would be more complicated than the direct-current table. This scheme was proposed by G. M. Armbrust of the Commonwealth Edison Company of Chicago, who is investigating the feasibility of such an outfit.

Referring to the possibility of reproducing the transient phenomena in generating stations under short-circuit conditions, it may be of interest to mention that a study and detail design has been made of a miniature generating system, reproducing in small generators the same relation of momentum, reactance, armature reaction, etc., as exists in the actual large units. It thus appears feasible to represent with a small number of machines a relatively large variety of combinations of units. It may be of interest also that these miniature machines are not a geometrical reproduction of the larger machine on a small scale, since such a machine, even if practically feasible to build, cannot be made to represent the actual machines.

G. M. Armbrust: Direct-current calculating tables have been used extensively in large systems to determine short-circuit currents for use in determining relay settings, design of systems, etc. A high degree of accuracy has been obtained in systems having considerable reactance. There has been some doubt, however, as to how extensively the method could be used on cable systems owing to errors introduced by varying impedance angles of the component parts of the system.

Mr. Schurig's paper clears up much of this doubt, and considerably extends the use of the calculating table by outlining its

1. The generator reactance which is active under sudden short circuit.

*See p. 605 this issue.

limitations and defining the probable degree of error under a classification of conditions representing most distribution problems.

The Commonwealth Edison Company of Chicago operates some 900 miles of transmission cable, the system being practically entirely underground. Using Mr. Schurig's method described in his paper, I have checked a number of typical cases on this system and obtained results of a reasonable degree of accuracy, agreeing with his conclusions.

The layout of a system such as this, a combination of network and radial distribution, is determined by economy, limitations due to possible short-circuit currents, and feasibility of relay protection. Theoretically the best transmission economy is obtained by an extensively inter-connected network, but the necessity for limiting short-circuit current to the ability of existing equipment to handle it, makes necessary considerable sectionalizing of the system. Determination of the economical design with this limitation requires the solution of many such cases having a wide variation of characteristics—also the changing standards of equipment used, such as larger-sized cables having greater impedance angles, use of reactors of various values, complicate the problem and make it a continuous one.

These considerations make desirable the use of an alternating-current calculating table representing both resistance and reactance, though not to replace the direct-current table which, because of its simplicity of operation offers a quick and sufficiently accurate solution for most problems. Another valuable use of an alternating-current representation of this system could be obtained by designing the scheme to include units representing loads and their power factors for the purpose of determining the most economical arrangement of the transmission system for load distribution within the limitations of operation, short-circuit currents, etc.

O. R. Schurig: Both Mr. Doherty and Mr. Armbrust have referred in their discussions to the problem of determining experimentally, by miniature equivalent circuit, the division of normal current flow in a network. The following discussion is devoted to the question of determining whether this problem may be solved satisfactorily by a d-c. miniature system such as the "short-circuit calculating table." There are three reasons why a d-c. device is not to be recommended for general application to load-current division problems; viz:

(1) For normal current flow in the lines of a network a higher degree of accuracy is generally required than for short-circuit currents.

(2) Capacity currents frequently are a material portion of the total current flowing.

(3) Tie-line current flowing between generating stations or between substation busses may be greatly in error, when determined by a d-c. method.

The first point may be considered with reference to the accuracy data presented in the paper: If, for example, the power factors of the loads in a system range from 0.70 to 0.95, the corresponding range of impedance angles is from 46 deg. to 18 deg., and the load reactances in these two cases are 71 per cent and 31 per cent, respectively, of the load impedance magnitudes. Since the load currents depend on impedances, rather than reactances, it will be seen at once that the reactance method is entirely unsuitable under load conditions similar to those mentioned. Thus the impedance method, only, comes into consideration. Its accuracy for load current division will be considered below.

Capacity currents cannot be represented together with load currents in a d-c. miniature system, because of the wide phase difference between them. It follows, then, that for systems having large capacity charging currents—such as high-voltage aerial systems with long lines—the d-c. method applied to the determination of normal-current division cannot give representative results.

Interchange currents flowing over tie lines between generator busses are frequently displaced in phase from the generator currents feeding these busses. Since a d-c. representation of these currents cannot take account of their respective phase relations, considerable errors in these interchange currents may be encountered if the d-c. method is applied.

Similarly, the currents flowing in tie lines between substation busses are likely to be greatly misrepresented by the d-c. method, when the power factors of the loads on these busses differ materially. This will be shown by the following example. Let the circuit be that of Fig. 1. The load currents I_{L1} and I_{L2} are given and will be considered fixed in magnitude and phase. The problem is to determine currents I_A, I_B, I_C, and I_G by the d-c. method employing impedance magnitudes. Let

I_{L1} = 420 amperes at power factor 1.0

I_{L2} = 500 amperes, lagging 41 deg. behind I_{L1}, (*i. e.* at power factor 0.75)

$Z_A = 0.307 + j\,0.599 = 0.673 \;\underline{/\,63}$ deg. ohms.

$Z_B = 0.276 + j\,0.485 = 0.558 \;\underline{/\,60}$ deg. ohms.

$Z_C = 0.246 + j\,0.148 = 0.287 \;\underline{/\,31}$ deg. ohms.

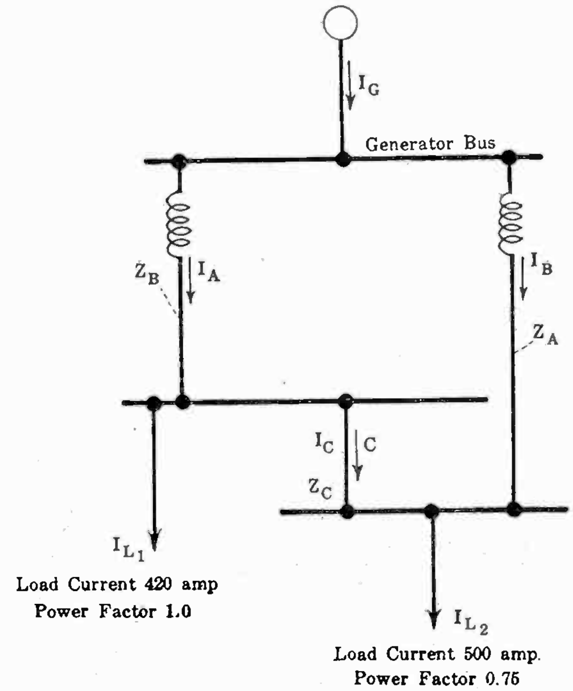


FIG 1—DIAGRAM OF CIRCUIT ILLUSTRATING DETERMINATION OF NORMAL CURRENT FLOW (DUE TO LOADS) IN A DISTRIBUTION NETWORK

Circuit at Z_A represents three cables in multiple with a current limiting reactor in each cable at the generator end.

Circuit at Z_B represents two cables in multiple with a current limiting reactor in each cable at the generator end.

NOTE: These line impedances are for 12-kv., 3-conductor, cables at 60 cycles per sec. The values of Z_A and Z_B include current limiting reactors.

The results are as follows, for the above fixed values of I_{L1} and I_{L2}.

Current symbols referring to Fig. 1	Correct currents determined by complete a-c. solution. Amp.	Currents by d-c. method employing impedance magnitudes. Amp.	Error of approximate currents
I_A	406	417	3% too high
I_B	459	503	10% too high
I_C	135	—3	98% too low
I_G	863	920	7% too high

It is seen that the currents over circuits *A* and *B* and in the generator are not over 10 per cent in error, while the tie-line current I_C is entirely misrepresented by the d-c. method. The large error is due to the phase displacement between load current I_{L1} and tie-line current I_c, the latter current being substantially "wattless." This example, therefore, illustrates how the d-c. method may grossly mislead in the determination of tie-line current for systems having loads of dissimilar power factors.

It should be pointed out here that in short-circuit current determinations with the calculating table the likelihood of excessive errors in tie-line currents is far more remote since there is only one load—*i. e.* the short-circuit—and since parallel lines of widely dissimilar impedance angles are generally avoided on account of the interchange currents they produce in normal operation.[2]

In a strictly radial system of distribution, *i. e.* with no tie lines between substations, the last-mentioned errors will not occur in a d-c. representation of the system. On the other hand, it may be argued that in the purely radial type of distribution system calculation of load current division is less complicated and the need for a miniature system less urgent than for systems having a complex distribution network.

To summarize: For the determination of normal current division in a-c. distribution networks, the d-c. miniature test method is not generally applicable on account of errors due to dissimilar load impedance angles (*i. e.* dissimilar load power factors) and to the neglect of capacity currents. Under these conditions, the solution of this problem by miniature test calls for an a-c. miniature system having reactors and resistors, and, in some cases, condensers. These conclusions corroborate those presented by Mr. Armbrust and by Mr. Doherty.

DISCUSSION ON "PUBLIC ADDRESS SYSTEMS*" (Green and Maxfield) and "USE OF PUBLIC ADDRESS SYSTEM WITH TELEPHONE LINES†" (Martin and Clark)

New York, N. Y., February 14, 1923

Frank B. Jewett: To you, members of the American Institute of Electrical Engineers, and to you, our guests assembled together in New York and Chicago, I wish in opening this first evening meeting of our Midwinter Convention especially to call your attention to the unique significance of the occasion which brings us together and of the epoch in engineering history which it marks, not only in electrical development but in the conduct of human affairs as well.

For the first time in the history of the world, groups of men and women, separated by hundreds of miles, are gathered together in a common meeting under a single presiding officer to listen to papers presented in cities separated by half the span of a continent, and to take part in the discussion of these papers with an ease characteristic of discussions in small and intimate gatherings. At the same time unnumbered thousands in their homes are auditors of our deliberations through radio broadcasting.

Who can picture the limits of the effect and influence which will flow from the developments of electrical science and electrical engineering which have made this night possible. In truth, we are participants in an historical event and our children, nay even many of us, may see the agency we here use employed with mighty effect in controlling our collective relations in state and nation. Someone has said that the greatest political engine ever devised was the colonial town meeting where every question of importance was debated and discussed in an open forum of all the citizens. Be that as it may, we are well aware that our best government today is found in those small political units where the town meeting in some form is feasible and still persists. It is only when we come to the larger units of city, state and nation that the limitations on common discussion of vital matters, which are imposed by sheer physical size, evidence themselves in cumbersome and inadequate substitutes for personal discussion and oft-times in unsatisfactory results.

May it not be that in this two-way working telephone with its sensitive transmitters and loud speaking receivers we have the instrumentality for insuring a simpler and better ordering of our affairs—an instrumentality which will enable us to derive many of the benefits of the town meeting in the greater concerns of our national life. The mechanism which we are here using is one adapted to permit many speakers in many distant audiences to be heard by all who care to listen and take part in a common discussion. In voicing the opinion that this mechanism is destined profoundly to affect our political and economic machinery, I intend to convey no thought or picture of a pure democracy but only of a representative form of government in which all questions that would be helped by oral discussion can be so discussed without restraint from the physical limitations of the human voice or of distance. They might be discussions between widely separated groups on some matter of common concern or between a designated representative and his constituents, or in any of the thousand and one ways in which human beings better their conditions by oral discussion.

In the hands of the members of this Institute the telephone has been developed from the first crude concept of Alexander Graham Bell's great contribution to knowledge and great gift to mankind, into a machine of incalculable influence in human affairs. The successful realization of a dream, a hope and an inspiration dating back to the pioneer days of Bell himself, namely, the production of a loud speaking telephone which would reproduce the human voice faithfully but in stentorian tones and in many places simultaneously has now been accomplished. In the solemn exercises attendant upon the burial of the Unknown Soldier at Arlington on Armistice Day a year ago, we had the curtains of the future drawn partially aside and saw vast audiences in New York and San Francisco co-mingled, as it were, with those who listened on the banks of the Potomac, but those exercises and all subsequent exercises and demonstrations have been in the nature of one-way transmission; that is, they have been arrangements in which the speakers were at one place and the audience at one or more other places, or they have been arrangements where a single audience listened to speakers in different places. Tonight, for the first time, we are witnessing and making use of the next step in the development by employing an arrangement which enables many speakers and many audiences in many places to meet as one body.

From the arrangement at Arlington to that of tonight may seem a logical next step. So it is for those who have the imagination to picture the future, but so too was the concept of a loud speaking telephone a simple logical next step to anyone who had witnessed the operation of an ordinary telephone. In both cases the next step that was easily logical in the imagination has been technically difficult in reality. It is neither my purpose nor my place as the presiding officer to trench upon the papers and discussion intended to describe and exemplify this new instrumentality. Before proceeding to the more formal part of our program, however, I wish merely to call your attention to the fact that we lack only direct distant vision to make this joint meeting one in very fact save only for the element of the personal proximity of those in attendance, and who among us is hardy enough to believe that this last limitation may not be removed within the lifetime of many of those now here. Fundamental and applied research are opening new doors daily in bewildering succession. When they open that last door which now prevents man from exercising at a distance all of his powers of personal intimate communication we will have another noteworthy meeting of this Institute.

2. This particular cause of interchange currents in normal operation is largely eliminated by designing parallel distribution circuits to have equal impedance angles, *i. e.*, to have substantially equal ratios of reactance to resistance. Equality of line impedance angles does not, however, do away with tie-line currents caused by the nature of the *loads* on a system.

*A. I. E. E. Journal, 1923, Vol. XLII, April, p 347.

†A. I. E. E. Journal, 1923, Vol. XLII, April, p 359.

Tonight, however, we must be content with full powers of speech and hearing but with partially defective vision. So it comes about that you, Mr. Schuchardt, our Vice President, in Chicago, and you, Mr. Rhodes, my Vice-chairman, are each in a unique position, a position in which one of you is acting in place of the President at a meeting where the President himself is in attendance in his official capacity, and the other is acting similarly for the President in his capacity as presiding officer. Some day this may not be necessary, but for the moment we are really acting as the eyes of this great joint meeting and are transferring as best we can the functions of distant vision by means of human speech.

R. F. Schuchardt: Mr. President, members and guests of the Institute gathered in the metropolis on the Atlantic shores and in this active city of the great central west, and those many others who with radio detectors are participating in this truly national meeting:

This is indeed a wonderful experience for all of us—an epoch-making event in history, as you, President Jewett, have so well said. Through the agency of devices which are already the familiar tools of telephone engineers, though still marvels to most of us, we are living for a few hours this evening in the identical mental atmosphere though vast stretches of our country separate us physically. In contemplating the means which make all this possible we recognize the debt that the world owes to the men whose achievements this represents—the patient, enthusiastic, talented engineers of the American Telephone & Telegraph Company and of that splendid Research Bureau of the Western Electric Company where Col. Frank B. Jewett has played such a leading role.

Never in history has there been such advance in the things that progress civilization, chief among which is transportation—transportation of material things, as done by the ocean greyhounds that bring Europe within a few days of our eastern coast and by the railroads that cross the continent in even less time, and now also by the still swifter airships; transportation of energy from hydro or steam plants over great electric transmission lines to distant markets; and that transportation of thought, the broadcasting of intelligence, that we enjoy this evening. All of these things annihilate distance and bring people closer together, into more intimate kinship. Yet we have the paradoxical situation that in the past decade, in the midst of this advance, there occurred the greatest outburst of barbarism known to the history of civilization.

The Phoenix that rises from the ashes must be largely the work of the engineer, and what can be more potent here than this contribution of the telephone engineer. President Jewett has eloquently pictured its possibilities in relation to our national affairs and no doubt his picture will materialize. May we not hope that the ease with which peoples on opposite sides of boundary lines in Europe can thus be brought together, ear to ear, if not face to face, will serve powerfully to show them that their fundamental interests and their aspirations are common and in reality they are all kin. The engineers of those countries must and will lead the way.

This wonderful work of the American telephone engineer, so forcefully brought home to us all by this evening's experience, will serve as an inspiration to engineers in other fields. It emphasizes splendidly the great value of engineering research, it stimulates the imagination, and will encourage others to renewed efforts. The engineer appreciates his obligation for worth-while accomplishment for the common weal, and he rejoices in all opportunities in which to express this appreciation.

In conclusion, Mr. President, may I tell you how deeply the Great Lakes District feels the honor and the special favor of being permitted to join in this memorable meeting so uniquely, and we thank you and your associates for making this opportunity possible.

E. B. Craft: The papers to which we have listened this evening establish another milestone in the art of electrical communication.

The system which has been described and demonstrated for us would seem to almost complete the picture of the possibilities of the transmission and reception of the spoken word.

During the past ten years we have seen the range of the wire communication systems extended so that it is now possible for an individual to converse directly with any other *individual* within the confines of the continent.

The developments in radio broadcasting during the same period have made it possible for an individual to speak directly and simultaneously to *unlimited numbers* of individuals located at a similar number of different points.

Now this latest development which we have christened the public address system, adds another and tremendously important possibility which is that an individual may converse directly with *groups* of individuals of practically unlimited size. Furthermore, they can be assembled in direct view of the speaker or through the agency of wires or radio these large groups may be located anywhere within the confines of our land, on the islands adjacent or on the ships at sea.

Truly we have in these agencies all that would seem essential to Man's dream of universal intercommunication.

It may be of interest to consider briefly some of the possible uses to which this new instrument may be put.

It is a noteworthy fact that many of our largest and most beautiful places of assembly are, in spite of their costliness and artistic perfection, sadly deficient in their acoustic qualities. Through the use of the system which we are now considering, the limitations which seem to be inherent in the design and construction of many of these great structures, are removed, their usefulness as places of public assembly fully attained.

In outdoor spaces Man's voice is a rather puny thing, but now science has brought to his aid a perfectly controlled volume of energy by which his voice may be made to reach audiences of thousands of persons, many of whom would, under former circumstances, be merely indifferent onlookers.

The growth of our urban centers has reached such a point that for an individual to speak directly and at one time to any considerable portion of its inhabitants has become a physical impossibility. These physical limitations have been removed and the public speaker will now be able to much more effectively play his part in developing and molding public opinion.

In rural communities it is seldom, if ever, that any considerable number of its inhabitants have the opportunity to hear the voices of our National figures. On great public occasions whether they be State or National, it will now be possible for these people to gather in their local centers and have the voices of public men and the music of great bands or orchestras brought directly and naturally to their ears, whether the event itself be a hundred or a thousand miles away.

One could go on indefinitely and enumerate specific examples of the valuable applications of this new development, but it seems sufficient to point out some of these broader applications and to express the confidence that as new uses arise, the technical means will be available to accomplish the desired results.

B. E. Sunny: The American Institute of Electrical Engineers is tonight collecting an extra dividend on its investment, *in time and effort*, in helping for so many years in the development of the electrical industry.

It is holding a joint meeting in New York and Chicago by means of the long distance telephone and the loud speaker. The occasion is a scientific triumph, in the achievement of which, the Institute will cheerfully be given a generous share.

For forty years it has been the international agency for assembling and coordinating the human elements required by a new industry of unlimited significance in its possibilities for public service.

It has been the common gathering place,—the home, in fact, of the fraternity, where theories and problems have been fully and frankly discussed. It has been the clearing house for electrical ideas, plans and methods. In its meetings the rivalries growing out of keen and continuous competition have been forgotten, and a spirit of unity has always prevailed.

The success in the various branches,—electric lighting, transportation, telephone, etc., has necessarily come by slow degrees, but at a very much earlier date than could have been the case, were it not for the opportunities and assistance given by the Institute.

The awarding of the Edison Medal is one of the inspiring and stimulating processes of the Institute, by which 14,000 or more men are held together, in an earnest and enthusiastic campaign for the advancement of the profession.

The Edison Medal is an impressive tribute to the men who, in a large degree, represent the remarkable strides that have been made in modern electrical application.

In the list are men who differed in their theories and practises with respect to manufacture and operation, but these differences have long since been disposed of by the law of the survival of the fittest, which seems to have unusual applicability to electrical ideas.

The public service is no respector of persons and, as the final judge, accepts or rejects our efforts, without emotion.

The contributions to the art by each of these men have been tremendously important and valuable, and they are highly deserving of the distinguished recognition they have received. In their genius, industry, integrity, leadership and achievements, they are our glory, and we are indebted to the Institute for having placed them in our Hall of Fame.

We members of the Institute who have felt that the many important discoveries and inventions in electricity should give us permanently a place in the center of the stage, in the strong light of public approval, are gratified at the announcement by our brothers in the medical profession that they have found the cause of influenza, and discovered a remedy for diabetes. We extend to them our hearty congratulations, and if they will forego dislodging us entirely and be satisfied with a division of the spotlight, we shall be glad to welcome and share with them.

The marvelous thing about history of science and medicine is that so comparatively little was accomplished up to fifty years ago and so much has been accomplished since then. If we today lifted out of the office, shop, home and from the streets, the electrical devices that have been put into them in recent years, what a demoralization would result.

In the practise of medicine and surgery, where the same type of patient, determined and skillful men have been diligently laboring, the average length of life has been increased some 25 per cent in fifty years.

The electric lamp, X-Ray and other electric appliances have greatly helped to this result. In other lines gratifying progress has been made.

Unlike our frequent experiences in civil and governmental matters, in science we hold onto our advances and continually go forward. There is never danger that we will give up electric light and go back to the candle, or give up the trolley and return to the horse car. We hold fast to the serums as they come along, for prevention and cure. But in our ordinary affairs and governmental matters, we ofttimes go forward and slip back, the succeeding generations repeating the old mistakes. Most of the things that are wrong in the economic situation in the nation duplicate the experiences immediately after the civil war, while the situation with respect to the merchant marine is substantially identical to that which existed 142 years ago.

Our hope must be that as the years go on, one after another of these problems can be worked out on a *scientific* basis, where the gain can be held, and we will not slip back and have to begin all over again.

We can therefore congratulate ourselves that in the scientific advances that we are making we are securing permanent values, well worth all of the expenditures that may be made in their seeking.

John J. Carty: Of all the agencies employed in the electrical communications of the world, the telephone is the most wonderful. More than any other the telephone art is a product of American institutions and reflects the genius of our people. The story of its wonderful development is the story of our own country. It is a story of American enterprise and American progress. This story forms part of the proud record of the American Institute of Electrical Engineers.

It was one of our members, Alexander Graham Bell, who revealed to mankind the method of electrically transmitting the tones of the human voice to distant places. He was the first to provide the apparatus to do this marvel; he was the first to speak through the electric speaking telephone; and his voice was the first to be heard in the telephone receiver. It was another of our members, Thomas A. Watson, who made for Bell the first telephone, and who ran the first wire, and who heard the first words which were ever transmitted by electricity.

It is a cause for special gratification tonight that in the office of President, which Bell himself once occupied, we have such a distinguished successor. In those laboratories in which Bell was the original worker, President Jewett and his associates who are also our fellow members, have transmuted into realities those grand visions of science which inspired the founders of our Institute.

Nothing could appeal more to the genius of our Institute than the telephone, for not only have our members built upon it an electrical system of communication of transcendant magnitude and usefulness, but they have made it into a powerful agency for the advancement of civilization, eliminating barriers to speech, binding our people together into one nation, and now reaching out to the uttermost limits of the earth with the sublime hope that some day it will be utilized in bringing together the people of all the nations of the earth into one common brotherhood.

Strange to say, it is from the discoveries of the new school of biologists that we realize how fundamental electrical communication systems are in the tremendous evolution of the human race which is now being manifested in the organization of society, and how vital to the welfare of mankind is the daily work of the members of this Institute.

Speaking always of communication in its broadest meaning, but emphasizing the importance of speech, Wilfred Trotter, one of our great authorities in biology, says: "The capacity for free intercommunication between individuals of the species has meant so much in the evolution of man, and will certainly come in the future to mean so incalculably more, that it cannot be regarded as anything less than a master element in the shaping of his destiny." And again, in speaking of human society as a gregarious unit, he says: "The ultimate and singular source of inexhaustible moral power in a gregarious unit is the perfection of communion amongst its individual members." As long as intercommunication was limited, he tells us, the full possibilities of evolution were concealed. But at length appeared man a creature endowed with speech, in whom this capacity for intercommunication could develop indefinitely. Then Trotter goes on to say: "At once a power of a new magnitude was manifest. Puny as were his individuals, man's capacity for communication soon made him master of the world . . . . In his very flesh and bones is the impulse towards closer and closer union in larger and larger fellowships. Today he is fighting his way towards that goal, fighting for the perfect unit which nature has so long foreshadowed, in which there shall be a complete communion of its members, unobstructed by egoism or hatred, by harshness or arrogance or the wolfish lust for blood. That perfect unit will be a new creature, recognizable as a single entity; to its million-minded power and knowledge no barrier will be insurmountable, no gulf impassible, no task too great."

Here we have portrayed the foward march of humanity toiling ever onward to attain its goal. The realization that their wonderful art is destined to play such an important part in the final attainment, opens up a never-ending source of power and inspiration for electrical engineers everywhere. It adds new dignity to their calling.

We are living in the golden age of communications which has achieved the extension of the spoken word throughout both space and time. But this golden age has not yet ended; it has only just begun. Already, the human voice has been carried with the speed of light across the Atlantic Ocean, and across our continent, and far out into the Pacific. But still greater things are to come. We may hope for the time foretold by the poet,

"Wherein each earth-encircling day shall be
A Pentecost of Speech, and men shall hear,
Each in his dearest tongue, his neighbor's voice
Tho' separate by half the globe."

I believe that when mankind is prepared to receive the message, a great voice will be heard throughout the world which will proclaim "Peace on earth, good will toward men."

DISCUSSION ON "OBSERVATIONS ON ELECTRIC RAILWAY PRACTISE"*

(POTTER), New York, N. Y., February 14, 1923

A. Le Blanc: Mr. Potter's paper gives a very good idea of the existing differences between American and European practise. I would like to call your attention to some points applying merely to French railways.

The practise of screwing up the couplers until the buffers are always compressed, as explained by Mr. W. B. Potter, is commonly used for high-speed passenger trains, but not for freight trains. These trains are hauled by locomotives weighing less than 100 metric tons, with train weights as high as 1200 metric tons, and 80 cars. Cars are loosely coupled and this allows a better starting; the cars are started successively and consequently the draw bar pull may be considerably less than would be necessary if the whole train started at once.

The dissymetrical arrangement of rail joints, as proposed by Mr. Potter, looks to be very interesting and I am sure that our French engineers would like to know more about it, we fear they will not change their actual practise before having seen it tested in other countries.

The P. O. railway for very high-speed locomotives is conducting experiments with the gearless type as made by the G. E. Co., the geared with quill drive, the connecting rod-type; two different machines of this last type are to be tested, and one of these from the designs of O. L. Parodi, Chief Electrical Engineer of the Paris-Orleans Railway.

The better condition of our French engines as compared to the American is due mainly to the fact that our engines are always driven by the same men; they consider their machines as their own and that is why they look so clean and are in such good adjustment—the men receive a special bonus for this. We fear that in the near future, and due to economic factors, our practise will come nearer to the American.

As to the brake equipment, we are pleased to say that our Consul General of Railroads has just passed a resolution adopting the Westinghouse brake equipment for all freight trains, to start immediately with all new cars.

Direct current has been adopted for all French electric railways at 1500 volts plus or minus 5 per cent. While regenerating, this tension may reach 1800 volts on the generating locomotive.

From figures produced by Mr. Potter our country is classified second in the number of electric locomotives and the fourth only for the electrified mileage. This is due to the fact that, actually, orders have been placed for a greater number of locomotives than the electrified tracks would require. But we must remember that our program of electrification in France is set up to be accomplished in 15 years; and that it applies to about 5500 miles. During 1923, the expenditure for electrification is to be 270 million francs (from a total of 1,050 million francs, total expenditure for the French railroads). This shows that France is now offering a very interesting field of investigation and of commercial value.

*A. I. E. E. JOURNAL, Vol. XLII, May, p. 490.

DISCUSSION ON "THEORY OF ELECTRIC WAVE FILTERS BUILT UP OF COUPLED CIRCUIT ELEMENTS"*

(PETERS) New York, N. Y., February 15, 1923

Kenneth S. Johnson: There are certain statements made in the Peters paper to which I wish to take exception and which, unless pointed out, I believe are likely to be misleading.

The coupling or mutual impedance, Z_m, is represented in the paper symbolically as a network with *two* pairs of terminals. Since, however, it introduces the same impedance into both adjacent sections and is completely defined by a single impedance, Z_m, it is actually only a network with *one* pair of terminals. Consequently with no loss of generality whatsoever Fig. 1 of the paper can be represented by the following sketch.

But since any network with only one pair of accessible terminals is always completely represented by a single impedance element the above sketch and hence Fig. 1 of the paper may be shown with complete generality by Fig. 2. Comparing this with one of Campbell's figures[1] it is evident that the two figures are exactly the same. It should be noted, however, that there is a difference in the method of designating the impedances. Although the Z_m of the Peters paper is exactly equal to the Z_2 of the Campbell paper, Campbell defines his Z_1 so that it includes

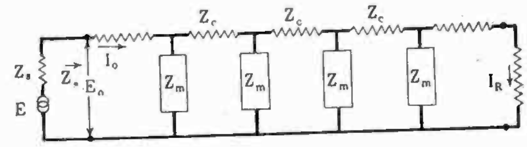


FIG. 1

only the series impedance component while Peters' Z_c comprises the series impedance plus twice the shunt impedance. That is

$$Z_c\,(\text{Peters}) = Z_1 + 2\,Z_2\,(\text{Campbell})$$

Evidently the two figures are identical. Either of them properly represents any periodic recurrent structure. We should understand, however, that Campbell's Z_1 and Z_2 or Peters' Z_c and Z_m (assuming one assigns to his work the broadest application) are symbolic and may not be actually realizable impedance elements as indicated. This is a commonplace to those familiar with electric circuit theory and its symbolism. Any of these impedances may be a complicated network in itself. The essential thing is that, as regards the structure in which it is inserted, it is a network with *one* pair of accessible terminals only.

However, if Mr. Peters prefers the symbolism of the "square box" to that of the equivalent "*T*" or "π" network the filter may be represented as shown in Fig. 3.

Each box represents a network with *two* pairs of terminals and is completely defined by three impedance parameters. The theory and formulas of the filter may then be developed in terms of these parameters[2] without explicit reference to the equivalent "*T*" network as is done by Zobel.[3] This procedure, of course,

*A. I. E. E. JOURNAL, Vol. XLII, May, p. 445.

1. See Fig. 4 in G. A. Campbell's paper on the "Physical Theory of the Electric Wave Filter," *Bell Technical Journal*, Vol. 1, No. 2, (Nov. 1922).

2. See "Cisoidal Oscillations" by G. A. Campbell, TRANS. A. I. E. E., 1911, Vol. XXX, Part II.

3. "Theory and Design of Uniform and Composite Electric Wave Filters," *The Bell System Technical Journal*, January 1923, Page 32.

gives no gain whatsoever in generality. Mr. Peters, evidently not appreciating the equivalence of the circuits noted above, makes the following statements in his paper.

"The conception of circuital and transfer impedance as a broad basis for filter theory and the type of section to which the treatment leads directly are thought to be original."

"The general theory presented in the following sections is somewhat broader than that presented by Campbell and Wagner as it introduces, as a special case, the filter built up of series and shunt elements, as the shunt element may be considered as a coupling element."

Evidently the forms discussed by Mr. Peters may be properly considered to be special cases of the Campbell treatment. In this connection reference to an article by Luschen and Krause[4] is of interest. They, incidentally, also discuss in more or less detail the particular type of inductively coupled structure shown in Fig. 3 of Mr. Peters' paper.

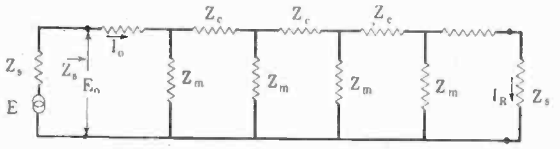


FIG. 2

In the next to the last paragraph on page 449 he states that "If Z_n and Z_o are to be fixed resistance then in general we can satisfy the above relation for only *one* particular frequency within the transmitted band . . .". This statement is not, in general, true as may be seen by reference to Fig. 5 on page 18 of the paper by Mr. Zobel which has already been referred to. In fact it is possible in certain types of band pass filters to satisfy the above relation for as many as *four* particular frequencies within the transmitting band.

A few sentences later we read that "In general . . . . the impedance curve is fairly flat for quite a range of frequencies within the transmitted band but falls to *zero* at the cut-off points." The characteristic impedance of a large number of filters does become zero at the cut-off points but for practically an equally large number of filters it becomes of infinite value at one or more of the cut-off points.

With regard to the specific forms of wave filters discussed by

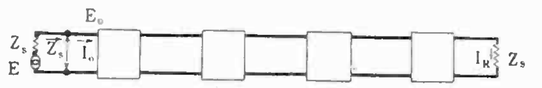


FIG. 3

Mr. Peters the type shown in Fig. 3 of the paper appears to have been investigated several times previously.[5] Since two separate inductances coupled together by a mutual inductance are always replaceable by an equivalent "T" or "π" network each arm of which is an inductance, it is evident—as has already been pointed out by Luschen and Krause as well as by Zobel[6]—that the structure shown in Fig. 3 of Mr. Peters' paper is electrically equivalent to a structure of the series-shunt or "ladder" type whose series arms consist of an inductance in series with a capacity and whose shunt arms consist merely of an inductance. In a like manner the structure shown in Fig. 15 of Mr. Peters' paper is reducible by the same procedure to a structure of the ladder type whose series arms comprise an inductance and condenser in series and whose shunt arms are likewise comprised of an inductance in series with a condenser. Complete design formulas for those latter structures, which have been used commercially and which are equivalent to the ones which Mr. Peters has shown in Fig. 3 and 15, are given on page 42 (V_1 and $VIII_1$) of Mr. Zobel's paper to which we have already referred.

On page 456, Mr. Peters states that " . . . . with the exception of frequencies in the vicinity of the cut-off frequency and for very large frequencies the loss figured from the attenuation constant alone gives a very close approximation to the total loss occasioned by the introduction of the filter." It should be pointed out that this statement is not true for very low frequencies where the reflection effects in band pass wave filters are equally as large as they are for very high frequencies and consequently greatly increase the loss caused by the introduction of the filter.

The statement is also made at the top of the second column on page 456 "That the losses in condensers can be made negligible." This is never true with reference to paper condensers and is by no means true even with mica condensers, at relatively high frequencies. For example, the losses in the best mica condensers will approximate the losses assumed by Mr. Peters to exist in the coils *i. e.* the ratio of their resistance to their effective reactance is of the order of magnitude of 0.001. It should be pointed out however in this connection, that the value of 0.001 for "d," which is the value Mr. Peters has assumed in computing the curves shown in Figs. 19, 20 and 21, is very much smaller than has ever been encountered commercially so far as we know. To our knowledge coils with a value of "d" of 0.005 are about as efficient as have ever been commercially constructed. The effect of this greater amount of dissipation, is, of course, to increase the loss proportionally in the center of the transmitted band and to make the attenuation curves much more rounded near their cut-off frequencies.

L. J. Peters: I greatly appreciate Mr. Johnson's discussion of my paper, first, because he has called attention to some points of which I was aware but stated rather loosely, and second, because he has called attention to some things of which I was not aware. However, in regard to the broadness and suggestiveness of the series—shunt impedance treatment as given by Campbell and others and the circuitual—transfer impedance treatment as given by myself, I would like to state clearly in what way I regard the latter treatment as being the broader. I agree with Mr. Johnson that either treatment can be used to design or to investigate all of the types of filter sections which we have in mind. I further agree that one treatment can be thrown over into the other by a suitable transformation of the equations. My contention is that the circuitual—transfer impedance terminology and view point is broader in its suggestiveness, at least to the average engineer, than the series-shunt impedance terminology. In order to state more clearly what I mean, I will designate as Class 1 those filters actually constructed as shown by Fig. 4, and as Class 2 those filters actually constructed as shown by Fig. 5. Then my contention is that the circuitual-transfer impedance terminology at once suggests filter sections of Class 1 and Class 2 whereas the series-shunt impedance terminology suggests to the average engineer only filters of Class 2. I infer that the series-shunt viewpoint did not immediately suggest filters of Class 1 even to those very familiar with the electrical equivalence of various kinds of networks, as Dr. Campbell's original patent specifications, to which I have referred in my paper, do show diagrams for the possible variations of Class 2 filters but show no diagrams even indirectly suggesting a Class 1 type of filter. Also the published works with which I was familiar at the time my paper was written did not suggest to me at least that filter sections of Class 1 had been considered.

In this connection I would like to point out that there is a vast difference between having enough general theoretical

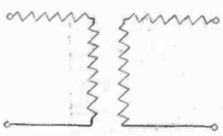
4. See Vol. 1, Third Issue (Nov. 1921), Wissenschaftliche Veroffentlichungen aus dem Siemens-Konzern.

5. See the article by Luschen and Krause previously referred to. See also K. W. Wagner's article on "Multiplex Telephony and Telegraphy with High Frequency Alternating Currents," *Elektrotechnische Zeitschrift*, August 14, 1911, Note 1 on page 395.

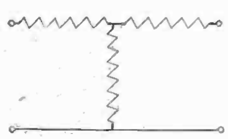
6. See paragraph 1 on page 30 of the paper already mentioned.

knowledge to cover a given phenomenon and the actual consciousness that the phenomenon exists. As an illustration of what I mean, consider the thermionic vacuum tube. Nearly every engineer and physicist who came into contact with the two element tube had enough electrodynamic theory to know that the interposition of the third element would convert the tube into a device having untold possibilities. Yet the third element was not put in for years after the discovery of the two element device, and even after it was inserted, the possibilities of the device developed slowly over a number of years. That is, a realization of the possibilities of the device came about only by stating the general electrodynamic theory in such a way as to specifically cover the applications. I claim that the circuitual-transfer treatment is broader than the series-shunt treatment because it does state filter theory in such a way as to specifically cover filters of both Class 1 and Class 2, whereas the series-shunt treatment does not.

Now besides the broader suggestiveness of the circuitual-transfer impedance viewpoint over that of the series-shunt impedance viewpoint, there is also a correspondingly greater broadness in its immediate applicability. Even though the sets of equations arrived at by the two treatments are equivalent in that one set may be transformed into the other, the set of equations which I have given apply directly to both Class 1 and Class 2 filters, whereas before the series-shunt equations can be used to treat Class 1 filters, either the equations must be transformed into the form given in my paper or else the Class 1 network must be replaced by an electrically equivalent Class 2 network. That is, in order to use the series-shunt treatment to handle Class 1 networks, one must have in addition to the filter theory an in-



Class 1
FIG. 4



Class 2
FIG. 5

sight into the possibilities of the replacement of one type of network by an electrically equivalent one. Under these conditions I believe that it would be customary to regard the circuitual-transfer impedance treatment as being more general than the series-shunt impedance treatment.

Lest it be overlooked by some, I would like to call attention to the dates of the wave filter papers by Campbell and Zoebel referred to in Mr. Johnson's discussion. I do this, not to show that the filters of Class 1 were just recently considered by Mr. Johnson and his co-workers as Mr. Johnson has just sent me a memoranda from his files which shows that he considered this class of filter as early as 1919, but to call attention to the fact that these papers were not available when my paper was written.

ONLY SEVEN WATER POWER GENERATING PLANTS IN GREAT BRITAIN

A total of 536 public service generating stations in Great Britain is shown by the report of the "Electricity Commission" for the year ending March 31, 1922. Of this number 366 utilized steam as a source of power, 55 producer gas, 47 oil engines and the remainder other means, including water power. The Electrical Division of the Department of Commerce states that only seven stations depend exclusively upon water power, the largest of which produced 18,763,000 of the total of 29,107,000 kw-hr. generated from this source.

The total electric power generated during the year amounted to 4,884,666,038 kilowatt hours, of which steam supplied power for approximately 97 per cent.

ILLUMINATION ITEMS

By the Lighting and Illumination Committee

The following figures have recently been compiled to show the approximate annual total and per capita consumption of incandescent lamps in the United States and several European countries.

	Population	No. of Lamps	Lamps per Capita
United States	112,000,000	205,000,000	1.83
Switzerland	4,000,000	6,500,000	1.62
Germany	57,000,000	50,000,000	0.88
France	41,475,000	30,000,000	0.72
Austria	6,000,000	4,000,000	0.67
England	44,000,000	20,000,000	0.45
Italy	40,000,000	15,000,000	0.38
Hungary	7,250,000	2,700,000	0.37

NOTES ON ELECTRICAL ADVERTISING

Few people outside advertising circles realize that there is a very highly organized trade association which controls the appearance and service of a large part of the best poster boards in the country. There is a very real and sincere effort behind the rules of standardization and maintenance of the Porter Advertising Association to make poster advertising as dignified and thoroughly respectable as possible. It is obligatory upon each of the nearly ten thousand members in ten thousand cities and towns to keep his boards in the very best of condition; to change his posters regularly once a month and to observe all of the very strict rules and regulations of the association. It is a thorn more painful in the side of the association than in the side of any other organization that there are, in prominent places, some boards and displays owned by non-members of the association and over which it has no control of course, but which are far below association standards.

A quite recent accomplishment of the association was the appointment of a committee to investigate all methods of poster board illumination and to arrive if possible at some standardization of practise. It is characteristic of the association that its course of action will be determined only after very thorough investigation and experimentation in which all of the standard methods and apparatus now available will be given a thorough trial. When the rules are standardized and completed it will be incumbent upon each member to observe them and to illuminate only those boards which are, according to the associations judgment, suited to illumination.

It is estimated that ten thousand poster boards are illuminated each year; probably an equal or an even greater number of bulletin boards are also illuminated.

One of the most striking developments in electric sign practise during the past year has been the gradual replacement of lamps with the open barrel type of filament by lamps with a concentrated coil type of filament.

This has been due to two major causes. The concentrated filament lamps are considerably more durable and apparently brighter than are the barrel filament lamps. Many lamps of the older type fail by filament breakage before the end of their normal life. The comparative fragility of these lamps, therefore, has placed a handicap on the cleaning of a display and has resulted in poorer maintenance than should obtain now that stronger lamps are available. While the new lamps are still subject to breakage, of course, if roughly handled, they are very much more durable than the old ones were and the general appearance of the shorter-viewed displays should be improved.

The concentrated filament lamps are apparently brighter because of the greater proportion of light in the direction of the observer and the smaller projected area of the filament in sight. Brightness is a characteristic which has been capitalized extensively in electric signs and especially recently since higher wattage lamps have become so popular for this purpose.

In signs of trough or channel construction, it was formerly the practise to space barrel filament lamps fairly wide apart and depend upon the relatively high side light from the lamps to illuminate the trough, thus filling out the stroke of the letters between the spots of comparatively low brightness from the filaments themselves. Best practise at the present time is to ignore the trough illumination which is greatly reduced because of the lower side light from the concentrated filament lamps, and to space the lamps closely enough so that an unbroken pattern is formed of the more intensely bright spots of light from the concentrated filaments themselves.

It is probable that for exposed lamp sign practise, the concentrated filament lamps will in the near future entirely replace all barrel filament lamps.

There has recently been placed on the market a new color medium intended primarily for exposed lamp sign displays. It is called "Spray Color Coating for Standard Lamps" and consists of a diffusing coating with which the lamp manufacturers spray clear glass sign lamps.

Among the other color media, laquer dips have long been popular. The colors are more brilliant and practically any color may be obtained by mixing laquers of standard colors. The color may be applied easily a short time before the lamp is put into use. However, laquer dips are not permanent. They burn and peel off readily and are subject to rapid fading by the actinic rays of sunlight. They are, therefore, suitable only for displays in which the color is to be changed or renewed once a week or more often.

Colored glass caps or hoods are also used very extensively and are very satisfactory. These colors are also brilliant and are at the same time permanent. It is a little more costly to use color caps except for organizations in which the caps can be used over and over again for many years. The chief disadvantages are the necessity for frequent cleaning, which means removing entirely from the display, and the heavy dark appearance by daylight. Also, it is necessary to install the caps carefully so that their added weight will not loosen the lamp in its base or overcome the tension of the holding spring causing the cap to fall off.

The new spray colored lamps are less brilliant because the coating is diffusing in nature, and the efficiency of color production is somewhat lower. In spite of these limitations, however, spray colored lamps are rapidly becoming popular. Their appearance in daylight is very similar to their excellent appearance at night. The colors are permanent, the lamps are easily installed, and are very easily cleaned. There seems to be very much to recommend this new color medium.

A NEW INDUSTRIAL LIGHTING UNIT

A new industrial lighting unit, in which a diffusing globe is combined with a steel reflector or diffuser has recently been designed and is being put into production by a number of reflector manufacturers. The unit, shown in Fig. 1, consists of an enameled steel reflector and a glass diffusing globe which completely encloses the lamp.

With ordinary types of steel reflectors most of the light is provided on the working plane, and where the

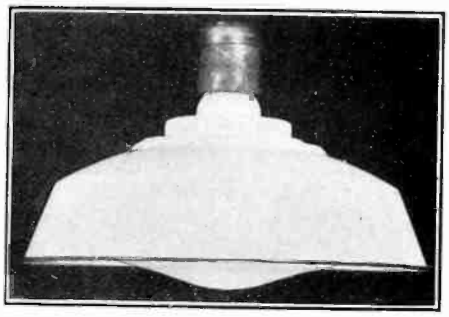


Fig. 1—The Glassteel Diffuser with a Cast Aluminum Holder

floor, walls, or material in the room have a good reflection factor a sufficient amount of light is reflected to the ceiling to soften the contrasts between the lighted parts of the room and the darker ceiling. All-glass reflectors light the ceiling abundantly, but their use in most industrial work rooms has been somewhat limited owing to a fear that excessive breakage might result. This combination glass and steel diffuser is so designed that a carefully predetermined proportion of the light is directed through openings in the top of the steel reflector to the ceiling. The steel reflector protects the glass enclosing globe, minimizing the likelihood of breakage; in addition, the reflector directs the light downward to the working plane very much more efficiently than does an enclosing globe without reflector. Fig. 2 shows the various parts of the unit; the design of the steel reflector permitting some of the light to be reflected toward the ceiling is clearly shown.

One of the important functions of all reflecting equipment is to reduce the apparent brightness of the light source and thereby minimize glare. A great advantage which the *R L M* Dome possesses over its predecessors in reflecting equipment is a reduction in brightness in the direction of the eye from the exceedingly high values of these earlier units to a value as low as 15 candle power per square inch when used with a bowl-enameled lamp. Since, in the new unit, the lamp is entirely enclosed by the glass diffusing globe, clear Mazda *C*

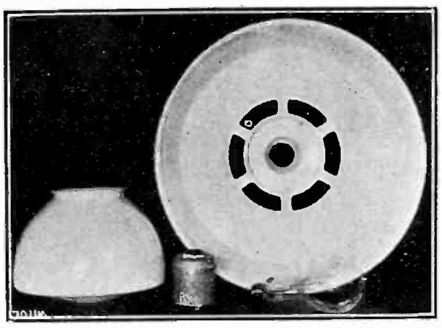
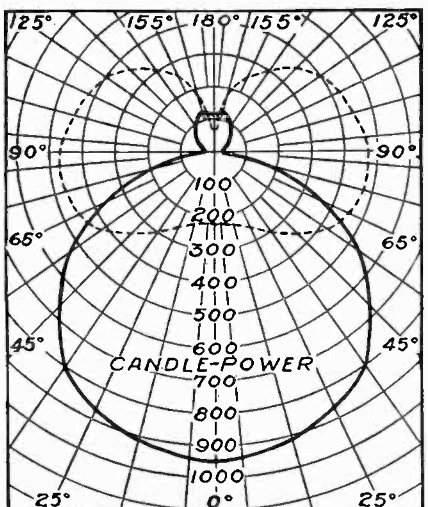


Fig. 2—An Unassembled View of the Glassteel Diffuser
Showing the apertures in the steel reflector through which a portion of the light is directed upward.

lamps are employed and the brightness is further reduced to 3 or 5 candle power per square inch. The total light output of both the *R L M* Dome and bowl-enameled lamp combination and this diffuser is slightly better than 65 per cent. With *R L M* Dome all of this light is below the horizontal, while with the new diffuser about 7 per cent is directed toward the ceiling. The



— The Glassteel Unit - 300 Watt Clear MAZDA C Lamp

----300 Watt Clear MAZDA C Lamp

ZONE	LUMENS	% TOTAL CLEAR LAMP
0- 60	2265	46
0- 90	2924	60
90-180	340	7
0-180	3264	67

Fig. 3—Distribution Curve of a Typical 20-in. Glassteel Diffuser Using a 300-watt Mazda C Lamp

curve in Fig. 3 shows the distribution of the light from a typical equipment.

This unit is available in two sizes, the reflectors of which are 18 and 20 in. in diameter respectively. The 18-in. unit has a 2¼ in. neck to take a medium screw socket and uses a 100, 150, or 200-watt lamp. The 20-in. size is equipped with a mogul socket for the use of 300 or 500-watt lamps. A feature in the design of the 20-in. unit is its adaptability for use with 150-watt or 200-watt lamps by the use of a standard socket adapter. The adapter extends the light-center length so that it practically coincides with the light-center length of the 300 or 500-watt lamps, thus avoiding a distortion of the light distribution. A 20-in. unit therefore permits 150 or 200-watt lamps to be used efficiently and at the same time provides for future requirements, since it is only necessary to remove the adapter and substitute any lamp up to 500-watts without change in the reflector. This equipment is designated as the Glassteel Diffuser.

AN EXHIBIT OF MODERN STREET LIGHTING

An interesting exhibition of street lighting standards, shown in the accompanying illustration Fig. 1, has been installed at Nela Park, Cleveland, at the instance of lamp and equipment manufacturers. Its purpose is to provide a composite or cross-section of modern street lighting equipments for the study of city officials, civic organizations, engineers, and other interested persons.

The modern units on exhibition present a marked

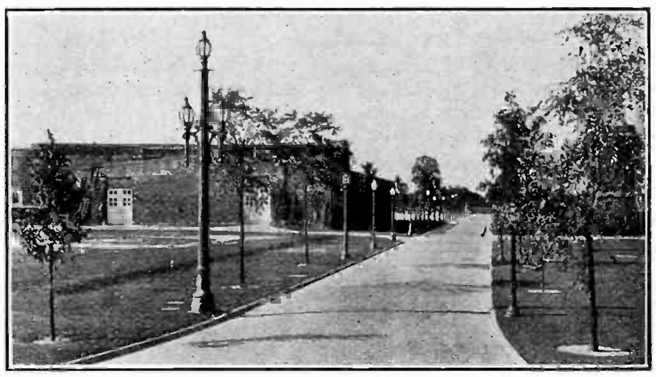


Fig. 1

contrast to the inefficient multi-lamp clusters that were at one time widely used for White-Way lighting, and to the unsightly wooden-pole, mast-arm, dangling-wire type which have been used extensively in the past for the lighting of thoroughfares and residence streets.

It will be noted that most units show the result of efforts to combine pleasing appearance with effective light control. Lantern type luminaires in which this purpose has been accomplished are well represented. A number of examples of bracket type standards, which are rapidly gaining in favor for the lighting of thoroughfares and residence streets, are shown. Most striking of all, perhaps, is the distinct tendency toward a higher mounting height in all branches of ornamental lighting.

One of the valuable features of the exhibition is that it affords an intimate comparison of the most up-to-date equipments which are available at the present time. Definite ideas can be obtained of the day and night appearance of the units. Each unit can be turned on and off individually so that its appearance when lighted, as well as its particular characteristics of light diffusion and light distribution, may be observed without interference from adjoining units.

JOURNAL OF THE American Institute of Electrical Engineers

PUBLISHED MONTHLY BY THE A. I. E. E.
33 West 39th Street, New York
Under the Direction of the Publication Committee

FRANK B. JEWETT, *President*
GEORGE A. HAMILTON, *Treasurer* F. L. HUTCHINSON, *Secretary*

PUBLICATION COMMITTEE
DONALD MCNICOL, *Chairman*
E. E. F. CREIGHTON WM. MCCLELLAN
F. L. HUTCHINSON L. F. MOREHOUSE

GEORGE R. METCALFE, *Editor*

Subscription. $10.00 per year to United States, Mexico, Cuba, Porto Rico, Hawaii and the Phillipines; $10.50 to Canada and $11.00 to all other countries. Single copies $1.00. Volumes begin with the January issue.

Changes of advertising copy should reach this office by the 15th of the month for the issue of the following month.

The Institute is not responsible for the statements and opinions given in the papers and discussions published herein. These are the views of individuals to whom they are credited and are not binding on the membership as a whole.

The Spring Convention

PITTSBURGH, PA., APRIL 24-27

The Spring Convention of the A. I. E. E., held in Pittsburgh, April 24-27, proved a record breaker in point of attendance and was equally notable in the interest and enthusiasm displayed by all present. In both its technical and entertainment features the Convention was a marked success and reflected the highest credit upon the local convention committee whose efficient co-operation and well-laid plans were constantly in evidence in the conduct of the meeting.

The technical program, while covering a wide variety of subjects was selected with a view of making it especially applicable to the large lighting and power developments in the vicinity of Pittsburgh. Most of the papers presented dealt with the practical features of plant equipment and operation, and the discussion on the operating data submitted apparently unified opinion on many points that had been in controversy.

The entertainment features of the convention were well attended and thoroughly enjoyed. The banquet on Wednesday evening at the William Penn Hotel filled the ball room to capacity, and the visitors to the Westinghouse plant, where dinner was served, included nearly all of the registered attendance. A large proportion of the visiting members was represented in the numerous inspection trips arranged for Friday following the convention by the local committee, whose efficient handling of the various affairs was a subject of general comment.

At the meeting of the A. I. E. E. Board of Directors held in New York, May 18, the following resolution was unanimously adopted:

RESOLVED: That the Board of Directors of the American Institute of Electrical Engineers hereby expresses its hearty appreciation of the effective services rendered by the members of the Spring Convention Committee in making, and carrying out with gratifying success, the arrangements for the comfort and entertainment of the members and guests of the Institute in attendance at the Spring Convention held in Pittsburgh, April 24-27, 1923.

Similar resolutions were adopted expressing appreciation of the many courtesies extended by various local corporations and other organizations and individuals.

Tuesday Afternoon, April 24

The first technical session of the convention was called to order by Mr. E. C. Stone, Chairman of the Pittsburgh Section, who welcomed the members present in a few words and turned the meeting over to President Jewett. Owing to the very full program for the afternoon President Jewett announced that the remarks which he intended to make would be deferred to a later session. He called attention to the sudden death of Past-President Schuyler S. Wheeler which occurred only a few days before, and suggested that a fitting tribute to his memory be paid by the Institute at its first meeting after his death. On motion, the President appointed a committee to draw up suitable resolutions to be forwarded to Dr. Wheeler's family, his company and to be engrossed upon the records of the Institute. The resolutions are printed elsewhere in this issue. President Jewett then called upon Mr. H. R. Woodrow, Chairman of the Protective Devices Committee to conduct the technical session.

Chairman Woodrow announced that the four papers scheduled for the session would be presented in the order they are listed in the program. These are as follows:

Economical Value of Resistance in the Grounded Neutral, by H. H. Dewey.

The Neutral Grounding Reactor, by W. W. Lewis.

Operating Performance of a Petersen Coil, by J. M. Oliver and W. W. Eberhardt.

A committee report on *Present Day Practises in Grounding of Transmission Systems*, the latter being presented by E. C. Stone.

These papers were discussed as a group by R. W. Atkinson, F. C. Hanker, J. B. Taylor, L. P. Ferris, H. W. Smith, H. M. Trueblood, H. H. Dewey, R. D. Evans, C. L. Fortescue, J. A. Johnson, L. F. Blume, H. L. Wallau and W. I. Slichter. The discussion was followed by closures by H. H. Dewey, W. W. Lewis and W. W. Eberhardt.

Tuesday Evening

The Tuesday evening session convened at eight o'clock and was called to order by President Jewett. After making a few announcements President Jewett called on Mr. Stone to preside. The papers scheduled for this session were as follows:

Third Class Conductors and Mechanism of Arcing Ground, by C. P. Steinmetz.

Surges on Transmission Lines, by J. Slepian and J. F. Peters.

Chairman Stone read a letter from Dr. Steinmetz regarding his absence from the convention due to ill health and his paper was abstracted by Mr. R. E. Doherty. This was followed by an abstract of the second paper by Mr. Peters. The discussion which followed was by H. R. Woodrow, J. Slepian, E. P. Peck, J. W. Doron, S. L. Nicholson, E. E. F. Creighton, H. Halperin, W. A. Lillibrand and C. L. Fortescue, with closures by R. E. Doherty and J. Slepian.

Wednesday Morning, April 25

The meeting convened at ten o'clock with President Jewett presiding. The Chairman called attention to the fact that the papers of the preceding day had to do primarily with problems connected with the transmission of electrical energy in large quantities and at this session the general topic dealt with a phase of the utilization of energy. He called upon Mr. J. L. M. Yardley to preside. The first paper scheduled was, *Some Fuel Determinations on the Southern Pacific System*, by A. H. Babcock.

Mr. Babcock was unable to be present but his paper was abstracted by his representative, Mr. R. S. Twogood, and was at once open to discussion. The paper was discussed by letter by C. T. Hutchinson, which was read by H. Goodwin, Jr., N. W. Storer, W. J. Davis, Jr., W. I. Slichter, with closure by Mr. Twogood. The four remaining papers for the session all treated of some phase of electrical heating and after presentation in abstract by the authors were discussed as a group. The papers were as follows:

Some Problems in Electric Furnace Operation, by F. V. Andreae, in whose absence the paper was abstracted by Mr. R. D. Evans.

Improvements in Ferro-Alloy Electric Furnaces of High Power Input, by B. D. Saklatwalla and A. N. Anderson—abstract by Mr. Saklatwalla.

Heating of a Cotton Weave Shed by Electricity, by C. T. Guildford.

Development of the Large Electric Melting Furnace, by Frank Hodson, in whose absence the paper was presented by John Seede.

The discussion which followed was by John Seede, W. E. Moore, W. S. Scott, E. T. Moore, F. W. Brooks, E. B. Dawson, with closure by Mr. Saklatwalla.

Wednesday Afternoon

President Jewett called the meeting to order and announced that the afternoon session would include a program largely on relays. He requested Mr. N. W. Storer to preside at this session. Mr. Storer took the chair, stating that the subject of the afternoon was one of the most important in the electrical field today. "The relay is the little article that comes as near replacing the human brain as is possible. The relay is much more active than the average human being. It is always on the job, is always ready for business and is usually very reliable." The Chairman then called for the presentation of the following papers in the order given:

Relay System of Duquesne Light Co., by H. P. Sleeper.

Ground Reactor Relay Scheme, by P. Ackerman.

The Distance Relay for Automatically Sectionalizing Electrical Networks, by L. N. Crichton.

Lighting and Control Equipment for the Eastman Theater, by F. A. Mott and L. A. Jones.

These papers were abstracted by the authors, with the exception of the last paper—the authors not being present, was abstracted by Mr. G. H. Stickney. The discussion which followed was participated in by R. S. Conwell, P. Ackerman, W. V. Lovell, E. A. Hester, H. A. P. Langstaff, C. MacMoss, O. C. Traver, L. P. Ferris, E. P. Peck, F. M. Billhimer, with closures by H. P. Sleeper, P. Ackerman, L. N. Crichton and F. C. Taylor, for Messrs. Mott and Jones.

Wednesday Evening Banquet

The large ball room of the William Penn Hotel, where the banquet was held Wednesday evening, was barely large enough to accommodate about 700 members and guests in attendance. After the dinner Mr. Stone addressed the gathering, stating that it was very seldom that Pittsburgh had the honor and privilege of entertaining so large and so representative a gathering of electrical men. The meeting was truly representative, as there were registered at the Convention some engineers as far away as Italy and Norway on the one side and Japan on the other side. Mr. Stone then presented the toastmaster of the evening,—President Jewett. The subject of the after-dinner speeches had been announced as "Superpower as a National Resource" and before introducing the speakers of the evening Dr. Jewett made a brief address, emphasizing the growing use of power and its constantly increasing rate of use. "At the present time our power is derived from two main sources only—fuels and waterpower. It is perfectly clear that sooner or later we are going to come to a diminution and possibly to an extinction of the fuels which we now know—oil and coal. We are using up our fuel resources faster than they are being produced, if produced at all, and at sometime we will be confronted with a necessity of depriving ourselves of things which we wish to do, merely because we haven't got the motive power to do them. Sooner or later we shall have to find some additional and entirely new source of motive power, if we are going to be able to follow the lines which have been opened out to us by our researches in the last couple of decades in science. For the moment the one promising lead is the development and the harnessing of our waterpowers to supplement and take the place of power derived from fuels." Following the toastmaster's remarks, addresses were given by Paul T. Brady, R. F. Schuchardt and M. H. Aylesworth on different phases of the superpower project. These addresses are published elsewhere in this issue of the JOURNAL. The toastmaster then introduced the last speaker of the evening, Mr. Jack Armour, who entertained the meeting with numerous humorous stories and sketches.

Thursday Morning, April 26

The final technical session was called to order Thursday morning by President Jewett, who after some preliminary remarks asked Professor Morrow to preside during the meeting. The four papers on the program for this morning were as follows:

Survey of Lightning Disturbances on a Distribution System, by M. MacLaren.

Experiences with Reactors, by N. L. Pollard.

Short-Circuit Forces on Reactor Supports, by R. E. Doherty.

A committee report by a subcommittee of the Standards Committee on—Proposed Insulator Tests and Specifications, which was presented by Mr. A. H. Marvin.

The discussion which followed was by E. C. Stone, P. S. Mack, Ivan Light, W. B. Kirke, J. F. Peters, H. O. Stephens and C. L. Fortescue.

Thursday Afternoon and Evening

On Thursday about noon practically all in attendance at the convention boarded a special train for a visit to the works of the Westinghouse Electric and Manufacturing Company. The party was first taken to the new high-tension laboratory of the Company in North Trafford, where facilities are installed for testing up to a pressure of a million or more volts. Several high-tension experiments were made for the benefit of the visitors, including arcover tests of strings of insulators both dry and under the spray representing a heavy rainfall. A spectacular feature was the maintenance of a high-voltage arc over a length of 25 ft. At the close of the demonstration the apparatus was thrown open to inspection by the public. From the high-tension laboratory the guests were taken back to the main works of the Company in East Pittsburgh, where they were segregated into groups, each under the direction of a guide. These groups were taken through various parts of the works and at various points on the trip were shown special demonstrations which had been prepared for the occasion. While more than two hours were consumed on this trip of inspection, the size of the works is such that only some of the most important and interesting departments could be covered. Between five and six o'clock the different parties assembled in a large hall where various Westinghouse products had been assembled for exhibition and at about six-thirty the party was ushered into the dining hall where dinner was served. During the dinner the guests were entertained by a series of musical and comedy sketches. The Local Committee and officers of the Westinghouse Company were subject to congratulations for the very smooth and efficient handling of approximately 1000 visitors who enjoyed the trip to the utmost.

On Friday morning a large proportion of the visitors to the convention made up various inspection parties to the Colfax Power Station, the Springdale Power Station, the Allegheny Plate Glass Works, the Aluminum Company of America, New Kensington Works, Insulator Factory at Derry, Pa., Vanadium Corporation, Bridgeville, Pa., and several other points of engineering interest, by all of which invitations had been kindly extended.

Prior to the closing of the last session President Jewett spoke in appreciation of the conduct of the convention, saying "There is an action which I think it would be appropriate for us to take this morning and I think I am safe in saying, not only from my own personal feelings but as a result of the many expressions that we have had from members of the Institute, that this convention in all of its aspects has been a most successful one, not only from the standpoint of the technical papers but in the arrangement also of the meeting and in the arrangements for our physical comfort, entertainment and general pleasure. It would seem to me that it would be an act of appreciation on our part before we disband to let the Meetings and Papers Committee and the Local Committee which had the arrangements in charge know how much we have enjoyed every phase of this meeting. I should be glad to entertain some appropriate resolution which would convey the idea of our thanks." On motion by Mr. L. D. Bliss, the following resolution was passed:

RESOLVED That we hereby go on record as expressing our hearty appreciation to the Meetings and Papers Committee for the most excellent program which we have enjoyed and particularly to the Local Committee for the way in which it has taken care of our physical comfort, for the delightful banquet which we enjoyed last night and for the many ways in which it has made our visit here so delightful.

Annual Convention at Swampscott

INTERESTING TECHNICAL PROGRAM AND EXTENSIVE ENTERTAINMENT FEATURES WILL BE COMBINED TO REWARD PARTICIPANTS IN SUMMER GATHERING OF A. I. E. E.

As the week of June 25-29 rapidly approaches, final plans for the summer convention at Swampscott, Mass. are practically complete, and as this issue of the JOURNAL reaches the reader, a harmonious and enticing professional and entertainment program is taking its "permanent set." The cooperation of all the leading electrical engineering, manufacturing and utility organizations of eastern New England is responsible for a prospective welcome to delegates and guests that will vie with Western cordiality and Southern hospitality in the endeavor to make those attending feel at home among the brethren of the Northeast. The details of this program are published below. Just how keenly the individual members of the Institute who reside in New England are anticipating this visit of their fellow-members and guests would be difficult to put in a few lines of cold type; but as the members of the convention committee have been at work on the plans for the meeting at Swampscott, they have been impressed with the unanimous feeling of joyous expectation with which the local officials and the rank and file of the A. I. E. E. membership are looking toward this memorable week. It is believed that a delightful convention is close upon us.

To single out any particular items of the program for emphasis exposes one to some risk. On the technical side a broad range of topics has been determined upon for presentation and discussion at the sessions. The interests of electrical engineering today are so diversified and progress in different lines is so rapid notwithstanding more than forty years of intensive development in the fields of design, manufacturing and operation that it is going to be hard to find time enough for the work to be done upon the topics to be brought before those attending. Every great convention of the Institute reflects the latest thought of the professional engineer upon the highly specialized problems with which he is confronted, but this Swampscott meeting has an unusually appetizing mental menu. More than ordinary curiosity is being developed around the continent as to the line of attack which is being followed to insure successful operation of the 1000-1200 pound boiler and turbine equipment selected for the new Weymouth station of the Boston Edison company. The problems of design involved in a three-fold upward leap in steam pressures are interesting to electrical as well as to mechanical engineers, and undoubtedly there will be a discussion of great technical interest at the half session assigned for the consideration of the leading features of this super-station. While nothing has been put on paper for this convention regarding the prospects for commercially successful mercury boiler and turbine development at Hartford, the bearing of each of these two striking developments in the prime mover field upon the future cost of electrical energy production from fuel in the large

LONGFELLOW HOUSE, CAMBRIDGE, MASS.

Headquarters of Washington in the Revolutionary War and the home of the poet Longfellow. One of the finest Colonial type mansions in New England. Built in 1759.

central station is of such immense economic importance that if the specialists responsible for these parallel developments arrive at a point of synchronous revelation of their methods, problems and prospective solutions thereof, the regular meeting or at least the piazza conference which is so important a part of a successful convention will be enriched beyond easy measurement.

The "tie-in" between the problems of the physicist and of the practising engineer in electrical fields is illustrated in more than

OLD NORTH BRIDGE, CONCORD, MASS.

Scene of the battle between the Minute Men and the British regulars. April 19, 1775, marking the approximate limit of the enemy advance before the retreat to Lexington and Cambridge.

one paper on the Swampscott list, and the attention to be given to the important questions of cable design and functioning in service, to the cooling of electrical machinery, to certain phases of lamp quality and manufacture, to new methods of lightning protection, to proximity effect in wires and thin tubes—these features of the program promise interest and profit to the delegate whose concerns lie within the borders of this field, to say nothing of the new view which they will give the man who specializes elsewhere of the one-ness of pure and applied science.

Transmission lines occupy another vitally important place on the program and finally, radio engineering will play a part in the Swampscott gathering worthy of its deeper technical significance to the specialists who will assemble to interchange the latest ideas in this remarkable branch of electricity.

TECHNICAL PROGRAM

MONDAY, JUNE 25

Meeting of the A. I. E. E. Sections' Delegates

TUESDAY MORNING, JUNE 26

10:00 A. M.

FIRST SESSION

Address of Welcome by Governor Cox of Massachusetts.

Address by President Jewett.

Technical Papers

Cable Charge and Discharge, by C. P. Steinmetz, Chief Consulting Engineer, General Electric Co.

Dielectric Strength Ratio between Alternating and Direct Voltages, by J. L. R. Hayden and W. N. Eddy, both of General Electric Company.

Cable Geometry and the Calculations of Current Carrying Capacity, by D. M. Simons, Standard Underground Cable Company.

WEDNESDAY MORNING, JUNE 27

(Two meetings in parallel)

SECOND TECHNICAL SESSION—10:00 A. M.

Some Engineering Features of the Weymouth Station, by I. E. Moultrop and Joseph Pope.

Cooling of Electric Machines, by G. E. Luke, Westinghouse Elec. & Mfg. Co.

Free and Forced Convection of Heat in Gases and Liquids, by C. W. Rice, General Electric Co.

THIRD TECHNICAL SESSION—10:00 A. M.

Electrical Plant of Transoceanic Radio Telegraphy, by E. F. W. Alexanderson, A. E. Reoch and C. H. Taylor, all of Radio Corporation of America.

Transatlantic Radio Telephony, by H. D. Arnold, Western Electric Co., and L. Espenschied, American Tel. & Tel. Co.

Frequency Measurements in Electrical Communication, by J. W. Horton, N. H. Ricker and W. A. Marrison, all of Western Electric Co.

Telephone Equipment for Long Cable Circuits, by C. S. Demarest, American Tel. & Tel. Co.

Electrical Loud Speakers, by A. Nyman, Westinghouse Elec. & Mfg. Co.

WEDNESDAY EVENING

8:00 P. M.

Brief Review of progress during the year, by Chairman of several Technical Committees.

These reviews are to be followed by new colored movies commencing at 9:00 p. m.

THURSDAY MORNING, JUNE 28

10:00 A. M.

FOURTH TECHNICAL SESSION

Transmission Line Transients, by V. Bush, Associate Professor Elec. Eng., M. I. T.

Artificial Transmission Lines with Distributed Constants, by F. S. Dellenbaugh, Asst. Professor Elec. Eng., M. I. T.

General Consideration of the T and Pi Type Artificial Electric Lines in Connection with a Proposed Compensated Pi Line, by H. Nukiyama and K. Okabe, both of Tohoku Imperial University, Japan.

A Miniature A-C. Transmission System for the Practical Solution of Network and Transmission System Problems, by O. R. Schurig, General Electric Co.

Simplified Method of Analyzing Short-Circuit Problems, by R. E. Doherty, General Electric Co.

Proximity Effect in Wires and Thin Tubes, by H. B. Dwight, Canadian Westinghouse Co., Ltd.

Floating Neutral, by L. A. Doggett, Professor Elec. Eng., U. S. Naval Academy.

FRIDAY MORNING, JUNE 29

(Two sessions in parallel)

FIFTH TECHNICAL SESSION—10:00 A. M.

Quality of Incandescent Lamps, by J. W. Howell and Henry Schroeder, both of Lamp Works, General Electric Co.

The Art of Sealing Base Metal Through Glass, by W. G. Houskeeper, Western Electric Co.

The Standardization of Electrical Measuring Instruments, by H. B. Brooks, Bureau of Standards.

Pellet Type of Oxide Film Lightning Arrester, by N. A. Lougee, Stone & Webster.

A Continuous-Current Generator for High Voltages, by S. R. Bergman, General Electric Co.

Desirable Duplication and Safeguard in the Electrical Equipment of a Generating Station, by W. F. Sims, Commonwealth Edison Co.

SIXTH TECHNICAL SESSION—10:00 A. M.

The Axially-Controlled Magnetron, by A. W. Hull, General Electric Co.

Gaseous Ionization in Built-Up Insulation, by J. B. Whitehead, Dean, School of Eng., Johns Hopkins University.

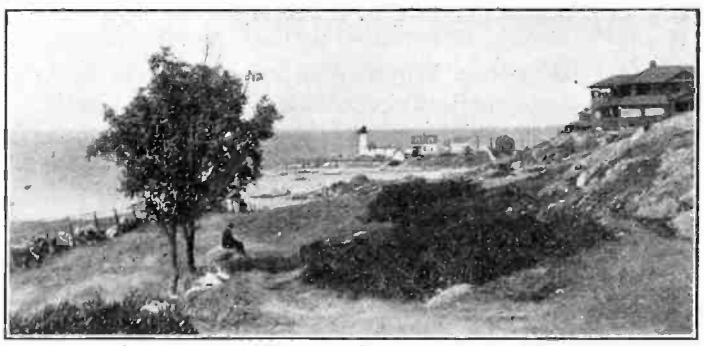
Effect of Transient Voltages on Dielectrics, by F. W. Peek, Jr., General Electric Co.

Two Photographic Methods of Studying High-Voltage Discharges, by K. B. McEachron, General Electric Co.

Advance copies of the papers are being prepared and on request to headquarters will be sent to members desiring to discuss them as soon as available.

Opportunities for Productive Recreation

To the delegate who visits New England for the first time, the prospect that time will hang heavy upon his hands is exceedingly dim. Open house will be the policy of the New England electrical world; and the great and the small industries of that



ANNISQUAM LIGHT, GLOUCESTER, MASS.
Typical North Shore coastal view.

section will not be far behind in their hospitalities to interested visitors. A variety of land and water trips beckons the delegate to combine recreation and physical refreshment with the technical activities which are the major appeal of the convention to the engineer, and the arrangements made for outdoor and indoor sports for both men and women have been completed under the personal eyes of some of the best known devotees of these diversions in the New England electrical circle.

Provision has been made for trips to many historical spots in eastern Massachusetts within reach of the convention, for drives along the beautiful North Shore and parkways of the metropolitan district and for inspections of universities, museums, electrical and other factories, government buildings, utility plants and substations. It is expected to include some attractive musical and lecture features besides a demonstration of the transmission of a Boston Symphony "Pop Concert" by radio and the public address system. Those who hear Captain Belknap's illustrated lecture on the North Sea Mine Barrage, Professor Karapetoff's piano recital and other "inside doings" will find that they have real treats in store; and if the program can be trusted, the whole week will be a well-balanced and worth-while combination of work and play, stimulating intellectually, bodily and socially to those who attend.

PULPIT ROCK, NAHANT, MASS.
Tip of noted promontory on Massachusetts North Shore.

Entertainment

MONDAY, JUNE 25

MORNING

Registration
10:00-12:30 a. m.—Meeting of Section Delegates.

AFTERNOON

Registration
2:00-4:00 p. m.—Meeting of Section Delegates.
2:00 p. m.—Inspection Trip to River Works of the G. E. Co., Lynn.
2:00 p. m.—Inspection Trip to West Lynn Works of G. E. Co.
2:30 p. m.—Automobile Trip to Salem and Marblehead.
2:30 or 3:00 p. m.—Sightseeing Trip to historical Boston every afternoon.
3:00 p. m.—Automobile bus trip to Boston, with trip to top of Custom House Tower.
4:00-500 p. m.—Meeting of District Delegates.

EVENING

Registration
8:30 p. m.—Informal Reception.
9:00 p. m.—Dancing.
9:00 p. m.—Special meetings of section and district delegates.

TUESDAY, JUNE 26

MORNING

10:00 a. m.—Address of Welcome, by Governor Channing Cox.
10:10 a. m.—Address by President Frank B. Jewett. Technical Session (for details see "Technical Program").

AFTERNOON

1:00 p. m.—Golf tournament—Kicker's Handicap.
2:00-6:30 p. m.—Inspection Trip to L Street Station of Edison Co. via boat viewing also Navy Dry Dock (largest in country), and Army Base.
2:00 p. m.—Inspection Trip to River Works of the G. E. Co., Lynn.
2:00 p. m.—Inspection Trip to the West Lynn Works of the G. E. Co.
2:00 p. m.—Inspection Trip to Creighton's Shoe Factory at Lynn, Mass.
2:30 p. m.—Automobile Drive along North Shore.
2:30 p. m.—Tennis tournament—Preliminaries.
3:00 p. m.—Automobile Trip to Boston with trip up Custom House Tower.
5:00 p. m.—Afternoon Tea.

EVENING

8:00 p. m.—Music.
8:30 p. m.—President's Reception.
9:00 p. m.—Dancing.
9:00 p. m.—Special Illumination.

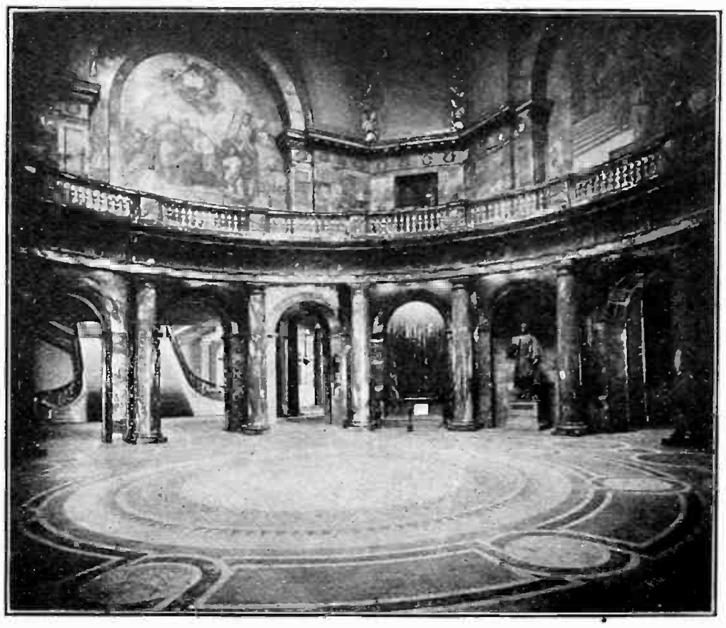
WEDNESDAY, JUNE 27

MORNING

9:00 a. m.—Social Hour.
10:00 a. m.—Technical Session (for details see "Technical Program.")

AFTERNOON

1:00 p. m.—4-Ball Golf Tournament.
2:00 p. m.—Inspection Trip to G. E. Co. Works at Lynn.
2:00 p. m.—Inspection Trip to Naumkeg Mills at Salem.
2:00 p. m.—Inspection Trip to Mass. Ave., Service Building of Edison Co. and Beacon Street Substation.
2:00 p. m.—Inspection Trip to Mass. Inst. Tech.
2:00 p. m.—Inspection Trip to Simplex Wire & Cable Co.
2:00 p. m.—Inspection Trip Harvard University and its Museum.
2:30 p. m.—Tennis Tournament Preliminaries.
3:00 p. m.—Bridge Tournament for Ladies.
5:00 p. m.—Buffet Tea.
5:30 p. m.—Lecture and Slides by Professor C. E. Magnusson.



HALL OF FLAGS, STATE HOUSE
Here stand the Battle flags of Massachusetts regiments returned from war, torn with projectiles and stained with blood.

EVENING

8:00 p. m.—Orchestra.
8:30 p. m.—Symphony "Pops" Concert on Public Address System.
9:00 p. m.—Special Illumination.
9:00 p. m.—Colored Motion Pictures (Prizma Co.)
10:00 p. m.—Dancing (Special).

THURSDAY, JUNE 28

MORNING

9:00 a. m.—Soc al Hour.
10:00 a. m.—Technical Session (for details see "Technical Program").
10:30 a. m.—All day drive to Boston, Lexington and Concord. Lunch at Country Club. Ladies Free.

AFTERNOON

1:00 p. m.—Putting Contest for Ladies. Qualifying Round.
1:00 p. m.—Golf Tournament Handicap Medal Play for Mershon Cup.
1:30 p. m.—Inspection Trip to Watertown Arsenal.
1:45 p. m.—Meeting of Board of Directors.
2:00 p. m.—Inspection Trip to G. E. Works at Lynn.
2:00 p. m.—Inspection Trip to Harvard and to Agassi Museum.
2:30 p. m.—Automobile Trip to Boston, with trip to top of Custom House Tower.
2:30 p. m.—Tennis Tournament Semi-finals and Finals.
5:00 p. m.—Afternoon Tea.
5:30 p. m.—Musicale by Professor Vladimir Karapetoff.

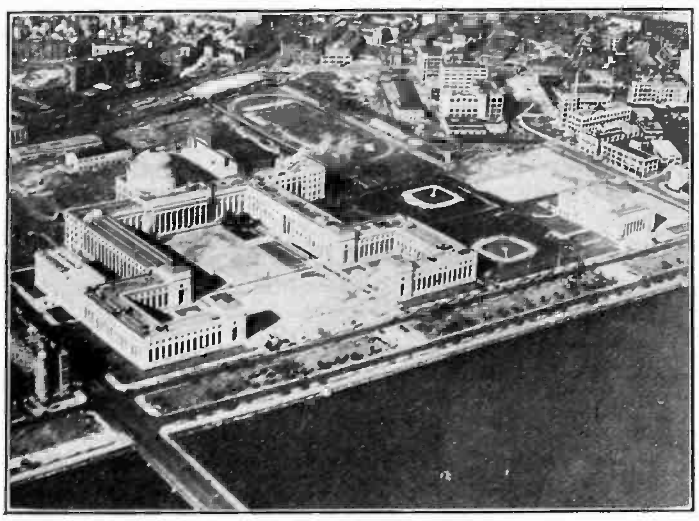
EVENING

8:15 p. m.—Lecture on the "North Sea Barrage" by Capt. R. R. Belknap, U. S. N.
9:30 p. m.—Dancing.
9:30 p. m.—Symphony "Pops" Concert on Public Address System.

FRIDAY, JUNE 29

MORNING

10:00 a. m.—Technical Session (for details see "Technical Program").
11:00 a. m.—Putting Contest for Ladies—Finals.



AIRPLANE VIEW, MASS. INST. TECH.
The most famous engineering university in America.

AFTERNOON

1:00 p. m.—Inspection Trip to Arlington Mills at Lawrence.
1:00 p. m.—4-Ball Golf Tournament.
2:00 p. m.—Inspection Trip to River Works of the General Electric Company, Lynn.
2:00 p. m.—Inspection Trip to M. I. Tech. Exhibit of Industrial Lighting (Rogers Bldg. on Boylston Street).
2:30 p. m.—Inspection Trip to West Lynn Works of the General Electric Company.
3:30 p. m.—Baseball Game.
5:00 p. m.—Afternoon Tea.

SATURDAY, JUNE 30

Arrangement for special trips and inspections will be made upon request. (Top Custom House, Watertown Arsenal, Public Library, State House, Old State House, Educational Specialties, Automatic Telephone Exchange, L-Street Station, First National Bank.)

Hotel Accomodations and Rates

NEW OCEAN HOUSE, SWAMPSCOTT, MASS.

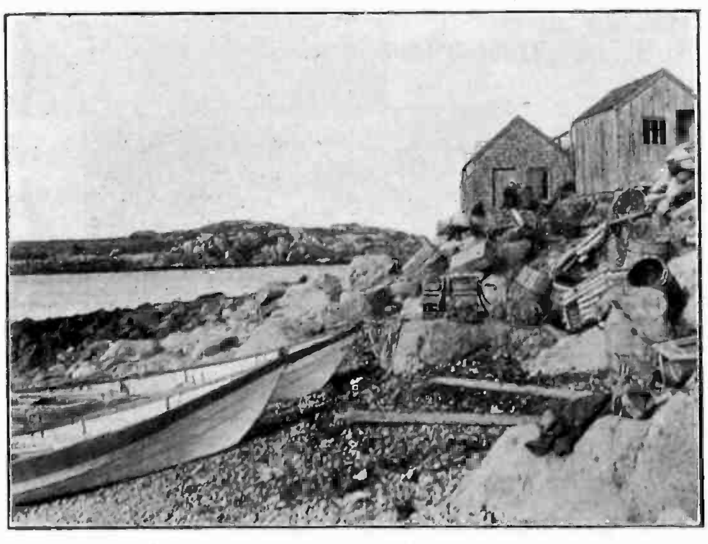
The Headquarters Hotel for the 1923 A. I. E. E. Summer Convention. The rates, American plan, are:

Double room with twin beds and private bath. $8.00 per day person.—Double room with twin beds and running water. $7.00 per day person.—Extra large double room and bath with 3 single beds. $7.00 per day per person.—Suite of two double rooms with bath between for four persons. $7.50 per day per person.—Two extra sized double rooms, reception hall and private bath for party of five. $7.00 per day per person.—

WASHINGTON ELM, CAMBRIDGE
Under this elm Washington took command of the American Army at the outbreak of the Revolutionary War.

Single room and bath. $9.00 or $10.00 per day.—Single room with running water. $8.00 per day.

The New Ocean House will be the center of all the activities of the summer convention. Reservations should be made direct to the New Ocean House, Swampscott, Mass. Most of the rooms are double rooms with bath and it is suggested that, as

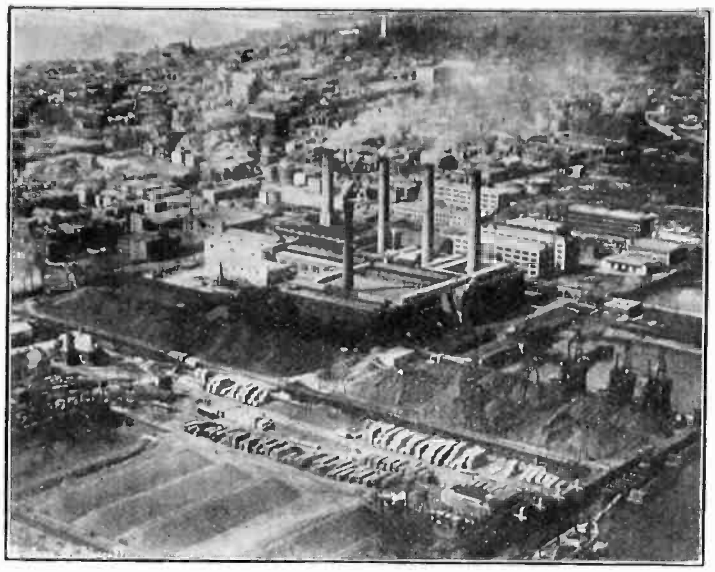


TYPICAL NORTH COAST VIEW

far as possible, members should request reservations in parties of two, since some of the single reservations will have to be sent to the Hotel Preston. Some of the most desirable rooms situated on the ocean side are for three, four or five persons so that members who make up a congenial party and apply for such a suite, will be assured of desirable rooms. Members who plan to come alone and who signify on their request for reservations that they will share a double room with another member, will in general, get a more desirable room than if a single room were engaged.

There is a garage in connection with the hotel. The storage charge is $1.00 per day.

Other available hotels in Swampscott and vicinity are Hotel Preston, Beach Bluff, Mass; Bellevue Hotel, Beach Bluff, Mass.; Willey House, 80 Humphrey St., Swampscott, Mass.; Cliff House, 175 Humphrey St., Swampscott, Mass.



SUBSTATION. BOSTON EDISON COMPANY
Airplane View

Transportation

The following information has been drawn up as a guide to the membership in planning a trip to Swampscott. From distant cities only the principal trains are given and many others are available. Regular one-way rates and round trip summer tourist rates will be in force at the time of the meeting. In every case members are advised to consult their local ticket agents relative to trains, fares and most desirable routes.

On arriving in Boston at South Station (via N. Y., N. H. & H. or B. & A. R. R.'s) proceed to Lynn from North Station (B. & M. R. R.). Transfer from South Station to North Station

NEW OCEAN HOTEL

by Taxi (fare approximately 50c.) or by Elevated trains. The Elevated stations are at the entrances of the two terminals. Running time, Boston to Lynn, about 30 minutes. The time (Daylight Saving) of departure of trains for Lynn from North Station (B. & M. R. R.) is as follows:—LEAVE BOSTON, A. M.—8:17; 9:01; 10:00; 10:45; 11:25. P. M.—12:00; 12:40; 1:40; 2:15; 3:15; 3:45; 4:27; 5:17; 5:22; 5:30; 5:53; 6:40; 7:20; 8:10; 9:10; 9:24; 10:25; 11:25; 11:30; 11:45.

Leave train at Lynn and go to Waiting Room on ground floor where busses to Ocean House will be found. Fare from Lynn to Ocean House 50c.

Tickets

Delegates arriving at Boston via N. Y., N. H. & H. or B. & A. R. R. should purchase tickets to Boston; those arriving at North Station via B. & M. may purchase through tickets to Lynn.

Baggage

Delegates arriving in Boston via N. Y., N. H. & H. R. R. check baggage to Boston and at Boston recheck to Lynn via Transfer Co. Those arriving in Boston via B. & M. R. R. should check baggage direct to Lynn. Starter for Ocean House busses will arrange for transfer of baggage from Lynn Station to Ocean House upon receipt of notice from you.

Annual Meeting

ELECTION OF OFFICERS

The Annual Business Meeting of the A. I. E. E. was held in the Engineering Societies Building, New York, Friday, May 18, 1923, President Frank B. Jewett presiding.

The annual report of the Board of Directors was presented. Pamphlet copies of this report were distributed at the meeting, and are available to any member upon application to the Secretary of the Institute.

The report of the Committee of Tellers on the election of officers was presented (printed elsewhere in this issue); and in accordance therewith President Jewett declared the election of the following officers whose terms will begin August 1, 1923:

PRESIDENT:	Harris J. Ryan, Stanford University, Calif.
VICE-PRESIDENTS:	
District No. 2	William F. James, Philadelphia
District No. 4	H. E. Bussey, Atlanta
District No. 6	Herbert S. Sands, Denver
Distric No. 8	J. E. Macdonald, Los Angeles
District No. 10	S. E. M. Henderson, Toronto
MANAGERS:	
	H. P. Charlesworth, New York
	William M. McConahey, Pittsburgh
	W. K. Vanderpoel, Newark, N. J.
TREASURER:	George A. Hamilton, Elizabeth, N. J. (Reelected)

The above, together with the following hold-over officers, will constitute the Board of Directors for the next administrative year, beginning August 1:—E. B. Craft, New York; H. W. Eales, St. Louis; G. Faccioli, Pittsfield, Mass.; H. M. Hobart, Schenectady, N. Y.; Frank B. Jewett, New York; G. L. Knight, Brooklyn; James F. Lincoln, Cleveland; Ernest Lunn, Chicago; William McClellan, New York; A. G. Pierce, Pittsburgh; H. T. Plumb, Salt Lake City, Harlan A. Pratt, Hoboken, N. J.; R. F. Schuchardt, Chicago; W. I. Slichter, New York; Harold B. Smith, Worcester, Mass.; R. B. Williamson, Milwaukee.

The wide geographical distribution of the Institute's Directors is indicated by the fact that twelve states and Canada are represented in the above list.

DINNER IN THE EVENING

On the evening of Friday, May 18, a group of Past Presidents, present officers, and a few others, including the President-elect, met at dinner at the University Club, upon the invitation of President Jewett.

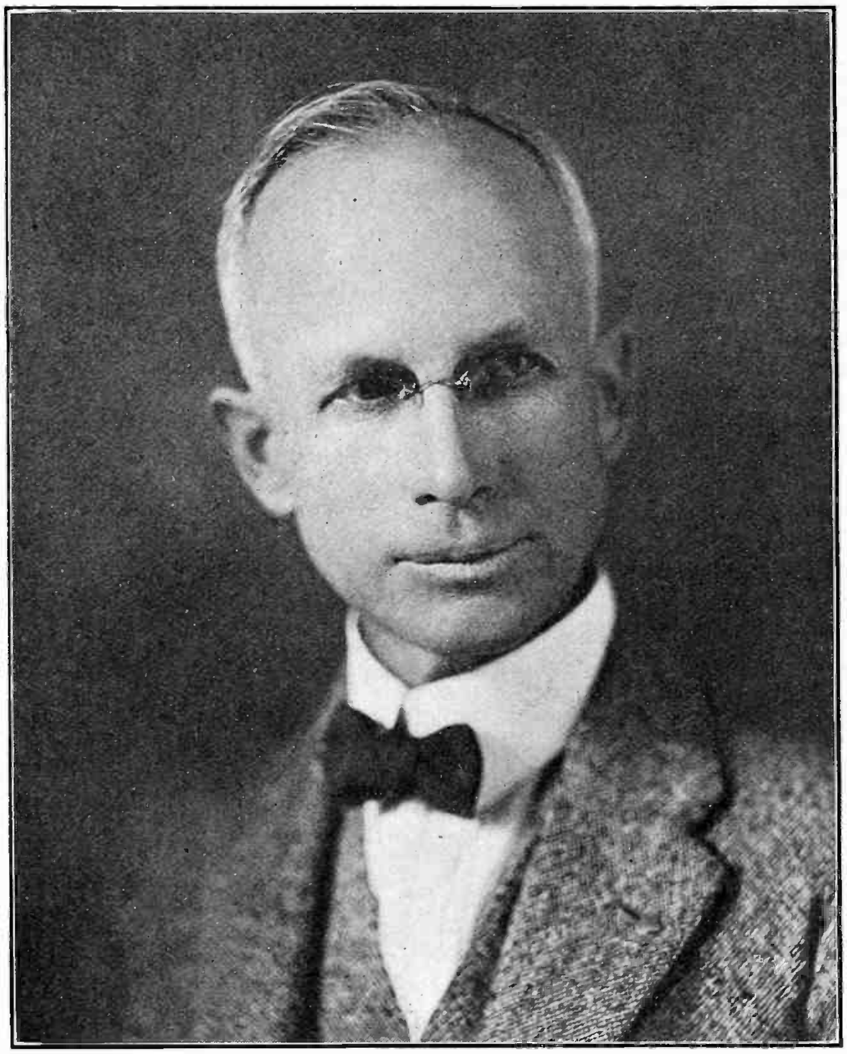
The occasion afforded an opportunity for the officers and Past Presidents to greet President-elect Ryan, and to discuss informally the affairs of the Institute. President Jewett presided and in his opening remarks presented briefly the facts in regard to the status of Institute activities, and brought up many questions regarding policies of the future. The interchange of ideas of the Past Presidents and others present was exceedingly profitable; and the discussion continued until late in the evening.

Harris J. Ryan

PRESIDENT-ELECT OF THE A. I. E. E.

Harris J. Ryan, Professor of Electrical Engineering, Leland Stanford Junior University, Palo Alto, California, has been elected President of the American Institute of Electrical Engineers for the year beginning August 1, 1923, as anounced in the report of the Committee of Tellers published elsewhere in this issue.

He was born in Powells Valley, Pa., January 8, 1866. He studied at Baltimore City College, 1879 to 1880; Lebannon Valley 1880 to 1882 and received the degree of M. E. in Electrical Engineering, from Cornell in 1887. In 1888 he became a member of the Western Engineering Company at Lincoln, Nebraska, and in 1889 Instructor in charge of the electrical machinery laboratory at Cornell. From 1890 to 1895 he served as Assistant Professor of electrical engineering in provisional charge of the department and from 1895 to 1905 was Professor in charge of the department of electrical engineering. In 1905 he accepted the same position at Stanford University which he holds today. In 1909 Prof. Ryan became consulting engineer for the Los Angeles Aqueduct Power Development. During the war as a member of the Pacific Coast Section of the Submarine Group of the National Research Council he carried on valuable work and in 1918 and 1919 was in charge for the Research Council Supersonics Laboratory at Pasadena. Professor Ryan has written and presented before the Institute numerous papers, among which might be mentioned treatises on conductivity of the atmosphere at high voltages, sphere gap discharge voltages and frequencies, ceramics in relation to durability of insulators, flashover of 220-kv. insulators, etc.



HARRIS J. RYAN
PRESIDENT-ELECT OF THE A. I. E. E.

In the Chicago Exposition of 1893 Prof. Ryan was a member of the Jury of Awards of the Dept. of Electricity and in 1904 was a delegate to the International Electrical Congress, St. Louis Exposition. He is a Fellow of the American Association for the Advancement of Science, member of the American Electrochemical Society, Institute of Radio Engineers, Society for Promotion of Engineering Education, American Physical Society and National Academy of Science. In 1887 he was elected as Associate of the A. I. E. E.; in 1895 was transferred to Member and in 1923 became a Fellow. He was a Manager of the Institute from 1893 to 1896; Vice-President, 1896 to 1898; Honorary Vice-President representing the Institute at the Panama-Pacific International Exposition, San Francisco, 1915; and has served on the Edison Medal Committee, Meetings and Papers, Electrophysics, Transmission and Distribution and Research Committees.

The Pacific Coast Convention

As previously announced, the date of the Pacific Coast Convention to be held in Del Monte, Cal., has been changed from September 25-28 to October 2-5, 1923. The local committee has practically completed the general details of the meeting, which will consist of three technical sessions at which papers dealing with various phases of long-distance power transmission will predominate. The presentation of the Edison Medal to Dr. R. A. Millikan, and a banquet are scheduled, and the remaining time during the meeting will be devoted to inspection trips to the many points of engineering and historic interests which abound in this vicinity.

Board of Directors' Report

FOR THE YEAR ENDING APRIL 30, 1923.

The Annual Report of the Board of Directors of the A. I. E. E. was presented at the Annual Business Meeting of the Institute held in New York, Friday afternoon, May 18, 1923.

This report consists of a brief summary of the principal activities of the Institute during the year, including abstracts of various reports submitted by officers and committees, covering their respective branches of work. The more important matters referred to in the report have been, or will be, covered in much more detailed form in the JOURNAL, and therefore the report will not be published in full herein, but any member of the Institute may obtain a pamphlet copy upon application to the Secretary of the Institute.

The growth in Institute membership during the year is indicated in the following tabulation:

	Honorary Member	Fellow	Member	Associate	Total
Membership, April 30, 1922	6	558	2,097	11,602	14,263
Additions:					
Transferred		25	110		
New Members Qualified		9	125	1,850	
Reinstated			11	84	
Deductions:					
Died		5	10	48	
Resigned		2	15	206	
Transferred			20	115	
Dropped		7	34	717	
Membership, April 30, 1923	6	578	2,264	12,450	15,298
Net increase in Membership during the year					1035

The activity of the Sections and Branches during the year and the growth in the number of these organizations, also in the number of meetings held by them and in the aggregate attendance, are shown in the following statement:

	For Fiscal Year Ending						
	May 1 1917	May 1 1918	May 1 1919	May 1 1920	May 1 1921	May 1 1922	May 1 1923
Sections							
Number of Sections	32	34	34	36	42	45	46
Number of Section meetings held	265	245	217	262	303	373	344
Total Attendance	31,299	34,614	25,837	30,741	37,823	54,378	46,672
Branches							
Number of Branches	59	59	61	62	65	67	68
Number of Branch meetings held	368	268	156	360	443	439	503
Attendance	16,107	10,683	6,441	16,827	21,629	25,358	26,893

The Finance Committee's Report, together with the general balance sheet and detailed financial statements of the Certified Public Accountants who audited the Institute books, are included in the report.

Report of Committee of Tellers on Election of Officers

To the President,
American Institute of Electrical Engineers.

Dear Sir:

This committee has carefully canvassed the ballots cast for officers for the year 1923-1924. The result is as follows:

Total number of ballot envelopes received		4175
Rejected on account of bearing no identifying name on outer envelope, according to Art. VI, Sec. 34, of the Constitution	72	
Rejected on account of voter being in arrears for dues on May 1, 1923, as provided in the Constitution and By-laws	104	
Rejected on account of ballot not being enclosed in inner envelope, or being improperly marked, or on account of inner envelope bearing an identifying name, according to Art. VI, Sec. 34, of the Constitution	200	
Rejected on account of having reached the Secretary's office after May 1, according to Art. VI, Sec. 34, of the Constitution	23	399
Leaving as valid ballots		3776

These 3776 valid ballots were counted, and the result is shown as follows:

For President

Harris J. Ryan	3744
Blank	32

For Vice-Presidents

District

No. 2. *Middle Eastern*	
William F. James	3713
Blank	63
No. 4. *Southern*	
H. E. Bussey	3693
Blank	83
No. 6. *North Central*	
H. S. Sands	3662
*F. W. Springer	45
Blank	69
No. 8. *Pacific*	
J. E. MacDonald	3650
*Robert Sibley	55
Blank	71
No. 10. *Canada*	
S. E. M. Henderson	3687
Blank	89

For Managers

H. P. Charlesworth	3712
William M. McConahey	3708
W. K. Vanderpoel	3708
Blank	200

For Treasurer

George A. Hamilton	3727
Blank	49

Respectfully submitted,

H. T. Kohlhaas, *Chairman*
E. W. Loomis
Lawrence E. Frost
E. R. DeCastillo
J. W. Nostrand
Committee of Tellers.

May 8, 1923.

*Withdrew prior to distribution of ballots.

Memorials to Past President Wheeler

As announced in the May issue of the Journal, Past President Schuyler Skaats Wheeler died in New York, April 20.

At the Spring Convention of the Institute, held in Pittsburgh, April 24-26, the following resolution was adopted:

Whereas, death has suddenly removed Dr. Schuyler Skaats Wheeler, a revered Past President of the American Institute of Electrical Engineers, be it

Resolved: That we, the members of the Institute in attendance at our Spring Convention in Pittsburgh, hereby record our personal grief and our deep regret at this great loss to the electrical engineering profession; and that we express our sincere sympathy to the members of Dr. Wheeler's family.

At the meeting of the Board of Directors of the Institute held in New York on May 18, the following minute was adopted:

In recognition of the grievous loss to the electrical engineering profession sustained on April 20, 1923, through the death of Schuyler Skaats Wheeler, the Board of Directors of the American Institute of Electrical Engineers decrees that the following minute be inscribed in the records:

Whereas, the hand of Death has removed from the ranks of his co-workers Schuyler Skaats Wheeler, electrical engineer, inventor, manufacturer, and Past President of this Institute, and

Whereas, he, through his invaluable work in the development and application of electrical engineering wherein a true engineering mind and a broad judgment enabled him to determine the salient principles of innumerable problems, through devotion to learning as evidenced by his presentation to the Institute of the Latimer Clark Library, through his public spirit and able efforts in the establishment of the Engineering Societies Building and as one of the original Trustees of the United Engineering Society, and through intense interest in the establishment of a code of principles of professional conduct, placed himself in the foremost rank in the field to which the work of the Institute is especially devoted, be it

Resolved: That as a tribute to his memory and as a testimonial of appreciation of indebtedness to him for his faithful services, the members of the Board of Directors hereby record a realization of this great loss, and hereby express their deep and heartfelt sympathy to the members of his family in their bereavement.

Licensing of Engineers

Early in 1920, as outlined in the August 1920 Journal, as law requiring "Professional engineers" to be licensed was passed by the New York State Legislature and an attempt was made to administer it, but it was so defective in certain essential details that it was amended in 1921. As amended, it became effective in May of that year, forming part of "the general business law, in relation to licensing of professional engineers and land surveyors, generally." The law made the licensing of "professional engineers" employed in engineering work in the State permissive up to May 5, 1923, and mandatory after that date. Details relative to the examining board, its first session, etc., were noted in the January 1922 JOURNAL.

A close study of the law brought out the fact that contrary to the general belief that it applied only to consulting engineers it may be interpreted to apply to everybody in the State doing any kind of engineering work to which the term "responsible" can be applied, and that any person not licensed on or before May 5, who publicly calls himself an engineer is liable upon trial and conviction to fine or to imprisonment or both.

To ascertain the actual situation with regard to licensing, as committee was authorized by the Directors of the Institute at their meeting of March 16, 1923, with power to act separately or jointly with representatives of other societies. The following committee was appointed by President Jewett: Francis Blossom, Chairman, Gano Dunn, H. W. Buck, L. E. Imlay and E. W. Rice, Jr. Other national societies took similar action and these committees sent out questionnaires to the membership concerned. Results in the case of the Institute showed that but about 16 per cent of the New York membership were licensed and 64 per cent were opposed to the law. Through the medium of the Ferris Bill, recently passed by the legislature and signed by the Governor, the Committee with the cooperation of the other societies sought and obtained the postponement of the application of the New York law until August 1, 1923.

All engineers who have not applied for a license and whose work it is believed is such as to require a professional engineer's license are urged to make application without delay. The Institute Committee has prepared the following statement of its understanding of this law:

An engineer who has (or offers from an office in the State to take) charge of engineering work for a client or as a salaried employe must be licensed if this work involves "the planning, designing, constructing, inspecting and supervising of engineering work, or appliances involved in public or private projects, or in making investigations for proposed engineering projects."

The technical head of the engineering department of any manufacturer of "appliances involved in public or private projects" and the engineer who "supervises" the operation of the engineering branch of a public utility must be licensed just as much as the engineer engaged in consulting practise. If the principal engineer has a deputy who has full responsible charge in the principal's absence, the deputy must also be licensed. An operating engineer of a power plant holding an operating engineer's license issued under other laws of the State does not have to be licensed under the professional engineer licensing law in order to continue his engagement as an operating engineer.

An engineer who neither resides nor has an office in New York State may, without taking out a New York license, offer to do engineering work in the State and actually do such work there for not more than thirty days in a calendar year if he is legally qualified as an engineer in his own State.

If a manufacturer sells a product which his men erect in the field by methods not involving engineering skill and knowledge, the erectors need not be licensed. But if the manufacturer furnishes in addition to his own products, plans for structures not made in his shops and calling for more than the ordinary skill of a skilled workman to execute, such plans must be made by a licensed engineer and the field work must be supervised by a licensed engineer.

Salesmen employed by manufacturers, who give advice to customers on "planning, constructing, inspecting and supervising of engineering work or appliances" other than those produced by the manufacturer, must be licensed as professional engineers.

Engineers employed in "service departments" or "trouble departments" of manufacturers of "appliances", who must give advice about other engineering matters than those "appliances" in order that the latter may function satisfactorily, must probably be licensed. It is often difficult to fix the place where skilled craftsmenship ends and professional engineering begins, in the work of these men.

Engineers who may be called into court to testify as engineers will doubtless find the possession of a license helpful in qualifying even though they are not compelled by law to be licensed.

For detailed information, license forms, etc., apply to Herbert J. Hamilton, Asst. in Charge Professional Examinations, State Education Bldg., Albany, N. Y.

Science Abstracts

Published monthly by the Institution of Electrical Engineers, London, in association with the Physical Society of London, "Science Abstracts" provides all electrical engineers actively engaged in the practise of their profession, with a certain and efficient means of keeping in touch with what is being done and what is being published in the engineering world, a reliable record of progress.

The Institution of Electrical Engineers has subsidized the publication of this magazine for many years to a total of about £15,000, but it is the belief of the Council of the I. E. E. and the Board of Directors of the A. I. E. E. that it should be possible to immediately place such an unquestionably valuable magazine upon its feet financially, if the attention of engineers particularly in this country was called more frequently to what an aid "Science Abstracts" would be to them in keeping abreast of the times. It deals with some 160 journals published throughout the world, giving an abstract of every article of value. It constitutes an invaluable work of reference. "Science Abstracts" is published in two sections, as follows: "A" — PHYSICS —deals with electricity, magnetism, light, heat, sound, astronomy, chemical physics; "B" — ELECTRICAL ENGINEERING — deals with electrical plant, power transmission, traction, lighting, telegraphy, telephony, wireless telegraphy, prime movers, engineering materials, electrochemistry. Through special arrangement, members of the A. I. E. E. may subscribe to "Science Abstracts" at the reduced rate of $5.00 for each section, and $10.00 for both. Rates to non-members are $7.50 for each section and $12.50 for both. Subscriptions should start with the January issue. The first volume was issued in 1898. Back numbers are available, and further information regarding these can be obtained upon application to A. I. E. E. headquarters.

American Engineers Meet in Honor of the 75th Anniversary of Societe des Ingenieurs Civils de France

In commemoration of the founding, 75 years ago, of the Société des Ingenieurs Civils de France, meetings were held in Paris, occupying three days and opened with an address by the President of France, and in New York. A cablegram expressing the felictations of the Institute was sent to the French Society by President Jewett who also appointed A. S. Garfield, A. I. E. E., Honorary Secretary for France, as a delegate to the exercises in Paris. The New York meeting was a joint meeting of the four national societies of Civil, Mechanical, Electrical and Mining Engineers and the American Section of the French society and was held on the evening of May 4. Harrington Emerson, President of the American Section of the Société des Ingenieurs Civils presided. The speakers of the evening were Gaston Liebert, director of the French Bureau of Information; Dr. C. O. Mailloux, president of the I. E. C.; William Barclay Parsons, Arthur S. Dwight and Henry Vigneron. As expressing the sentiment of the meeting, the following resolution was unanimously adopted:

RESOLVED: That the members of the American Section, Société des Ingenieurs Civils de France, American Society of Civil Engineers, American Institute of Mining and Metallurgical Engineers, American Society of Mechanical Engineers, and American Institute of Electrical Engineers, here gathered, extend to their French colleagues their heartiest congratulations on the Seventy-fifth Anniversary of the founding of their great Société, expressing at the same time their appreciation of the debt of gratitude owed by American Engineers to France for her many contributions to the profession of engineering.

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, May 18, 1923, at 2:30 p.m.

There were present: President Frank B. Jewett, New York; Past president William McClellan, New York; Vice-Presidents G. Faccioli, Pittsfield, Mass., R. F. Schuchardt, Chicago, W. I. Slichter, New York, N. W. Storer, Pittsburgh; Managers E. B. Craft, L. F. Morehouse, New York, H. M. Hobart, Schenectady, G. L. Knight, Brooklyn, N. Y., Ernest Lunn, Chicago, A. G. Pierce, Pittsburgh, Harlan A. Pratt, Hoboken, N. J., Harold B. Smith, Worcester, Mass., R. B. Williamson, Milwaukee; Treasurer George A. Hamilton, Elizabeth, N. J.; Secretary F. L. Hutchinson, New York.

A memorial resolution in honor of the late Dr. Schuyler Skaats Wheeler, Past President of the Institute, was adopted, and is printed elsewhere in this issue.

Reports were presented of meetings of the Board of Examiners held April 9 and May 14, 1923. Upon the recommendation of the Board of Examiners the following action was taken upon pending applications: 136 Students were ordered enrolled; 222 applicants were elected to the grade of Associate; 11 applicants were elected to the grade of Member; 5 applicants were transferred to the grade of Member; 1 applicant was transferred to the grade of Fellow.

Plans were reported in progress for the Annual Convention, Swampscott, Mass., June 25-29, and the Pacific Coast Convention, Del Monte, Calif., October 2-5. An application was presented from the St. Louis Section for the holding of an Institute convention in St. Louis in the fall of 1924, which was referred to the Meetings and Papers Committee for recommendation.

Resolutions were adopted expressing appreciation of the excellent manner in which the Spring Convention, held in Pittsburgh, April 24-26, was managed by the Convention Committee, and of the many courtesies extended by the local members and organizations to the members and guests in attendance.

The Board accepted, with thanks, an offer from Past President Ralph D. Mershon to donate a suitable trophy for competition in the tennis singles at the Annual Conventions, similar to the Mershon Golf Cup which was donated several years ago.

Approval by the Finance Committee of monthly bills amounting to $20,686.53 was ratified.

The annual report of the Board of Directors for the fiscal year ending April 30, 1923, as prepared by the Secretary, was presented and accepted for presentation at the Annual Business Meeting of the Institute to be held later in the day. The annual report of the Treasurer, for the fiscal year ending April 30, 1923, which agreed with the annual report of the auditors included in the Board of Directors' report, was presented, accepted, and ordered filed. Annual reports of various standing committees (not including the technical committees), abstracts of which had been incorporated in the Directors' report, were presented, received, and ordered filed for reference, particularly by the chairman of the incoming committees of the next administration.

In accordance with Section 37 of the constitution, the appointment of a Secretary for the administrative year commencing August 1, 1923, was considered. Secretary F. L. Hutchinson was reappointed.

Upon petition, authorization was given to the establishment of a Student Branch of the Institute at the University of Tennessee, Knoxville, Tenn.

Mr. John Price Jackson was reappointed as a representative of the Institute upon the Commission of Washington Award, for the term of two years commencing June 1923.

A report was made to the effect that the special committee which had been appointed to confer with similar committees of the other societies on the licensing situation in New York State, with power to act, had been instrumental in obtaining by legislative action, the postponement of the date of enforcement of the New York State law requiring the licensing of professional engineers, from May 5 to August 1, 1923.

Approval was given to the admission of a Telephone Group, consisting of the U. S. Independent Association and the Bell Telephone Group, to representation in the American Engineering Standards Committee.

There was considerable discussion regarding the present organization of the technical activities of the Institute; and it was voted that the President be authorized to appoint a committee to review the organization of the committees in charge of technical activities, and to make recommendations regarding any revisions that seem desirable of the Institute's machinery for handling technical matters of all kinds.

Reference to other matters discussed may be found in this and future issues of the JOURNAL under suitable headings.

Farewell Dinner to Dr. Margerie, Exchange Professor from France

On Friday, May 18, a farewell dinner was given at the Harvard Club by the national societies of civil, mechanical, mining and electrical engineers to Dr. Emmanuel de Margerie, French exchange professor to the United States. Dr. Albert Ledoux, past president of the A. I. M. E., presided. A number of French officials were also the guests of the societies, including Dr. Imlay Benet, Consul General in New York. Prof. de Margerie, who as representative of the Ministry of Education has just finished a year of lecturing at Columbia, Cornell, Harvard, Johns Hopkins, Massachusetts Institute of Technology, Pennsylvania and Yale, is an international authority on geology. He has just been awarded one of the highest honors of the National Academy of Sciences of the United States, the Mary Clark Thompson gold medal for services to geology and paleontology. In his address, Prof. Margerie said, "to the engineers, after God and George Washington, the American people owes most of its present prosperity. . . . . Great possibilities are now in your hands, in directing a large part of public opinion towards that fundamental problem of democracy, the proper education of young men". Other speakers were M. Benet, M. Liebert and Dr. A. E. Kennelly of Harvard, former engineering exchange professor to France.

Second Edition of the E M F Electrical Year Book

The second edition of the E M F Electrical Year Book, has recently been issued by the Electrical Trade Publishing Company. The first edition, published last year, received appropriate comment in the JOURNAL. The new edition is greatly enlarged and contains comprehensive electrical data, covering the field of electricity from many different angles. Some of these are: Definitions of electrical terms, historical and statistical information about electrical applications and activities, biographical sketches of prominent scientists and engineers, information about electrical associations, schools, colleges, patents and exports. The book is arranged alphabetically, so that its use is convenient and simple.

Kansas University Engineering Exhibit

Electrical Exhibits at the Kansas University Engineering Exhibit, April 21st, received high honors. The department of Electrical Engineering, Professor George C. Shaad head of department, was awarded a cup for the best department exhibits, by the committee of judges composed of members of the engineering profession from Kansas City. Many ot the exhibits representing the various phases of electrical engineering were of a spectacular nature, notably the high-tension transformer exhibit.

The cup offered by the Kansas City Section A. I. E. E., was awarded to the Civil Engineers for the miniature Electric Railway representing one mile of track over varied country, built to scale and embodying the design of every type of railroad structure, from tunnels, bridges, culverts, cut and fills, as well as the electric transmission and contact system, all designed as for an actual railroad.

AMERICAN ENGINEERING COUNCIL

POWER DEVELOPMENT IN NEW YORK STATE TO CONTEMPLATE SUPERPOWER SURVEY

When the policy of the Governor of New York in regard to power development was made known in his message to the legislature Executive Secretary Wallace addressed to him a letter stating that many engineers were much interested in having secured for the public the economies and benefits which would follow the building up of a superpower system in the Boston-Washington area. He asked if that plan had been considered and was informed by the Governor, through the Water Power Commission of the State of New York, that they were not acquainted with the superpower survey and wished to be advised concerning the plan which it proposed.

It will be recalled that the Governor's recent message to the legislature declared in effect that the undeveloped water power on the Niagara and St. Lawrence should be developed by the state—that the base power available therefrom should be transmitted to the various municipalities over lines state-owned and controlled—that the electricity so generated be sold to the municipalities at approximately the cost of production and delivery—that the final distribution to the ultimate consumer be made through the agency of the municipality through existing companies or by the municipalities, subject to the approval of a state hydroelectric commission as to rates and service. This statement evidently did not contemplate the plan for the superpower development and Secretary Wallace took the opportunity to advise that the advantages to New York would be many were resort had to greater interconnection. He pointed out that so far as New York is concerned it would probably be a matter of importing power, since exports of current would be confined largely to off-peak loads which would make possible uniform operation of plants in New York.

Copies of the superpower report have been sent to the Water Power Commission.

At the same time attention of the members of the Superpower Advisory Board was directed to the fact that many engineers are interested in the question of superpower development. Having assisted materially in providing for the survey, engineers are now anxious to render such service as seems wise by stimulating effort to pave the way for the active consideration of the matter.

STORAGE OF COAL

The appointment of W. L. Abbott as Chairman of the committee which was organized to make an investigation of the storage of coal was noted in the May issue of the JOURNAL. Others who will serve on the committee are: P. F. Walker, dean of engineering, University of Kansas; S. W. Parr, professor of applied chemistry, University of Illinois; H. Foster Bain, Director of the U. S. Bureau of Mines, and L. E. Young, Union Light and Power Co., St. Louis.

The chairman of this committee has had large experience in the successful storage of coal. Dr. Stoek, up to the time of his death, was considered the most eminent authority on this subject and Mr. Abbott had collaborated with him in much of his pioneer work. Mr. Parr and Mr. Young had also worked extensively with Dr. Stoek in developing ways and means of effective storage of coal. Mr. Parr was highly recommended by the American Institute of Chemical Engineers and the American Chemical Society, because of his national reputation as a coal chemist. Mr. Young has had wide and responsible engineering experience, is a member of the American Institute of Mining and Metallurgical Engineers and in addition to his engineering acquirements he is accomplished in accounting and economics. Dean Walker is from the southwest and is especially familiar with the transportation and industrial conditions that will enter into this study. Dr. Bain as Director of the Bureau of Mines, is in most intimate touch with all that the Government has done with this subject. Four or five additional members of this committee are yet to be selected. Consideration is now being given to recommendations that have been made by several member organizations, so that it is probable that the additional members will be named in the near future.

A bibliography of the subject is already in course of preparation, as well as a compilation of data and records that have already been made by other organizations that will relate to this subject in various ways.

National Research Council

Under this heading are included news items of the National Research Council and its activities and summaries of progress made by the research committees of its Division of Enigineering during the current month.

National Research Council, as most of our members know, was organized during the war to coordinate the research facilities of the country in solving war problems. Its success led to its perpetuation on a peace-time basis.

The Division of Engineering, one of the thirteen divisions affiliated with the Council, has its headquarters in the Engineering Societies Building, and is cooperating with the Engineering Societies in the encouragement, initiation, organization and coordination of fundamental and engineering research. At the present time this Division has some 20 projects under way. The Council is filling a long needed place in this country in the promotion of research. In order that our members may become familiar with its activities, and particularly those of the Division of Engineering, it is planned to include in this publication a resumé of the progress made during the current month.

Problems undertaken for study are of broad fundamental character and are aimed at the increase of the bounds of human knowledge. They may also be of importance to a group of industries or public utilities or to some branch of the engineering profession.

Progress in complex work of this nature requires the combined efforts and knowledge of competent scientists and engineers. By its scheme of organization, the Council is especially fitted to bring together the scientists and technologists, able and willing to contribute the varieties of knowledge and experience requisite for the successful attack on any problem accepted for study.

USEFUL INFORMATION SERVICE

One of the most useful activities of the Research Information Service of the National Research Council in Washington is the compilation and issuance in convenient form of significant facts about scientific research and its industrial relations.

Often the facts assembled to meet the immediate needs of an individual engineer-investigator, firm or association, are of sufficiently wide-spread interest and general value to justify mimeographing, printing or publishing. Informational reports thus prepared by Information Service ordinarily are available either at cost or free.

Among the compilations which have been made available by Research Information Service or by other divisions or committees of the National Research Council, of special interest to engineers are:

Bulletin No. 3, List of "Periodical bibliographies and abstracts of the scientific and technological journals of the world;"

Bulletin No. 9, "Funds available in 1920 in the United States of America for the encouragement of scientific research;"

Bulletin No. 16, "Research laboratories in industrial establishments in the United States including consulting research laboratories;"

Bulletin No. 22, "Mechanical aids for the classification of American investigators, with illustrations in the field of psychology;"

Reprint No. 9, "Reading list on scientific and industrial research and the service of the chemist to the industry;"

Reprint No. 33, "Informational needs in science and technology;"

Reprint No. 35, "American research chemicals;"

Reprint No. 40, "The usefulness of analytical abstracts."

Several lists of scientific and technological bibliographies also have been issued. Among them are lists of published and unpublished bibliographies of corn and corn products, colloid chemistry, geology and geography, astronomy, mathematics and physics.

Research Committees of the Division of Engineering

A list of the committees of the Division is included below, followed by a resumé of the progress made during the current month. Further information may be obtained from the office of the Division, 29 West 39th Street, New York:

Advisory Board on Highway, A. N. Johnson, Chairman; Research (W. K. Hatt, Director); with committees on: Character and Use of Road Materials, H. S. Mattimore; Economic Theory of Highway Improvement, T. R. Agg; Tractive Resistance of Roads, C. J. Tilden; Structural Design of Roads, A. T. Goldbeck; Highway Traffic Analysis, G. E. Hamlin; Highway Finances, J. D McKay.

American Bureau of Welding, C. A. Adams, Director, W. Spraragen, Secretary, with committees on: Electric Arc Welding, H. M. Hobart; Gas Welding, S. W. Miller; Welding of Storage Tanks, J. C. Lincoln; Pressure Vessels, H. L. Whittemore; Welding Wire Specifications, C. A. McCune; Training of Welding Operators, J. C. Wright; Standard Tests for Welds, F. M. Farmer; Specifications for Steel to be Welded, W. J. Beck; Resistance Welding, H. Lemp; Thermit Welding, J. H. Deppeler; Welded Rail Joints, G. K. Burgess; Electrical Core Losses, A. E. Kennelly; Electrical Insulation, J. B. Whitehead; Deoxidizers, G. K. Burgess; Fatigue Phenomena of Metals, H. F. Moore; Hardness Testing of Metals, A. E. Bellis; Heat Treatment of Carbon Steel, F. B. Foley; Marine Piling Investigations, W. G. Atwood; Director, R. T. Betts; Molding Sands, R. A. Bull; Neumann Bands, C. E. Munroe; Physical Changes in Iron and Steel below the Thermal Critical Range, Zay Jeffries; Pulverizing, G. H. Clevenger; Uses of Tellurium and Selenium, V. Lenher; Heat Transmission (organizing committee) H. C. Dickinson.

Resume of the Month

The purpose of this section is to give a resumé of the progress made during the past month and to point out the objective and method of attack for each project.

Fatigue Phenomena of Metals

Object: To extend our knowledge of the nature of fatigue phenomena of metals and to determine general laws for the guidance of engineers and manufacturers in selecting materials, making designs, and choosing methods of manufacture and operation.

Present Activities: (1) Investigation of Fatigue of wrought ferrous metals under cycles of stress, repeated but not reversed. (2) Study of the effect of heat treatment on fatigue strength of steel. (3) Obtaining further evidence for the guidance of a definite endurance limit for wrought ferrous metals; new apparatus and methods being developed.

Progress: A second progress report has just been published as Bulletin No. 136 of the Engineering Experiment Station of the University of Illinois. $30,000 has been secured for continuing investigations in the field of non-ferrous metals.

Engineering Foundation made possible the investigation through an original grant of $30,000 and is acting as Treasurer for the funds received. University of Illinois, General Electric Company, Western Electric Company, Copper and Brass Research Association and Allis-Chalmers Manufacturing Company are cooperating.

Important conclusion as to the fatigue properties of wrought ferrous metals has already been secured.

American Bureau of Welding

The annual meeting of the American Bureau of Welding, which is the welding research committee of National Research Council and the American Welding Society, held its annual meeting on April 26. Considerable progress has been made by the eleven research committees now functioning under the Bureau.

The annual report of the Bureau, copies of which may be obtained from Secretary Wm. Spraragen, 29 W. 39th Street, New York, shows that fifteen reports have already been prepared and published. The Bureau is filling a long felt need for an unbiased authority in solving the many complex problems arising in the welding field.

Marine Piling Investigations

Object: To learn more of the marine boring animals now causing wide destruction to wharves and marine piles, and to devise methods for protection against these ravages; to study the cause of deterioration of cement concrete in and near seawater, and methods of prevention.

Present Activities: A comprehensive study is being made of the habits, breeding seasons and life of the worms; chemical investigations to note toxic effect of different poisons to be placed in water near the piles are being made. Effect of impregnation of poisonous salts and strips of metal on piles are also being investigated.

A comprehensive survey is being made of the literature dealing with deterioration of concrete in and near seawater, including foreign literature.

Progress: Complete progress report dealing with the investigations on wooden structures, which includes many illustrations and covers 60 pages, has been published by the American Railway Engineering Association as Bulletin No. 255.

Pressure Vessels

Object: To assist the Boiler Code Committee of the American Society of Mechanical Engineers in drawing up a satisfactory code governing the use of welding in the construction of unfired pressure vessels.

Method: Over 40 tanks have been tested to destruction at the

Bureau of Standards to obtain reliable information on strength of welded joints and proper safety tests.

Progress: The entire program involving an expenditure of over $15,000 has been completed and a report is being compiled.

ELECTRICAL CORE LOSSES

Object: To reduce the calculation of electrical core losses as well as of eddy current losses in machines and conductors to a more rational and scientifically-exact basis.

Method: Four phases of the work are being conducted by four universities: Harvard, Washington (St. Louis), Missouri, and Massachusetts Institute of Technology. Several manufacturers are also cooperating.

Progress: A bibliography relating to literature on the subject of core losses is being prepared, and two papers giving results of the work of the Committee to date are nearing completion.

PHYSICAL CHANGES IN IRON AND STEEL BELOW THE THERMAL CRITICAL RANGE

Object: To correlate experimental results of deformation of iron and steel in the blue heat range at ordinary and slightly elevated temperatures, accompanied by a change in physical properties usually called "aging" and to study the effect of temperature on the mechanical properties of iron and steel, particularly boiler plate.

Methods and progress: Two papers were presented at the February 1920 meeting of the American Institute of Mining & Metallurgical Engineers by H. J. French and Zay Jeffries, entitled "Tensile Properties of Boiler Plate at Elevated Temperatures" and "Physical Properties of Iron and Steel Below the Thermal Critical Range." A paper was published in "Mining and Metallurgical Engineering," June 15, 1921 on "Slip Interference Theory of the Hardening of Metals," by Zay Jeffries and R. S. Archer. The evidence presented in these reports shows clearly that rolling and forging steel or iron without closely regarding temperatures may harm the product. Useful variations in properties produced by deformation in the blue heat range may also be possible. A series of papers published in "Chemical and Metallurgical Engineering" June 15 to November 1, 1922 issues, by Zay Jeffries and R. S. Archer, completed the work of the Committee, and at the February 23, 1923 meeting of the Division of Engineering, it was discharged.

American Engineering Standards Committee

SECTIONAL COMMITTEE ON ILLUMINATING ENGINEERING NOMENCLATURE ORGANIZED

Thirteen men, consisting of six representatives of producers, three representatives of consumers, and four representatives of general interests, constitute the personnel of the Sectional Committee on Illuminating Engineering Nomenclature and Photometric Standards, one of the projects officially before the American Engineering Standards Committee.

The Illuminating Engineering Society has been named sponsor for this project. The men who constitute this committee, and the organizations which they represent, follow:

American Gas Association, W. J. Serrill; American Institute of Electrical Engineers, A. E. Kennelly; Bureau of Standards, A. S. McAllister; Illuminating Engineering Society, Howard Lyon, G. H. Stickney; National Committee of International Commission on Illumination, Louis Bell; National Committee of International Electrotechnical Commission, C. O. Mailloux; National Council of Lighting Fixture Manufacturers, E. C. McKinnie; National Electric Light Association, C. H. Sharp; Optical Society of America, E. C. Crittenden; American Physical Society, E. P. Hyde; Individuals, G. A. Hoadley, M. Luckiesh.

STANDARDIZATION OF TRAFFIC SIGNAL COLORS

Forty-two men, representing the manufacturers and users of traffic signals, federal and state governmental departments, associations interested in the prevention of traffic accidents, and representatives of the general public, are now at work on the drafting of a national code on the proper colors for traffic signals, which it is expected will not only cut down the annual loss of life through traffic accidents, but will eliminate many of the existing irritations to motorists and to the operators of steam and electric railways.

This work is being carried on under the auspices of the American Engineering Standards Committee whose approval of a code or standard insures its ultimate acceptance and observance throughout the country. The American Engineering Standards Committee is composed of seven departments of the U. S. Government, the principal technical, industrial and engineering societies and individual business concerns interested in standardization.

The sectional committee drafting this code is made up of seven representatives of the manufacturers of traffic signals, nine representatives of the purchasers of such equipment, three representatives of the users of traffic signals, twelve representatives of governmental bodies, five technical specialists, and six insurance representatives.

Charles J. Bennett, State Highway Commissioner of Connecticut, who represents the American Association of State Highway Officials, has been selected chairman of the sectional committee. M. G. Lloyd of the U. S. Bureau of Standards, who is the representative of both the Bureau and the American Society of Safety Engineers, is vice-chairman, and Walter S. Paine, Research Engineer of the Aetna Life Insurance Co., who is the representative of the National Safety Council is secretary of the sectional committee. There are 38 other members of the Sectional Committee.

Addresses Wanted

A list of members whose mail has been returned by the Postal Authorities is given below, together with the addresses as they now appear on the Institute records. Any member knowing the present address of any of these members is requested to communicate with the Secretary at 33 West 39th Street.

1.—W. De V. Bealey, 410 Artisans Bldg., Portland, Ore.
2.—F. G. Burka, 10 Roulo Ave., W. Fort St. Sta., Detroit, Mich.
3.—L. Clyde Chatfield, Matangi Esplanade, New Brighton, Christchurch, N. Z.
4.—Harold B. Clymer, 26 Klein Ave., Trenton, N. J.
5.—Roy Danner, Amer. Motor Body Co., Detroit, Mich.
6.—John Hamilton, 2610 Lawrence St., Butte, Mont.
7.—Howard W. Key, 506 W. 32nd St., Austin, Texas.
8.—Albert H. Keys, Lawton, Okla.
9.—Daniel Maass, Compania De Luz Electrica De Sta. Ana, Rep. De El Salvador, Central America.
10.—R. H. McKibben, Cortaro, Pima County, Ariz.
11.—T. H. McWhirk, 153 East 86th St., New York, N. Y.
12.—P. B. Munro, 462 Sherbrooke St., Peterboro, Ont.
13.—Karl W. Radcliffe, Apt. B, 174 13th St., Milwaukee, Wis.
14.—N. T. Sauerborn, 1206 Grape St., Syracuse, N. Y.
15.—Kalman C. Tissinay, Westinghouse E.& M.Co.,Newark,N.J.
16.—James Wallace, 3951 Denker Ave., Los Angeles, Calif.
17.—Peter C. Winther, Jr., 174 Martin St., Milwaukee, Wis.
18.—Tobias F. Zeigler, Torrington, Wyo.

PERSONAL MENTION

A. G. von Norman is engineer for the A. G. Manufacturing Company, of Seattle, Washington.

E. M. Watts, in partnership with C. E. Macdonald, is conducting a sales engineering business in Toronto, Canada.

Bertrand Smith has accepted a position as Outside Engineer, Service Dept. with the Westinghouse Elec. & Mfg. Co., Seattle, Wash.

E. B. Lamb has resigned from the Commonwealth Edison Company in Chicago, and is now connected with the Inland Steel Company in Indiana Harbor, Ind.

M. L. Harned has become Plant Engineer for the Stearns & Foster Co., Lockland, Ohio. He was formerly Production Manager for Stewart & Co., Cincinnati, Ohio.

John Allan, formerly Electrical Engineer for the Agua Santa Nitrate and Railway Company of Iquique, Chile, is now with the Cia. Cubana de Electricidad, Santa Clara, Cuba.

Richard J. Johnston, formerly with the Navy Department, Washington, D. C., has been appointed Illuminating Engineer of the George Cutter Works, South Bend, Indiana.

H. H. Hutchinson has accepted the position as Works Manager with the National Soapstone Co., Baldwin, N. C. He was formerly with the F. C. Mesa Co., Irvington, N. J.

L. W. Abbott has resigned as Division Superintendent of the New England Telephone Co., to become Division Superintendent of Installation for the Western Electric Company.

J. P. Catlin has severed his connection with the General Electric Co., at Bridgeport, Conn., to become affiliated with the Wood Newspaper Machinery Corporation, Plainfield, N. J.

Fred E. Wright, formerly with the Alpha Electric Company, New York, N. Y., has been appointed Sales Engineer for the New York territory for Hubbard & Company, Pittsburgh, Pa.

A. E. Flowers, formerly Consulting Engineer with the Chemical Machinery Construction Co., Flushing N. Y., is now connected with the De Laval Separator Company, Poughkeepsie, N. Y.

Edwin W. Petty, formerly with the Western Electric Company as subsection head in charge of power switchboard design, has resigned to take a position as Assistant Electrical Engineer with the Chicago Union Station Company.

Robert A. F. Jackson has resigned his position with the United Strip & Bar Mills, Ltd., Sheffield, England, to take up a partnership in the firm of A. C. Borthwick & Co., Glasgow, Scotland.

S. Okuwa has resigned his position as Electrical Engineer of Hitachi Engineering Works, and has been appointed a designing engineer of Yasukawa Electric Company, Kurosaki, Fukuoka-ken, Japan.

H. L. Brueck, who for the last eight years has been connected with the Electric Appliance Company of New Orleans, La., has recently become affiliated with W. N. Matthews & Bro. of St. Louis, Mo.

Geoffrey T. Cooper, who was formerly with the Narraganset Electric Lighting Company of Providence, R. I., is now associated with Stone & Webster, Inc., Boston, Mass. as Electrical Designer.

W. H. Rudisill, has recently become associated with the Manilla Electric Company, Manilla, P. I. He was formerly Chief Engineer of the Richmond Light & Railway Co., West New Brighton, N. Y.

Harold F. Rice has resigned from the employ of the General Electric Company, Schenectady, N. Y., and is now in the Electrical Engineering Department of the Denver Gas & Electric Light Co., Denver, Colorado.

Granville B. Smith resigned his position with the Engineering Dept. of the Western Electric Company on account of his health, and is now with the New England Mutual Life Insurance Company at Pittsfield, Mass.

D. K. Lewis has recently become associated with the Compania Mexicana de Luz y Fuerza Motiz, S. A., Mexico, D. F. Prior to this connection he was Manager of the Camaguey Electric Light Co., Camaguey, Cuba.

T. E. Overbey has recently become Sales Engineer with the Haughton Elevator and Machine Company, New York City. He resigned from the employ of the Reliance Electric & Engineering Company to accept this position.

John F. Banthin, formerly in the Engineering Office of the General Electric Company, has severed his connection with that concern and has accepted the position of Plant Engineer at the Artistic Bronze Company, Bridgeport, Conn.

John C. Karcher severed his connection with the Bureau of Standards, Washington, D. C. in February, 1923, and entered the service of the Western Electric Company as Research Engineer at the Hawthorne Plant, Chicago, Ill.

E. W. Rockafellow, formerly Assistant General Sales Manager of the Western Electric Company, resigned to become Vice-President of the National Pole Company, of Escanaba, Mich., and will represent them at 200 Broadway, New York City.

Eric A. Lof, who has been connected with the Power & Mining Engineering Department of the General Electric Co. since 1909, has resigned to take up work with American Cyanamid Company. His new duties will begin on June 1, with headquarters in New York.

Ernest Hagenlocher resigned from Frazer & Company in November, 1920, to accept a position in Tokyo, Japan, with Sale & Frazar, Ltd. In 1922 he took a trip around the world, and is now connected with Briggs United Electrical Service, of Erie, Pa.

W. W. Smith has resigned as an electrical and pyrometric engineer with the Chemical Warfare Service, Edgewood Arsenal, Edgewood, Md., has accepted a position with the General Electric Company, Pittsfield, Mass., as a electrical engineer in the Fan Motor Dept.

Obituary

O. B. Moorhead, President and Chief Engineer of the Moorhead Laboratories, Inc., of San Francisco, Calif., died suddenly in February, 1923. He was a graduate of the Polytechnical School of Engineering at Oakland, Calif. From 1901 to 1915 he was connected with the Pacific Coast Marconi Wireless Tel. & Tel. Co., and while in this work he installed semi high power stations in Mexico, Alaska and the United States. Later he became the head of the Moorhead Laboratories, manufacturing radio and electrical apparatus and contractors for the U. S. Government and the British Government. Mr. Moorhead was an Associate of the A. I. E. E. and a member of the Institute of Radio Engineers.

William E. Kampf, Chief of the Meter Department, Northern Connecticut Light and Power Company, Thompsonville, Conn., died suddenly on April 28, 1923. He attended Pratt Institute and Brooklyn Polytechnic Institute, taking electrical engineering courses. For a number of years he was with the Edison Electric Illuminating Company of Brooklyn, and was also connected with the Rutland Railway, Light & Power Co. in charge of the Meter Department. He became an Associate of the A. I. E. E. in 1918.

Joseph A. Leahy, Chief Electrician of the Polar Wave Ice & Fuel Company, St. Louis, Mo., was fatally injured by electric shock, resulting in his death on April 21, 1923. He had been connected with the above company for eighteen years. Mr. Leahy became an Associate of the A. I. E. E. in 1920.

ARTHUR GORDON WEBSTER, Professor of Physics of Clark University, Worcester, Mass., committed suicide at his office in in the University on May 15, 1923. Professor Webster was a physicist of world wide fame and it is believed he took his life as the result of a very sudden impulse. He was born in Brookline, Mass. on November 28, 1863. Graduated from Harvard with an A. B. in 1885; studied at the Universities of Berlin, Paris and Stockholm and in 1890 was granted his Ph. D. from Berlin. He was instructor in mathematics at Harvard 1885-86; Parker Fellow 1886-89; Docent in Physics at Clark University 1890-92; Assistant Professor 1892-1900, and Professor in 1900. He was Professor of Physics at Clark College from 1902-07; and was granted an Sc. D. from Tufts in 1905 and LL.D. from Hobart in 1908. Professor Webster stood very high in scientific circles and was a recognized authority on electricity and sound. During the war he rendered invaluable service to the Government as a member of the Naval Consulting Board applying his thorough knowledge of ballistics to the testing of ordnance. Professor Webster wrote numerous books on electricity, magnetism, mathematics and dynamics and lectured extensively on those subjects. In 1895 he received the Elihu Thompson prize of 5000 francs at Paris. He was a member of the National Academy of Sciences; the American Philosophical Society; American Physical Society, Resident Fellow of the American Academy of Arts and Sciences; Fellow of American Association for the advancement of Science, Member American Mathematical Society and was elected Fellow of the A. I. E. E. in 1919. He acted as expert in numerous patent cases and had invented mechanical, electrical and acoustical apparatus, perfecting a device for the determination of fog signals.

Past Section and Branch Meetings

PAST SECTION MEETINGS

Akron.—April 24, 1923. Subject: "The Los Angeles Goodyear Plant and Western Electrification." Speaker: P. C. Jones, of the Goodyear Tire & Rubber Co. Attendance 20.

Atlanta.—April 19, 1923. Subject: "Panel Type Machine Switching Telephone Central Office." Speaker: George Bush, of the Southern Bell Telephone Co. Attendance 125.

Baltimore.—April 20. 1923. Subject: "Insulator Design and Manufacture." Speaker: K. A. Hawley, of the Locke Insulator Corp. Attendance 70.

Boston.—April 14, 1923. Subject: "Some Recent Developments in Radio." Speaker: Lloyd Espenschied. Attendance 225.

Cincinnati.—April 19, 1923. This was a joint meeting of the Engineers Club of Cincinnati and the A. I. E. E. Section. A dinner in honor of the speaker was held at the Chamber of Commerce. Subject: "Recent Development in Hydraulic Turbine Design." Speaker: W. M. White, of the Allis-Chalmers Co. Attendance 140.

Cleveland.—April 19, 1923. Subject: "Manufacture of Copper Wire and Cable." Speaker: C. F. Hood, of the American Steel & Wire Company, of Worcester, Mass. Attendance 75.

Connecticut.—April 12, 1923. William E. Farnham, of the American Tel. & Tel. Co., spoke on the directory problem in large cities and described machine switching equipment and its operation. Attendance 110.

Denver.—April 25, 1923. This was a joint meeting of the A. I. E. E. and the Colorado Section of the A. S. C. E., under the auspices of the Colorado Engineering Council. President Harrington of the A. S. C. E., made an address on the engineer's place in the world. L. D. Carpenter, President of the Colorado Engineering Council, outlined the work of that council at the present time.

Detroit-Ann Arbor.—April 19, 1923. Subject: "Principles and Use of the Oscillograph." Speaker: Prof. J. C. Cannon. Attendance 105.

Erie.—April 24, 1923. Subject: "The Use of Relays on Power Systems." Speaker: E. K. Huntington, of the Rochester Gas and Electric Corp.

Fort Wayne.—April 9, 1923. A special meeting to hear the transmission over radio of an address by Brig.-Gen. Herbert M. Lord, Director of the Bureau of the Budget. Before the meeting the details of the transmission were explained by M. J. Payton, and after the meeting a demonstration of the G-E. Radiola IV. was given by Mr. B. H. Rohrbaugh. Attendance 140.

April 19, 1923. Subject: "Motion Pictures of the Invisible." Speaker: Jamison Handy, of the Picture Service Corp. of Chicago. Attendance 80.

Indianapolis-Lafayette.—April 27, 1923. The meeting was preceded by a dinner. Subject: "Instrument Transformer Errors and their Measurements." Speakers: D. D. Ewing, and L. D. Rowell, both of Purdue University. Attendance 92.

Ithaca.—April 27, 1923. Subject: "The Growing Power and Responsibility of our Engineering Societies." Speaker: Calvert Townley. Attendance 115.

Kansas City.—April 13, 1923. Inspection trip through the building of the Kansas City Telephone Company, and explanation of the machine switching equipment. Lantern slides were shown and dinner was served by the Telephone Company. Attendance 85.

May 2, 1923. Joint meeting with the A. S. M. E., Kansas City Electric Club, and the Engineers Club. Subject: "My Observations in Europe." Speaker: Judge John H. Atwood. Attendance 109.

Los Angeles.—March 27, 1923. Subject: "The Development of the Electrical Transformer." Speaker: W. C. Smith. Attendance 87.

Lynn.—March 14, 1923. Ladies' Night. Subject: "A Trip through Kashmir." Speaker: Prof. B. C. Gupta, of the University of Calcutta. Attendance 455.

March 31, 1923. Annual Banquet. Subject: "The Fairy Land of Clouds." Speaker: M. Luckiesh. Attendance 285.

April 10, 1923. Subject: "Industrial Heating Devices." Speaker: E. E. Collins, Consulting Engineer of the Industrial Heating Dept. of the General Electric Company. Attendance 108.

April 18, 1923. Subject: "Physical Measurements in the Medical Sciences." Speaker: Prof. H. P. Williams, of Columbia University. Attendance 110.

New York.—A joint meeting of the metropolitan Sections of the A. I. E. E., the A. S. M. E., the A. S. C. E., and the A. I. M. E., was held in the Engineering Societies' Building, New York on the evening of Tuesday, May 8, 1923. The subject under discussion was: "The Engineer in Public Affairs." Gano Dunn, president of the J. G. White Engineering Corporation presided. He dwelt particularly on the fact that the engineer today must be an all-around man if he wishes to reach the top of his profession, as engineering is becoming increasingly intimate in its relations to the habits of the daily life of the people. At the same time Mr. Dunn warned against the possibility of overemphasizing the desirability of direct participation of engineers in public affairs.

Admiral John K. Robison, engineer-in-chief of the U. S. Navy pointed out that the Navy's chief problems were engineering problems and made a strong appeal for that branch of the national defence.

President Jewett of the Institute then urged that the Federated American Engineering Society receive the earnest support of all engineering bodies, and that individual viewpoints be discarded when these conflict.

Oklahoma.—April 27, 1923. Election of officers, and inspection trips to Oklahoma Public Service Co. Power Plant, Oklahoma Iron Works Plant, Texas Refinery, Oklahoma Power Co. Plant, Tulsa New Water System, Pipe Manufacturing Plant.

April 28, 1923. Subjects: "National Gasoline." by H. B. Bernard, "Modern Cracking Methods," by H. L. De Barr and "Radio", by C. M. Willis. This was a joint meeting with the A. S. M. E. Attendance 58.

Panama.—February 25, 1923. Inspection trip on the U. S. S. Maryland. Attendance 55.

Pittsfield.—April 12, 1923. Subject: "Influence of Earth Potential on the Operation of Transmission Lines." Speaker: L. F. Blume. Attendance 100.

April 26, 1923. Subject: "The Efficiency of Modern Methods of Manufacture as Illustrated in the Ford Automobile Plant." Speaker: Cummings C. Chesney, Manager of the Pittsfield Works. Attendance 300.

Providence.—May 4, 1923. Subject: "Spectacular Illumination." Speaker: W. D'A. Ryan, Director, Illuminating Engineering Laboratory of the General Electric Company. Attendance 650.

Rochester.—April 27, 1923. Subject: "Railway Electrification." Speaker: W. R. Steinmetz, Manager of the Heavy Traction Division, Westinghouse Electric & Mfg. Co. Attendance 105.

San Francisco.—April 27, 1923. Subject: "The Electric Transformer." Speaker: W. C. Smith, of the General Electric Company. Attendance 80.

Schenectady.—March 2, 1923. Subject: "Zion National Park." Speaker: C. J. Blanchard, of the Department of the Interior. Attendance 200.

March 16, 1923. Subject: "Efficient Sources of Electrons, New Types of Hot Cathodes." Speaker: Irving Langmuir, of the General Electric Company. Attendance 75.

April 6, 1923. Subject: "The Human Equation." Speaker: R. W. Adams, of the General Electric Co. Attendance 180.

April 20, 1923. Subject: "Unknown Baffin Land." Speaker: Capt. Donald B. MacMillan. Attendance 1100.

May 4, 1923. Subjects: "Operation of Electric Locomotives," by W. S. H. Hamilton, and "Present Status of Railway Electrification," by W. D. Bearce. Attendance 110.

Seattle.—March 21, 1923. Subject: "A Radio Evening." Speaker: J. D. Ross. Messrs. Marriott, Fuller and Mong assisted in presenting the program. Attendance 94.

Springfield.—April 24, 1923. Subject: "Recent Developments in Radio Apparatus and Broadcasting." Speaker: Q. A. Brackett. Attendance 63.

Syracuse.—March 14, 1923. Subject: "Modern Telephony." Speaker: H. L. Davis, of the New York Telephone Co.

March 26, 1923. Joint meeting with the Technology Club of Syracuse. Subject: "How Syracuse Gets Its Power." Speaker: W. C. Pearce.

April 23, 1923. Subject: "Antennas." Speaker: Prof. Ballard, of Cornell University.

May 7, 1923. Annual meeting and election of officers. A two-reel picture was shown entitled "The Wizardry of Wireless."

Toledo.—April 20, 1923. Joint meeting with the Doherty Fraternity. Subject: "High-Tension Electrical Development in Japan." Speaker: S. Q. Hayes, of the Westinghouse Electric & Mfg. Co. Attendance 60.

Toronto.—April 20, 1923. Subject: "South Africa from the Cape to Victoria Falls." Speaker: A. P. Coleman. Attendance 49

Utah.—April 23, 1923. The Engineering Council of Utah, of which the A. I. E. E. Section is a member held their annual banquet, at which President Harrington, of the A. S. M. E. was the principal speaker. Other speakers were: Senator Wm. H. King, Congressman E. O. Leatherwood, Mr. Percy E. Barber, Mr. M. D. Williams, Mr. R. K. Brown and Vice-president H. T. Plumb. Attendance 215.

Vancouver.—March 2, 1923. Subject: "Electricity on Board Ships." Speaker: W. W. Fraser, Electrical Engineer and Contractor. Attendance 9.

April 6, 1923. Subject: "Travalogue of South America." Speaker: Calvin W. Rice, Secretary of the A. S. M. E.

Worcester.—April 12, 1923. "City Planning." Speaker: Maurice F. Reidy. This meeting was held in conjunction with the A. S. M. E. Section. Attendance 100.

PAST BRANCH MEETINGS

University of Alabama.—April 24, 1923. Election of officers as follows: M. S. Merritt, President, William Graham, Vice-president, J. A. Zobel, Sec. and Treasurer and O. A. Reed, Publicity Secretary. Attendance 11.

University of Arizona.—April 18, 1923. Prof. Paul Cloke gave a talk on Radio, supplemented by a moving picture on the "Audion Bulb," by courtesy of the Western Electric Co. Attendance 29.

University of Arkansas.—February 20, 1923. Subject: "Hydroelectric Practise." Speaker: Dean W. N. Gladson. Attendance 24.

March 13, 1923. Subjects: "Water Wheel Design," by R. C. Mason, "Pit River Power Project," by Joe Cunningham and "Automatic Hydroelectric Control," by Dean Ault. Attendance 16.

April 17, 1923. Subject: "The Underlying Principles of Radio," by Prof. W. B. Stelzner. Attendance 15.

Armour Institute of Technology.—April 19, 1923. Subject: "Manufacture of Communicating Apparatus," Speaker: A. E. Holstedt, of the Western Electric Co. Attendance 43.

May 3, 1923. Subject: "Substation Operation." Speaker: D. E. Richardson, of the Commonwealth Edison Co. Attendance 41.

Bucknell University.—April 23, 1923. Subject: "Motor Control." Speaker: Prof. G. A. Irland, of the Electrical Engineering Dept. Attendance 25.

April 30, 1923. Subject: "Automatic Stokers." Speaker: Prof. B. J. Wilson. Attendance 23.

University of California.—April 18, 1923. Subject: "New Types of Elevators." Speakers: H. S. Delanzi, of the Westinghouse Electric & Mfg. Co., and Mr. Skaife, of the Spencer Elevator Company of San Francisco. Attendance 48.

Carnegie Institute of Technology.—April 12, 1923. Subject: "Manufacture of Porcelain Insulators." Speaker: John M. Peck, of the Porcelain Insulator Company, Lima, N. Y. Attendance 42.

Case School of Applied Science.—April 26, 1923. Subject: "Salesmanship." Speaker: E. S. Jordan, of the Jordan Motor Car Co. Attendance 30.

Clemson College.—April 12, 1923. Subjects: "The Life of George Westinghouse," by L. B. Dyches, "Indiana Company Changes to 60 Cycles," by R. W. Pugh, "Current Events," by O. A. Roberts. Attendance 24.

April 19, 1923. Subject: "Some Recent Applications in Electrical Engineering." Speaker: A. F. Riggs, of the General Electric Company. Attendance 45.

April 26, 1923. Subjects: "Most Economical Power Factor," by S. C. Rice, "Dynamic Braking and Regeneration," by Prof. S. R. Rhodes, "Current Events," by G. N. Spear. Attendance 17.

Colorado Agricultural College.—April 23, 1923. Business meeting. Attendance 10.

University of Colorado.—April 11, 1923. Subject: "Psycology for Engineers." Speaker: Prof. Cole. Attendance 62.

April 25, 1923. Subject: "Rotary Converter." Speaker: Mr. Eastman, of the Electrical Engineering Dept.

Denver University.—April 18, 1923. Subject: "Specialization for Engineers." Speaker: H. B. Barnes, Chairman of the Denver Section of the A. I. E. E.

Georgia School of Technology.—March 16, 1923. Subject: "Manufacture of Telephone Cable." Speaker: Mr. Thomas, of the Western Electric Co. Attendance 15.

March 26, 1923. Subject: "The Engineer in the Business World." Speaker: H. L. Wills, of the Georgia Railway & Power Co. Attendance 50.

April 16, 1923. Subject: "Telephone Transmission." Speaker: W. F. Oliver, of the Southern Bell Telephone Co. Attendance 16.

State University of Iowa.—April 16, 1923. Subjects: "Power Development at Coralville, Iowa," by Mr. Stover, and "Methods of Grounding," by Mr. Stanton. Attendance 50.

University of Kansas.—April 12, 1923. Subject: "Boiler Room Economy." Speaker: H. O. Smead. Attendance 53.

Kansas State College.—April 23, 1923. Talks by two students were given on "Inductive Interference of Transmission Lines" and "Management of a Large Company." Attendance 52.

Lehigh University.—April 6, 1923. Subject: "Transformer Problems Connected with Large Power Developments and High-Voltage Transmission." Speaker: H. O. Stevens, of the General Electric Company. Attendance 38.

Lewis Institut .—April 11, 1923. Business meeting. Attendance 16.

Marquette University.—April 30, 1923. Subject: "The General Features of the Electric System of the T. M. E. R. & L. Co." Speaker: G. G. Post, Chairman of the Milwaukee Section of A. I. E. E. Attendance 49.

Michigan Agricultural College.—March 6, 1923. Subject: "The Commercial Engineer." Speaker: S. M. Dean, of the General Electric Co. Attendance 30.

April 11, 1923. Business meeting, and showing a four-reel film on the Sperry gyroscope. Attendance 41.

University of Michigan.—April 5, 1923. Subject: "Recent Central Station Developments." Speaker: F. A. Delay. Attendance 55.

School of Engineering, Milwaukee.—April 27, 1923. Subject: "The Unaflow Steam Engine." Speaker: V. Stankoff. Attendance 46.

University of Minnesota.—April 18, 1923. Talks on electrical subjects of local interest. Attendance 120.

University of Missouri.—April 9, 1923. Subject: "Electric Ship Propulsion." Speaker: E. Fugua. Attendance 24.

Montana State College.—April 11, 1923. Five reels of moving pictures, dealing with the manufacture, assembly and installation of telephone apparatus by the Western Electric Company of Hawthorne. Attendance 225.

April 18, 1923. Subject: "Personal Characteristics Sought for in Selecting Men for the Bell Telephone Company." Speaker: R. C. Bonney, of the Western Electric Company. Attendance 100.

University of Nebraska.—May 9, 1923. Election of officers. Subject: "Electrical Rates." Speaker: Prof. V. L. Hollister. Attendance 21.

University of North Carolina.—April 19, 1923. Illustrated lecture entitled "The Message of the Curtis Steam Turbine." Attendance 43.

University of North Carolina.—May 10, 1923. Subject: "History of Aeronautics." Speaker: Prof. E. G. Hoefer. Attendance 35.

North Carolina State College.—April 18, 1923. Subjects: "Telephone Repeaters," by Blair Jenkins, and "Machine Switching," by Elmir King. Attendance 50.

University of North Dakota.—April 16, 1923. Subjects: "Manufacturing Methods in Western Electric Factory," by W. E. Edwards, and "Requirements of a Successful Engineer," by C. W. Brotherton. Attendance 27. Four reels of motion pictures were shown on "Compressed Air." Attendance 27.

April 30, 1923. Joint meeting of A. I. E. E. and General Engineering Society. Moving pictures were shown entitled "Coal is King" and "The Elimination of Waste in the National Cash Register Factory." Attendance 27.

Northeastern University.—May 4, 1923. Moving pictures were shown as follows "Queen of the Waves" and "The X-Ray" and "Cable Manufacturing." Attendance 22.

Notre Dame University.—April 23, 1923. Subject: "Interference between Telephone Lines and Power Lines," by Messrs. Curran and Linckinger of the Indiana Bell Telephone Company, and "History of the Telephone," by Edward P. Kreimer. Attendance 34.

Ohio State University.—April 13, 1923. Election of officers. Attendance 60.

Ohio Northern University.—April 19, 1923. Subject: "Ship Propulsion." Attendance 14.

May 4, 1923. Election of officers and social meeting. Attendance 35.

Oklahoma A. & M.—April 19, 1923. Subjects: "Work Being Done by the Alumni," by Prof. W. J. Miller, and "Some of My Experiences with the Westinghouse Electric & Mfg. Co," by Harry Hoke. Attendance 21.

University of Oklahoma.—April 19, 1923. Subjects: "Light and Lighting Principles," by B. F. Thompson and "Public Address Systems," taken from the A. I. E. E. JOURNAL. Attendance 12.

Oregon State Agricultural College.—April 12, 1923. Subject: "Some Operating Features of Modern Power Plants." Speaker: D. W. Proebstel, of the Portland Railway Light & Power Co. Attendance 86.

University of Pittsburgh.—April 5, 1923. Subjects: "The Battle of the Colorado," by R. A. Young, and "The Conservation of Heat of the Insulation of Piping," by R. H. Hilman. Attendance 29.

April 12, 1923. Subjects: "Mechanical Offices in Telephone Work," by J. C. Krehmery, "Central Station Development," by R. S. McCarty. Attendance 29.

April 19, 1923. Subjects: "Westinghouse Distribution Transformer," by P. B. Long, and "Development and Problems in Integrating Metering," by A. R. Rudder. Attendance 30.

Purdue University.—April 24, 1923. Illustrated lecture by C. L. Harrod, of the Indiana Coal Operators' Power Association. Attendance 56.

Rose Polytechnic Institute.—March 27, 1923. Election of officers. Attendance 16.

Rutgers.—March 22, 1923. Joint meeting of A. I. E. E., A. S. C. E. and A. S. M. E. Subject: "Customer Ownership of Public Utilities." Speaker: P. S. Young, of the Public Service Corp. of New Jersey, Attendance 25.

April 26, 1923. Annual business meeting and election of officers. Attendance 13.

May 3, 1923. Joint meeting of A. I. E. E., A. S. M. E. and A. S. C. E. Subject: "The Human Equation in Industry and Engineering." Attendance 65.

University of Southern California.—April 18, 1923. Inspection trip to the Pacific Electric Shop at Torrance, Cal. Attendance 58.

Stanford University.—April 12, 1923. Business meeting. Attendance 20.

April 26, 1923. Subject: "Problems in Electrical Transmission." Speaker: Mr. Jollyman, of the Pacific Gas & Electric Co. Attendance 42.

April 28, 1923. Inspection tour of the Pacific Studios at San Mateo, Cal. Attendance 9.

Swarthmore College.—April 13, 1923. Joint meeting of the A. I. E. E., A. S. M. E. and A. S. C. E. branches. Mr. Patterson and Mr. Hyde, both of the Bell Telephone Company of Pennsylvania spoke on the work of their company and opportunities offered college graduates there. Attendance 35.

April 20, 1923. Joint meeting of engineering branches, at which Mr. Nichols spoke on the construction of the heating plant at Cornell University. Attendance 35.

April 27, 1923. Subject: "The Multiple Plant Method for the Equitable Apportionment of Fixed Charges." Speaker: T. S. Oliver. Attendance 8.

May 11, 1923. Planning of a trip of inspection of the Holtwood Hydroelectric plant and several plants at Lancaster, Pa. Attendance 8.

Syracuse University.—March 2, 1923. Subject: "Electric Motors in the Rubber Industry," by Nellis D. Smith, and "Radio Activities," by Lyle L. Edwards. Attendance 24.

March 9, 1923. Subject: "Power Factor Correction." Speaker: Kenneth Liedy. Attendance 19.

March 23, 1923. Subject: "Photography." Speaker: John Channell. Attendance 20.

April 6, 1923. Subject: "Importance of Good Power Factor." Speaker: Dunham Conger. Attendance 21.

April 13, 1923. Subjects: "Electric Welding," by Paul A. Klinkert, "Electric Cables," by C. N. Chase, "Application of Electric Motors," by Earl B. Clark, and "Systems of Industrial Organization," by Harold A. Olson. Attendance 21.

University of Washington.—April 10, 1923. Subjects: "Construction of a 110,000-volt Transmission Line Across Two Mountains," by W. D. Shannon, of the Puget Sound Light & Power Co., and "How the General Electric Company Fills an Order," by A. W. Trabert, of the General Electric Co. Attendance 71.

West Virginia University.—April 16, 1923. Subjects: "Locating Faults in Direct-Current Armature Windings," by C. W. Addis, "The Production of Porcelain for Electrical Insulation," by R. Lee, "Furnace Reactance," by T. N. Farman, "The Use of Fuel Oil During Coal Shortage," by C. B. Hutson, "Cost of Installation of Transmission Lines," by C. C. Cantner, "Three-phase Four-wire Distribution Systems," by C. Snyder, "The Oxide Film Lightning Arrester," by S. R. Hall, and "One Man Street Cars," by Ira O. Meyers. Attendance 29

April 30, 1923. Subjects: "Heating by Electricity," by C. E. Hutcheson, "Nature of Speech in Telephone Works," by L. I. Faulkner, "Electric Oven and Furnace," by A. Chabamel, "The Thermocouple," by Paul Callahan, "Shall We Paint or Galvanize our Steel Structures?" by M. W. Kellerman, "The Electrons from Hot Filaments," by P. F. Hill, "Ovens for Baking Railway Armatures," by S. R. Hall, "Speed Adjustment of Direct-Current Motors," by A. A. Winters, "Collections of Fares in Congested City Districts" and "White Coal," by T. N. Farman. Attendance 28.

University of Wisconsin.—April 11, 1923. Subject: "Automatic Substations," by C. V. Seastone. Attendance 40.

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 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 6 p. m.

BOOK NOTICES (APR. 1-30, 1923)

Unless otherwise specified, books in this list have been presented by the publishers. The Society does not assume responsibility for any statements made; these are taken from the preface or the text of the book.

All the books listed may be consulted in the Engineering Societies Library.

AMERICAN PETROLEUM REFINING.

By H. S. Bell. N. Y., D. Van Nostrand, 1923. 456 pp., illus., diagrs., 9 x 6 in., cloth. $5.00.

The first American book exclusively devoted to refining. Discusses the manufacturing process, the arrangement of refineries, the apparatus and treatment used, the storage and transportation of oil, etc. Intended to give the fundamental information needed by those about to erect refineries or by those engaged in the industry who wish a picture of it as a whole.

EL ARTE DE LOS METALES.

By Alvaro Alonzo Barba. N. Y., John Wiley & Sons; Lond., Chapman & Hall, 1923. 288 pp., illus., 8 x 6 in., cloth. $3.50.

"El Arte de los Metales," written in Spanish by Alvaro Alonzo Barba, Curate of San Bernardino parish, Potosi, Bolivia, is undoubtedly the earliest published work on American metallurgy. Originally presented as a report to the Crown representative at Sucre, it was reviewed by the Mayor and representatives of the Amalgamators' Guild of Potosi in 1637 and recommended to the King of Spain for publication. It was published at Madrid in 1640.

A poor English translation of the first two of its five books as made in 1669 by Edward Montagu, Earl of Sandwich, but the present publication is the first complete, accurate rendering in the English language.

Book one summarizes the geological knowledge of Barba's time. Books two to five deal with metallurgical practise in a region already famous for its production of gold and silver. Barba describes the methods of treating the ores and of refining the bullion and illustrates the furnaces used. He also describes the equipment and methods in use for assaying. He describes a method for amalgamating silver ores discovered by him in 1690, which was rediscovered many years later on the Comstock lode as the "Washer process." His book will be welcome to all interested in the history of metallurgy or of early Spanish industrial achievements in South America.

AUOTMOTIVE REPAIR, V. 3, For Battery Service Men; v. 4, For Tire Service Men. By J. C. Wright.

N. Y., John Wiley & Sons; Lond., Chapman & Hall, 1923. v. 3, 387 pp., v. 4, 305 pp., illus., tables, 9 x 6 in., cloth. $3.00 each.

These two volumes complete this extensive work on the repair of automobiles by presenting methods for repairing tires and batteries. They follow the plan of the earlier volumes in giving for each job, first, an outline of the necessary operations, then the materials, tools and parts required and, finally, a detailed description of the method. The reasons for each operation are also given. The directions are clear and practical, and cover almost every emergency that can arise.

ELEKTROTECHNIK, v. 4; Die Erzeugung und Verteilung der. Elektrischen Energie. By Immanuel Hermann.

Ber. und Lpz., Walter de Gruyter & Co., 1923. 138 pp., illus., diagrs., 6 x 4 in., boards. .25.

One of a series of small volumes giving an outline of electrical engineering in greatly condensed form. The present volume is concerned with the generation and distribution of electricity and discusses in five chapters, power plants, methods of distribution, switch apparatus, distributing networks and the cost of electric power.

ELEMENTS OF APPLIED PHYSICS.

By Alpheus W. Smith. 1st edition. N. Y., & Lond., McGraw-Hill Book Co., 1923. 483 pp., illus., diagrs., 9 x 6 in., cloth. $3.00.

Prepared for students who are primarily interested in the practical applications of physics, this book has been written with their training and habits of thought in mind and includes those topics that they can assimilate thoroughly. A large number of illustrations of the applications of physics to engineering and everyday life are given in an effort to stimulate the student to recognize the universality of physical laws and to find in them the explanation of everyday experiences.

FOUR LECTURES ON RELATIVITY AND SPACE.

By Charles Proteus Steinmetz. 1st edition. N. Y., & Lond., McGraw-Hill Book Co., 1923. 126 pp., diagrs., plates in pocket, 9 x 6 in., cloth. $2.00.

In these lectures the extensive use of mathematics has been avoided. Dr. Steinmetz has attempted to give the layman and the engineer who is not an expert mathematician a general knowledge and understanding of the new ideas of time, space, the laws of nature and the characteristics of the universe which the relativity theory has deduced, and of the researches on which the theory rests.

HISTORY OF THE THEORY OF NUMBERS, vol. 3; Quadratic and Higher Forms. By Leonard E. Dickson.

Wash., D. C., Carnegie Institution of Washington, 1923. 313 pp., 10 x 7 in., paper. $3.25.

The third volume of this exhaustive history treats of the arithmetical theory of forms and is concerned mainly with general theories rather than with special problems and special theorems. The investigations here in question are largely those of leading experts and deal with the most advanced parts of the theory of numbers. Many of the papers are so recent that all previous reports and treatises are entirely out of date. Every effort has been made to make the list of references complete.

MODERN ELECTRICAL THEORY; Supplementary Chapter 16, RELATIVITY.

By Norman R. Campbell. Cambridge, Eng., University Press, 1923, (Cambridge Physical Series). 116 pp., 9 x 6 in., cloth. 7s 6d. (Gift of Macmillan Co., N. Y.)

Dr. Campbell has added another book to the immense literature of relativity for two reasons. The first of these is to complete his treatise on electrical theory, which cannot be considered complete without some description of this important branch of physics. The second is that he has found the average physicist still ignorant of Einstein's work and not very interested in it. He thinks this ignorance is because certain features in the theory present greater difficulty to them than to others, and as he believes he has discovered their stumbling block, he has written this book to help them surmount their difficulty.

PRINTING TELEGRAPH SYSTEMS AND MECHANISMS.

By H. H. Harrison. Lond., & N. Y., Longmans, Green & Co., 1923. (Manuals of telegraph and telephone engineering). 435 pp., diagrs., 9 x 6 in., cloth. $7.00.

Intended as a reference book for designers of telegraph machinery and as a textbook for those engaged in telegraphy, this book is a comprehensive study of the principles and mechanisms involved in printing telegraphs and a history of the development of the art.

WAVELENGTH TABLES FOR SPECTRUM ANALYSIS.

By F. Twyman. Lond., Adam Hilger, 1923. 106 pp., tables, 9 x 6 in., cloth, 7s 6d.

This book is a collection of wavelength tables intended for use in the laboratory and containing only matter essential for this purpose. It is of a convenient size and weight. It includes standard wavelengths from 2375 to 8495 I. A., the persistent and sensitive lines of most of the elements arranged under the names of the elements, and the most persistent and sensitive lines rearranged in order of wavelengths. There is also a list of wavelengths useful in the determination of stellar radial velocities. The values are from the most competent authorities and the source of each is carefully indicated.

X-RAYS.

By G. W. C. Kaye. 4th edition. Lond., & N. Y., Longmans, Green & Co., 1923. 320 pp., illus., diagrs., 9 x 6 in., cloth. $5.00.

Dr. Kaye's book does not profess to be a treatise or a handbook on X-rays. It aims at giving an account of such of the present-day methods and apparatus as appear valuable or novel; it deals with the physics of a number of the main principles of radiology; and it attempts to convey a notion of the historical trend of events from the discovery down to the present. It is intended for students of physics, men of general scientific interest and members of the medical profession. The present edition has been thoroughly revised.

Employment Service Bulletin

OPPORTUNITIES.—Desirable opportunities for service from responsible sources are announced in this Bulletin, and no charge therefor is made.

MEN AVAILABLE.—Under this heading brief announcements will be published without charge to the members. Announcements will not be repeated except upon request received after a period of three months, during which period names and records will remain in the active files.

NOTE.—Notices for the JOURNAL should be addressed ***EMPLOYMENT SERVICE, 33 West 39th Street, New York, N. Y.,*** *the employment clearing house of the National Societies of Civil, Mechanical, Mining and Electrical Engineers.*

Notices for the JOURNAL are not acknowledged by personal letter, but if received prior to the 16th of the month will appear in the issue of the following month.

All replies to either "Opportunities" or "Services Available" should be addressed to the key number indicated in each case and forwarded to ***EMPLOYMENT SERVICE,*** *as above.*

Replies received by the bureau after the position to which they refer has been filled will not be forwarded, and will be held by the bureau for one month only.

OPPORTUNITIES

HIGH CLASS ELECTRICAL SALES REPRESENTATIVES wanted by manufacturers of carbon, graphite, electro-graphitic and metallic brushes for motors and generators, also general line of carbon specialties. Exclusive rights given to each of territories on liberal straight commission sales proposition. Specify in detail past engineering and sales experience. Territory open Cleveland, Chicago and St. Louis. Application by letter. V-3338.

INSTRUCTOR IN ELECTRICAL ENGINEERING. Work consists of Electrical Engineering Laboratory and a class in either Radio or Telephony. Prefer a man with from 1 to 3 years' experience. Salary depends on qualifications. Application by letter. Location, South. R-879.

ELECTRICAL ENGINEER. Experienced in the application of electrical equipment in the coal mining industry. Duties involve substation design, application of electric hoists, pumps, ventilating fans, and locomotives. Must be capable of detailing equipment, requisitioning all necessary supplies for completing the installation. Location Pa. R-948.

DRAFTSMAN. We can use several men experienced in special machinery, tools, electrical appliances, or mechanical lines. Application by letter. Salary not stated. Location, Ill. R-1073.

INVESTIGATOR for plant capacity problems. Large industrial plant. Application by letter. Salary not stated. Location, Ill. R-1074.

INSTRUMENT ENGINEER, graduate mechanical or electrical engineer with several years' experience on electrical apparatus or precisino instruments. Liberal starting salary, permanent connection. Application by letter. Location, Ill. R-1075.

ELECTRICAL ENGINEER. Want man familiar with industrial plant and power lighting layouts, design of electrical equipment and installation of electrical machinery. Application by letter. Salary not stated. Location, Ill. R-1076.

YOUNG ENGINEERS. Large industrial organization in middle west, can use a few young men who have had mechanical or electrical engineering training. These men will be given a short course in our vestibule training school to fit them for positions as telephone engineers. Liberal starting salary. Permanent position with exceptional opportunities for promotion. Application by letter. Location, Middle West. R-1081.

TOOL DESIGNER capable of running a department. Must be able to organize department and must know small machine tools and latest methods of quick acting, jigs, and fixtures and well versed on automatic screw machinery. Potter and Johnson grinding (internal and external) and milling machinery. All of above for large quantity production. Application by letter. Salary not stated. Location, Pa. R-1082.

INSTRUCTOR IN ELECTRICITY. Equivalent of High School education. 8 years. practical experience including apprenticeship time-50 per cent of time spent in technical school allowed. Location, Mass. R-1095.

SEVERAL ENGINEERS, experienced in construction of power plants and substations. Building, mechanical and electrical, knowledge desirable for work of perpetual inventories. Some knowledge of cost accounting desirable. Good opportunity. Application by letter. Salary not stated. Location, New York City. R-1108.

SEVERAL ELECTRICAL ENGINEERS, experienced in construction and layouts of electrical distribution systems for work on perpetual inventories. Some knowledge of cost accounting desirable. Good opportunity. Application by letter. Salary not stated. Location, New York City. R-1109.

SUPERINTENDENT OF MUNICIPAL light and power department in town of 2500. Distribution system only; energy purchased wholesale. Should be thoroughly familiar with maintenance of watthour meters and distribution system. Application by letter. Salary not stated. Location, Minn. R-1170.

YOUNG ENGINEERS OR DRAFTSMEN, familiar with detailing of the power station equipment for hydroelectric development. Application by letter. Salary not stated. Location, Central South. R-1184.

HYDRAULIC ENGINEER to go South, in the position as assistant to resident engineer in charge of a hydraulic electric project which will cost about $1,250,000. Transport expenses to job paid. Application by letter. Salary not stated. Location, Central South. R-1185.

ENGINEER having a thorough knowledge of theoretical engineering and mathematics for general engineering and calculation work, dealing especially with thermodynamic problems. Application by letter. Salary not stated. Location, New York City. R-1195.

ASSISTANT SUPERINTENDENT of power for textile plant in India; unmarried, college graduate, age 27-31 years, good health and habits. Electrical training necessary. Power plant and all transmission, including telephone, fire alarm, and usual mill equipment, is American machinery. Applicant should give qualifications and experience fully. 3 years contract. Application by letter. Salary not stated. Location, India. R-1209.

CHIEF ENGINEER for steam plant, 4500 kw. for textile mill in India: water tube boiler, G. E. turbines, and all American equipment and electric transmission. Must have good experience, health and habits, and be not over 35 years old. Reply should give qualifications and experience fully. 3 years contract. Application by letter. Salary not stated. Location, India. R-1210.

SEVERAL ENGINEERS, experienced in 2300-4000 volts a-c. and 600 volts d-c. Railway overhead distributing system. Application by letter. Salary not stated. Location, La. R-1221.

MANAGER for high-tension insulation department, experienced in manufacturing insulators (power line work), familiar with machinery and clays. 25-30 years old. Application by letter. Salary not stated. Location, not stated. R-1257.

MECHANICAL ENGINEER with practical experience in welding, for research work. Must be able to make reports. Application by letter. Salary not stated. Location, New York City. R-1259.

INSTRUCTOR for employees' classes in organized educational department of a large electric utility corporation. Must be Electrical Engineering graduate with experience in teaching and in an operating company desirable. Write full particulars and state salary acceptable for first year, beginning not later than August 1st. Also enclose kodak photograph. Application by letter. Location, Ill. R-1264.

INSTRUCTOR for employees' classes in organized educational department of a large electric utility corporation, also having gas properties. Must be a technical graduate with experience in teaching and in operating company. Principal classes, manufacture and distribution of gas and steam engineering. Write full particulars and state salary acceptable for first year, beginning not later than August 1st. Also enclose kodak photograph. Application by letter. Location, Ill. R-1265.

LUBRICATION ENGINEER. The Vacuum Oil Company is seeking an experienced mechanical engineer for service in the West Indies. The vacancy requires a man of the following qualifications: Age. 30-40. Practical experience with Sugar Mill Machinery and power plant operation. Knowledge of Spanish desirable. **Do not call.** Write us giving a complete outline of your education and experience, stating age, salary desired, how many dependents, if any. VACUUM OIL COMPANY, Technical Employment Committee, 61 Broadway, New York City. R-1276.

SALESMAN to sell Spencer heating boilers. Application by letter stating age, education and experience. Salary not stated. Location, New York City. R-1292.

ELECTRICAL DESIGNER, experienced on hydroelectric power plant design. Application by letter. Salary not stated. Location, Canada. R-1295.

ELECTRICAL DRAFTSMAN (2) experienced on hydroelectric power plant work. Application by letter. Salary not stated. Location, Canada. R-1296.

MECHANICAL ENGINEER about 35 years of age, having steam electric station operating experience and having been in charge of one or more plants, to fill position of superintendent of power plants in charge of 6 or more plants. Application by letter. Salary not stated. Location, Pa. R-1299.

ASSISTANT ELECTRICAL ENGINEERS who has had more or less experience on switchboard layouts and switchboard design work. Should also have experience in connection with both outdoor and indoor substation layouts as well as a certain amount of experience in design of high-tension transmission line. R-1326.

ASSOCIATE PROFESSOR for experimental engineering, 3 years teaching and 3 years practical experience essential. Application by letter. Salary not stated. Location, South. R-1328.

RECENT GRADUATE ELECTRICAL ENGINEER to teach radio engineering. Application by letter. Salary not stated. Location, Ga. R-1329.

MEN who are qualified draftsmen and designers in electric generating and substation equipment installations. Must be thoroughly familiar with layouts of switchboard, conduit, remote control, and d-c. and a-c. apparatus. Should have at least 2 years' practical experience in this class of design. Application by letter. Salary not stated. Location, New York City. R-1334.

SALES ENGINEERS — WANTED. Young single men for positions as sales and service engineers, calling on superintendents, managers, engineers, chemists and metallurgists, for manufacturers of well-known high-grade automatic electrical and temperature equipment, extensively used in factories, power plants, chemical and industrial works. Knowledge of physics and elementary electricity required. Graduates of technical schools preferred. Candidates must be free to travel in the great manufacturing and industrial districts. Young men of good address and ability to talk convincingly to engineers wanted, but no previous experience demanded. Write describing education and earning experience, if any, and stating age and salary desired. R-1406

MEN AVAILABLE

ELECTRICAL ENGINEER, tech. graduate, thoroughly practical, experienced in maintenance operation supervision, 2 years G. E. test, 6 years Allis Chalmers, erecting and testing, mechanical and electrical. Also held chief operator's, asst. superintendent and superintendent's positions. 37 years old, hard worker, efficient. Wishes position of worth and responsibility. E-4293.

ELECTRICAL AND MECHANICAL ENGINEER, technical graduate, age 32, 7 years' experience, industrial and power plant design and purchasing, one year teaching. Desires responsible connection. Will consider foreign commission. E-4294.

TECHNICAL GRADUATE, Electrical Engineering course, 1921, desires a sales or technical position in any capacity. Have six years of good practical electrical experience in shop-work, testing and drafting. At present engaged in La Salle business administration correspondence course. E-4295.

ANNAPOLIS GRADUATE (1922). Assoc. A. I. E. E., Jr. A. S. M. E., experienced in power plant operation and maintenance, desires position as assistant to executive in electrical or marine industry. Character analysis recommends this position. E-4296.

ELECTRICAL AND MECHANICAL ENGINEER 6 years hydroelectric power plant operation, 9 years street railways rolling stock. Willing to go abroad. Have worked in S. A. Can speak Spanish. Available now. E-4297.

INSTRUCTORSHIP. Young man receiving Master's degree in Electrical Engineering from M. I. T. desires a teaching position. Age 27; location immaterial. E-4298.

STEAM STATIONS SUP'T. 31, unmarried, Rennselaer Polytechnic Institute. 13 years experience construction, and operation, plants up to 120,000 kw. 5 years as power plant efficiency engineer. Desires connection as above or as Sales Manager branch office of concern manufacturing high grade plant machinery. Specialist in steam plant efficiency work. E-4299.

MECHANICAL AND POWER ENGINEER, B. S. and M. E. 8 years' broad experience, machine shop, metallurgy, sugar refinery design, layout, industrial and power plant design, layout, construction, operation, calculations of heat balance, steam, water, power requirements, etc., investigation and reports. Available immediately. E-4300.

SALES ENGINEER graduate E. E., 30 years old, married, at present employed, desires to make a change. Three years' experience selling mechanical and electrical specialty, used extensively in power plants and factories. Well acquainted in northern New Jersey, New York and Conn. Would prefer work on a salary and commission basis. Also have had two years' General Electric testing department experience. E-4301.

SALES ENGINEER, Cleveland Ohio. A. S. M. E. and A. I. E. E. One or two accounts desired. E-4302.

STEAM-ELECTRIC PLANT ENGINEER—Technical engineering and business education. 12 years' experience—General Electric test, development, factory and commercial engineering, three years efficiency engineering in modern steam-electric plant. At present in charge of operation and maintenance of boiler plants generating 9000 boiler horse power in southern California. Desire connection with steam-electric plant in Southwest. E-4303.

PROFESSOR OF EXPERIMENTAL ENGINEERING. E. E., M. E. Nine years commercial research and development. Two years' teaching experience. Can organize department of Experimental Engineering or take charge of existing department. Location unimportant. E-4304.

ELECTRICAL AND MECHANICAL ENGINEER, Graduate of Cornell University. Age 30. 5 years' experience since graduation in electrical plant operation, street railway and structures, hydroelectric and transmission line design and construction. Now completing work in large hydroelectric development. Available June 1st. E-4305.

WANTED. A permanent position with a well established organization as research or development engineer in applied physics or high-frequency electrical field. 12 years as head of Physics Department in first class American College. Former officer, Signal Corps, U. S. A. 3 years' experience as director of research and development work for a Radio Corporation specializing in guided-wave and radio equipment. Doctor of Philosophy. Fellow, A. I. E. E. Member Institute Radio Engineers. Author various papers on theory and application of electromagnetic waves. E-4306.

TECHNICAL GRADUATE 1922, several years' practical experience with central station. At present G. E. Test, desires position with contracting or consulting firm, central or substation work, including automatics, preferably in the field. Location immaterial. Age 25. E-4307.

GENERAL MANAGER OR CHIEF ENGINEER. Past 18 months as General Manager of 100 mile Interurban also three city systems taken over from a receiver. Unlimited energy and time unable to overcome handicap. Desire to establish elsewhere in interurban or public utility field. 12 years engineering constructing, operating experience. Minimum salary $5000.00. E-4308.

YOUNG MAN, ambitious, technically trained, (Degree B. S. in E. E. 1922) desires connection with production department of well established manufacturing company. 18 months' industrial engineering experience. Acquainted with modern methods of cost keeping, time study, rate setting and general production work. 5 years' experience general administrative office routine. Age 29, single. Salary 160 dollars. Location immaterial, mid-west preferred. E-4309.

ELECTRICAL ENGINEER. B. S. degree, age 32, single. 4 years' practical experience along lines of light and power distribution and industrial installations and maintenance. For past 3 years has been assistant professor of mathematics and electrical engineering in New England. Now desires to make a change and to locate in the Southern States or in California. Would consider either teaching or industrial offer. Salary $3000. E-4310.

GRADUATE. University of Missouri, 1921; graduate. Chicago Central Station Institute, June 1922; Jr. Engr. Street Dept. Commonwealth Edison Co. Chicago to Mar. 26, 1923; inspector of overhead distribution lay-outs for above company at present. Age 25, unmarried. E-4311.

ELECTRICAL ENGINEER. College graduate Westinghouse Students Training course, engineering and sales experience is offering his services to American firms engaged in export trade in U. S. or abroad in sales or engineering capacity. Traveled extensively in Western Europe, Russia and Far East. Speaks Russian, German fluently. At present employed but desire change for bigger opportunities. Correspondence solicited. Salary open. E-4312.

YOUNG MAN, age 22, single, graduate in Electrical Engineering from Drexel Institute Evening School, desires position in transmission or electric railway engineering. At present engaged in telephone work, but is ambitious to succeed in other branches of electrical engineering. Willing to go anywhere. E-4313.

EXECUTIVE POSITION desired by technical graduate in E. E. Familiar with factory practise and routine, and with cost work. Expert in systematizing and scheduling, both from factor and office end. Over 12 years with present concern and now employed in engineering work, but desire a change. Have taken G. E. test work and am thoroughly familiar with all phases of testing and inspecting, with which my present work is closely connected. Position must be permanent and worth while. E-4314.

ELECTRICAL ENGINEER, EXECUTIVE, broad experience manufacturing field. Expert development and design of small apparatus such as testing equipment, telephone, telegraph, radio, instruments, etc. Manufacturing methods, quantity production, standardization designs, materials and parts, inspection and testing methods, factory organization and routine plant and department layouts, planning, etc. 14 years mfg. experience; 2 years plant operation. 1 year construction. Age 37. American, Christian. Desire connection with reliable manufacturing concern. Consulting or industrial engineer operating in manufacturing field. E-4315.

JUNIOR ELECTRICAL ENGINEER. 25 years of age associate A. I. E. E. Graduate from Armour Institute of Technology, Chicago, with 2 years' experience in estimating and 8 years' practical experience in electrical construction and contracting, desires permanent connection with responsibility. Best of references, hard worker. Salary not primary object. Would prefer to connect with construction company or with a consulting engineer. E-4316.

ENGINEERING EXECUTIVE, B. E. in electricity from the Johns Hopkins University, Assoc. A. I. E. E. and Assoc. I. R. E., who is at present employed as manager of radio department of an electrical manufacturing organization, desires new connection because of reasons which can be satisfactorily explained. Has broad experience in both the execution of sales promotion plans and engineering design as applied to radio receiving instruments. Character and ability references of the best. Available on short notice. E-4317.

ELECTRICAL ENGINEER, experienced central station industry, experimental engineering laboratory, teacher of Electrical Engineering, former Ass't. Engineer, Bureau of Standards. Desires summer employment. Salary requirements moderate. Age 29 years, married. E-4318.

STUDENT in the second year of an evening course in electrical engineering, age 21, desires position in New York City with electrical concern offering advancement and training. Practical experience limited. E-4319.

ELECTRICAL ENGINEER technical graduate, age 34, married, desires position as Electrical Engineer with public utility or engineering firm. Comprehensive experience in design and construction of power plants, transmission and distribution systems. At present employed but available on reasonable notice. Salary $3000.00. E-4320.

ELECTRICAL MOTOR DESIGNER AND INDUSTRIAL APPLICATION ENGINEER, age 39, technical graduate, member A. I. E. E. Wide experience in designing and industrial applications of all types and sizes of induction motors, synchronous motors and small d-c. motors. Desires a position as designing, or industrial motor application engineer. Salary $3600 per year. E-4321.

ELECTRICAL ENGINEER. Age 32, Mem. A. I. E. E. and A. I. & S. E. E. 15 years' extraordinary electrical and mechanical experience along executive lines, with central station companies, contractors, spent 6 years as electrical engineer of one of the largest industrial plants in the country, embracing high-tension transmission, electrical precipitation, electro-metallurgy automatic and remote controlled cranes, hoists, locomotives lighting and power lay-outs. Can handle men and work demanding organizing ability. At present acting as field engineer and designing engineer with large manufacturer. Desires connection as engineer, supt. sales, etc. in the Pacific Northwest with the idea of permanency. E-4322.

PROFESSOR OF EXPERIMENTAL ENGINEERING. E. E. & M. E. 9 years commercial research and development. 2 years' teaching experience. Can organize department of Experimental Engineering or take charge of existing department. Location unimportant. E-4323.

ELECTRICAL ENGINEER, 37 years old; shop, test, inspection, design, development, and executive experience. Leaving, after 3½ years, a position requiring high literary and technical ability; organized and built up a department. Wishes permanent position. Eastern or Middle Western location preferred. E-4324.

ELECTRICAL ENGINEER, age 37. Experience with lighting and railway companies and consulting engineers office. Experience in analyzing operating problems and records. Preparation of valuations and statistics. Investigations, estimates and reports on power stations, transmission lines and general engineering problems. Drafting experience. Want to connect with utility where this experience will be of value. E-4325.

ELECTRICAL AND MECHANICAL ENGINEER, technical graduate, 12 years' experience, design, construction, test and maintenance, appraisal, etc. of electrical and mechanical equipments, desires connection with an industrial concern or consulting engineering firm within commuting distance of Newark, N. J. E-4326.

ENGINEER (M. E. and Ph. B. degrees,—specialized in electrical engineering); age 38, U. S. citizen; several years' practical experience; desires assistant professorship of electrical engineering in a university having a technical press where book publication of scientific and other manuscript already completed by the writer will be considered. E-4327.

ENGINEER EXECUTIVE. 19 years' manufacturing, engineering and business experience and sales work; especially familiar with motor and controller lines, and material handling. 7 years college training. Resourceful and accustomed to responsibility. E-4328.

ELECTRICAL ENGINEER, 10 years' experience in the operation and maintenance of electrical apparatus for public utilities and 2 years' engineering experience with a manufacturing company, desires a position with an industrial or power company. Available on short notice. E-4329.

ELECTRICAL ENGINEER. University graduate, with 12 years' experience with central station companies including design, construction and operation of transmission systems, distribution systems, substations and hydroelectric plants, desires job, either as assistant to executive or manager of public utility company, or on engineering and management staff of consulting engineering firm. E-4330.

PROFESSOR OF ELECTRICAL ENGINEERING. Member A. I. E. E., A. B. and M. E. E. from Harvard. Age 34. 14 years' teaching experience, 10 in present position. Desires to change to another teaching position. E-4331.

ENGINEER EXECUTIVE. Technical graduate with broad practical experience in the design, construction and operation of steam and hydroelectric plants and in the management of industrial property. Experienced in the combustion of coal, crude oil, wood and bagasse and in the maintenance of heavy mill machinery. Can handle men, obtain and hold their confidence and maintain harmonious relations between departments. Position desired with industrial plant or public utility. E-4332.

ELECTRICAL AND MECHANICAL ENGINEER, graduate of leading university; four years of electrical construction steel mills, substations and power plants; 3 years resident and office engineer with large public utility on transmission lines, steam, gas and refrigeration work, estimates and reports on new projects. Desires position identified with large expansion program, either utility or engineering firm. E-4333.

ELECTRICAL ENGINEER. Technical graduate, age 27, married, desires position as engineer with public utility corporation or engineering organization. One year Westinghouse graduate student course. 4 years on design and construction of distribution and power apparatus. Now employed. E-4334.

ELECTRICAL ENGINEER. Married, 37 years old. Having 17 years' active experience in design and operation with the largest concerns in the East. Now in responsible position. Desires to open negotiations with an active concern, where a man of executive and technical ability, integrity and reliability are prime factors. Only proposition of a permanent nature is considered. E-4335.

ELECTRICAL ENGINEER. Technical graduate, age 29, married. 3 years with Westinghouse Company in testing and engineering departments. Three years with large copper mining company in Chile, S. A. as general engineer in connection with operation of mine, mills, smelter, substations and power house. Speak Spanish and the Scandinavian language. Desire to engage in commercial engineering work, preferably with export company. Can be interviewed N. Y. end of July and western cities first part of September. Best of references. Available October 1st. E-4336.

MEMBERSHIP — Applications, Elections, Transfers, Etc.

ASSOCIATES ELECTED MAY 18, 1923

ABEY, HARRY RAYMOND, Instrument Maker, Leeds & Northrup Co., 4901 Stenton Ave., Philadelphia, Pa.

*ALFORD, REUEL S., Development & Research Dept., American Tel. & Tel. Co., 195 Broadway, New York, N. Y.; res., Phoenixville, Pa.

ALLEN, CHARLES FRANKLIN, Asst. Engineer, Planning Bureau, New York Edison Co., 327 Rider Ave., New York, N. Y.

*ANDERSON, HAROLD WILLIAM, Instructor, Electrical Engineering Dept., University of Kansas, Lawrence, Kan.

ANDERSON, WILLIAM A., Bethlehem Shipbuilding Corp., Quincy, Mass.

BAILEY, JAMES CLETUS, Electrical Draftsman, Commonwealth Edison Co., 72 W. Adams St., Chicago, Ill.

BALDWIN, JOHN R., Foreman, General Electric, Co., Boston Ave. & Bond St., Bridgeport, Conn.

BAMBER, WILLIAM R., Asst. Engineer, New York Telephone Co., 104 Broad St., New York, N. Y.

*BARCLAY, J. ROY, Electrical Tester, Commonwealth Edison Co., 28 N. Market St., Chicago, Ill.

BARROW, FREDERICK ANTHONY, Resident Engineer, Marconi Wireless Telegraph Co., Ltd., Louisburg, C. B. I., Can.

BERGMAN, EARL, Instructor, Auto Electrical Work, Youngstown Institute of Technology, 26 E. Rayen Ave., Youngstown, Ohio.

BISHOP, JAMES WALTER, Supt. of Substations, The Detroit Edison Co., 2000 2nd Ave., Detroit, Mich.

BLODGET, HUGH YOUNG, Engineer, 446 Cherry St., Elizabeth, N. J.

BOHN, DONALD IVAN, Industrial Control Engineer, General Electric Co., Schenectady, N. Y.

BOOZIER, CHARLES C., Power Salesman, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

BOWER, WILFRED HUBERT, Operator, Southern California Edison Co., Ltd., 359 Ave. 52 E., Los Angeles, Calif.

BRADFIELD, PAUL EDGAR, Designing Electrical Engineer, Southern California Edison Co., Los Angeles, Calif.

BREISCH, EDGAR W., Electrical Engineer Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

BRINTON, HOWARD T., Sales Dept., Habirshaw Electric Cable Co., 10 E. 43rd St., New York; res., Yonkers, N. Y.

BROKAW, GEORGE ALEXANDER, Inspector, Engineering Dept., Westchester Lighting Co., First Ave. & First St., Mt. Vernon, N. Y.

*BROWN, CAMPBELL ALEXANDER, Electrical Engineer, Duquesne Light Co., 501 Chamber of Commerce Bldg., Pittsburgh, Pa.

BURTON, EVERETT T., Engineer, Western Electric Co., 463 West St., New York; res., Elmhurst, N. Y.

BUSHFIELD, CHARLES HUNTER, Tax, Agent, The Ohio Power Co., 17-19 S. Park Place, Newark, Ohio.

CALLAHAN, VINCENT THOMAS, Power Engineer, Western Electric Co., 463 West St., New York; res., Bridgeport, Conn.

CALLAHAN, WILLIAM F., Engineering Dept., Western Union Telegraph Co., 195 Broadway, New York; res., Brooklyn, N. Y.

CAMERON, STANLEY MALCOLM, Superintendent, The Howard P. Foley Co., International Bldg., Washington, D. C.

CAMPBELL, FRANK W., Sales Engineer, Westinghouse Elec. & Mfg. Co., Cleveland, Ohio.

CAMPBELL, RICHARD DODGE, Engg. Assistant, The Chesapeake & Potomac Tel. Co., 725 13th St., N. W., Washington, D. C.

CARD, THOMAS BUELL, Electrical Engineer, Asst. Superintendent, Elec. Distr., Dayton Power & Light Co., Dayton, Ohio.

CHAPMAN, FRED INGALLS, Salesman, Westinghouse Elec. & Mfg. Co., 10 High St., Boston; res., Marblehead, Mass.

*CLARK, WILLIAM ARTHUR, Telephone Engineer, American Tel. & Tel. Co., 195 Broadway, New York, N. Y.

CLAYTON, ARTHUR E., Engineering Dept., New York Telephone Co., 104 Broad St., New York; res., Hempstead, N. Y.

CONOVER, ALBERT WALTON, Engineer, Distribution Dept., Virginia Ry. & Pr. Co., 7th & Franklin Sts., Richmond, Va.

COOVER, WILLIAM E., Production Engineer, Brooklyn Edison Co. Inc., 360 Pearl St., Brooklyn, N. Y.; res., East Orange, N. J.

CORNELL, OLIVER KENNETH, Asst. Engineer, Middleport Gas & Electric Co., Middleport, N. Y.

CORNFORD, FRED JAMES, Foreman, Electrical Construction, Beech Bottom Power Co., Wheeling, W. Va.

CRAWFORD, THOMAS G., Chief Draftsman, General Electric Co., Pittsfield, Mass.

CUNHA, STANLEY HERBERT, Electrical Engineer, Montreal Light Heat & Power Co., Power Bldg., Montreal, Que., Can.

CUNNINGHAM, THOMAS, Asst. Superintendent, Central Hudson Gas & Electric Co., 127 Broadway, Newburgh, N. Y.

DALINE, OSCAR LAWRENCE, Station Wireman, Portland Railway, Light & Power Co., Portland, Ore.

DAVIDSON, RAY V., Assistant Chief, Briggs Mfg. Co., Harper Plant, 1551 Harper Ave., Detroit, Mich.

DAVIS, WHEELER BAILEY, Engineer, Western Electric Co., 463 West St., New York, N. Y.; res., Hackensack, N. J.

DAVOUST, ALBERT, Draftsman, Inside Plan Div., Commonwealth Edison Co., Edison Bldg., Chicago, Ill

de GOEDE, Arian Hendricus, Electrical Engineer, Testing Dept., General Electric Co., Schenectady, N. Y.

DEMONET, EUGENE ALBERT, JR., Engineering Dept., Western Union Telegraph Co., 195 Broadway, New York, N. Y.

de SOUZA, ANTONIO RODRIGUES, Main Superintendent, Pernambuco Tramways & Power Co., Ltd., Pernambuco, Brazil, S. A.

DICKINSON, ERNEST, Electrician, Consolidated Mining & Smelting Co., Kimberley, B. C.

DICKSON, THOMAS HAVELOCK, Electrical Engineer, New Brunswick Power Co., 174 Duke St., St. John, N. B.; Picton, N. S., Can.

DOBBS, OSCAR, City Manager, City of Nowata, Nowata, Okla.

DONELSON, LEROY EARL, Telephone Engineer, The Pacific Tel. & Tel. Co., 1413-J St., Sacramento, Calif.

DORAN, JAMES PATRICK, Telephone Engineer, The Bell Telephone Co. of Canada, 118 Notre Dame St., W., Montreal, P. Q., Can.

DUNCANSON, WALTER WALLACE, Station Operator, Bureau of Power & Light, City of Los Angeles, 951 Dewey Ave., Los Angeles, Calif.

EERNISSE, JAMES GUY, Asst. Electrical Engineer, Cushman Power Project, City Hall Annex, Tacoma, Wash.

ERBEN, HENRY V., Proposal Engineering, Lighting Engg. Dept., General Electric Co., Schenectady, N. Y.

FAIRGRIEVE, ROBERT PHYTHIAN, Insulation Engineer, Westinghouse Elec. & Mfg. Co., Rice Bldg., 10 High St., Boston; res., Brookline, Mass.

FARRAR, CARLOS ALONZO, Electric Meter Tester, Bureau of Power & Light, 211 E. Powers St., Los Angeles, Calif.

FITZGERALD, ROBERT LOUIS, R. M. Feustel & Co., 406 Carrol Bldg., Ft. Wayne, Ind.

FLANNERY, NEIL G., Asst. Electrician, Pacific Cable Board, Dennis Bldg., Halifax, N. S., Can.

FOGLER, FLORENCE, Turbine Calculator, Turbine Engg. Dept., General Electric Co., Schenectady, N. Y.

FOLAND, HARRY S., Long Lines Engineering Dept., American Tel. & Tel. Co., 195 Broadway, New York, N. Y.

FRASER, ROBERT ALLAN, Engineer, Arkwright Mutual Fire Insurance Co., 185 Franklin St., Boston, Mass.

FRASHER, GEORGE, Estimator, Engg. Bureau, Brooklyn Edison Co., Inc., 561 Grand Ave., Brooklyn; res., New York, N. Y.

FREDERICK, W. H., Electrical Engineer, Fargo Engineering Co., Jackson, Mich.

FREED, IRVIN, Operator, Consolidated Gas, Electric Light & Power Co. of Baltimore, Custom House Substation, Baltimore, Md.

*FREEZEE, WALTER D., Engineer, American Tel. & Tel. Co., 230 E. Grand River Ave., Detroit, Mich.

FRISBEE, JOSEPH ELLIOT, Equipment Supervisor, Western Union Telegraph Co., 175 Congress St., Boston, Mass; res., Portsmouth, N. H.
FROST, WILLIAM S. M., Plant Wire Chief The Chesapeake & Potomac Telephone Co., 817 Church St., Lynchburg, Va.
GARAHAN, STEPHEN J., Wire & Cables Sales, General Electric Co., Schenectady, N. Y.
GEROLD, FRANK G. M., Engineering Asst., The Western Union Telegraph Co., 195 Broadway, New York, N. Y.
GIBSON, LEONARD O., Electrician & Mechanic, Centralia, Ill.
GORDON, WALTER RAYMOND, General Radio, Cambridge; res., Boston, Mass.
GOUGH, WILLIAM JAMES, Chief Electrical Inspector, Sperry Gyroscope Co., Brooklyn; res., Sea Cliff, N. Y.
GOULD, WILLIAM I., Electrician, Pennsylvania Power & Light Co., 1129 Hamilton St., Allentown, Pa.
GOWAN, ARTHUR JEWELL, Electrical Engineer, General Electric Co., Federal St., W. Lynn; res., Lynn, Mass.
GRAVES, HERBERT CORNELIUS, JR., Automatic-Motor-Generator Set Installation & Maintenance, Union Gas & Electric Co., Cincinnati, Ohio.
GREEN, ESTILL I., Electrical Engineer, D. & R. Dept., American Tel. & Tel. Co.,195 Broadway, New York, N. Y.
GREENWAY, FRED NATHAN, Chief Electrician, Shepard Art Metal Co., 2700 Junction Ave., Detroit, Mich.
GRUNINGER, ANDREW F., Lighting Engineer, Beller Electric Supply Co., 283 Market St., Newark; res., East Orange, N. J.
HAHN, HERBERT JOHN, Wetsern Eecltric Co., Inc., 281 Washington St., Newark, N. J.
HANSON, J. WILLIS M., Instrument Maker, Leeds & Northrup Co., 4901 Stenton Ave., Philadelphia; res., Germantown, Philadelphia, Pa.
HARRIS, ALEXANDER W., Electrical Engineer, Westinghouse Elec. & Mfg. Co., 717 So. 12th St., St. Louis, Mo.
HART, C. D., Asst. Supt. of Development, Western Electric Co., Inc., Hawthorne Sta., Chicago; res., La Grange, Ill.
HARTMANN, RICHARD W., Teacher, Electrical Construction, Philadelphia Public Schools, Cedar & York Sts., Philadelphia, Pa.
HAYMAN, WILLIAM GEORGE I., Asst. Engineering Lecturer, Perth Technical School, Perth, Western Australia.
*HENNEQUIN, J. H., Engineer, Union Gas & Electric Co., 4th & Plum Sts., Cincinnati, Ohio.
HENRICKSON, WILLIAM S., Plant Engineer, Reed & Prince Mfg. Co., Duncan Ave., Worcester, Mass.
HERBIG, HENRY FRANK, Research Engineer, Postal Tel. & Cable Co., 253 Broadway, New York; res., Brooklyn, N. Y.
*HERKNER, CLARENCE GUSTAVE, Student, University of California, Berkeley; res., San Diego, Calif.
HIROSE, KEIICHI, Electrical Engineer, Shibaura Engineering Works, Shibaku, Tokyo. Japan.
HOLDCRAFT, JOHN M., Night Wire Chief, The Ohio Bell Telephone Co., 6205 Carnegie Ave., Cleveland, Ohio.
HOLMSEN, REIDAR, Diplomingeneer, Victor X-Ray Corp. and Head Examiner, Norwegian State, Drammensveien 4, Christiania, Norway.
HOPFEN, BERNARD, Engineering Salesmen, Prometheus Elec. Co., 360 W. 13th St., New York, N. Y.
HOSCHKE, WILLIAM BISMARK, West Penn Power Co., Kittanning, Pa.
HUTCHINS, CHARLES CLEON, Engineer, Power Dept., Westinghouse Elec. & Mfg. Co., East Pittsburgh; res., Wilkinsburg, Pa.
*HYNEMAN, JOHN RAYMOND Engineering Dept., Western Union Telegraph Co., 195 Broadway, New York, N. Y.
INGBERG, JOHN EDWARD, Electrical Engineer, Switchboard Dept., General Electric Co., Schenectady; res., Scotia, N. Y.
INGELS, CLARENCE W., Computer, Ordnance Drafting Room, U. S. Navy Yard, Washington, D. C.
JACKSON, GEORGE A., Electrical & Mechanical Engineer, Gamewell Fire Alarm & Telegraph Co., Newton Upper Falls; res., Waltham, Mass.
JANSSEN, GEORGE, Power Plant Engineer, Illinois Central Railway, Centralia. Ill.
JOHANSEN, JOHANNES, Chief Operator Fruitvale Power Station, Southern Pacific Co., Oakland, Calif.
JONES, G. RANDOLPH, Junior Equipment Engineer, Durant Motors of Canada, Ltd., Leaside, Ont., Can.
KASSENBROCK, CHRISTOPHER A., Asst. Chief, Electrical Div., Bureau of Mtce. Board of Education, City of New York, 131 Livingston St., Brooklyn, N. Y.
KATZ, ABRAHAM, Asst. Manager & Salesman, 73 Portland St., Boston; res., Chelsea, Mass.
KEITH, JOHN TAIT, Switchboard Wiring & Power House Construction, Spanish River Pulp & Paper Co., Sturgeon Falls, Ont. Can.
KENNEDY, CLIFTON DOUGLAS, Instructor, Coyne Engineering School, 1300 W. Harrison St., Chicago, Ill.
KOGA, ISAAC, Student, Electrical Engineering Dept., Tokyo Imperial University, Tokyo, Japan.
KUSANO, HIDEO, Electrical Engineer, Shibaura Engineering Works. Shiba Ku, Tokio, Japan.
LANE, RAYMOND ANDREW, Static Condenser Design, Westinghouse Elec. & Mfg. Co., East Pittsburgh; res., Wilkinsburg, Pa.
LEE, VICTOR L., Asst. Foreman, W. F. Schrafft & Sons, Inc., Charlestown; res., Everett, Mass.
LEWIS, NEWTON ALBERT, Journeyman, Berkshire Electric Co., Pittsfield, Mass.
LITTLETON, JESSE TALBOT, JR., Chief, Physical Laboratory, Corning Glass Works, Corning, N. Y.
LORMANN, ROBERT, Telephone Engineer, Ohio Bell Telephone Co., 4300 Euclid Ave., Cleveland, Ohio.
LOVELL, WILLIAM DOUGLAS, Deputy Electrical Supt., Cleveland & Durham Elec. Pr. Ltd., Middlesborough, Yorkshire; res., Billingham, Stockton-on Tces, Eng.
LUBERT, CHARLES G., Electrical Contractor, 73 Cranberry St., Brooklyn, N. Y.
MACY, RALPH GERARD, Chief Contract Engineer, Public Service Production Co., 80 Park Place, Newark, N. J.
MAHER, GEORGE FRANCIS, Service Engineer, Westinghouse Elec. & Mfg. Co., 12 Farnsworth St., Boston, Mass.
MALLORY, ROY, General Tester, Central Dist., Western Electric Co., 4300 Euclid Ave., Cleveland, Ohio.
*MANNEBACK, CHARLES, Teacher, University of Louvain, 27 Rue de la Tourelle, Brussels, Belgium.
MATHER, WALDO EMERSON, Shop Foreman & Vice-President, Electric Heating & Mfg. Co., Westlake & Republican, Seattle, Wash.
McCREA, HUGH A., Electrical Engineer, Lighting Engg. Dept., General Electric Co., Schenectady, N. Y.
McDOUGALL, DANIEL JOHN, 1510 Zenobia St., Denver, Colo.
McKINSTRY, SAMUEL, General Foreman, Motor Work, General Electric Co., Bridgeport, Conn.
McMICHAEL, FRANK HERRINGTON, Transformer Tester, Duquesne Light Co., Oakland Laboratory, Pittsburgh, Pa.
MERWIN, ELWOOD AUGUSTUS, Engineer, Electric Industrial Trucks, The Yale & Towne Mfg. Co., Stamford; res., Bridgeport, Conn.
MILLS, EDWARD A., Asst. Chief Electrician, American Smelting & Refining Co., 4th & Douglas St., Omaha, Neb.
MILLS, HARRY OSBORNE, Electrical Draftsman, Power Station Equipment, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
MOLYNEAUX, HENRY ANABLE, Salesman, Roberts Electric Supply Co., Electric Bldg., Syracuse, N. Y.
MOORE, DAVID A., Superintendent, Electrical Constr., Fred T. Ley & Co., Inc., 495 Main St., Springfield, Mass.
*MORISUYE, MASA MASANOBU, Graduate Student, Cornell University, 113 Dryden Road, Ithaca, N. Y.
*MURDOCH, PAUL STEIN, Sales Dept., Crocker-Wheeler Co., Ampere; res., Newark, N. J.
MUROZUMI, KUMAZO, Professor of Electrical Engineering, Meiji College of Technology, Tobata, Japan; for mail, Ithaca, N. Y.
MURRAY, GEORGE HENRY, Power Director, Eastern Connecticut Power Co., 617 Main St., Norwich, Conn.
NAETER, ALBRECHT, Instructor in Electrical Engineering, Cornell University, Ithaca, N. Y.
NAITOW, YOSO, Electrical Engineer, Okumura Electric Mfg. Co., Kyoto, Japan.
NAWN, JOHN A., Electrician, 60 Pearl St., Boston; res., Dorchester, Mass.
NELLES, ROY, Engineering Assistant, Western Union Telegraph Co., 195 Broadway, New York, N. Y.
NEWHALL, RALPH P., Research Physicist, Thomson Research Laboratory, General Electric Co., Lynn, Mass.
NORBERG, CLIFFORD MUNTHE, Experimental Electrical Engineer, Domestic Electric Co., 7209 St. Clair Ave., Cleveland, Ohio.
NULSEN, WILLIAM B., Switchboard Engineering Dept., General Electric Co., Schenectady, N. Y.
NUNN, DARRELL, 538 S. Oak Park Ave., Oak Park, Ill.
ORMEROD, HAROLD FRED, Laboratory Assistant, Habirshaw Elec. Cable Co., Yonkers, N. Y.
OVERBECK, HERMANN G., Asst. Manager, Electrical Dept., Mine & Smelter Supply Co., 1422—17th St., Denver, Colo.
*PARKER, FRANK HAROLD, Chief Engineer of Plant, Engineering Supervision Co., 280 Madison Ave., New York, N. Y.
PATEL, PHIRONZE ERACHSHAW, Managing Partner, Messrs. P. Patel & Co., Khandke House, Chawpaty, Bombay, India.
PAULSON, CARL G., Salesman, Westinghouse Elec. & Mfg. Co., 10 High St., Boston, Mass.; res., Providence, R. I.
PEARSON, ERNEST, Electrician, Columbus Railway Power & Light Co., Columbus, Ohio.
PECKHAM, JOHN J., General Foreman, Installation Dept., Western Electric Co., Inc., 4300 Euclid Ave., Cleveland, Ohio.
PENNY, HENRY BATTENBERG, Dist. Inspector of Electricity, Canadian Govt., Public Bldg., Nelson, B. C., Can.
PETERSON, ANDREW, Asst. Instructor, New York University, College of Engg., University Heights, New York, N. Y.
*PETIT, FRANCIS W., Control Engineer, Westinghouse Elec. & Mfg. Co., East Pittsburgh; res., Wilkinsburg, Pa.
PHELPS, BOYD, Asst. Editor, "QST," 1045 Main St., Hartford, Conn.

*PINOKARD, FRANK ELLIS, Engineer, Underground Dept., United Gas & Electric Co., Cincinnati, Ohio.

POHNAN, FRANK J., Testing Engineer, Commonwealth Edison Co., 28 N. Market St., Chicago, Ill.

PRIEST, LUCIAN CHARLES, Motor Tester, General Electric Co., Lynn; res., Charlestown, Mass.

PULHAM, WILFRED WALTER, Automatic Chief, Western Union Telegraph Co., 702 Railway Exchange Bldg., Denver, Colo.

PURDY, HARRY EARL, JR., Laboratory Assistant, Habirshaw Electric Cable Co., Yonkers, N. Y.

PURSELL, LEIGHTON COLEMAN, Asst. Statistician, Pennsylvania Power & Light Co., 802 Hamilton St., Allentown, Pa.

RALSTON, FRED W., Street Lighting Dept., General Electric Co., Lynn, Mass.

*REDMON, ROY SHAFTER, Chief Draftsman, Union Gas & Electric Co., Front & Rose Sts., Cincinnati, Ohio.

REY, WALTER JOS., Mechanical Engineering Dept., Chicago, Milwaukee & St. Paul Ry. Co., Milwaukee, Wis.

*RHODES, HAROLD ANSON, Equipment Attendant, American Tel. & Tel. Co., 24 Walker St., New York, N. Y.; res., Ridgefield Park, N. J.

RICE, BURLEIGH LEROY, Station Chief, Chino Substation, Southern California Edison Co., Chino, Calif.

RITTER, EDWARD L., Div. Supervisor of Mtce., Western Union Telegraph Co., 515 Bankers Investment Bldg., San Francisco, Calif.

ROBESON, C. E., Division Foreman, Western Electric Co., 4300 Euclid Ave., Cleveland, Ohio.

ROBINSON, LYLE BRADFORD, Electrical Engineer, Transformer Sales Dept., General Electric Co., Pittsfield, Mass.

ROY, JOSEPH ERNEST, Electrician, New England Mica Co., 66 Woerd Ave., Waltham; res., Newton, Mass.

RYSTEDT, SVEN E., Draftsman, Adirondack Power & Light Co., Schenectady, N. Y.

SALTMARSH, WILLIAM, Secretary & Manager, The McGraw Co., 2018 Locust St., St. Louis, Mo.

SANDESON, STEPHEN EDWARD, Salesman, Hendrie & Bolthoff Mfg. & Supply Co. Denver, Colo.

SCHMIDT, ALWIN, Switchboard Engineer, Westinghouse Elec. & Mfg. Co., 12 Farnsworth St., Boston; res., Clinton, Mass.

SCHOLL, CHESTER CHARLES, Asst. to Chief Engineer, Belden Mfg. Co., 2300 S. Western Ave., Chicago, Ill.

*SCHULTZ, BYRON WILLIAM, Outside Plant Engineering, American Tel. & Tel. Co., 311 W. Washington St., Chicago, Ill.

SCHWENNICKE, OTTO ALBIN, Transmission Engineer, Pacific Tel. & Tel. Co., 740 So. Olive St., Los Angeles, Calif.

SHERMAN, MAURICE, Tester, Bloomfield Wks, General Electric Co., Bloomfield, N. J.

SHIFFLETT, BERT RICHARD, Engineer, Northern Iowa Gas & Electric Co., Emmetsburg, Iowa.

SILL, HAROLD D., Electrical Inspector, Beech Bottom Power Co., Power, W. Va.

SKRETTING, ALMER, Asst. Switchboard Engineer, The Milwaukee Electric Railway & Light Co., Milwaukee, Wis.

SLADE, FRANK LESLIE, Sales Engineer, Roth Bros. & Co., 1400 W. Adams St., Chicago, Ill.

SMYTHE, JAMES DOUGLAS, Telephone Engineer, American Tel. & Tel. Co., 195 Broadway, New York, N. Y.

SNYDER, SHEBA Q., Asst. General Foreman, Brooklyn Edison Co., 251 Clinton St., Brooklyn, N. Y.

SOPER, ROBERT HAYWARD, Chief Electrical Engineer, Antonio Perez S. en C. Central Cespedes, Camaguey, Cuba.

SORENSON, CHARLES NELSON, Meter Engineer, Lee Electric Co., Clarinda, Iowa.

*SOULE, CLAYTON E., Motorman, Oklahoma Gas & Electric Co., Drumright, Okla.

*SPENCER, RHODES V., Substation Operator, City Light Dept., Seattle, Wash.

*SUMMERVILLE, ALAN OLIVER, Student Engineer, General Electric Co., West Lynn; for mail, Jamaica Plain, P. O., Mass.

SUTHERLAND, ROBERT GRAY, Chief Engineer, Cuban Portland Cement Corp., Cayo Mason, Pinar del Rio, Cuba.

TEPEL, HERMAN A., Electrical Estimator & Superintendent of Constr., Dingle-Clark Co., 436 Engineers Bldg., Cleveland, Ohio.

*TERRY, GERARD WILLIAMSON, Technical Employee, American Tel. & Tel. Co., 152 Temple St., New Haven, Conn.

THOMAS, HARRY MERRIMAN, H. M. Thomas Co., 708 Oakland Bank Bldg., Oakland, Calif.

TRIPP, WILLIAM A., Research Assistant, River Wks., General Electric Co., Lynn; res., Malden, Mass.

TURNER, CHARLES C., Asst. to Transformer Sales Manager, General Electric Co., Pittsfield Mass.

VEIT, WILLIAM A., JR., Asst. Superintendent, L. Kalischer, Inc., 288 Livingston St., Brooklyn, N. Y.

VOELCKER, JOHN WESTGARTH, Graduate Student, Massachusetts Institute of Technology, Cambridge; res., Boston, Mass.

VOELKER, WALTER RICHARD; res., 223 W. 79th St., New York, N. Y.

VOGELMAN, JACK, Underground Elec. Dept., Pacific Gas & Electric Co., 518—13th St., Oakland; res., Piedmont, Calif.

VOLLAND, ROLAND ALVIN, Transformer Tester, Moloney Electric Co., 7th Hickory St., St. Louis, Mo.

WAGNER, HARRY EWING, Electrician, Portland Railway, Light & Power Co., Portland, Ore.

WALLOF, ARTHUR LOUIS, Shop Foreman, Sterling Electric Co., 33 S. 5th St., Minneapolis, Minn.

WALSH, JOHN ROYAL, Plant Engineer, New York Telephone Co., 81 Willoughby St., Brooklyn, N. Y.

WARREN, ARTHUR JOSEPH, Electrical Engg. Draftsman, Dept. Gas & Electricity, City of Chicago, 614 City Hall, Chicago, Ill.

WATROUS, ROYAL ERNEST, Power Director, Eastern Connecticut Power Co., Montville Power Station, Uncasville, Conn.

WATSON, HOWARD EDWARD, Electrical Draftsman, Brooklyn Edison Co., 360 Pearl St., Brooklyn; res., New York, N. Y.

WERNER, JOHN FRANCIS, Junior Engineer, New York & Queens Elec. Lt. & Pr. Co., Bridge Plaza, Long Island City; res., Hicksville, N. Y.

WHITE, WILLIAM COMINGS, Engineer, Research Laboratory, General Electric Co., Schenectady, N. Y.

WHITELY, FRED, Electrical Engineer, Eastern Wisconsin Electric Co., 15 N. Main St., Fond du Lac, Wis.

*WILLBY, NORMAN HUDSON, Railway Engineer, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

WILLE, HENRY E., Load Dispatcher, Puget Sound Power & Light Co., 600 Electric Bldg., Seattle, Wash.

WILLIAMS, CHARLES K., Superintendent, Reliance Electric Co., 1088 Ivanhoe Road, Cleveland, Ohio.

WILLIAMSON, ANDERSON ROY, Turbine Generator Tester, Westinghouse Elec. & Mfg. Co., 646 Saude Ave., Essington, Pa.

WILSEY, FAY F., Div. Foreman, Western Electric Co. of Chicago, 225 E. 4th St., Cincinnati; for mail, Cleveland, Ohio.

WILSON, BENNETT D., Superintendent of Maintenance, Kentucky Utilities Co., Middlesboro, Ky.

WOLFORD, JAMES EARL, Electrician, Wheeling, W. Va.

YATES, CLARENCE CARPENTER, Assoc. Professor, Electrical Engg. Dept., Agricultural & Mechanical College of Texas, College Station, Texas.

YOST, DANIEL M., General Manager, Edmonds Independent Telephone Co., Edmonds, Wash.

Total 214.

*Formerly Enrolled Students.

ASSOCIATES RE-ELECTED MAY 18, 1923

CHAMPREUX, ALFRED JOSEPH, Transmission Engineer, The Pacific Tel. & Tel. Co., 505 Sheldon Bldg., San Francisco, Calif.

DAY, THOMAS HENRY, Electrical Engineer & Electrical Inspector, New England Insurance Exchange, 141 Milk St., Boston, Mass.; res., Hartford, Conn.

HUSSEY, RICHARD B., Physicist, Street Lighting Dept., River Wks., General Electric Co., West Lynn, Mass.

MASTICK, REUBEN WOOD, Engineer, Pacific Tel. & Tel. Co., 513 Sheldon Bldg., San Francisco, Calif.

NOACK, HARRY RICHARD, Vice-President, Pacific States Electric Co., 575 Mission St., San Francisco, Calif.

OKEY, PERRY, Proprieter, The Okey Mfg. Co., Maghten & Water Sts., Columbus, Ohio.

REILLY, WILLIAM F., President, Hub Engineering Corp., 352 W. 50th St., New York, N. Y.

RUNYON, J. C., Consulting Engineer, Carrere & Hastings, 52 Vanderbilt Ave., New York, N. Y.; res., Port Monmouth, N. J.

MEMBERS ELECTED MAY 18, 1923

BASCOME, GEORGE LIGHTBOURN, Chief Engineer, United Service Corp., 700 Scranton Life Bldg., Scranton, Pa.

BEST, FRED HELLER, Telephone Engineer, American Tel. & Tel. Co., 195 Broadway, New York, N. Y.

BOWMAN, FRANCIS HILL, Electrical Engineer, General Electric Co., West Lynn, Mass.

CASPER, LOUIS, General Inspector, Western Union Telegraph Co., 195 Broadway, New York, N. Y.

HENRICI, HERMAN C., Consulting Engineer, 222 Commerce Bldg., Kansas City, Mo.

HUBER, HAROLD LEIGH, Engineering Asst. Chesapeake & Potomac Tel. Co., 725-13th St., N. W., Washington, D. C.

NEEDHAM, ROBERT JAMES, Mechanical & Electrical Engineer, Grand Trunk Railway System, Montreal, Que., Can.

ROY, SURENDRA KUMAR, Chief Electrical Engineer, Indian Steel Wire Products, Ltd., Jamshedpur, India.

SMALL, FRED F., Mechanical Supt., Pacific Electric Railway, 728 Pacific Electric Bldg., Los Angeles, Calif.

WATSON, FRANK C., Electrical Superintendent The International Nickel Co., Huntington, W. Va.

WILSON, WILLIAM, Electrical Engineer, Western Electric Co., Inc., 463 West St., New York, N. Y.; res., Maplewood, N. J.

TRANSFERRED TO GRADE OF FELLOW MAY 18, 1923

RUNYON, FREDERICK O., Senior Partner, Runyon & Carey, Newark, N. J.

TRANSFERRED TO GRADE OF MEMBER MAY 18, 1923

HAMMATT, CLARENCE S., President, Consolidated Engineering Co., Jacksonville, Fla.

KEELER, HUGH E., Assistant Professor of Mechanical Engineering, University of Michigan, Ann Arbor, Mich.

KRAUSNICK, WALTER, Associate Professor of Electrical Engineering, College of Engineering, Newark Technical School, Newark, N. J.

MERRIAM, EZRA B., Executive Engineer, Switchboard Dept., General Electric Co., Schenectady, N. Y.

READ, WILLIAM G., Engineer-Accountant, Public Utilities Commission, State of Kansas, Topeka, Kans.

RECOMMENDED FOR TRANSFER

The Board of Examiners, at its meeting held May 14, 1923, recommended the following members of the Institute for transfer to the grades of membership indicated. Any objection to these transfers should be filed at once with the Secretary.

To Grade of Fellow

KLAUBER, LAURENCE M., Vice-President & General Superintendent, San Diego Consolidated Gas & Electric Co., San Diego, Calif.

To Grade of Member

CLOUD, FREDERICK W., Engineer & Contractor, Los Angeles, Calif.

FEY, WILLIAM L., Assistant Engineer, Board of Commissioners of the Port of New Orleans, New Orleans, La.

FOWLER, T. R., Assistant Chief Engineer, Kinloch Telephone Co., St. Louis, Mo.

GASKILL, JOSEPH F., Power Engineer, Philadelphia Electric Co., Philadelphia, Pa.

HOUSTON, ROBERT, Resident Electrical Engineer, Water Conservation & Irrigation Commission, Leeton, N. S. W., Australia

MACY, HENRY D., Field Engineer, Westinghouse Electric & Mfg. Co., New York, N. Y.

MARTINI, UMBERTO E., Administrateur Delegue & Directeur General, Societa Generale Italiano Imprese Elettriche, Rome, Italy

MIX, MARTIN I., Assistant Superintendent of Pressure, Peoples Gas, Light & Coke Co., Chicago, Ill.

RATHBUN, HARRY J., Vice-President & Treasurer, Colin B. Kennedy Corp., St. Louis, Mo.

RATHGEB, CHARLES C., Superintendent of Construction, L. K. Comstock & Co., New York, N. Y.

REINHOLDT, PAUL H., Electrical Engineer, Iowa Light, Heat & Power Co., and Consumers Electric Co., Carroll, Ia.

VICTORY, THORNTON M., Electrical Engineer, Havana Electric Railway, Light & Power Co., Havana, Cuba

WINDERS, FRANK R., Assistant Engineer, National Electric Light Association, New York, N. Y.

WOHLGEMUTH, M. J., Switchboard Engineer, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

APPLICATIONS FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated, the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before June 30, 1923.

Albert, W. A., West Penn Power Co., Pittsburgh, Pa.
Alden, D. W., Blackstone Valley Gas & Electric Co., Woonsocket, R. I.
Allen, C. M., Bureau of Power & Light, Los Angeles, Calif.
Anckers, N. J. H., Radio Corp. of America, Riverhead, N. Y.
Anderson, J. H., Newberry Electric Corp., Los Angeles, Calif.
Armstrong, G. O., Spanish River Pulp & Paper Mills, Smoky Falls, Ontario, Can.
Ashworth, J. J., Canadian General Electric Co., Toronto, Ont.
Bancker, E. H., General Electric Co., Schenectady, N. Y.
Barrett, W. M., Buckeye Steel Castings Co., Columbus, Ohio
Basta, C., Brooklyn Edison Co., Brooklyn, N. Y.
Bedell, W. B., American Tel. & Tel. Co., New York, N. Y.
Bernard, J. B., S. California Edison Co., Los Angeles, Calif.
Black, D. C., J. G. White Engineering Corp., New York, N. Y.
Bloomquist, E. G., Western Electric Co., Chicago, Ill.
Boggess, M. M., General Electric Co., Kansas City, Mo.
Bonneville, S., Bell Telephone Co. of Canada, Montreal, Canada
Bremner, J. A., Canadian General Electric Co., Toronto, Ont.
Burleigh, D. P. (Member), General Electric Co., New York, N. Y.
Burtt, E. J., Hodenpyl, Hardy & Co., Consumers Pr. Co., Jackson, Mich.
Bush, H. F., Bell Telephone Co. of Canada, Montreal, Canada
Cassell, R. L., Southern Power Co., Charlotte, N. C.
Chesholm, T. W., New York Telephone Co., New York, N. Y.
Cleaves, B. F., Penn Central Light & Power Co., Altoona, Pa.
Corcoran, T. F., (Member), Appraisal Engineer, New York, N. Y.
Craiglow, H. H., (Member), The Buckeye Steel Castings Co., Columbus, Ohio
Dans, M. W., New York Edison Co., New York, N. Y.
De Baum, H. J., E. L. Phillips & Co., New York, N. Y.
De Camp, S. M., General Electric Co., Kansas City, Mo.
Densmore, U. H., Western Electric Co., Chicago, Ill.
Dickey, C. F., Erie Lighting Co., Erie, Pa.
Dickson, A. C., Emerson Electric Mfg. Co., St. Louis, Mo.
Downs, B. W., St. Paul Electric Co., St. Paul, Minn.
Dudrear, A. C., William H. Taylor & Co., Allentown, Pa.
Dueland, R., Electric Bond & Share Co., New York, N. Y.
Dyment, A. E., Canadian General Electric Co., Toronto, Ont.
Elshoff, R. H., West Penn Power Co., Pittsburgh, Pa.
Eskil, W. A., Westinghouse Elec. & Mfg. Co., Brooklyn, N. Y.
Fischer, R., Union Electric Mfg. Co., Philadelphia, Pa.
Flanigan, J. M., (Member), The Ohio Public Service Co., Alliance, Ohio
Gilmore, C. T., The Ohio Utilities Co., Circleville, Ohio
Glatz, H., The Cleveland Metal Products Co., Cleveland, Ohio
Granger, G., Hershey Cuban Railway, Hershey, Cuba
Griffin, R. A., Western Electric Co., Chicago, Ill.
Haigh, R. A., Paducah Electric Co., Paducah, Ky.
Hall, W. N., General Electric Co., Schenectady, N. Y.
Harrington, O. J., Portland Railway, Light & Power Co., Portland, Ore.
Hartman, H. R., The Electric Power Equipment Co., Columbus, Ohio
Hearn, R. L., (Member), Washington Water Power Co., Spokane, Wash.
Holden, O. W., Bureau of Power & Light, Los Angeles, Calif.
Hurst, R. O., General Electric Co., Ft. Wayne, Ind.
Hutter, F. X., Western Electric Co., Chicago, Ill.
Jamieson, R., Western Electric Co., Inc., Detroit, Mich.
Jeong, J. Y., Cleveland Railway Co., Cleveland, Ohio
Jermain, H. F., Winchester Repeating Arms Co., New Haven, Conn.
Juergens, C. E., Stone Electric Co., St. Paul, Minn.
Keeler, W. H. E., General Electric Co., New York, N. Y.
Kelley, C. B., Kansas City Power & Light Co., Kansas City, Mo.
Kennedy, J. J., (Member), Pyle National Co., Chicago, Ill.
Krulikowski, H. J., Brooklyn Edison Co., Brooklyn, N. Y.
Leiner, W. J., So. California Tel. Co., Los Angeles, Calif.
Lerch, F. S., Westinghouse Electric & Mfg. Co., E. Pittsburgh, Pa.
Lindlof, F. A., Western Union Tel. Co., Los Angeles, Calif.
Lohr, C. P., Automatic Reclosing Circuit Breaker Co., St. Louis, Mo.
Love, H. W., Columbus Railway, Power & Light Co., Columbus, Ohio
Lundgren, W. B., Weirton Steel Co., Weirton, W. Va.
Lusk, S. W., Standard Oil Co., Linden, N. J.
Lynn, J. T., Hudson Coal Co., Scranton, Pa.
Mamartcheff, D., 628 E. 5th St., New York, N. Y.
McCarthy, J. B., International Nickel Co., Copper Cliff, Ontario
McCollom, J. G., Inter-Mountain Electric Co., Salt Lake City, Utah
McCormick C. M., (Member), University of Colorado, Boulder, Colo.
McCormick, E. L., Western Electric Co., New York, N. Y.
McFarland, I. E., Merchants' Refrigerating Co., New York, N. Y.
McNally, F. E., Alexandria Light & Power Co., Alexandria, Va.
Moorman, H. T., Jefferson Electric Mfg. Co., Chicago, Ill.
Morris, E. P., Bell Telephone Co. of Penna., Philadelphia, Pa.
Morris, S. B., Electrical Testing Laboratories, New York, N. Y.
Moynahan, P. O., New York Tel. Co., New York, N. Y.
Murnane, T. A., Erner & Hopkins Co., Columbus, Ohio
Murphey, C. W., Erner & Hopkins Co., Columbus, Ohio
Padalino, F., (Member) University of Detroit, Detroit, Mich.
Passburg, V. Jack H., General Electric Co., Schenectady, N. Y.
Pederson, P. R., Stone & Webster, Inc., Boston, Mass.
Perly, L. A., Pacific Gas & Electric Co., San Francisco, Calif.
Phillips, S., Electrician, Portland, Ore.
Porter, J. C., General Electric Co., Ft. Wayne, Ind.
Potter, E. E., Western Electric Co., New York, N. Y.
Procter, J. H., Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.
Reeve, C. H., Hibbing High School & Jr. College, Hibbing, Minn.
Reid, K. M., National Lamp Works, Gen. Elec. Co., Nela Park, Cleveland, Ohio
Rike, F. L., Chief Engr., Ohio Penitentiary, Columbus, Ohio
Rogers, W. H., Iron City Engineering Co., Columbus, Ohio
Rogge, H. H., Westinghouse Elec. & Mfg. Co., New York, N. Y
Schumaker, W. T., c/o J. O. Mills, Columbus, Ohio
Scott, S. M. Jr., Butler Bros., Brooklyn, N. Y.
Shoemaker, R. L., Buckeye Steel Castings Co., Columbus, Ohio

Shuman, M., Alexandria Light & Power Co., Alexandria, Va.
Sims, C. E., West Penn Power Co., Pittsburgh, Pa.
Smith, Paul H., (Member), Brooklyn Edison Co., Brooklyn, N. Y.
Smith, Platt H., Brooklyn Edison Co., Brooklyn, N. Y.
Smith, W. A., Ohio Insulator Co., Barberton, Ohio
Solomon, W. J., Penn.-Ohio Power & Light Co., Youngstown, Ohio
Stanley, R. M., (Fellow), Byllesby Engg. & Management Corp., Chicago, Ill.
Stone, D. D., Public Service Electric Co. of N. J., Hackensack, N. J.
Stone, Leland, General Electric Co., New York, N. Y.
Styff, E., Adirondack Power & Light Corp., Amsterdam, N. Y.
Svendsen, G. P., Boustead Electric & Mfg. Co., Minneapolis, Minn.
Thompson, E. F., Duquesne Light Co., Pittsburgh, Pa.
Tyrrell, C. J., Raritan Copper Works, Perth Amboy, N. J.
van der Stempel, T. M., Commonwealth Edison Co., Chicago, Ill.
Waedekin, C. W., Allis-Chalmers Mfg. Co. W. Allis, Wis.
Warren, E. R., Rochester Gas & Electric Co., Rochester, N. Y.
Watkins, J. S., Westinghouse Electric & Mfg. Co., St. Louis, Mo.
Weagant, R. A., (Member), Radio Corp. of America, New York, N. Y.
Weinfeld, A. B., Electric Power Equipment Co., Columbus, Ohio
Welker, V. I., The Northwest Paper Co., Cloquet, Minn.
Welsford, B. W. H., U. S. Veterans' Bureau Trainee, Drexel Institute, Philadelphia, Pa.
Wiesner, Fred K., Duquesne Light Co., Pittsburgh, Pa.
Winterbottom, W. A., Radio Corp. of America, New York, N. Y.
Wulfing, H. E., (Member), Commonwealth Edison Co., Chicago, Ill.

Total 120

Foreign

Cunningham, J. O., Hawera County Electric Co., Ltd., Normanby, Taranaki, N. Z.
Haeker, C., Metropolitan Bd. Water Sup. & Sewerage, Sydney, N. S. W.
Lane, E. S., Newcastle City Council, Newcastle, N. S. W.
Oka, Y., S. Manchuria Railway Co., S. Manchuria, China
Thomas, R. N., Tramway Car Shops, Christchurch, N. Z.
Tilly, C. S., Government of Burma, Public Wks. Dept., Rangoon, India
Uhalt, A. H., Truxillo R. R. Co., Point Castillo, Honduras
Villares, G. D., Sao Paulo Tramway, Lt. & Pr. Co., Sao Paulo, Brazil, S. A.

Total 8

STUDENTS ENROLLED MAY 18, 1923

17112 Ibach, John R., Pennsylvania State College
17113 Nye, John F., Rhode Island State College
17114 Stoddard, Raymond R., Mass. Inst. of Tech.
17115 Hogan, John X., Catholic Univ. of America
17116 Mulligan, John R. A., Catholic Univ. of America
17117 Laughlin, Thomas M., Catholic Univ. of America
17118 Swecker, Odes E., Catholic Univ. of America
17119 Berntha1, Victor O., Michigan Agricultural College
17120 Norris, George E., Michigan Agricultural College
17121 Wollman, Jerome R., Univ. of Missouri
17122 Cobb, Harold E., Ohio State University
17123 Smith, Roscoe H., Mass. Institute of Tech.
17124 Meyer, Harold F., Stevens Inst. of Tech.
17125 Kargaroff, Charles Brooklyn Poly. Inst.
17126 Latsen, Leonard O., State College of Washington
17127 Rodrigues, John R., Central Technological Inst. (Bombay, India)
17128 Beck, Walter, University of Illinois
17129 Nelson, Lee M., University of Nebraska
17130 Allen, Durham E., North Carolina State College
17131 Hostetter, Howard O., New Mexico College of A. & M. A.
17132 Thomson, Lawrence W., Univ. of Denver
17133 Archer, C. R., University of Maine
17134 Alexander, Donald F., University of Maine
17135 Schroeder, Edgar, School of Engineering of Milwaukee
17136 Hartmann, Robert J., School of Engineering of Milwaukee
17137 Bostwick, William E., School of Engineering of Milwaukee
17138 Hendricks, John B., School of Engineering of Milwaukee
17139 Green, Frederick, School of Engineering of Milwaukee
17140 Kissell, Alfred L., School of Engineering of Milwaukee
17141 Harry, Carlos L., School of Engineering of Milwaukee
17142 La Fever, Luther H., School of Engineering of Milwaukee
17143 Johns, Joe A., School of Engineering of Milwaukee
17144 Nebel, Charles N., University of Missouri
17145 Crago, Alan C., Carnegie Inst. of Technology
17146 Herrman, Mack, Columbia University
17147 Horne, Jacob M., Jr., University of Maine
17148 Curtis, Louis E., Jr., University of Maine
17149 Stuppy, Frank D., Pennsylvania State College
17150 Clark, Olpha S., University of Cincinnati
17151 Crump, Edward L., Univ. of Tennessee
17152 Addington, Wickliffe D., University of Tennessee
17153 Letsinger, L. T., University of Tennessee
17154 Brooks, Moses E., University of Tennessee
17155 Kavanagh, G. R., University of Tennessee
17156 Eichenberger, Oscar R., Univ. of Tennessee
17157 Lewis, H. P., University of Tennessee
17158 Thomas, James W., Johns Hopkins Univ.
17159 Spriggs, William, McGill University
17160 Betzer, Cecil E., University of Wisconsin
17161 Ditman, L. S., Johns Hopkins University
17162 Johnson, Willis T., Colorado State Agricultural College
17163 Little, Henry R., Rhode Island State College
17164 Baerthlein, Valentine J., Cooper Union
17165 Heinrichs, John A., Cooper Union
17166 Evans, James H., Mass. Inst. of Tech
17167 Kirkpatrick, Paul W., Univ. of Colorado
17168 Metzer, William R., Carnegie Institute of Technology
17169 Martin, Theodore A., Univ. of Vermont
17170 Hague, Edward C., McGill University
17171 Mullen, Joseph N., University of Maine
17172 Batzold, Harold A., Queen's University
17173 Smith, Elisha L., Oregon State Agricultural College
17174 Sedgwick, William D., Oregon State Agricultural College
17175 Woods, Harold, Oregon State Agricultural College
17176 Shipe, Winfield C., University of Tennessee
17177 Eubanks, Earl, University of Tennessee
17178 Moore, L. F., University of Tennessee
17179 Donaldson, Donald, University of N. Dakota
17180 Cooper, Jesse E., University of Utah
17181 Gallup, David L., Union College
17182 Malone, James F., Brooklyn Polytechnic Institute
17183 Ahern, Philip C., McGill University
17184 Pollard, Clayton L., Pennsylvania State College
17185 Urich, James, Colorado State Agricultural College
17186 Grant, Alexander J., McGill University
17187 Tzougros, George J., Mass. Institute of Technology
17188 Mithoug, Otis L., University of Washington
17189 Felch, Lewis D., University of Washington
17190 Sanders, John C., University of Washington
17191 Kamm, J. Lloyd, State Col. of Washington
17192 Weinhardt, Allen J., Jr., Rose Poly. Inst.
17193 St. Clair, Sylvester J., Rose Poly. Inst.
17194 Wolff, Edwin H., Rose Polytechnic Inst.
17195 Buffo, Baptist, Rose Polytechnic Institute
17196 Donham, Edward F., Rose Poly. Inst.
17197 Brown, Roy J., University of Toronto
17198 Listmann, Charles W., Univ. of Michigan
17199 Quigley, Francis P., Univ. of Pennsylvania
17200 Wilkinson, Henry B., Cornell University
17201 Thomas, Ray S., University of Utah
17202 Fancher, John H., Mass. Inst. of Tech.
17203 Meyer, William P., University of Nebraska
17204 Stirling, L. B., McGill University
17205 Nielsen, Harold V., Cornell University
17206 Adams, William F., A. & M. Coll. of Texas
17207 Clement, George K., A. & M. Coll. of Texas
17208 Haigh, James H., Michigan Agric. College
17209 Rainey, Merle, University of Nebraska
17210 Millar, Julian Z., University of Illinois
17211 Bolds, E. E., University of Illinois
17212 Grimley, Donald G., Wash. & Lee Univ.
17213 Halstead, George W., Wash. & Lee Univ.
17214 Altfather, Conrad T., Wash. & Lee Univ.
17215 Slack, Roy C., Washington & Lee Univ.
17216 Blitch, James D., Washington & Lee Univ.
17217 Bishop, Gwynn E., Mass. Inst. of Tech.
17218 Dreyer, William C., California Inst. of Tech
17219 Marburger, Thomas, Johns Hopkins Univ.
17220 Smith, Adam W. S., McGill University
17221 Park, Robert H., Mass. Inst. of Technology
17222 Overholt, Donald M., Univ. of Nebraska
17223 Milburn, John B., Pennsylvania State Col.
17224 Drenkard, Jr., Stevens Inst. of Technology
17225 Leisey, Claude F., Rose Polytechnic Inst.
17226 Bennett, Ralph B., Rose Polytechnic Inst.
17227 Hager, Richard W., Rose Polytechnic Inst.
17228 Mason, Albert F., University of Nebraska
17229 Dickinson, Edwin A., Stevens Inst. of Tech.
17230 Martin, Floyd M., Ohio State University
17231 Marshall, Cecil E., University of Nebraska
17232 Safarik, Edgar R., University of Nebraska
17233 Corlett, John A., University of Nebraska
17234 Amodei, John, Clarkson College of Tech.
17235 Brandenstein, Erroll W., Union College
17236 Erskine, James S., Northeastern University
17237 Opel, Earl E., Pennsylvania State College
17238 Smith, Stuart M., Clarkson Col. of Tech.
17239 Kadetsky, Jacob M., Penn. State College
17240 Manning, James O., Oregon Agric. Coll.
17241 Mercer, Robert A., Oregon Agric. College
17242 Rollman, Lawrence T., Oregon Agric. Coll.
17243 Berry, Henry P., Catholic Univ. of America
17244 Bailey, Merle P., Oregon Agric. College
17245 Beck, Albert D., Ohio Northern University
17246 Hakewessell, Reinhold W., Mass. Inst. of Technology
17247 Rousseau, Gabriel, Mass. Inst. of Tech.

Total 136

Officers A. I. E. E. 1922-1923

PRESIDENT.

(Term expires July 31, 1923)
FRANK B. JEWETT

JUNIOR PAST-PRESIDENTS

(Term expires July 31, 1923)
A. W. BERRESFORD

(Term expires July 31, 1924)
WILLIAM McCLELLAN

VICE-PRESIDENTS

(Terms expire July 31, 1923)
N. W. STORER
C. G. ADSIT
F. W. SPRINGER
ROBERT SIBLEY
F. R. EWART

(Terms expire July 31, 1924)
G. FACCIOLI
W. I. SLICHTER
R. F. SCHUCHARDT
H. W. EALES
H. T. PLUMB

MANAGERS

(Terms expire July 31, 1923)
L. E. IMLAY
F. F. FOWLE
L. F. MOREHOUSE

(Terms expire July 31, 1924)
HAROLD B. SMITH
JAMES F. LINCOLN
E. B. CRAFT

(Terms expire July 31, 1925)
R. B. WILLIAMSON
A. G. PIERCE
HARLAN A PRATT

(Terms expire July 31, 1926)
H. M. HOBART
ERNEST LUNN
G. L. KNIGHT

TREASURER / SECRETARY

(Terms expire July 31, 1923)
GEORGE A HAMILTON — F. L. HUTCHINSON

HONORARY SECRETARY

RALPH W. POPE

GENERAL COUNSEL

PARKER & AARON,
30 Broad Street, New York.

PAST-PRESIDENTS—1884-1922

*NORVIN GREEN, 1884-5-6.
*FRANKLIN L. POPE, 1886-7.
T. COMMERFORD MARTIN, 1887-8.
EDWARD WESTON, 1888-9.
ELIHU THOMSON, 1889-90.
*WILLIAM A. ANTHONY, 1890-91.
*ALEXANDER GRAHAM BELL, 1891-2.
FRANK JULIAN SPRAGUE, 1892-3.
*EDWIN J. HOUSTON, 1893-4-5.
*LOUIS DUNCAN, 1895-6-7.
*FRANCIS BACON CROCKER, 1897-8.
A. E. KENNELLY, 1898-1900.
CARL HERING, 1900-1.
CHARLES P. STEINMETZ, 1901-2.
CHARLES F. SCOTT, 1902-3.
BION J. ARNOLD, 1903-4.
JOHN W. LIEB, 1904-5.
*SCHUYLER SKAATS WHEELER, 1905-6.
*SAMUEL SHELDON, 1906-7.
*HENRY G. STOTT, 1907-8.
LOUIS A. FERGUSON, 1908-9.
LEWIS B. STILLWELL, 1909-10.
DUGALD C. JACKSON, 1910-11.
GANO DUNN, 1911-12.
RALPH D. MERSHON, 1912-13.
C. O. MAILLOUX, 1913-14.
PAUL M. LINCOLN, 1914-15.
JOHN J. CARTY, 1915-16.
H. W. BUCK, 1916-17.
E. W. RICE, JR., 1917-18.
COMFORT A. ADAMS, 1918-19.
CALVERT TOWNLEY, 1919-20.
A. W. BERRESFORD, 1920-21.
WILLIAM McCLELLAN, 1921-22.

*Deceased.

LOCAL HONORARY SECRETARIES

Carrol M. Mauseau, Caixa Postal No. 571, Rio de Janeiro, Brazil, S. A.
Charles le Maistre, 28 Victoria St., London, S. W., England.
A. S. Garfield, 45 Bd. Beausejour, Paris 16 E, France.
H. P. Gibbs, Tata Sons, Ltd., Navsari Building, Fort Bombay, India.
Guido Semenza, N. 10 Via S. Radegonda, Milan, Italy.
Lawrence Birks, Public Works Department, Wellington, New Zealand.
W. Elsdon-Dew, P. O. Box 4563, Johannesburg, Transvaal, Africa.

A. I. E. E. Committees

GENERAL STANDING COMMITTEES

EXECUTIVE COMMITTEE

F. B. Jewett, Chairman, 195 Broadway, New York
A. W. Berresford, H. M. Hobart, R. F. Schuchardt,
G. A. Hamilton, L. F. Morehouse, W. I. Slichter.

FINANCE COMMITTEE

L. F. Morehouse, Chairman, 195 Broadway, New York
C. G. Adsit, G. L. Knight.

MEETINGS AND PAPERS COMMITTEE

E. E. F. Creighton, Chairman, General Electric Co., Schenectady, N. Y.
J. C. Clark, John Mills, A. G. Pierce.
L. W. W. Morrow,
Chairman of Committee on Coordination of Institute Activities.
Chairmen of Technical Committees.
Chairmen of Sections.

PUBLICATION COMMITTEE

Donald McNicol, Chairman, 132 Union Road, Roselle Park, N. J.
E. E. F. Creighton, F. L. Hutchinson, Wm. McClellan.
L. F. Morehouse,

COMMITTEE ON COORDINATION OF INSTITUTE ACTIVITIES

W. I. Slichter, Chairman, Columbia University, New York
E. E. F. Creighton, F. L. Hutchinson, Donald McNicol.
L. F. Morehouse,

BOARD OF EXAMINERS

H. H. Norris, Chairman, 211 Lorraine Ave., Upper Montclair, N. J.
Philander Betts, G. L. Knight, J. H. Morecroft,
E. H. Everit, Donald McNicol, N. L. Pollard,
Erich Hausmann, E. M. Sawtelle.

SECTIONS COMMITTEE

A. W. Berresford, Chairman, 303 Hotel Astor, Milwaukee, Wis.
C. F. Harding, Vice-Chairman
John B. Fisken, H. B. Smith, J. Lloyd Wayne.
Chairmen of all Sections.

COMMITTEE ON STUDENT BRANCHES

C. F. Harding, Chairman, Purdue University, Lafayette, Ind.
A. C. Lanier, C. E. Magnusson, Harold B. Smith.
Charles F. Scott,

MEMBERSHIP COMMITTEE

R. B. Howland, Chairman, 125 E. 46th St., New York.
W. L. Amos, F. L. Kemp, H. T. Plumb,
R. L. Dodd, J. E. MacDonald, M. E. Skinner,
J. F. Dostal, G. H. Middlemiss, J. L. Woodress,
R. D. Parker.

HEADQUARTERS COMMITTEE

E. B. Craft, Chairman, 463 West St., New York.
F. L. Hutchinson, L. F. Morehouse.

LAW COMMITTEE

H. H. Barnes, Jr., Chairman, 120 Broadway, New York.
F. R. Ewart, G. E. Folk, Charles A. Terry.
P. Junkersfeld,

PUBLIC POLICY COMMITTEE

H. W. Buck, Chairman, 49 Wall Street, New York.
Gano Dunn, John W. Lieb, C. E. Skinner,
William McClellan,

COMMITTEE ON CODE OF PRINCIPLES OF PROFESSIONAL CONDUCT

John W. Lieb, Chairman, 124 E. 15th St., New York
C. A. Adams, G. Faccioli, George F. Sever,
A. H. Babcock, C. E. Skinner H. S. Wynkoop.

COMMITTEE ON SAFETY CODES

H. B. Gear, Chairman, 72 West Adams St., Chicago, Ill.
H. C. Cushing, M. G. Lloyd, Farley Osgood,
J. C. Forsyth, Ernest Lunn, H. R. Sargent,
H. O. Lacount, Wills Maclachlan, A. M. Schoen,
Johnston Livingston, R. W. E. Moore, H. S. Warren.
H. N. Muller,

STANDARDS COMMITTEE

Executive Committee

Harold Pender, Chairman, University of Pennsylvania, Philadelphia, Pa.
H. S. Osborne, Secretary, 195 Broadway, New York
W. A. Del Mar, H. A. Lardner, F. D. Newbury,
H. M. Hobart, A. M. MacCutcheon, F. L. Rhodes,
G. L. Knight J. F. Meyer, L. T. Robinson,
C. E. Skinner
Chairmen of A. I. E. E. delegations on other standardizing bodies.
Chairman of Working Committees of Standards Committee

EDISON MEDAL COMMITTEE

Appointed by the President for term of five years.

(Term expires July 31, 1923)
Frederick Bedell, L. T. Robinson, Calvert Townley.
(Term expires July 31, 1924)
E.D.Adams, Chairman, H. H. Barnes, Jr., B. G. Lamme.
(Term expires July 31, 1925)
H. M. Byllesby, D. E. Drake, W. L. R. Emmet.
(Term expires July 31, 1926)
B. A. Behrend, John H. Finney, C. S. Ruffner.
(Term expires July 31, 1927)
Gano Dunn, F. A. Scheffler, W. R. Whitney.

Elected by the Board of Directors from its own membership for term of two years

(Term expires July 31, 1923)
A. W. Berresford, L. F. Morehouse, R. B. Williamson.
(Term expires July 31, 1924)
E. B. Craft, G. Faccioli, William McClellan.

Ex-Officio

Frank B. Jewett, President, George A. Hamilton, Treasurer,
F. L. Hutchinson, Secretary.

RESEARCH COMMITTEE

J. B. Whitehead, Chairman, Johns Hopkins University, Baltimore, Md.
B. A. Behrend, W. P. Dobson, M. G. Lloyd,
Edward Bennett, C. I. Hall, L. F. Morehouse,
F. S. Clark, L. A. Hawkins, G. W. Pierce,
E. H. Colpitts, D. C. Jackson, H. J. Ryan,
E. E. F. Creighton, A. E. Kennelly, C. H. Sharp,
W. A. Del Mar, J. R. Klumpp, C. E. Skinner.

SPECIAL COMMITTEES

COLUMBIA UNIVERSITY SCHOLARSHIP

Francis Blossom, Chairman, 52 William St., New York.
Frank B. Jewett, W. I. Slichter.

AWARD OF INSTITUTE PRIZES

E. E. F. Creighton, Chairman, General Electric Co., Schenectady, N. Y.
Chairmen of Technical Committees.

TECHNICAL COMMITTEES

EDUCATIONAL

W. E. Wickenden, Chairman, 195 Broadway, New York.

W. C. Bauer, C. E. Magnusson, Harold B. Smith
Edward Bennett, G. H. Pfeif, W. L. Upson,
C. R. Dooley, H. W. Price, J. B. Whitehead,
Charles S. Howe, Charles F. Scott, Wm. R. Work.

ELECTRICAL MACHINERY

B. A. Behrend, Chairman, 85 Devonshire St., Boston, Mass.
A. S. McAllister, Secretary, 455 W. 153rd St., New York.

B. L. Barns, V. A. Fynn, P. M. Lincoln,
R. E. Brown, David Hall, H. P. Liversidge,
James Burke, H. U. Hart, F. D. Newbury,
N. A. Carle, H. M. Hobart, R. F. Schuchardt,
G. Faccioli, V. Karapetoff, Philip Torchio,
W. J. Foster, R. B. Williamson.

ELECTROCHEMISTRY AND ELECTROMETALLURGY

J. L. Yardley, Chairman, W. E. & M. Co., East Pittsburgh, Pa.

F. G. Clark, Carl Hering, J. A. Seede,
Saul Dushman L. E. Imlay, G. W. Vinal.

ELECTROPHYSICS

F. W. Peek, Jr., Chairman, General Electric Co., Pittsfield, Mass.

E. F. Burton, Wm. Fondiller, Chester W. Rice,
L. W. Chubb, Charles Fortescue, F. B. Silsbee,
J. C. Clark, Roy S. Glasgow, H. B. Smith,
C. P. Eldred, E. P. Hyde, J. B. Whitehead.
J. H. Morecroft,

INDUSTRIAL AND DOMESTIC POWER

H. D. James, Chairman, W. E. & M. Co., East Pittsburgh, Pa.

P. H. Adams, C. W. Drake, H. W. Rogers,
S. F. Davies, T. D. Montgomery, W. I. Slichter.

INSTRUMENTS AND MEASUREMENTS

G. A. Sawin, Chairman, W. E. & M. Co., East Pittsburgh, Pa.

P. A. Borden, A. L. Ellis, Irving B. Smith,
H. B. Brooks, Paul MacGahan, H. C. Snook,
F. P. Cox, F. V. Magalhaes, F. W. Springer,
E. D. Doyle, H. S. Vassar.

IRON AND STEEL INDUSTRY

E. S. Jefferies, Chairman, Steel Co. of Canada, Hamilton, Ont.

F. B. Crosby, W. S. Hall, G. E. Stoltz,
Gordon Fox, E. T. Moore, N. W. Storer,
Eugene Friedlaender, D. M. Petty, Wilfred Sykes,
R. B. Gerhardt, J. D. Wright.

LIGHTING AND ILLUMINATION

G. H. Stickney, Chairman, Edison Lamp Works, G. E. Co., Harrison, N. J.

A. B. Cooper, G. C. Hall, R. C. Powell,
E. C. Crittenden, Henry Logan, Charles F. Scott,
W. T. Dempsey, A. S. McAllister, B. E. Shackelford,
F. F. Fowle, J. F. Meyer, W. M. Skiff.

MARINE

G. A. Pierce, Jr., Chairman, W. Cramp & Sons S. & E. B. Co., Philadelphia, Pa.
L. C. Brooks, Secretary, Bethlehem Shipbuilding Corp. Ltd., Quincy, Mass.

J. B. Bassett, Wm. Hetherington, Jr., I. H. Osborne,
R. A. Beekman, H. L. Hibbard, Arthur Parker,
Maxwell W. Day, J. S. Isdale, H. A. Pratt,
E. G. Gallagher, Wm. F. James, H. M. Southgate,
Com. C. S. Gillette, Com. M. A. Libbey, W. E. Thau,
H. Franklin Harvey, Jr., Com. C. S. McDowell, A. E. Waller.
W. F. Meschenmoser,

MINES

Graham Bright, Chairman, W. E. & M. Co., East Pittsburgh, Pa.

Willard C. Adams, L. C. Ilsley, D. C. McKeehan,
R. T. Andrae G. M. Kennedy, W. F. Schwedes,
C. N. Beebe, R. L. Kingsland, F. L. Stone,
M. C. Benedict, A. B. Kiser, W. A. Thomas,
H. W. Eales, C. D. Woodward.

POWER STATIONS

Nicholas Stahl, Chairman, Turks Head Building, Providence, R. I.

H. A. Barre, F. C. Hanker, D. C. McClure,
J. T. Barron, C. F. Hirshfeld, I. E. Moultrop,
A. E. Bauhan, H. A. Kidder, A. L. Penniman,
E. T. Brandon, W. H. Lawrence, F. A. Scheffler,
D. H. Braymer, H. P. Liversidge, R. F. Schuchardt,
H. W. Eales, R. B. Williamson.

PROTECTIVE DEVICES

H. R. Woodrow, Chairman, 360 Pearl Street, Brooklyn, N. Y.

G. H. Bragg, B. G. Jamieson, F. E. Ricketts,
P. H. Chase, M. G. Lloyd, D. W. Roper,
L. B. Chubbuck, A. A. Meyer, C. H. Sanderson,
F. C. Hanker, W. H. Millan, E. R. Stauffacher,
S. E. M. Henderson, A. G. Pierce, E. C. Stone,
E. A. Hester, N. L. Pollard, A. H. Sweetnam,
F. L. Hunt, John B. Taylor.

TELEGRAPHY AND TELEPHONY

O. B. Blackwell, Chairman, 195 Broadway, New York.

C. W. Burkett, H. W. Drake, Chester W. Rice,
G. A. Cellar, D. H. Gage, J. K. Roosevelt,
H. P. Charlesworth, H. Hulatt, Gen. Edgar Russell,
L. W. Chubb, F. H. Kroger, Arthur B. Smith,
E. H. Colpitts, F. J. Mayer, I. J. Thorp,
R. N. Conwell, L. F. Morehouse, F. A. Wolff,
C. E. Davies, W. O. Pennell, C. A. Wright.
F. A. Raymond,

TRACTION AND TRANSPORTATION

N. W. Storer, Chairman, W. E. & M. Co., East Pittsburgh, Pa.

George Gibbs, W. S. Murray, Hugh Pattison,
Dugald C. Jackson, W. B. Potter.

TRANSMISSION AND DISTRIBUTION

E. B. Meyer, Chairman, 80 Park Place, Newark, N. J.

R. W. Atkinson, F. M. Farmer, C. N. Rakestraw,
A. E. Bauhan, L. M. Klauber, C. C. Robinson,
F. G. Baum, J. A. Koontz, Jr. D. W. Roper,
Wallace S. Clark, C. H. Kraft, C. E. Schwenger,
W. H. Cole, W. S. Lee, C. H. Shaw,
R. N. Conwell, G. J. Newton, Robert Sibley,
W. A. Del Mar, A. M. Perry, W. K. Vanderpoel,
L. L. Elden, G. G. Post, C. T. Wilkinson.

A. I. E. E. Representatives

ON AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, COUNCIL

A. E. Kennelly, John B. Taylor.

ON AMERICAN BUREAU OF WELDING

W. L. Merrill.

ON AMERICAN COMMITTEE ON ELECTROLYSIS

Bion J. Arnold, N. A. Carle, F. N. Waterman.

ON AMERICAN ENGINEERING COUNCIL OF THE FEDERATED AMERICAN ENGINEERING SOCIETIES

Comfort A Adams, W. A. Layman, Charles S. Ruffner,
*C. G. Adsit, *William McClellan, *Charles F. Scott,
John H. Finney, *L. F. Morehouse, C. E. Skinner,
F. L. Hutchinson, L. T. Robinson, L. B. Stillwell,
*Frank B. Jewett, Calvert Townley.

*Members of Executive Board.

ON AMERICAN ENGINEERING STANDARDS COMMITTEE

H. M. Hobart, Harold Pender, C. E. Skinner,
L. T. Robinson (Alternate)

ON BOARD OF TRUSTEES, UNITED ENGINEERING SOCIETY

H. H. Barnes, Jr., Bancroft Gherardi, H. A. Lardner.

ON CHARLES A. COFFIN FELLOWSHIP AND RESEARCH FUND COMMITTEE

Frank B. Jewett

ON ENGINEERING FOUNDATION BOARD

Frank B. Jewett, E. W. Rice, Jr.

ON FRANCO-AMERICAN ENGINEERING COMMITTEE

A. M. Hunt, L. B. Stillwell.

ON JOHN FRITZ MEDAL BOARD OF AWARD

A. W. Berresford, John J. Carty, Frank B. Jewett.
Wm. McClellan.

ON JOSEPH A. HOLMES SAFETY ASSOCIATION

John H. Finney.

ON LIBRARY BOARD OF UNITED ENGINEERING SOCIETY

Edward D. Adams, F. L. Hutchinson, W. I. Slichter,
E. B. Craft, Alfred W. Kiddle.

ON NATIONAL FIRE PROTECTION ASSOCIATION, ELECTRICAL COMMITTEE

The chairman of the Institute's Committee on Safety Codes.

ON NATIONAL RESEARCH COUNCIL, ENGINEERING DIVISION

C. A. Adams, Bancroft Gherardi W. R. Whitney.

ON U. S. NATIONAL COMMITTEE OF THE INTERNATIONAL ILLUMINATION COMMISSION

A. E. Kennelly, C. O. Mailloux, Clayton H. Sharp.

ON WASHINGTON AWARD, COMMISSION OF

John Price Jackson, Charles F. Scott.

U. S. NATIONAL COMMITTEE OF THE INTERNATIONAL ELECTROTECHNICAL COMMISSION

C. O. Mailloux, President, 111 Fifth Ave., New York, N. Y.
D. C. Jackson, Vice-President,
[1]James Burke, Vice-President,
C. H. Sharp, Secretary, 556 E. 80th St., New York.

C. A. Adams, W. C. Fish, L. F. Morehouse.
P. G. Agnew, H. W. Fisher, Harold Pender
[8]C. A. Bates, [6]Gen. G. H. Harries, [6]S. G. Rhodes,
B. A. Behrend, H. M. Hobart, Charles Robbins,
[8]A. W. Berresford, A. E. Kennelly, L. T. Robinson
J. J. Carty, B. G. Lamme, D. B. Rushmore,
L. W. Chubb, [5]R. A. Lundquist. [8]H. R. Sargent,
[8]Le Roy Clark, A. S. McAllister, C. F. Scott,
[1]C. L. Collens, 2d, [4]Com. C. S. McDowell, C. E. Skinner,
W. A. Del Mar, [7]J. Franklin Meyer, [3]Gen. George O. Squier.
[1]A. L. Doremus, W. S. Moody, Elihu Thomson,
Gano Dunn, A. H. Moore, [2]C. L. Warwick,
[6]L. L. Elden, R. W. E. Moore, R.B. Williamson,

[1]Representative of Electric Power Club.
[2]Representative of American Society for Testing Materials.
[3]Representative of War Department.
[4]Representative of Navy Department.
[5]Representative of Bureau of Foreign and Domestic Commerce.
[6]Representative of National Electric Light Association.
[7]Representative of Bureau of Standards.
[8]Representative of Associated Manufacturers of Electrical Supplies.

LIST OF SECTIONS

Name	Chairman	Secretary
Akron	S. C. Henton	A. P. Regal, Phila. Rubber Works Co., Akron, O.
Atlanta	G. K. Selden	H. N. Pye, Box 1743, Atlanta, Ga.
Baltimore	W. B. Kouwenhoven	F. T. Leilich, 550 Lexington Bldg., Baltimore, Md.
Boston	E. L. Moreland	F. S. Dellenbaugh, M. I. T., Cambridge, Mass.
Chicago	F. E. Goodnow	J. E. Kearns, General Electric Co., 230 S. Clark St., Chicago, Ill.
Cincinnati	A. M. Wilson	C. G. Eichelberger, Union Gas & Elec. Co., Cincinnati, O.
Cleveland	L. D. Bale	Chester L. Dows, Nela Park, Cleveland, O.
Columbus	F. C. Caldwell	F. C. Nesbitt, Huntington Bank Bldg., Columbus, O.
Connecticut	E. H. Everit	A.E. Knowlton, Dunham Laboratory, S. S. S., Yale University, New Haven, Conn.
Denver	H. B. Barnes	R. B. Bonney, 603 Wyoming Bldg., Denver, Colo.
Detroit-Ann Anbor	J. H. Cannon	E. L. Bailey, 1918 Ford Bldg., Detroit, Mich.
Erie	W. J. Seibert	M. W. Metzner, General Electric Co., Erie, Pa.
Fort Wayne	S. W. Greenland	A. B. Campbell, General Electric Co., Fort Wayne, Ind.
Indianapolis-Lafayette	D. C. Pyke	J. W. Hannon, Telephone Bldg., Indianapolis, Ind.
Ithaca	J. G. Pertsch, Jr.	Geo. F. Bason, Cornell University, Ithaca, N. Y.
Kansas City	Geo. C. Shaad	W. E. A. Nottorf, K. C. Tel. Co., Kansas City, Mo.
Lehigh Valley	D. M. Petty	H. G. Harvey, Penna. Edison Co., Easton, Pa.
Los Angeles	J. N. Kelman	E. R. Stauffacher, 700 Edison Bldg., Los Angeles, Calif.
Lynn	J. W. West	W. M. Howe, General Electric Co., West Lynn, Mass.
Madison	H. M. Crothers	R. G. Walter, 900 Gay Bldg., Madison, Wis.
Milwaukee	G. G. Post	F. A. Kartak, Marquette University, Milwaukee, Wis.
Minnesota	Fred A. Otto	H. W. Meyer, Northern States Power Co., Minneapolis, Minn
New York	Calvert Townley	A. E. Waller, Lawrence Park, Bronxville, N. Y.
Oklahoma	F. W. Insull	A. D. Stoddard, Box 382 Bartlesville, Okla.
Panama	F. B. Coyle	M. P. Benninger, Box 174, Balboa Heights, C. Z.
Philadelphia	E. B. Tuttle	Ross B. Mateer, 916 N. 63rd St., Philadelphia, Pa.
Pittsburgh	E. C. Stone	O. Needham, W. E. & M. Co., East Pittsburgh, Pa.
Pittsfield	W. P. White	A. C. Stevens, General Electric Co., Pittsfield, Mass.
Portland, Ore.	D. W. Proebstel	E. F. Pearson, Northwestern Electric Co., Portland, Ore.
Providence	R. W. Adams	F. N. Tompkins, Brown University, Providence, R. I.
Rochester	G. A. Scoville	E. A. Roeser, 34 N. Clinton Ave., Rochester, N. Y.
St. Louis	J. M. Chandlee	Lee S. Washington, 717 S. 12th St., St. Louis, Mo.
San Francisco	H. H. Henline	A. G. Jones, 807 Rialto Bldg., San Francisco, Calif.
Schenectady	C. M. Davis	C. W. Fick, General Electric Co., Schenectady, N. Y.
Seattle	C. F. Terrell	E. S. Code, 3451 E. Marginal Way, Seattle, Wash.
Southern Virginia	Wm. C. Bell	H. C. Leonard, P. O. Box 1194, Richmond, Va.
Spokane	H. L. Melvin	E. R. Hannibal, 424 Hutton Bldg., Spokane, Wash.
Springfield, Mass.	W. A. Dick	J. Frank Murray, United Electric Light Co., Springfield, Mass.
Syracuse	R. D. Whitney	Elmer E. Strong, 615 City Bank Bldg., Syracuse, N. Y.
Toledo	Gilbert Southern	Max Neuber, 1257 Fernwood Ave., Toledo, O.
Toronto	S. E. M. Henderson	D. B. Fleming, Hydro-Elec. Pr. Comm., 190 University Ave., Toronto, Ont.
Urbana	H. A. Brown	E. B. Paine, University of Illinois, Urbana, Ill.
Utah	C. C. Pratt	C. R. Higson, Utah Pr. & Lt. Co., Salt Lake City, Utah
Vancouver	T. H. Crosby	F. W. MacNeill, Canadian General Elec. Co., Vancouver, B. C.
Washington, D. C.	L. T. Blaisdell	Roland Whitehurst, Elec. Storage Battery Co., 1823-33 L. St. N. W., Washington, D. C.
Worcester	P. J. Adams	Stuart M. Anson, 1005 Park Bldg., Worcester, Mass.

Total 46

LIST OF BRANCHES

Name and Location	Chairman	Secretary
Alabama Poly. Inst., Auburn, Ala.	K. H. Stough	J. F. Nettles
Alabama, Univ. of, University, Ala.	J. M. Lakeman	R. L. Harris
Arizona, Univ. of, Tucson, Ariz.	R. A. Macdonald	H. A. Hillman
Arkansas, Univ. of, Fayetteville, Ark.	R. C. Mason	E. J. Anderson
Armour Inst. of Tech., Chicago, Ill.	L. E. Grube	H. M. Piety
Brooklyn Poly. Inst., Brooklyn, N. Y.	A. E. Shaw	H. B. Hanstein
Bucknell Univ., Lewisburg, Pa.	W. G. Gehring	E. S. Hopler
California Inst. of Tech., Pasadena,	H. Preston	C. A. Storms
California, Univ. of, Berkeley, Cal.	A. A. Emlen	F. C. Blockson
Carnegie Inst. of Tech., Pittsburg, Pa.	W. S. Andrews	W. J. Lyman
Case School of Applied Science, Cleveland, O.	M. S. Mead	A. S. Campbell
Cincinnati, Univ. of, Cinncinati, O.	W. F. Dunkl	C. B. Hoffmann
Clarkson Coll. of Tech., Potsdam, N.Y.	C. E. Tuiter	H. C. Allen
Clemson Agri. College, Clemson College, S. C.	J. R. Reardon	W. M. Clatworthy
Colorado State Agri. Coll., Ft. Collins,	Floyd Hall	W. M. Truesdell
Colorado, Univ. of, Boulder, Colo.	G. H. Dewey	R. H. Owen
Cooper Union, New York	G. E. Wilson	H. E. Thompson
Denver, Univ. of, Denver, Colo.	L. W. Thomson	Ray Hoover
Drexel Institute, Philadelphia, Pa.	D. Buchanan	R. E. Sidwell
Georgia School of Tech., Atlanta, Ga.	J. L. Torbett	F. R. McClellan
Iowa State College, Ames, Ia.	C. H. Hoper	G. L. Seaton
Iowa, Univ. of, Iowa City, Ia.	C. W. Peterson	M. Bushby
Kansas State College, Manhattan,	L. O. Sinderson	K. C. Frank
Kansas, Univ. of, Lawrence, Kans.	D. Eyer	Wm. Anderson
Kentucky, Univ. of, Lexington, Ky.	T. M. Riley	H. T. Broilsford
Lafayette College, Easton, Pa.	K. A. F. Pitt	L. Conover
Lehigh Univ., South Bethlehem, Pa.	E. H. Snyder	R. W. Barrell
Lewis Institute, Chicago, Ill.	E. Millison	C. P. Meek
Maine, Univ. of, Orono, Me.	C. R. Lappin	H. L. Durgin
Marquette University, Milwaukee, Wis.	G. E. Phelps	P. P. Stathas
Massachusetts Inst. of Tech., Cambridge, Mass.	E. J. Thimmie	H. D. McKinnon
Michigan Agri. Coll., East Lansing,	S. N. Galbraith	V. O. Bernthal
Michigan, Univ. of, Ann Arbor, Mich.	R. N. Olds	K. W. Richards
Milwaukee, Engg. School of, Milwaukee, Wis.	M. J. Maiers	J. P. Gibbons
Minnesota, Univ. of, Minneapolis,	R. H. Olson	C. L. Sampson
Missouri, Univ. of, Columbia, Mo	M. P. Weinback	D. C. Jackson, Jr.
Montana State Coll., Bozeman, Mont.	R. R. Thomas	J. A. Thaler
Nebraska, Univ. of, Lincoln, Neb.	O. J. Ferguson	O. E. Edison
North Carolina State College, West Raleigh, N. C.	Z. M. Harry	P. M. Sullivan
North Carolina, Univ. of, Chapel Hill,	W. K. Harding	O. R. Rowe
North Dakota, Univ. of, University,	C. W. Randall	Byron Hill
Northeastern Univ., Boston, Mass.	B. F. Keene	L. F. Hubby
Notre Dame, Univ. of, Notre Dame, Ind.	V. J. Brown	W. L. Shilts
Ohio Northern Univ., Ada, O.	D. J. Wolf	H. L. Vincent
Ohio State Univ., Columbus, O.	L. S. C. Neeb	J. M. Comly
Oklahoma A. & M. Coll., Stillwater,	I. T. Knight	L. C. Minich
Oklahoma, Univ. of, Norman, Okla.	Cecil Roush	R. B. Greene
Oregon Agri. Coll., Corvallis, Ore.	J. H. Murton	J. H. Casto
Pennsylvania State College, State College, Pa.	H. T. Axford	D. N. Yoder
Pennsylvania, Univ. of, Philadelphia,	O. W. Manz, Jr.	J. R. Sabina
Pittsburgh, Univ. of, Pittsburgh, Pa.	L. L. Hughes	G. K. Walton
Purdue Univ., Lafayette, Ind.	J. F. Welch	O. T. McIlvaine
Rensselaer Poly. Inst., Troy, N. Y.	F. M. Sebast	R. Paxton
Rose Poly. Inst., Terre Haute, Ind.	D. V. Eichen	R. B. Bennett
Rutgers College, New Brunswick, N. J	C. S. Beattie	E. H. Erickson
Southern California, Univ. of., Los Angeles, Cal.	K. C. Mobary	W. G. Angermann
Stanford Univ., Stanford University, Cal.	D. C. Bertrand	T. H. Shepherd
Swarthmore Coll., Swarthmore, Pa.	N. Landis	J. H. Thompson, Jr.
Syracuse Univ., Syracuse, N. Y.	L. E. Angwin	L. E. Lawrence
Texas A. & M. Coll., College Station,	T. E. Keeton	R. S. Drake
Texas, Univ. of, Austin, Tex.	C. R. Granberry	C. H. Linder
Virginia Military Inst., Lexington,	J. Girand	J. E. Woodward
Virginia Poly. Inst., Blacksburg, Va.	T. F. Cofer	F. L. McClung
Virginia, Univ. of, University, Va.	T. R. Bunting	P. L. Weir
Washington, State Coll. of, Pullman,	C. R. Studer	E. J. Leahy
Washington Univ., St. Louis, Mo.	A. B. Newell	H. J. Schwenk
Washington, Univ. of, Seattle, Wash.	E. B. Ehrke	A. W. Lundstrum
West Virginia Univ., Morgantown,	W. D. Stump	C. Snyder
Wisconsin, Univ. of, Madison, Wis.	O. F. Landkamer	J. C. Lotter
Yale Univ., New Haven, Conn.	J. T. Houk	G. L. Artamonoff

Total 70

DIGEST OF CURRENT INDUSTRIAL NEWS

NEW CATALOGUES AND OTHER PUBLICATIONS

Insulators.—Catalog 3, on high-tension porcelain insulators. Lapp Insulator Company, Inc., LeRoy, N. Y.

Lamp Guards.—Bulletin. Describes a new lamp guard, which may be adjusted to fit various size lamps. Flexible Steel Lacing Company, 4607 Lexington St., Chicago, Ill.

Valves.—Catalog, 28 pp. Descriptive of double packed stop cock valves; also special semi-steel valves for strong acid lines, steam and general use. Victory Manufacturing Company, Niles, Cal.

Radio Transmitting Apparatus.—Booklet, 12 pp. Describes continuous wave transmission and use of C. W. transformers, accessories, apparatus, choke coils and condensers, filament heating and modulation transformers. Acme Apparatus Company, Cambridge, Mass.

Radio Amplifying Apparatus.—Booklet, 24 pp. "Amplification without Distortion." Summarizes the points at which distortion may occur in radio transmission and reception, and describes the Acme line of amplifying apparatus. Contains a set of fifteen diagrams illustrating various receiving unit layouts. Acme Apparatus Company, Cambridge, Mass.

The Development o the Central Station Industry.—Bulletin 63, 36 pp., issued by the Sangamo Electric Company, Springfield, Ill. A brief history of the advance in electrical science which made possible the central station of today, and an interesting historical account of the work of Gilbert, Galvani, Volta, Ohm, Ampere and other pioneers. The manufacture of Sangamo meters is illustrated in pictures.

Triplex Ammeter for Three-Phase A-C. Circuits.—Bulletin 30, 4 pp. Describes a new type of ammeter recently developed for one of the large central stations and used for taking simultaneous readings in each of the three phases of a three-phase high-tension metering circuit. Three separate ammeter mechanisms, each independent of the others, are mounted in one 7½" case, and possess all the advantages of three individual instruments in that any one of the three mechanisms can be removed, if necessary, without interruption of the circuit. Roller-Smith Company, 233 Broadway, New York.

Wood Pipe.—Catalog 18, 248 pp., cloth bound, devoted to the subject of wood pipe and creo-wood flume, profusely illustrated. Contains a great deal of hydraulic data, flow tables, and much practical information of value to the hydraulic engineer or plant superintendent, who may be confronted with hydraulic problems both in the design and construction of water conduits, municipal water systems, hydroelectric developments, mining and sluicing operations, irrigation systems, sewerage and drainage systems, paper mills and other industries. Continental Pipe Manufacturing Company, Seattle, Wash.

NOTES OF THE INDUSTRY

Black, McKenny & Stewart, engineers, have removed their offices to 1653 Pennsylvania Avenue, N. W., Washington, D. C.

Pure Carbon Company, Wellsville, N. Y.—The Charles A. Etem Company, 917-A Marquette Avenue, Minneapolis, Minn., have been appointed Minneapolis representatives.

Gibb Instrument Company, Bay City, Mich.—Manufacturers of electric welding equipment, have been appointed distributors of the General Electric Company's arc welding electrodes in the middle west.

Electric Power Equipment Corporation have moved to their new building, 412-420 No. 18th Street, Philadelphia. They were located formerly at 13th & Wood Streets. In their new headquarters, 30,000 sq. ft. of floor space will be devoted exclusively to the manufacture of high-tension apparatus.

Mr. Henry Woodland, secretary and treasurer of the Allis-Chalmers Manufacturing Company, died suddenly in Milwaukee on May 14. When in 1901 this company was taken over in the consolidation which formed the Allis-Chalmers Company, he became assistant treasurer of the new organization and afterward its treasurer. In 1916 he was elected secretary-treasurer of the company. At the time of his death he was also vice-president and director of the Hanna Engineering Company of Chicago.

Westinghouse Electric & Manufacturing Company, East Pittsburgh.—The net income of the company for the year ending March 31, 1923, was $12,263,485 as shown by the annual report. The dividend requirements were $6,033,428, so that over twice this amount was earned and more than six million dollars added to the surplus. Gross sales for the year were $125,000,000, which represents an increase of $25,000,000 over the sales of last year. The cash position of the company is a strong one, the current assets totaling over $106,000,000, and the current liabilities less than $17,000,000.

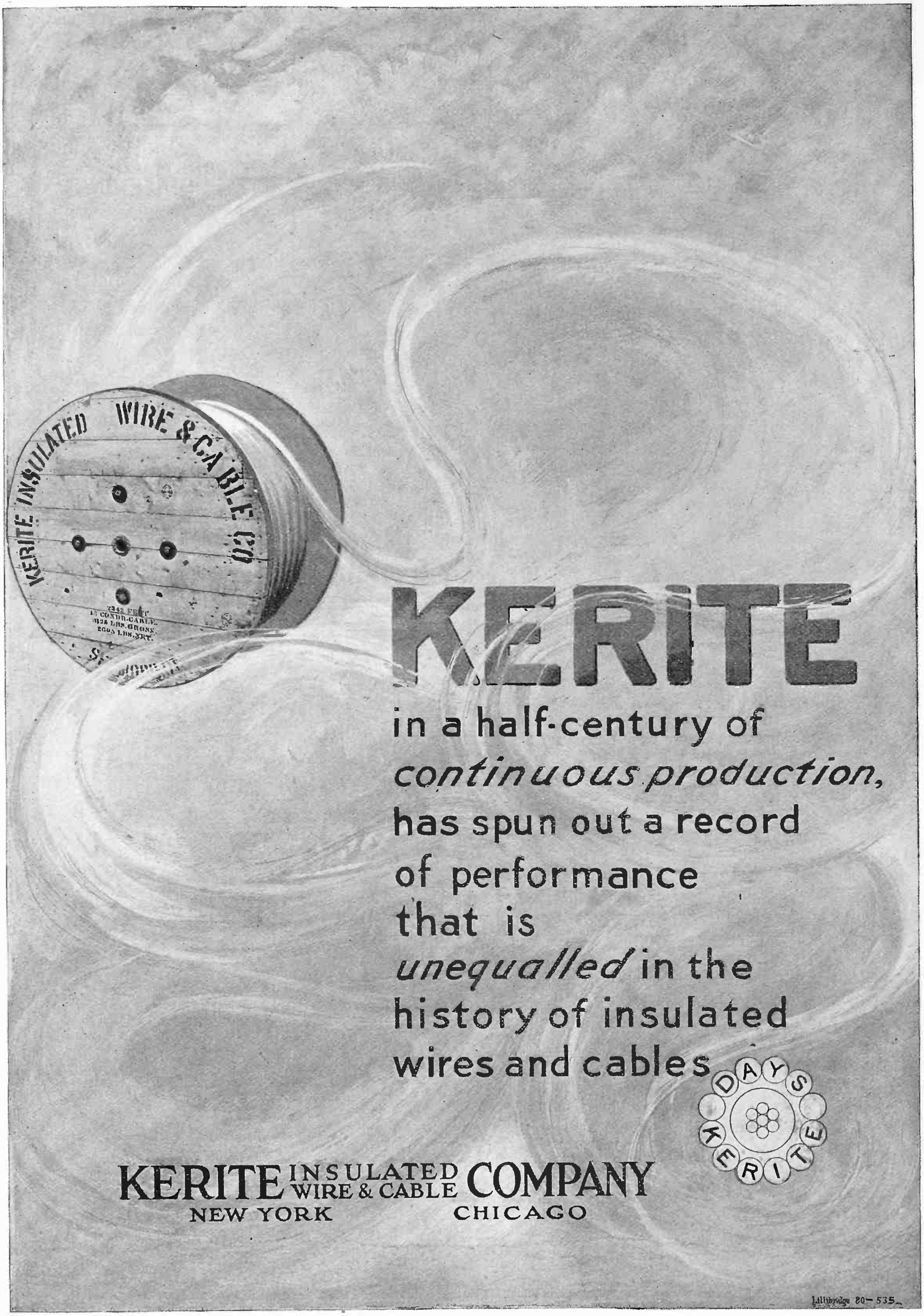
"The bookings of new business steadily increased during the year," states Guy E. Tripp, Chairman of the Board of Directors, "and the value of unfilled orders at the close of the year was $61,914,237, as compared with $50,740,696 at the close of the previous year.

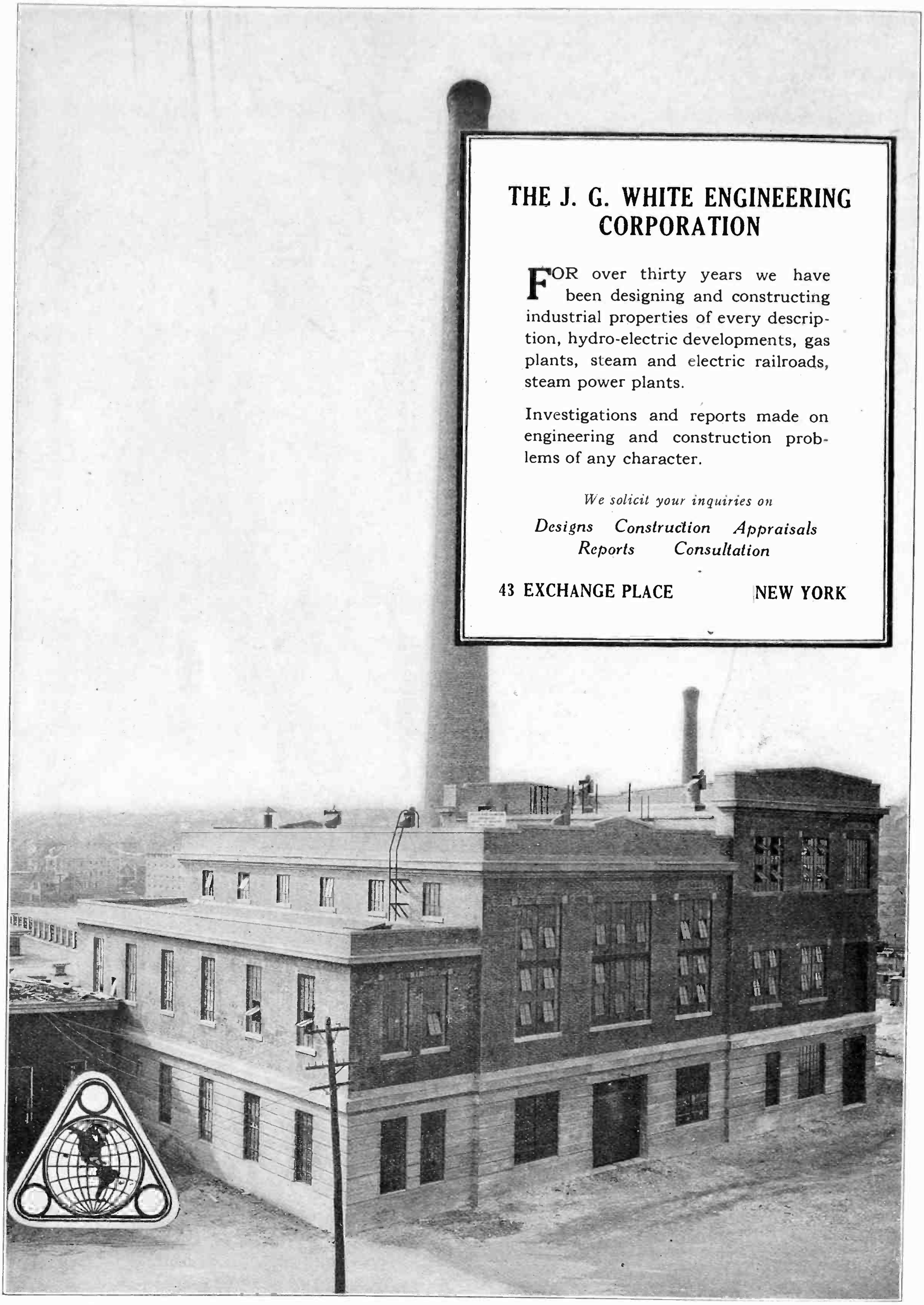
"The relations between the company and its employees are satisfactory. Under the company's insurance and savings plan, two-thirds of the employees owned insurance of $500 or more each. The deposits by the employees in the Savings Fund are accumulating at a rate in excess of $100,000 a month, and the total savings to date are in excess of $2,000,000. The savings are invested for the benefits of the employees and are not used in any way in the company's operations."

A plant located at Sharon, near Pittsburgh, was acquired during the year, and it is planned to concentrate the manufacture of transformers there. Two hundred dwelling houses located near the company's South Philadelphia Works and formerly the property of the Emergency Fleet Corporation, were purchased and are being sold to employees.

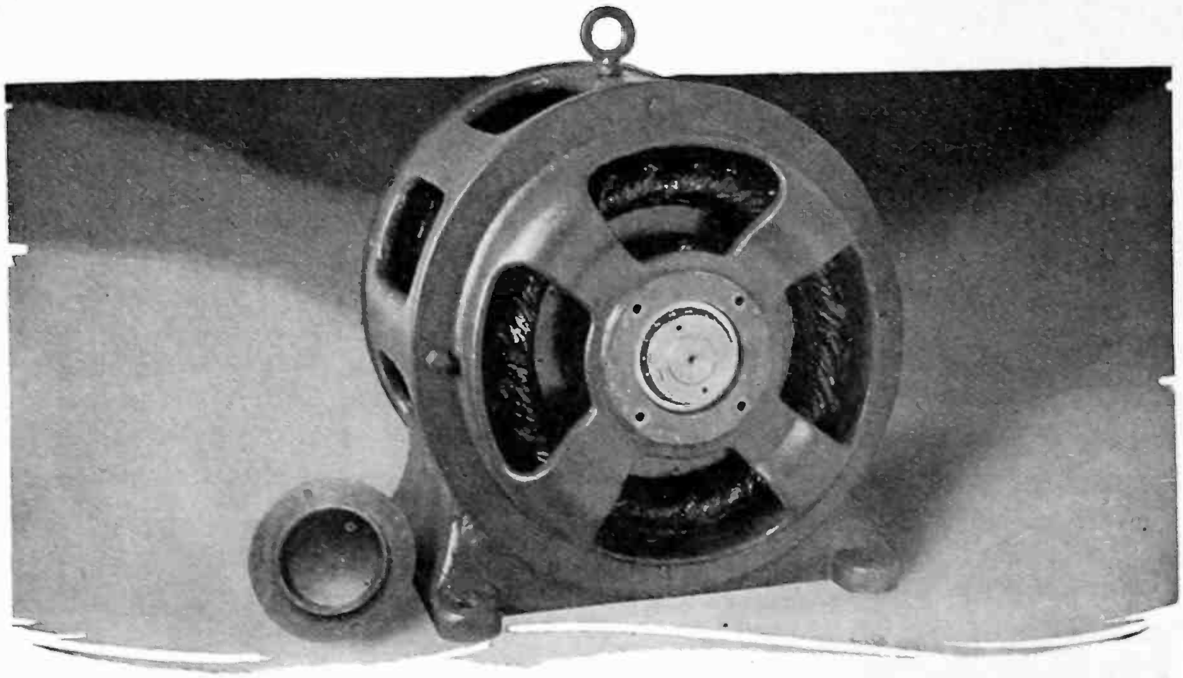
Transformer Thermal Indicator.—A new device known as the Transformer Thermal Indicator has been placed on the market by the Westinghouse Electric & Manufacturing Company to indicate the temperature of the hot oil in distribution transformers. The new indicator, which may also be adapted for use on any oil-insulated electrical apparatus, was developed to meet a demand on the part of central stations for a device that could be easily installed and would indicate accurately the actual and maximum temperature of the oil. All other devices developed heretofore have been of the semaphore or flag type.

The new indicator is actuated by an alcohol thermometer with the bulb at the end of a flexible type which can be placed at any desired point in the oil of the transformer. Pressure from the bulb is transmitted by means of a capillary tube to an operating mechanism constructed on the principle of the Bourbon gage. Two pointers are used on the indicating dial, one red to indicate the maximum temperature of the oil and the other black to indicate the actual temperature of the oil at the time of reading. The red pointer makes it possible to detect either an underloaded or an overloaded transformer.


KERITE INSULATED WIRE & CABLE CO
KERITE
in a half-century of
continuous production,
has spun out a record
of performance
that is
unequalled in the
history of insulated
wires and cables
DAYS
KERITE
KERITE INSULATED WIRE & CABLE COMPANY
NEW YORK
CHICAGO


THE J. G. WHITE ENGINEERING CORPORATION
FOR over thirty years we have been designing and constructing industrial properties of every description, hydro-electric developments, gas plants, steam and electric railroads, steam power plants.
Investigations and reports made on engineering and construction problems of any character.
We solicit your inquiries on
Designs Construction Appraisals
Reports Consultation
43 EXCHANGE PLACE NEW YORK

SKF



Ball Bearings on Electric Motors
Reduce Maintenance and Production Losses

WITH plain-bearing equipped motors, bearing adjustments and replacements are of frequent occurrence and if bearing wear is not detected in its early stages, more serious trouble such as damaged windings will occur.

Furthermore oil leaks out onto the motor parts resulting in serious damage. As a result motor maintenance charges are high and machines must often be shut down when most needed, to remedy motor troubles.

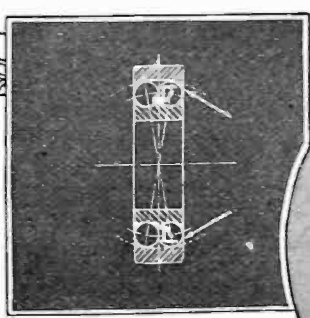
When motors are equipped with SKF marked self aligning ball bearings, continuous, uninterrupted service with minimum maintenance is assured. Air gaps are maintained and bearing adjustments and renewals are unnecessary for ball bearings develop no appreciable wear. Furthermore, they are mounted in sealed housings from which grease, the lubricant used, cannot escape. So little lubricant is needed and at such infrequent intervals that the oil man is released for more productive work.

Let our engineers submit plans for changing over your present equipment.

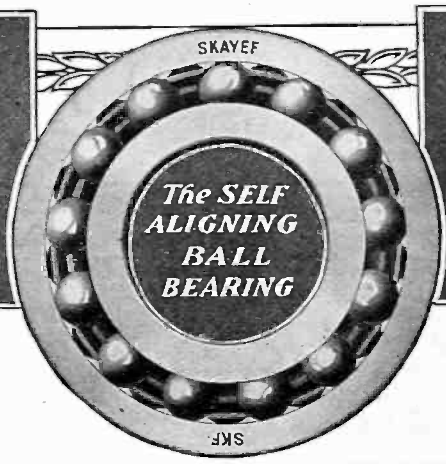
THE SKAYEF BALL BEARING COMPANY

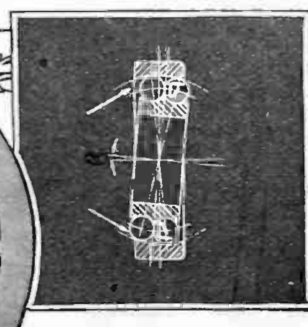
Supervised by SKF INDUSTRIES, INC., 165 Broadway, New York City

947



Normal View





Deflected View

BALL BEARINGS

The Highest Expression of the Bearing Principle

The Genuine!

There is only one "Guaranteed Penetration Process" - its "the P & H". It guarantees- in writing - a **full one half inch** uniform penetration throughout the ground line area.

A written guarantee goes with every shipment of "P & H Guaranteed Penetration Process" poles agreeing to refund the butt-treating price on any pole that does not have the full specified half-inch penetration.

The "P & H" Guaranteed Penetration Process

gives you absolutely certain results no guesswork. For the most reliable pole service - for the longest pole life - insist on the genuine "P & H"

We can fill any pole needs - for Butt-Treated and untreated Northern White and Western Red Cedar poles - or for any form of Butt-Treatment.

Prompt Shipment assured by the convenient location of our yards in the North Central and Western States.

Our interesting folder on the Butt-Treatment of cedar poles will tell you the why and wherefor of the "P & H Guaranteed Penetration Process." Write for a copy.

Copyright, 1922 by P & H Co.

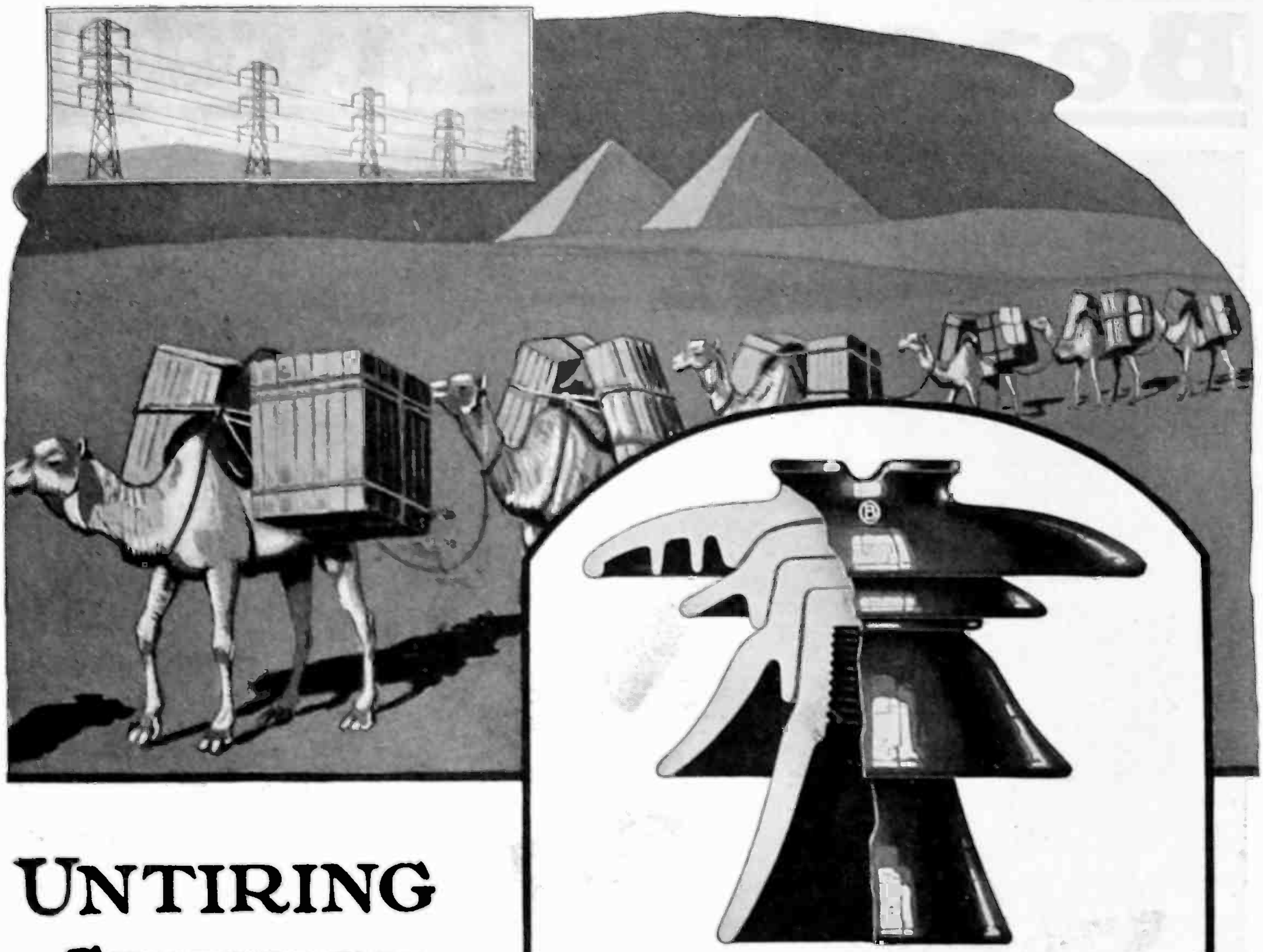
"P & H" Guaranteed Penetration Process Poles in lines of Chicago, North Shore and Milwaukee R. R.

PAGE AND HILL CO.

MINNEAPOLIS, MINN.

Grand Rapids, Mich., Powers Bldg.

New York, N. Y. 50 Church St.
Chicago, Ill., 19 So. LaSalle St.
Kansas City, Mo. 717 Bryant Bldg.
Omaha, Neb., 513 Electric Bldg.
Houston, Texas, 1111 Carter Bldg.
Dallas, Texas, 311 Sumpter Bldg.
Buffalo, N. Y. 950 Ellicott Sq. Bldg
Louisville, Ky. 1416 Starks Bldg.



Pin type insulator with general voltage rating of 66.00. For potentials as high as 88.000, suspension units are commonly used, but where special conditions require a pin type insulator, this unit will usually meet the requirements.

UNTIRING SERVICE

ACROSS the trackless desert, frequently guided only by the stars, the plodding caravan moves toward its appointed destination, each camel bearing its own heavy burden. Travelling far from human habitation, the caravan is often dependent upon its own resources for days, and sometimes for weeks, with no alternative but to keep plodding until the goal is reached. In like manner, the insulators on the transmission line must render untiring service month after month and year after year, holding in check electrical forces of tremendous destructive power and at the same time carrying heavy mechanical loads.

Under these severe conditions, millions of O-B High Efficiency Insulators are giving satisfactory service and maintaining the O-B Reputation for thoroughly reliable operation.

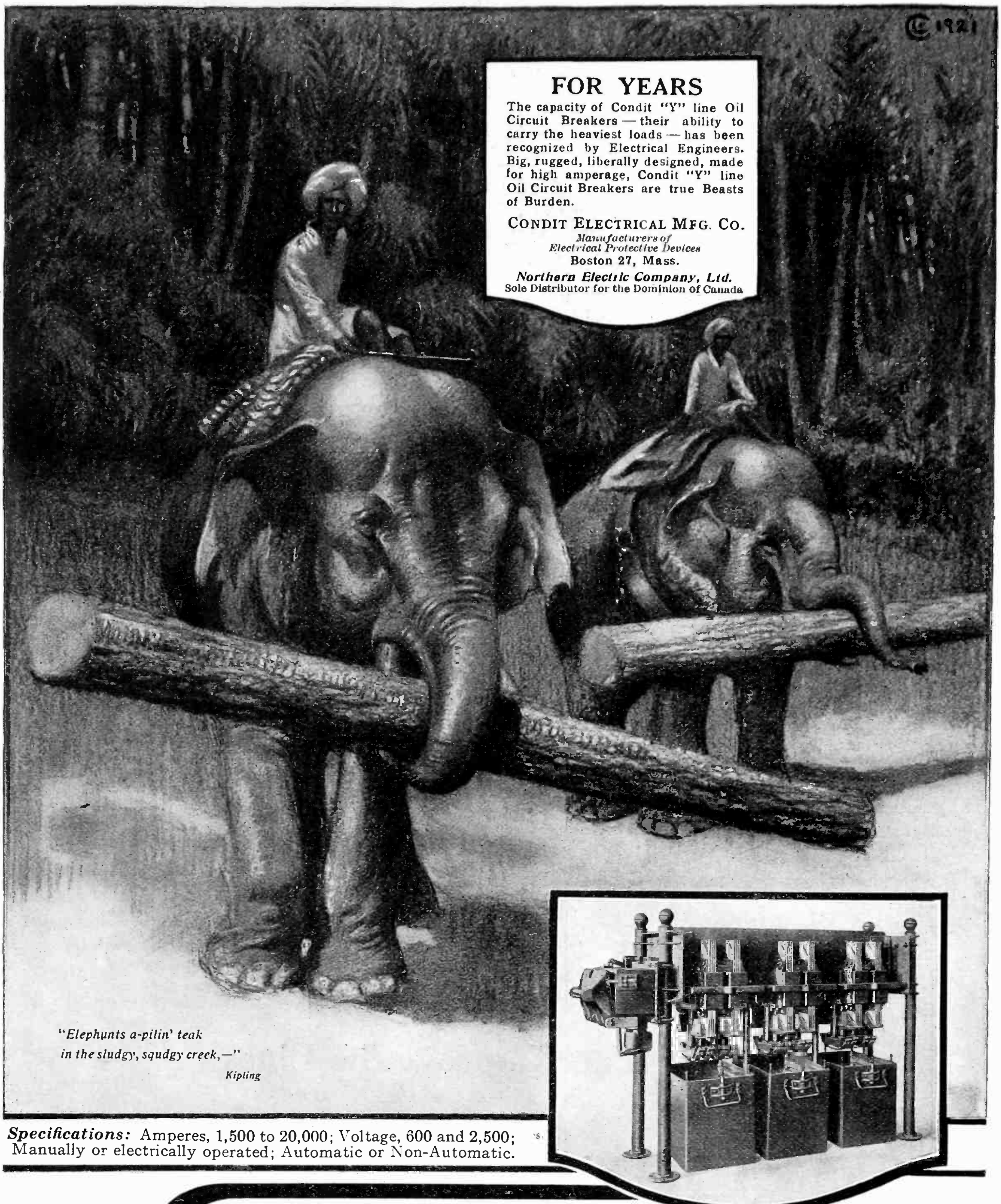
(B) Designs Improve the Lines

The Ohio (B) Brass Co.
Mansfield, Ohio, U.S.A.

New York Philadelphia Pittsburgh Charleston, W. Va. Chicago Los Angeles San Francisco Paris, France

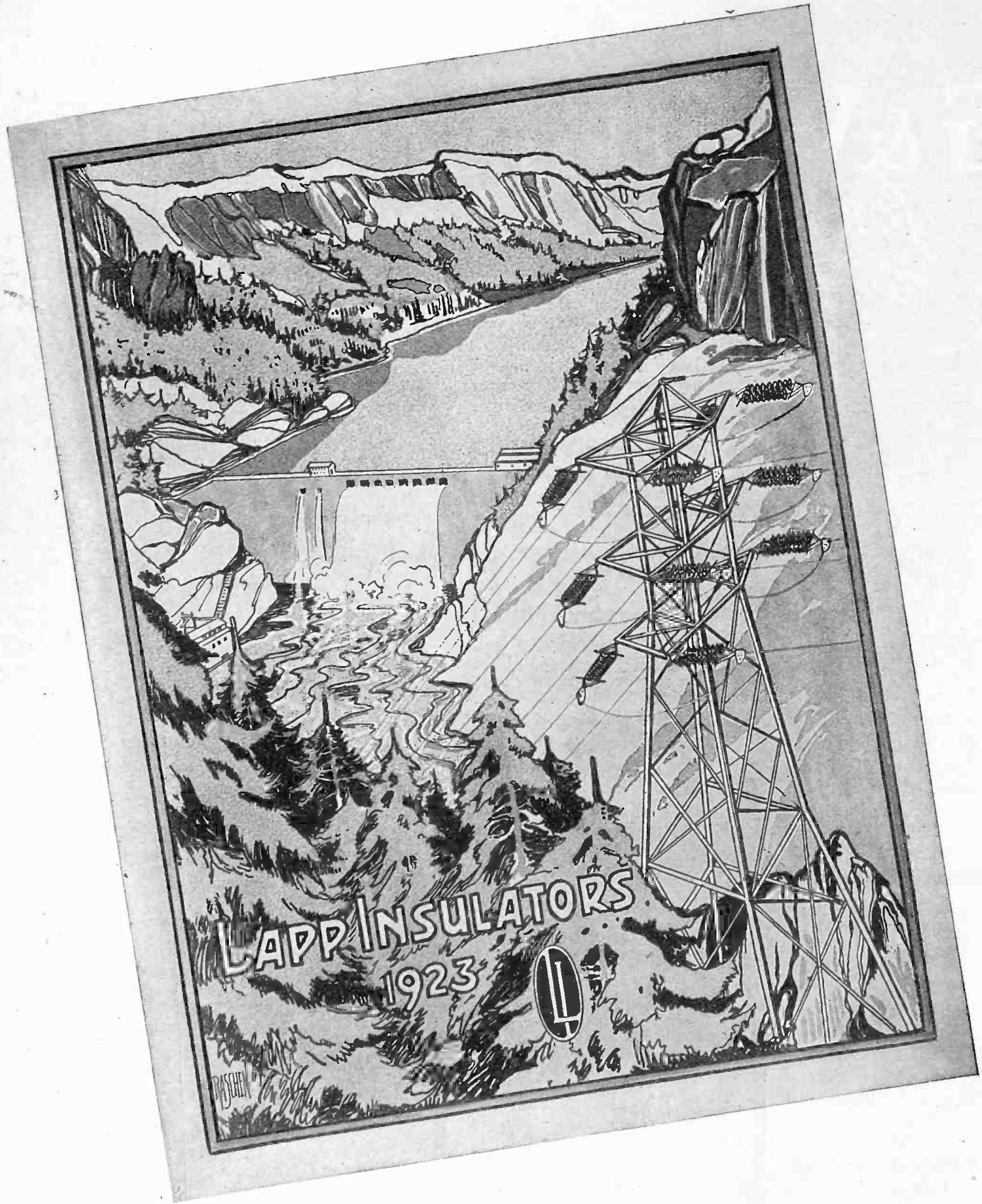
Products: Trolley Material, Rail Bonds, Electric Railway Car Equipment, High Tension Porcelain Insulators, Third Rail Insulators

Beasts of Burden



Specifications: Amperes, 1,500 to 20,000; Voltage, 600 and 2,500; Manually or electrically operated; Automatic or Non-Automatic.

CONDIT



Lapp Catalog No. 3 is now being mailed.
Let us know if you don't get your copy.

LAPP INSULATOR CO., INC., LE ROY N. Y., U. S. A.

Sales Representatives

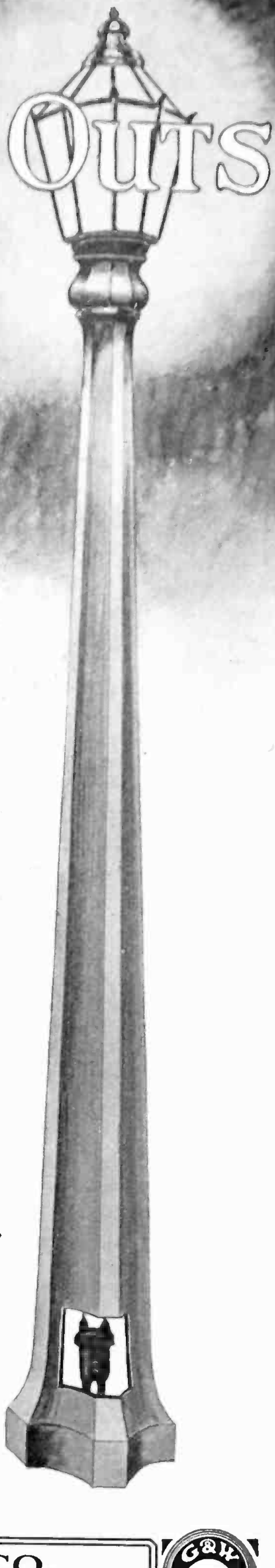
SAN FRANCISCO, S. H. Lanyon, 509 New Call Bldg.
DENVER, O. H. Davidson Equipt. Co., 1633 Tremont St.
ST. LOUIS, Commercial Elec. Supply Co., Broadway & Spruce Sts.
MINNEAPOLIS, J. E. Sumpter Co., 222 Security Bldg.
DETROIT, F. R. Jennings Co., 805 Ford Bldg.
INDIANAPOLIS, W. D. Hamer Co., 518 Trac. Terminal Bldg.

Sales Representatives

PITTSBURGH, Union Electric Co., 933 Liberty Ave.
BUFFALO, Robertson-Cataract Electric Co.
CHARLOTTE, N. C., J. W. Fraser Co.
PHILADELPHIA, Rumsey Electric Co., 1007 Arch St.
NEW YORK CITY, Shield Electric Co., 149 Broadway
BOSTON, Wetmore-Savage Co., 76 Pearl St.

WELLINGTON, New Zealand, Jas. J. Niven & Co.

Specify G & W SERIES CUT OUTS for Your Street Lighting



Points You Will Like

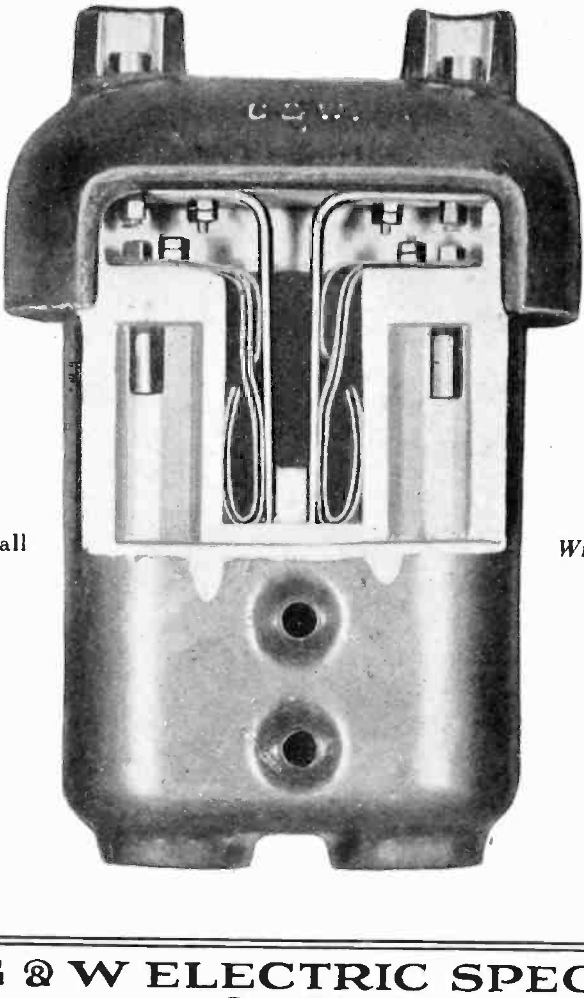
(1) All Porcelain. Safe.
(2) Long laminated springs of special form. Absolute certainty of action.
(3) Ample contact surface.

Points the Erector Will Like

(1) Long cable seal making accurate running of cable sheath unnecessary.
(2) Ample length of insulation under compound. Eliminating danger of flashover.
(3) Cable lugs assembled on cable outside pothead. Simple to connect.

Points the Operator Will Like

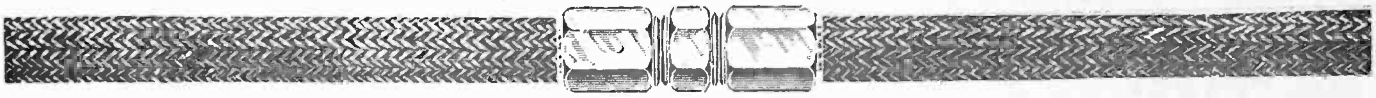
(1) Complete visible electrical and mechanical disconnection.
(2) Secondary contacts eliminating all danger of arcing.
(3) Rugged porcelain, easy and safe to operate.



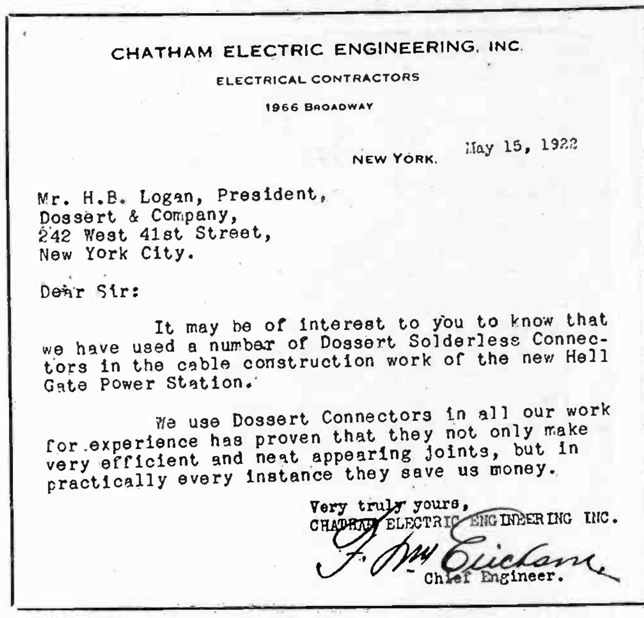
Representatives in all Principal Cities

Write for Catalogue and prices

G & W ELECTRIC SPECIALTY CO.
CHICAGO ILLINOIS



Read this ¶


CHATHAM ELECTRIC ENGINEERING, INC.
ELECTRICAL CONTRACTORS
1966 BROADWAY
NEW YORK. May 15, 1922

Mr. H.B. Logan, President,
Dossert & Company,
242 West 41st Street,
New York City.

Dear Sir:

It may be of interest to you to know that we have used a number of Dossert Solderless Connectors in the cable construction work of the new Hell Gate Power Station.

We use Dossert Connectors in all our work for experience has proven that they not only make very efficient and neat appearing joints, but in practically every instance they save us money.

Very truly yours,
CHATHAM ELECTRIC ENGINEERING INC.
Chief Engineer.

and Save $

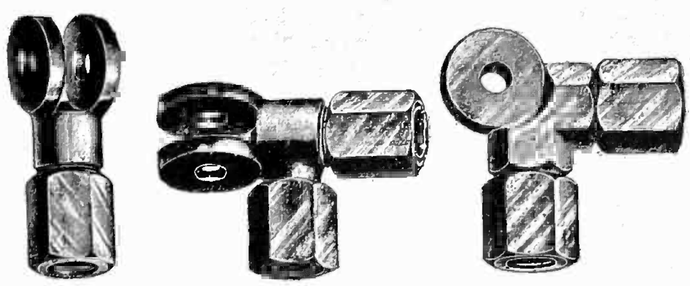
—*with* DOSSERTS

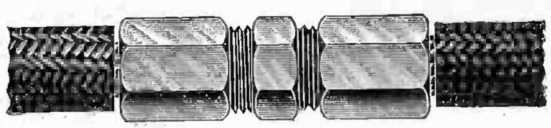
IN EVERY power house, substation and distribution system you'll find joints that DOSSERTS will do quicker and better than old methods.

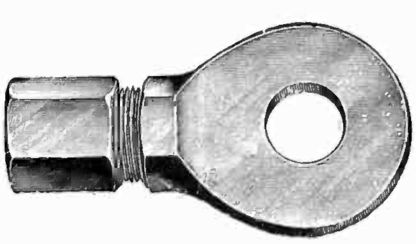
If you will figure up the year's costs for making taps, splices and connections on your system, you'll find that it represents a cost that you can cut materially if you follow the lead of a number of companies that keep a supply of DOSSERTS in the stock room.

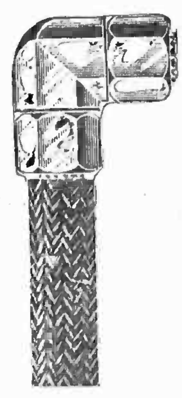
A Dossert Catalog in the hands of your men will show them the kind of connections that can be done so quickly with this Tapered Sleeve Principle of Solderless Connection. ***Write for a copy.***

DOSSERT & CO., H. B. LOGAN, President
242 West 41st Street, New York


Cable Anchors

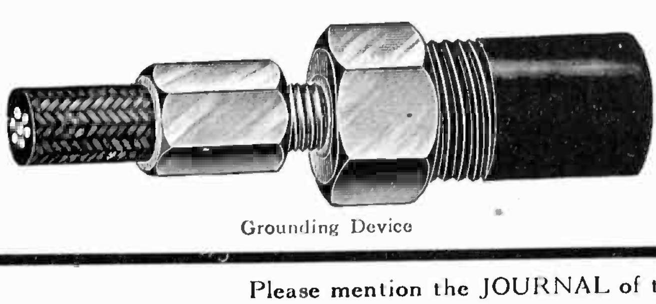

2-Way, Type A

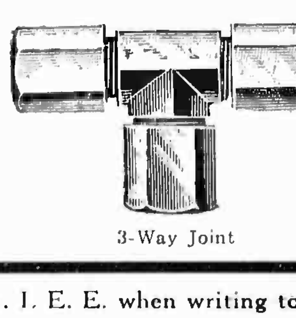

Back Lug


Elbow


Y-Joint


Cable Tap


Grounding Device


3-Way Joint


Swivel Lug

FERRANTI
TRANSFORMERS

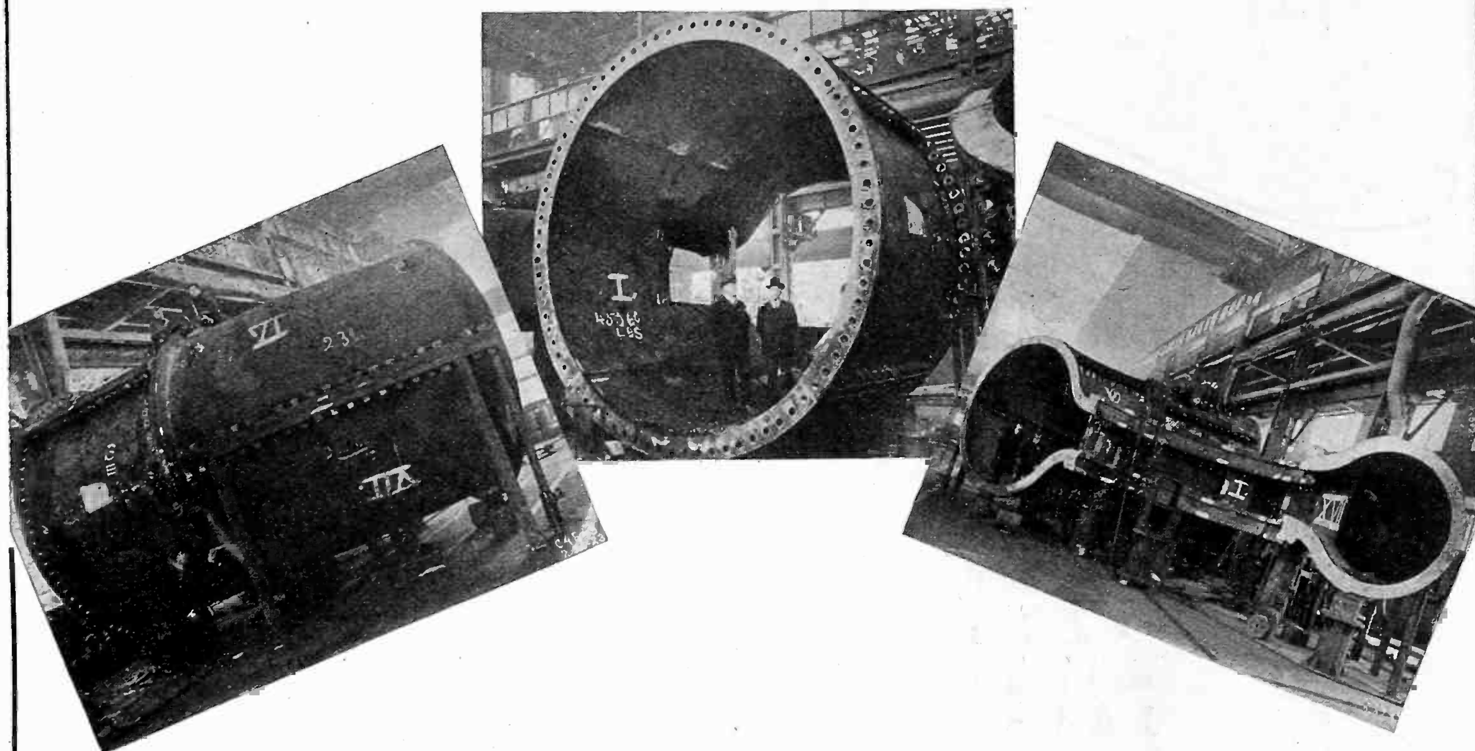
Ferranti Limited.
Hollinwood.
Lancashire.

ENGLAND

I. P. Morris Hydraulic Turbines

The Wm. Cramp & Sons Ship & Engine Building Co.

Richmond and Norris Streets, Philadelphia



Cast Steel Casing Sections for Two 70,000 H. P. Turbines—"Most Powerful in the World" are now under construction for installation in Plant No. 3-C of

THE NIAGARA FALLS POWER CO.

HEAD 213.5 FEET SPEED 107 R. P. M.

Special Features included in design of these units:—

Pneumatic Lubricating System
Moody Spreading Draft Tube
Automatic Governor Control
Offset Operating Gear
Taylor Sectionalized Cast-Steel Casing
Adjustable Lignum vitae Guide Bearing
Labyrinth Runner Seals
Disk Guide Vanes
Double Floating Lever Governors

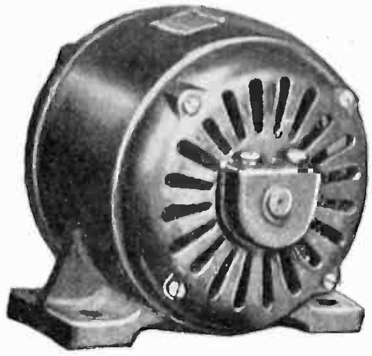
Thirteen 10,000 H.P. turbines, two 1000 H. P. turbines and two 37,500 H.P. turbines have previously been installed in the above Power Company's Plant. The first of these units was installed in 1907, and the service rendered by this plant is demonstrative of the dependability of I. P. MORRIS HYDRAULIC TURBINE MACHINERY.

Three Johnson Hydraulic Penstock Valves—"Largest in the World"
are also under construction for the above development

Designers and Builders of the Johnson Hydraulic Valve

Associated Companies

THE PELTON WATER WHEEL COMPANY, San Francisco and New York
DOMINION ENGINEERING WORKS, LTD., Montreal, Canadian Licensees
M. HILPERT & CO., Rio de Janeiro, Brazilian Licensees



When small motors "keep going" trade keeps coming—*but*—

ABOUT all the average buyer of a small motor knows or cares about a motor is that he (or she) wants one that will "go" and "keep going". If it does go and keeps going after he gets it, he is satisfied—and keeps coming back to you when he wants something electrical. And his friends will come, too.

That is why the sale of Wagner, Quality Small Motors is business insurance for dealers who sell them. Wagner, Quality keeps the motor "going"—keeps the customer coming back for more purchases. And Wagner, Quality costs no more!

Ask for a copy of Bulletin 1266, which tells how carefully every Wagner Small Motor is made.

WAGNER ELECTRIC CORPORATION
SAINT LOUIS

Wagner, Quality

Fractional Horsepower Motors

61-5430-1

Suppose you were to change your position tomorrow

And suppose you went into an entirely different industry and had to meet entirely new mechanical conditions—had to operate different types of power units, had to maintain new types of machines. You'd have a new set of mechanical problems to work out.

But there is one problem that need not worry you in the least—an important one, too.

And that is the question of the kind and amount of lubricants to use.

You—and the next man—have only to call on The Texas Company, tell us what you have to lubricate, and we'll supply you with the right oils—promptly.

We can do it—because we are doing it. We are doing it in every industry, on every kind of machine under every conceivable working condition.

We have the *lubricants*
And we have the *men* who understand their application.

If you have any lubricating problem, new or old, which you want solved once and for all, give us the opportunity to "Demonstrate."

When you see the way we go about things, you, who are responsible for maintenance, will know that Texaco Lubricants and Texaco Service are your Allies in your fight against waste of power and unwarranted consumption of lubricants.

Texaco Lubricants will be promptly delivered from one of our 700 warehouses all over the country and Texaco Service can be readily secured by calling on our nearest district office.

TEXACO

The Correct Lubricants and Lubricating Service

One Thing More.

And that is to give you the opportunity of getting our Magazine "Lubrication." This magazine, published by The Texas Company, contains technical, authoritative articles covering the use of lubricants in many industries. Anyone, whose business or profession guarantees his sustained interest in this important branch of engineering practice, may receive it. Thus the present list includes: Engineers, mechanical executives, purchasing agents, technical libraries, universities—and YOU, when you reach for your pen or pencil and do the necessary.

THE TEXAS COMPANY, U. S. A.

TEXACO Petroleum Products

Dept. EE, 17 Battery Place, New York City

Kindly put me on the mailing list to receive your magazine "LUBRICATION"

Name.. Street..

City.. State..

6-23

These men made your telephone

British Indian. A swarthy miner of mica—insulation inside the telephone.

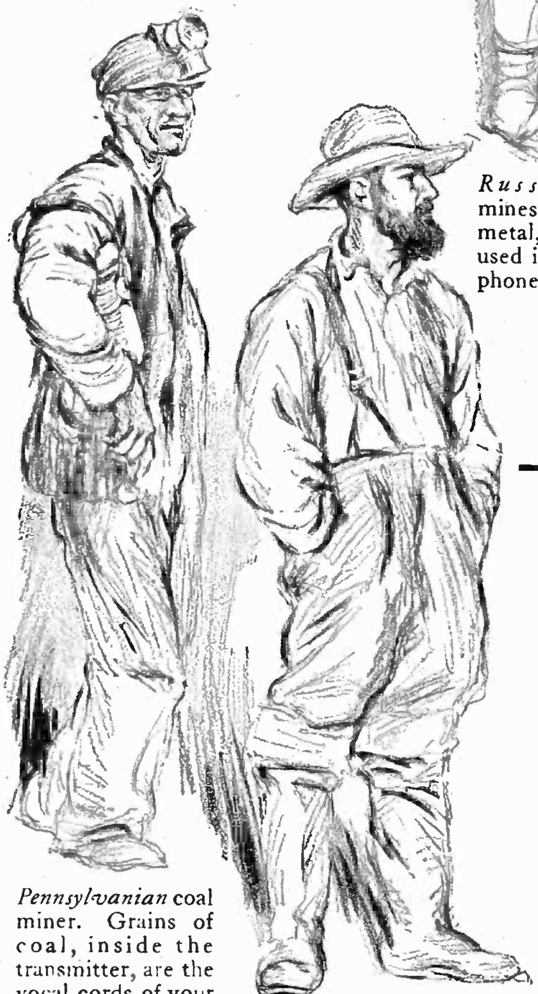
Brazilian. He drains rubber from a tree. Rubber forms the case of the receiver.

Japanese. Prepares the silk used in the covering on the telephone cord.

Irishman raises flax, from which is made linen paper — used in the condenser.

Russian. He mines the noble metal, platinum, used in your telephone.

Egyptian. We must go to the Nile Valley for certain cottons used to insulate wires.



Pennsylvanian coal miner. Grains of coal, inside the transmitter, are the vocal cords of your telephone.

Alaskan. Your telephone needs gold too, and here's the man who digs it.

—and the workman at Chicago

FROM a slab of rubber, a bundle of vegetable and animal fibres and a curious medley of minerals brought from every corner of the world, this man's skill produces a marvel of precision and ruggedness—your telephone.

He is one of 28,000 men and women at the Western Electric works in Chicago. As makers of telephones and the countless items of telephone apparatus, they are setting the standard for the whole world.

Amid strange scenes in strange lands, the picturesque types above are gathering some of the 19 materials needed to make your telephone.

Western Electric

Since 1869 Makers of Electrical Equipment

No. 2 of a series on raw materials.

Please mention the JOURNAL of the A. I. E. E. when writing to advertisers.

As smoothly as grandmother wound a bobbin of thread

THERE is really no reason why your coils should not be wound as easily and smoothly as grandmother wound a bobbin of thread.

Simply see that your next specifications call for Acme Wire—*it goes in the space.*

Acme Wire is made by a company that for years has specialized in the endeavor to make a better wire for a particular purpose. In our own plant we wind hundreds of thousands of coils, and so know exactly what magnet wire should be and what it should do.

The difference between Acme Wire and other magnet wire is only a matter of degree. Probably with the naked eye you could not detect this difference. Yet the fact remains that in many instances Acme Wire has reduced winding costs as much as ten to twenty per cent.

Acme Wire is uniform and free from lumps and imperfections. It insures better-wound coils and fewer rejections. A coil wound with Acme Wire will take the specific number of turns without piling up.

Throughout the entire process of making Acme Wire it is inspected to see that it is up to the high Acme standard. The result is a quality product, one that we are proud to make and you will be glad to use.

Illustrated Catalog on Request to Engineers, Purchasing Agents, Executives and Operators.

THE ACME WIRE CO., New Haven, Conn.

NEW YORK CHICAGO CLEVELAND

Acme Wire

"It goes in the space"

Some Users of Acme Magnet Wire

Atwater Kent Mfg. Co.
Azor Motor Mfg. Co.
Century Electric Co.
Dayton Engineering Laboratories Co.
Delco-Light Co.
Diehl Mfg. Co.
Domestic Electric Co.
Eisemann Magneto Corporation
Electric Auto-Lite Corp.
Electric Specialty Co.
Electrical Products Mfg. Co.
Eureka Vacuum Cleaner Co.
Ford Motor Co.
Gray & Davis, Inc.
Hamilton Beach Mfg. Co.
Holtzer-Cabot Electric Co.
Hoover Suction Sweeper Co.
Klaxon Co.
Robbins & Myers Co.
Sangamo Electric Co.
Sunlight Elec. Mfg. Co.
U. S. Auto Supply Co.
Wagner Electric Corporation
Western Cartridge Co.
Westinghouse Elec. & Mfg. Co.

Acme Wire Products

"Enamelite," plain enameled Magnet Wire; "Cottonite," Cotton-covered Enamelite; "Silkenite," Silk-covered Enamelite; Single and Double Cotton Magnet Wire; Single and Double Silk Magnet Wire. We also have a complete organization for the winding of coils in large production quantities.

Acme Electrical Insulations

Flexible Varnished Tubing in all standard sizes and colors.

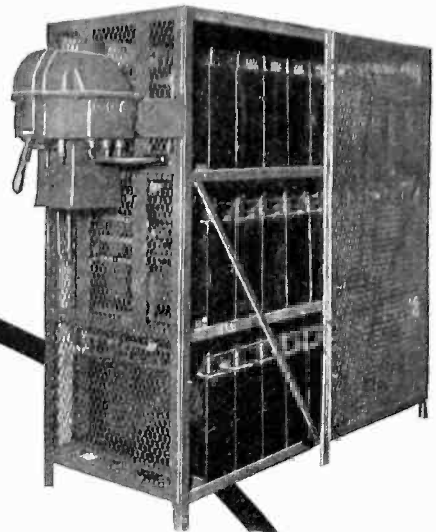
Acme Radio Specialties

Audio Transformer windings.
Radio Frequency windings.
Magnet windings for Head Sets.
Enameled wire—especially the finest sizes, 40-44 B & S gauge.
Silk and cotton-covered magnet wire.
Enameled Aerial wire—single wire and stranded.

For Power-Factor Correction

Secure Dependable Operation by Installing —

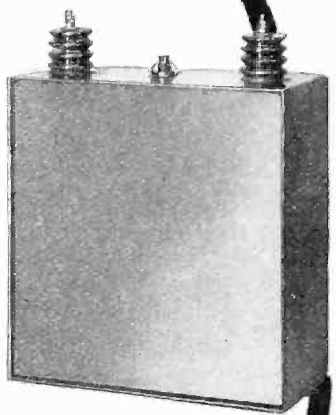
Type LD Static Condensers



120 Kv-a., 3-Phase, 2300-volt Type LD Static Condenser complete with F-10 Oil Circuit Breaker. One section of grill removed to show assembly of units.

The outstanding characteristics of the Type LD Static Condenser are ruggedness and reliability of operation. A radical departure from previously established principles of condenser design gives a unit that is absolutely dependable. The high insulation factor assures the same satisfactory service as is secured in transformers, motors and generators.

In many cases the first cost of a static condenser equipment can be *earned* in a few months by the saving in power bills. Losses are almost nothing—less than ½ of 1% in the 2300 volt condensers, and in the lower voltage equipments, using transformers, the losses are less than 3½%.



Type LD Individual Static Condenser Unit.

No special foundation is required, as there are no moving parts. Operation is noiseless and requires no attention.

The condenser does not "drop off" the line if the voltage should fail for a short time.

The reliability of this equipment has been proved by tests of many months' duration under actual service conditions.

For more complete information on the Type LD Static Condenser ask for Descriptive Leaflet No. 20044.

Westinghouse Electric & Manufacturing Co.
East Pittsburgh, Pa.

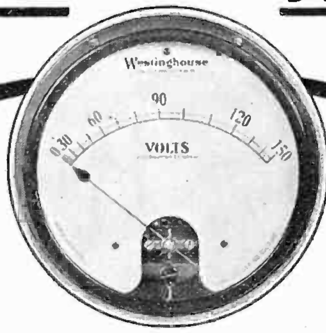
WESTINGHOUSE ELECTRIC

Westinghouse

ANNOUNCING

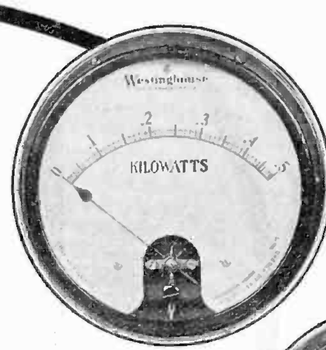
A Complete New Line of Ideal Alternating-Current Switchboard Instruments

Type DY, 4⅜ in. Diameter **Type SY, 7½ in. Diameter**

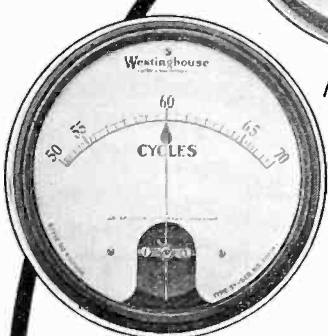


Voltmeter

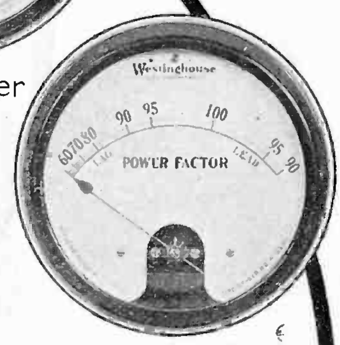
Ammeter



Kilowatt Meter



Frequency Meter



Power Factor Meter

"Achievement Is the Measure of Progress, The Prophecy of Greater Things."

The electric light and power industry has achieved results unparalleled by any other primary industry and stands today on the threshold of still greater things.

Its enormous growth emphasizes the necessity for instruments of great inherent accuracy.

Westinghouse Type Y Instruments have the following important advantages:

- High accuracy
- Reduced weight of instruments
- Reduced weight of movement in bearings
- Readings practically unaffected by frequency
- Readings practically unaffected by wave form
- Readings practically unaffected by temperature
- Readings practically unaffected by power factor
- Will better withstand vibration
- Will better withstand dampness and climatic conditions
- Waterproof construction, if desired
- Scale divisions widest at important operating loads
- External zero adjuster
- Can be calibrated on direct current

Write for Leaflet 20045 which gives full particulars.

Westinghouse Electric & Manufacturing Company
Newark Works, Newark, N. J.

WESTINGHOUSE ELECTRIC

Westinghouse

MICA-MICARTA BARRIERS

In Steel-Clad Type S

Transformer and Tank.
10 KV-A Steel Clad Type S.

W
WESTINGHOUSE ELECTRIC

The Steel-Clad Type S Transformer has concentric coils, and the high- and low-voltage windings are insulated by unbroken machine-formed mica-micarta barriers.

This type of insulation is ideal for distribution service. The barriers have an extremely high dielectric strength and, under oil, will withstand an insulation test of over 50,000 volts.

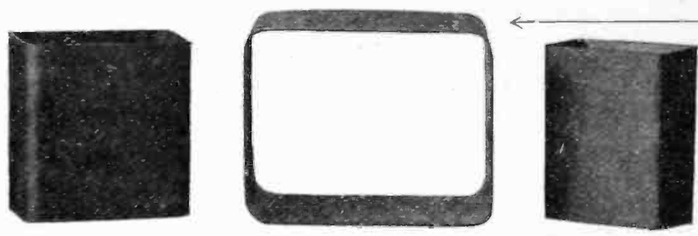
Mica-micarta barriers are a distinct feature of Steel-Clad Type S Transformers.

Westinghouse

Please mention the JOURNAL of the A. I. E. E. when writing to advertisers.

ASSURE RELIABILITY
Distribution Transformers

Mica-Micarta barrier between high-voltage and inner low-voltage coil.



Mica-Micarta barrier between high-voltage and outer low-voltage coil.

Micarta barrier between iron and inner low-voltage coil.

Machine-Formed Mica-Micarta Barriers.

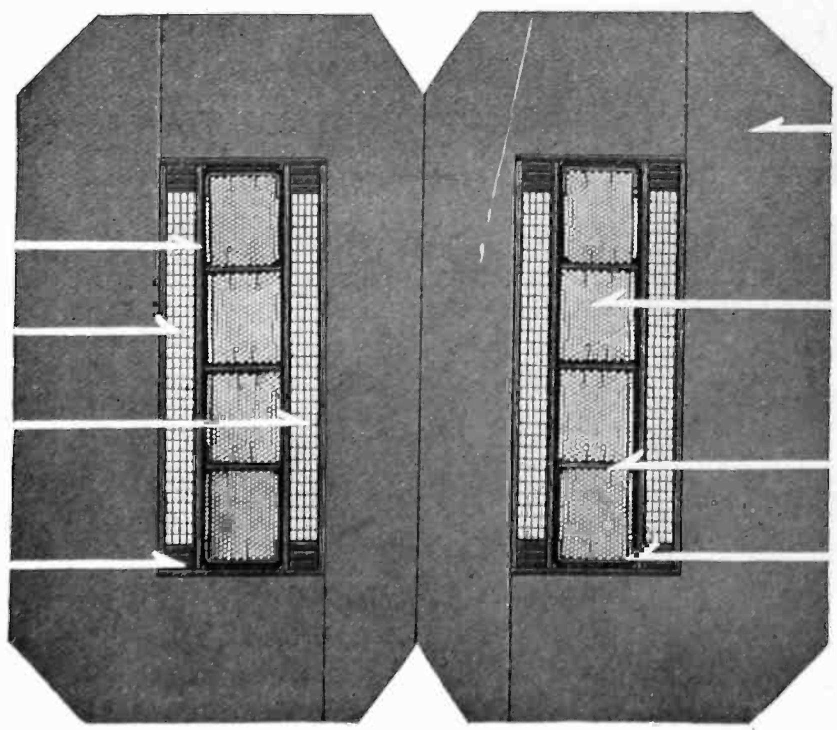
High dielectric strength.
Withstand high temperatures.
Uniform and solid mechanically
Maintain open oil ducts.
Smooth winding surface.

Mica-Micarta barrier between high and low-voltage windings.

Outer low-voltage winding.

Inner low-voltage winding.

Extra padding to increase the leakage distance between ends of windings.



L-shaped laminations of carefully graded silicon steel. (Annealed after punching).

High-voltage windings consisting of 4 coils, thus reducing the voltage stresses between layers. The high-voltage coils are wound with double cotton-covered enameled wire.

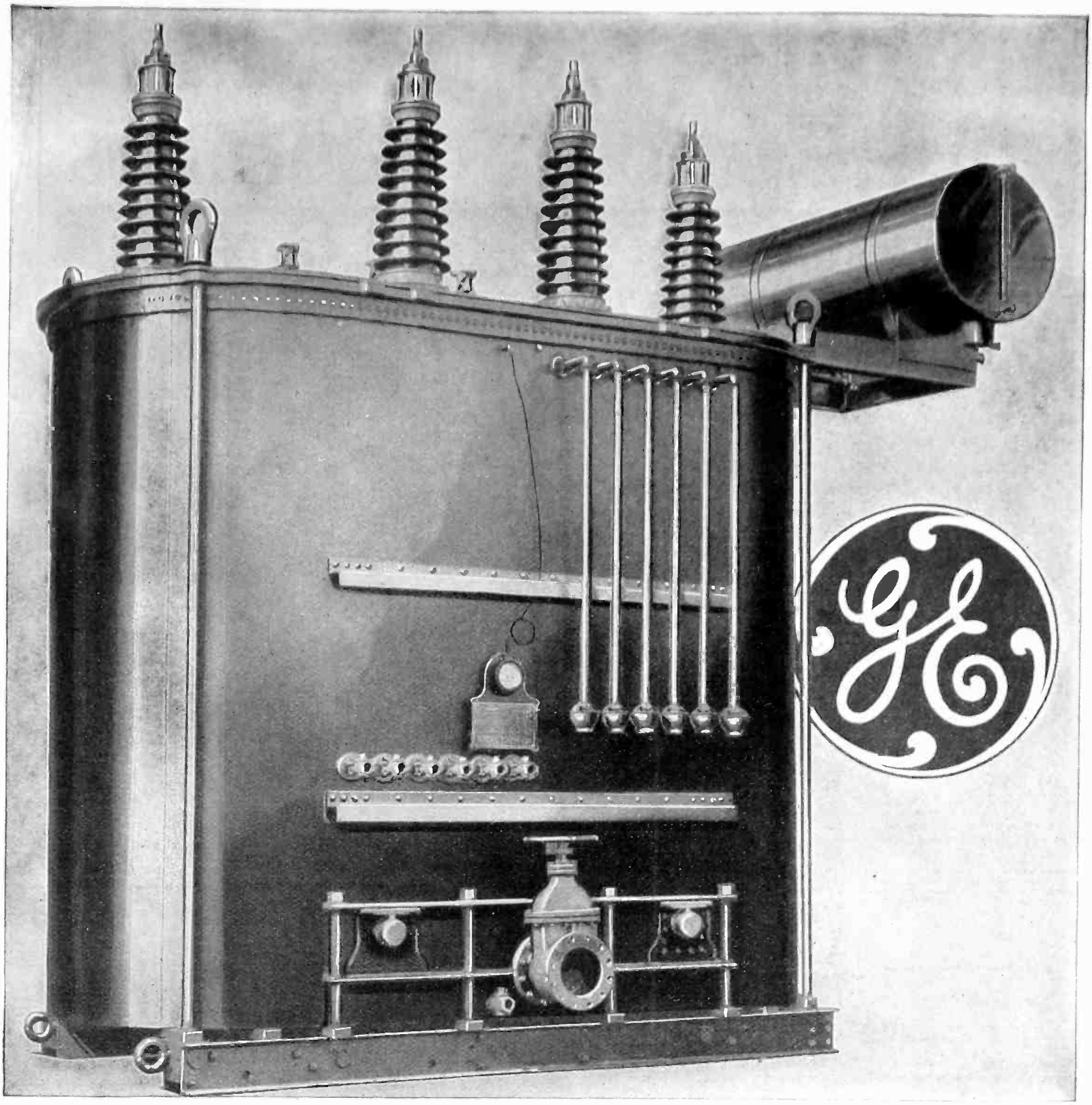
Fuller-board washers between high-voltage coils.

Mica-Micarta channel insulates the high-voltage windings from the magnetic circuit and prevents breakdowns from lightning or from line surges.

Cross Section of 10 KV-A Steel-Clad Type S Distribution Transformer

Westinghouse Electric & Manufacturing Company
East Pittsburgh, Pa.

Westinghouse



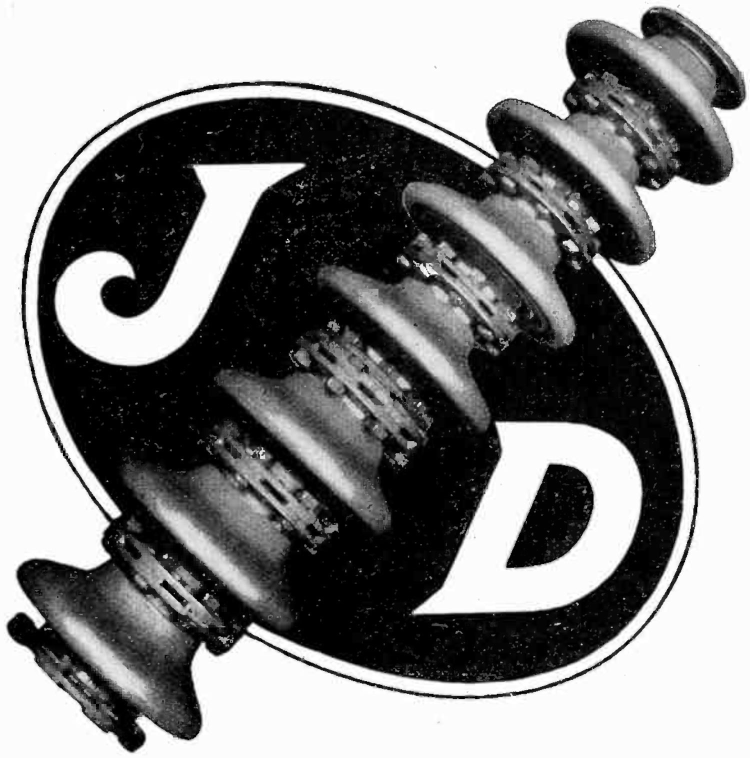
One of the eleven 24,500 (Max.) kv-a., 101,200-V. (Max. HV) 3-phase transformers for the Southern Power Co. These machines are physically larger than the G-E 50,000-kv-a. Auto Transformers built in 1918

America's Largest Transformer

THE full value of the Research, Workmanship, and Quality built into Type H Transformers today must be appraised by the future generations who will also operate them.

General Electric Company
Schenectady, N. Y.
Sales Offices in all Large Cities

GENERAL ELECTRIC



No cement to crack or crumble under vibration or mechanical impact

Why Engineers Select J-D Flange Insulators for Out-Door Sub-Station Installations

The many superiorities engineers recognize in J-D flange insulators are rapidly winning for them a decided preference for the heavy duties of out-door sub-station installations.

As a matter of both convenience and economy they appreciate the fact that units of J-D stacks are interchangeable. Injury to one unit does not mean the scrapping of the entire post. A new unit immediately replaces the old with complete accuracy.

Every J-D flange insulator, whether shipped rigidly assembled in posts, or as individual unassembled units, has been put through a severe jig test for perfect alignment. This test also provides for the determination of exact heights of posts within the allowable tolerances established by the engineers.

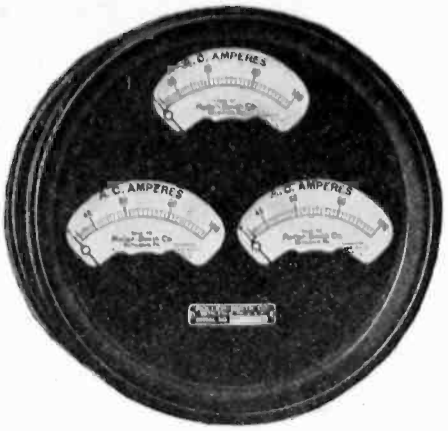
These advantages, combined with the greater cantilever strength of J-D flange post insulators and their high flashover value, make them supreme in this field.

Possibilities of interrupted service are reduced to the minimum and the factors of safety and economy are the largest available in the insulator market.

Jeffery-Dewitt Insulator Company
Kenova, W. Va.

Executive Sales Offices: 50 Church Street, New York City

JEFFERY-DEWITT INSULATOR CO KENOVA, W.VA. U.S.A.



ANNOUNCEMENT

The **Roller-Smith Company** in cooperation with one of the largest Central Stations in the Country, has developed and now offers a

NEW INSTRUMENT

The "Triplex" Three Phase Ammeter

Its outstanding feature is the **simultaneous** indication of the current in all three phases. Other distinguishing features are set forth in Bulletin AE-30, sent on request.

ROLLER-SMITH COMPANY
Electrical Instruments, Meters and Circuit Breakers

MAIN OFFICE
12 Park Place, NEW YORK

WORKS
Bethlehem, Penna.

Offices in Principal Cities in U. S. and Canada

First to the left

-then to the right

- turn the handle

U-RE-LITE unhesitatingly calls to your mind its ability to give your motors "100% I-T-E Protection."

It eliminates *all* fuses and the so called *safety switch.*

It now can be supplied to protect your 250-volt direct current motors from 1 to 300 hp. and your 550 volts alternating current motors from 1 to 200 hp.

For further information "We stand at attention!"

The CUTTER COMPANY
ESTABLISHED 1888 PHILADELPHIA

1829 Hamilton Street

TRADE MARK
BRISTOL'S
REG. U. S. PAT. OFFICE.

Recording Ammeters

are unequaled for settling complaints

You can tell every fluctuation and quantity of current—also the length of time—by just glancing at the Ammeter chart.

These Recording Ammeters keep you informed as to the true conditions in the Central Station and on the distributing lines. For settling complaints they are in a class by themselves.

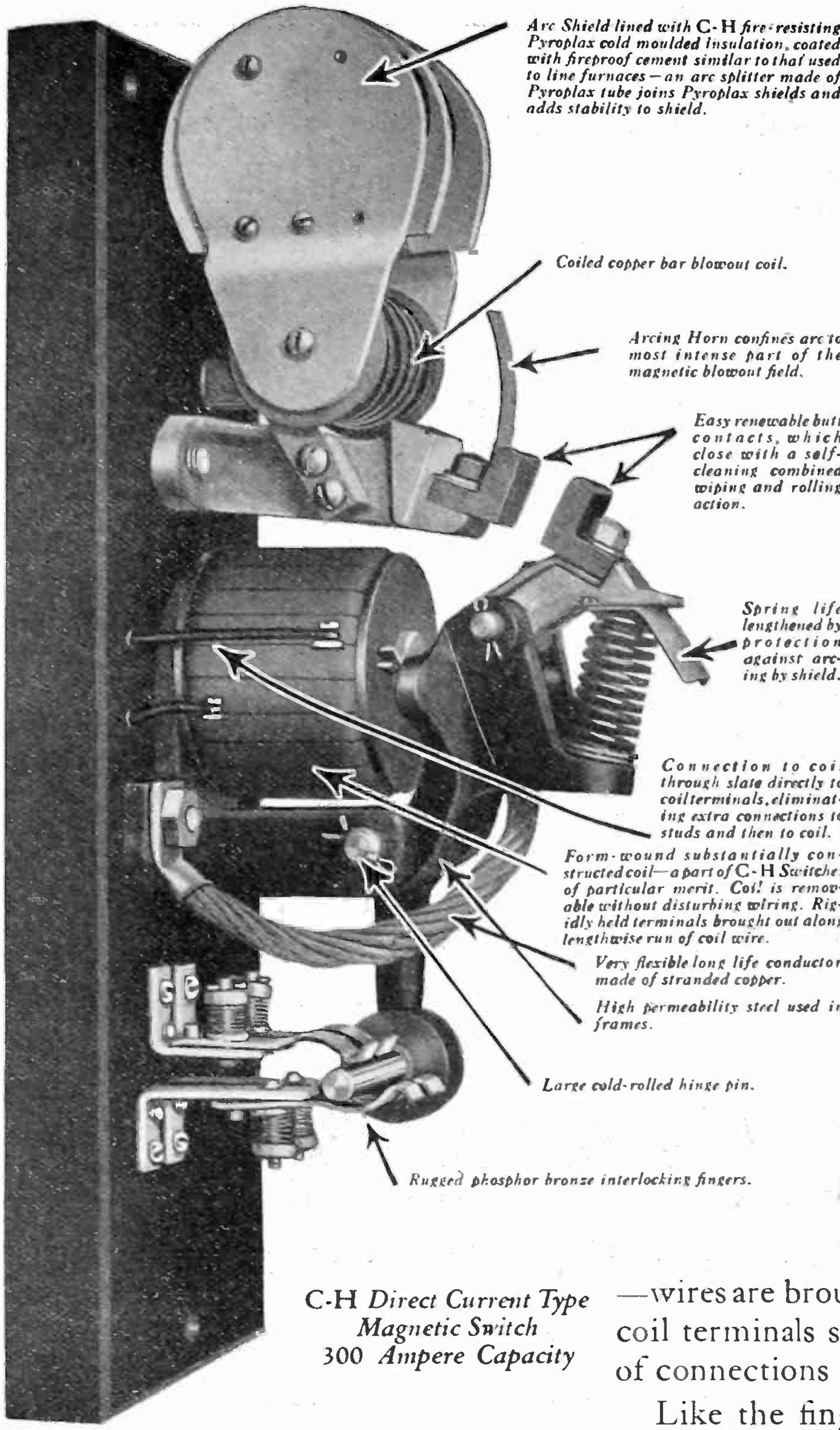
Bristol's Recording Ammeter

Let us submit quotations on equipment for your special needs. Write for Catalog BC-1501 anyway.

The Bristol Co., Waterbury, Conn.

Branch Offices:

Boston, New York, Philadelphia, Pittsburgh, Chicago, San Francisco, Detroit, St. Louis



C-H *Direct Current Type*
Magnetic Switch
300 *Ampere Capacity*

Quick Action Long Life

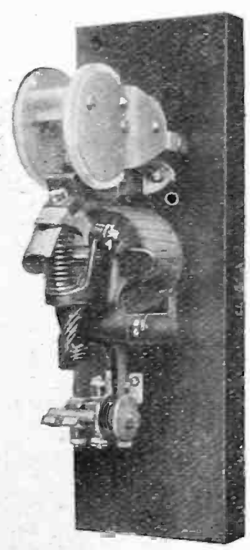
Every part of C-H Magnetic Contactors has had the most careful attention in the design and construction—based on experience in controller design and manufacture covering more than a quarter of a century.

The No. 142 Contactor is a substantial, quick-acting small switch, which has proven particularly satisfactory in thousands of Cutler-Hammer Magnetic-type Controllers. The small size is important—less space is required, control panels are of smaller dimension.

The closing time and opening time are as follows:

.14 *sec. to close*
.10 *sec. to open*

Besides the operating features, this switch has many other advantages as pointed out to the left. All bolts are accessible from the rear—wires are brought directly to the coil terminals so that the number of connections are reduced.



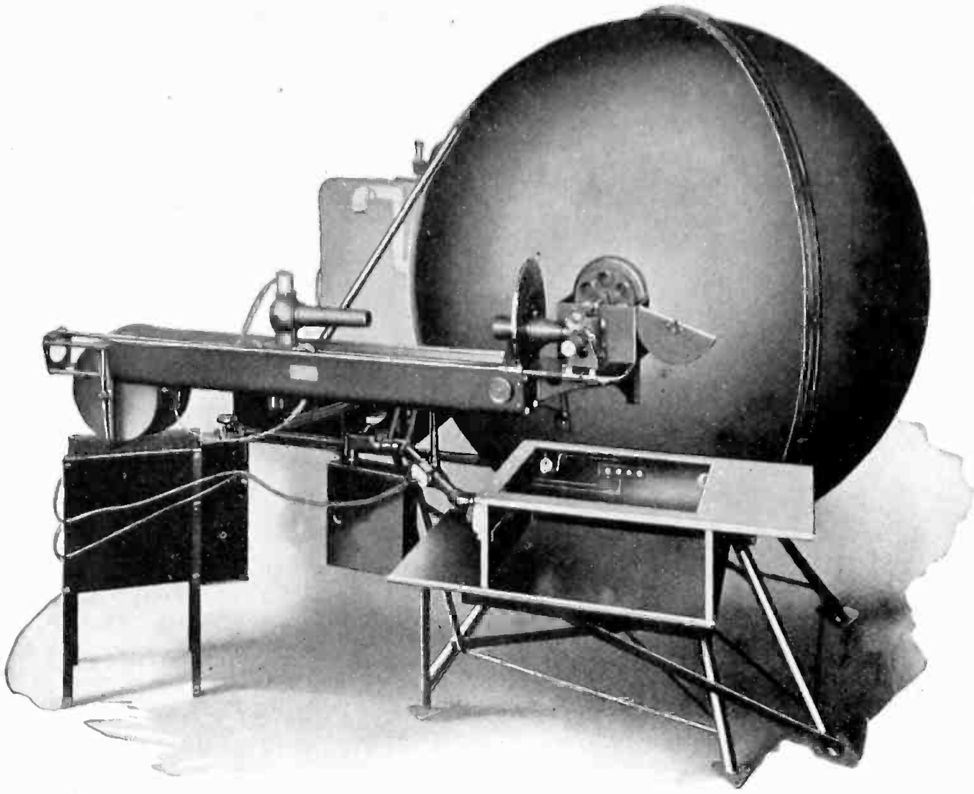
Like the fingers used on C-H Drum Controllers, the auxiliary contact fingers may be readily removed without disconnecting or disturbing the wiring.

And, in addition, the ability of Cutler-Hammer engineers in the use and grouping of contactors in controller design is of more than ordinary importance—ability which again has been gained through long experience in the field of motor control.

THE CUTLER-HAMMER MFG. CO.
Motor Control Department
Works: MILWAUKEE *and* NEW YORK
Offices and Agents in Principal Cities
Northern Electric Co., Ltd., Can.

C-H CUTLER-HAMMER **MAGNETIC CONTACTORS**

New 60-Inch Integrating Spherical Photometer



MEASURES Lumens or Mean Spherical Candlepower of Lamps up to 1500 Watts.

Using the Well Known Permanently Built in Sharp-Millar Photometer.

Scale Range 50 to 45000 Lumens.

Standardized by The Electrical Testing Laboratories.

Average Capacity 80 to 100 Lamps per Hour.

Entirely Self-Contained.

No Darkroom Required.

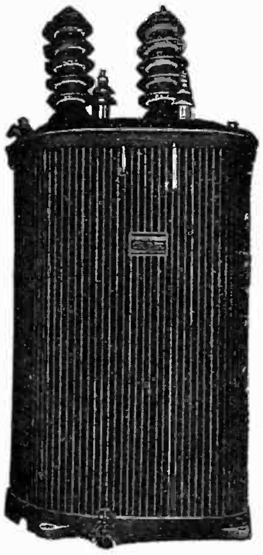
Write for Catalogue No. 32.

FOOTE, PIERSON & CO., Inc., 160 DUANE STREET NEW YORK CITY

MOLONEY TRANSFORMERS

for

Power and Substation Service



The exacting service required of transformers in the Large Power and Substation Field calls for Quality of the highest order.

Moloney Power Transformers are designed and built with the idea of not just meeting, but of *exceeding* the requirements of this field of service. Supreme Quality is built into every part of a Moloney Power Transformer.

Write for Catalogs No. 217 and 218 describing Moloney Power Transformers.

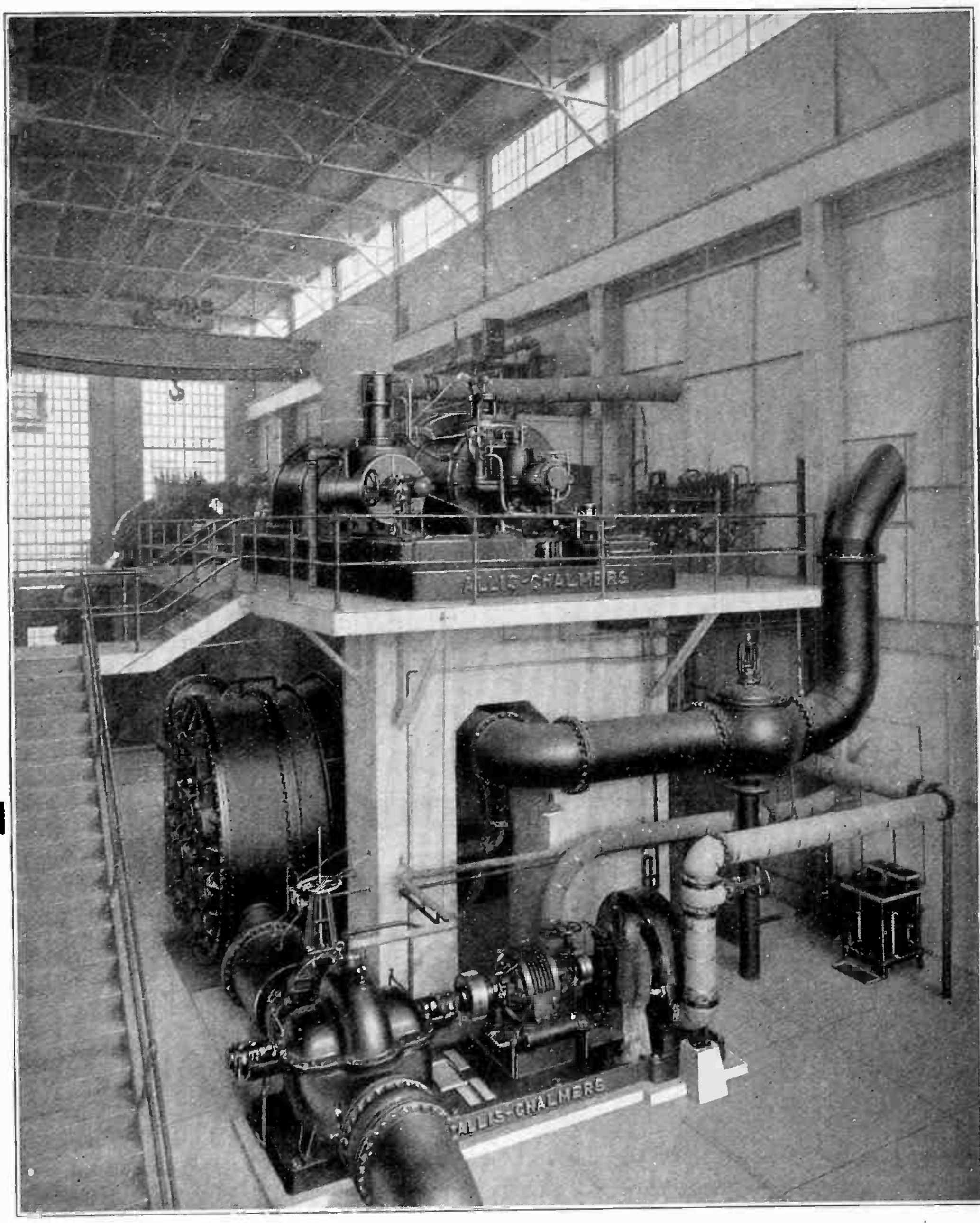
Moloney Electric Company

Manufacturers of Transformers Only

Factories:

St. Louis, Mo. Windsor, Canada

Offices in All Principal Cities



Steam Turbo-Generators

12,500 k. w. Steam Turbine Generator Unit, complete with Surface Condenser, Turbine-driven Circulating and Condensate Pumps, all of Allis-Chalmers manufacture.

The relatively low steam velocities employed in Allis-Chalmers Steam Turbines combined with low blade velocities and highest type of blade construction insures long blade life and sustained efficiency.

Serving Public Utilities

Many public service companies testify to the advantages and appreciable savings under the Allis-Chalmers plan of "Undivided Responsibility," where the manufacturer assumes complete responsibility for the design, building and placing in operation of the principal equipment for the power plant.

Complete equipment "from prime mover to switchboard" is built by the Allis-Chalmers organization. This includes all types of prime movers—steam turbines, hydraulic turbines, steam, gas and oil engines, together with complete electrical equipment. Condensers of all types, pumps, air compressors and many other auxiliaries are also supplied. Allis-Chalmers equipment is used in plants of all sizes, and includes some of the largest power units ever built.

Let Allis-Chalmers Engineers Serve You.

ALLIS-CHALMERS PRODUCTS
Electrical Machinery
Steam Turbines
Steam Engines
Gas and Oil Engines
Hydraulic Turbines
Crushing and Cement Machinery
Mining Machinery

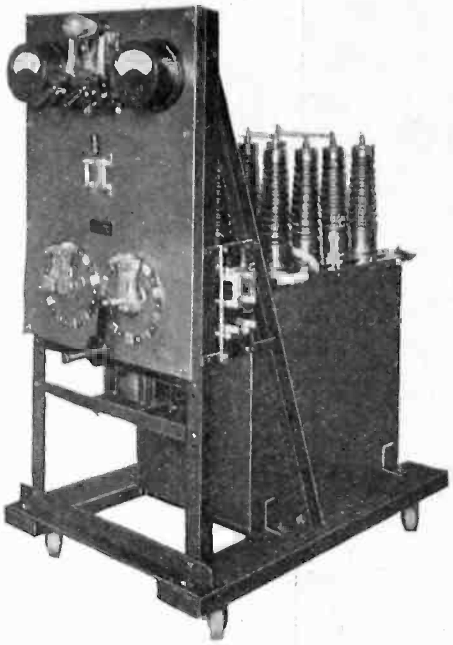
ALLIS-CHALMERS MANUFACTURING COMPANY

MILWAUKEE, WISCONSIN. U.S.A.

ALLIS-CHALMERS PRODUCTS
Flour and Saw Mill Machinery
Power Transmission Machinery
Pumping Engines-Centrifugal Pumps
Steam and Electric Hoists
Air Compressors - Air Brakes
Agricultural Machinery
Condensers

Please mention the JOURNAL of the A. I. E. E. when writing to advertisers.

Portable High Voltage Testing Sets



Type TS-10

AMERICAN TRANSFORMERS

For Difficult Transformer Problems

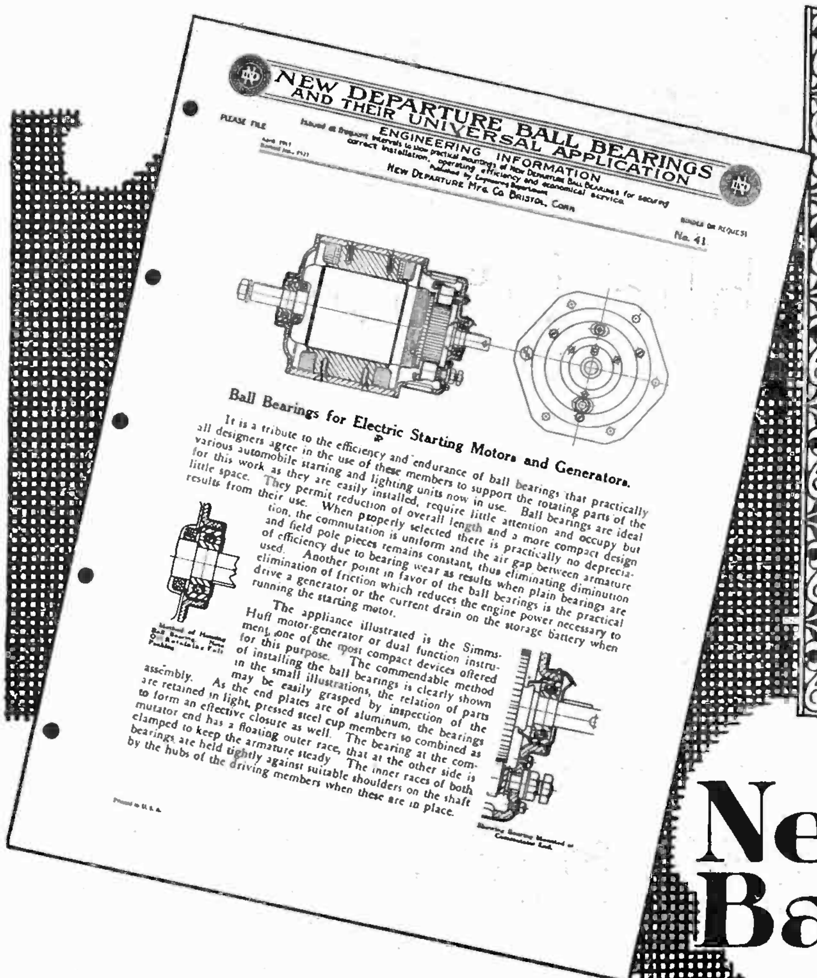
THE equipment illustrated here is designed in sizes of 5 kva., and above, for testing insulation requiring greater capacity than the average sample testing outfit affords. It is particularly adapted for testing cables, insulators, oil, mica, varnish, paper, rubber gloves, or any electrical apparatus or material on which insulation tests over a period of time are necessary. All essential parts of the set are combined in a single unit mounted on a platform, with large castors, so that it can be easily transported.

An exclusive, patented feature of such American Transformer equipment is the voltage regulator, whereby two radial switches, one provided with ten 10% taps and the other with ten 1% taps, automatically and smoothly advance the voltage in one per cent unbroken increments, from zero to maximum. The advantage of this method of voltage control lies chiefly in the absence of wave distortion in the regulating device.

This testing equipment can be modified and adapted to individual requirements for all capacities. We shall be glad to forward descriptive bulletin No. 1010 to those interested.

The American Transformer Company
176 Emmet Street, Newark, N. J.

To Radio Engineers and Enthusiasts.—The new AmerTran,—audio frequency amplifying transformer, has less distortion and far greater amplifying power than any similar device now on the market. Send for Bulletin 1005, containing an unusual chart of audibility amplification of the transformer, and musical scale. The AmerTran is moderately priced and is distributed through jobbers and dealers.



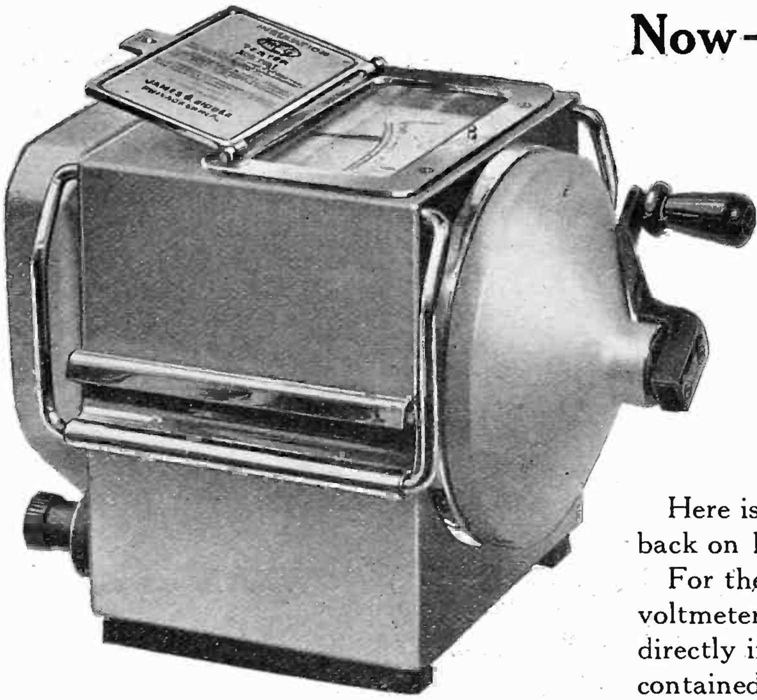
MOTORS need not be lubricated more than once a year when equipped with New Departure ball bearings—an especially valuable feature when motors are installed in out-of-the-way and easily-overlooked places.

This is only one of the scores of reasons why ball bearings in motors will eventually be as universal as they are in automobiles.

New Departure Engineering Data Bulletins keep you in touch with developments in this industry. "This Binder is my most prized reference work," said the designer of a foremost motor manufacturer. Free to qualified persons who write on their company letterhead.

The New Departure Manufacturing Company
Detroit Bristol, Conn. Chicago

New Departure Ball Bearings



Now—*Anyone can afford to make insulation tests!*

The "MEG"

Small Size — $5\frac{1}{2}$ x $7\frac{3}{4}$ x $6\frac{1}{4}$ inches.
Light Weight — $6\frac{3}{4}$ pounds.

Write for special price.

Here is *the* opportunity for engineers who have held back on Insulation Testing on account of cost.

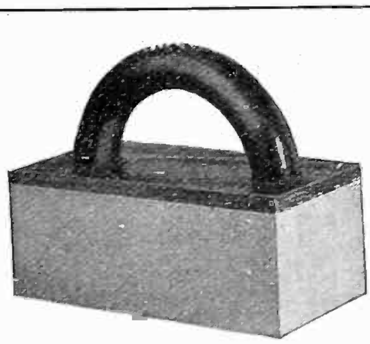
For the approximate price of a good high resistance voltmeter you can now have an instrument which reads directly in ohms (range 0 to 100 Megohms) with a self-contained 500 volt direct current generator.

Pocket Manual 1010-J. "Concerning Insulation Testing with Special Reference to the Meg." This contains valuable information on the subject. *Write today for your free copy.*

The "Meg" Insulation Tester is an important recent addition to the world-famous **"Megger" Family**

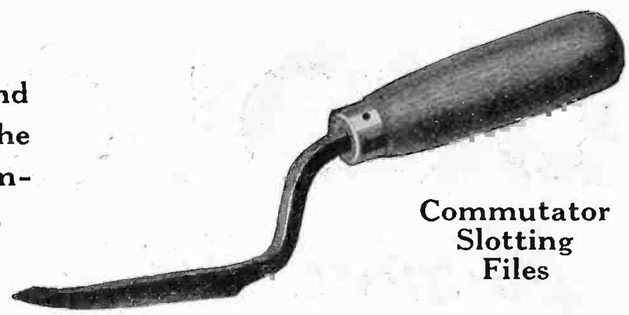
It Merits Your Investigation

JAMES G. BIDDLE
1211-13 Arch Street, Philadelphia



Flat-iron Handle

Send in the Coupon and get a free copy of the Carbon Brush and Commutator Trouble Chart.



Commutator Slotting Files

THE MAN WHO WINS
IS THE MAN WHO GRINS
AND MAKES ONE DOLLAR
LOOK JUST LIKE TWINS

Double Saw Handle

IMPERIAL COMMUTATOR STONES WILL PRODUCE THE GRIN.

If they do not make your dollars look at least like triplets, you need not pay the invoice.

MARTINDALE ELEC. CO.
11717 Detroit Ave., Cleveland, Ohio

Gentlemen: Please send me information on your products and a copy of the trouble chart.

Name and Title ....
(Please Print)

Company ....

Street ....

City and State ....

It is wise to use
OVERHEAD GROUND LINES
but they
SHOULD NOT RUST AWAY

TELEPHONE LINE WIRES
on tower lines or on separate pole lines may be built with
MORE SAFETY and LESS COST

LONG SPANS and RIVER CROSSINGS
require great strength and good conductivity on
TRANSMISSION LINES

For these uses modern engineering judgment calls for

ARISTOS "COPPERWELD" WIRE and STRAND

TRADE MARK REG. U. S. PAT OFF.
(Made by the Molten Welding Process)
Welded, rolled and drawn exclusively at the mills of

COPPER CLAD STEEL COMPANY

NEW YORK SALES OFFICE: 30 CHURCH STREET, NEW YORK
CHICAGO SALES OFFICE 129 S. JEFFERSON ST., CHICAGO
MAIN OFFICE AND WORKS: BRADDOCK P. O. RANKIN, PA.

You may have Wire Tables, Sag and Tension Charts or any of our technical data publications by requesting nearest office. Engineering cooperation gladly given if desired.

DUDLO

Magnet Wire and Windings

have for over twelve years been standard among electrical manufacturers due to their dependable quality and reasonable price. Find out the economy and improvement we can effect for you.

Write today for prices and samples.

Dudlo Manufacturing Company
Fort Wayne, Ind.

Rubber Covered Wires and Cables

National Electrical Code Standard

FOR FACTORIES AND OFFICE BUILDINGS

FOR SCHOOLS AND PUBLIC BUILDINGS

Complete detail specifications for your files upon request.
Ask for Simcore Specifications No. 2053.

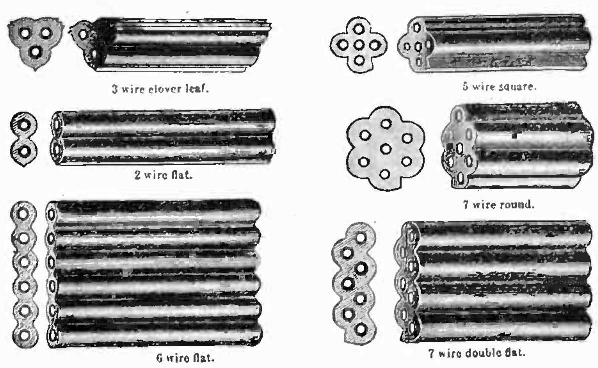
SIMCORE

SIMPLEX WIRE & CABLE Co

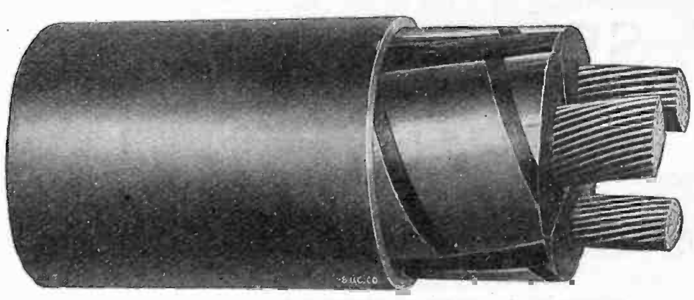
MANUFACTURERS

201 DEVONSHIRE ST., BOSTON 9
15 SOUTH DESPLAINES ST., CHICAGO
612 HOWARD ST., SAN FRANCISCO

SIMCORE



Waring Anti-Induction Cable
1882



Standard Type H 33,000 Volt Cable—½ actual size
1923

Over 41 years ago

this company began the manufacture of lead covered underground cables, being the pioneer in that branch of the electrical industry. We have devoted our energies exclusively to wire and cable manufacture all these years and, by constant research and continuous improvement in design and manufacturing methods, have striven to retain this leadership.

Standard Products now include Bare and Insulated Electric Wires and Cables for all classes of service, also Cable Terminals, Junction Boxes and other Cable Accessories.

Standard Underground Cable Co.

BOSTON PHILADELPHIA ATLANTA CHICAGO ST. LOUIS LOS ANGELES
NEW YORK WASHINGTON PITTSBURGH DETROIT SEATTLE KANSAS CITY
SAN FRANCISCO

For Canada: Standard Underground Cable Co. of Canada, Limited, Hamilton, Ont.

"AMERICAN BRAND"

T. B. W. P. Copper Wire

Weatherproof Copper Wire and Cables

We cannot talk quality into our wire. We put it there.

A sample of our "AMERICAN BRAND" Weatherproof Wire will convince you. Send for it today.

American Insulated Wire & Cable Co.
954 West 21st Street, Chicago

ELECTRICAL WIRES

AND CABLES

WIRE ROPE WIRE STRAND

WELDING WIRE

John A. Roebling's Sons Co.
Trenton, New Jersey

DOLPHIN ATLANTIC

ATLANTIC

INSULATED WIRES

DOLPHIN Insulated Wire

A code wire of high quality known for its great dielectric strength and resiliency, and used for its dependability and maximum service. Built on the same lines as the widely known and used "Triton"—Intermediate Grade 25%; and "Neptune"—30% para.

ATLANTIC Insulated Wire & Cable COMPANY
General Sales Office
52 Vanderbilt Avenue New York, N. Y.
Factory, Stamford, Conn.

WIRE PRODUCTS
For Varied Applications

We manufacture many types of wires, cords and cables for specific uses. Among them are:

Rubber Covered Wire—Solid Conductor, Stranded Conductor, Flexible Conductor, Extra Flexible Conductor. Lamp Cords, Reinforced Cords, Heater Cord, Brewery Cord, Canvasite Cord, Packinghouse Cord, Deck Cable, Stage Cable, Border Light Cable, Flexible Armored Cable, Elevator Lighting Cable, Elevator Operating Cable, Elevator Annunciator Cable. Switchboard Cables, Telephone Wire, Flameproof Wires and Cables, Railway Signal Wires, High Voltage Wires and Cables. Automobile Ignition Cables, Automobile Lighting Cables, Automobile Starting Cables, Automobile Charging Cables. Moving Picture Machine Cable.

Boston Insulated Wire & Cable Co.
Main Office and Factory:
Dorchester District Boston, Mass.
Canadian Branch, Office and Factory, Hamilton, Ont.

TRANSFORMER SPECIALISTS

We are pleased to quote prices and delivery on transformers singly or in quantity

Acme Apparatus Co.
198 Massachusetts Ave.
Cambridge, 39, Mass.
Transformer Engineers and Manufacturers

THE SILSBEE CURRENT TRANSFORMER TESTING SET

is a compact *portable* set for making precision tests of current transformers in position. Checks ratio and phase angle.

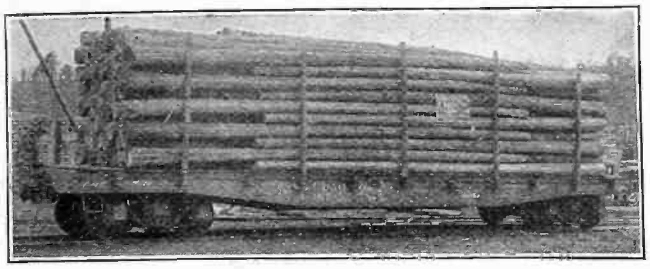
Described in Bulletin 715F.

LEEDS & NORTHRUP CO.
4901 Stenton Ave. Philadelphia

Pittsburgh Transformer Company

Largest Manufacturers of Transformers exclusively in the United States

Pittsburgh, Pennsylvania



CEDAR POLES NORTHERN WHITE WESTERN RED

PLAIN OR BUTT-TREATED

Satisfaction Guaranteed

THE MAC GILLIS & GIBBS COMPANY

Milwaukee, Wis.

CEDAR POLES

NORTHERN WHITE CEDAR

WESTERN RED CEDAR

PLAIN OR TREATED BUTTS.

Prompt shipments guaranteed.

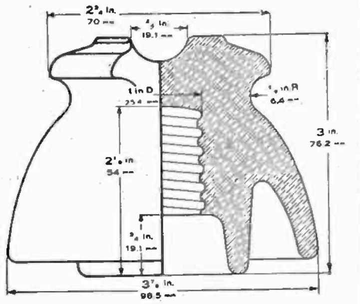
Ask for our delivered prices.

T. M. PARTRIDGE LUMBER CO.

729-32 Lumber Exchange,

MINNEAPOLIS, MINN.

HERE is the **Improved 1009 Insulator** of the "THOMAS QUALITY" Group

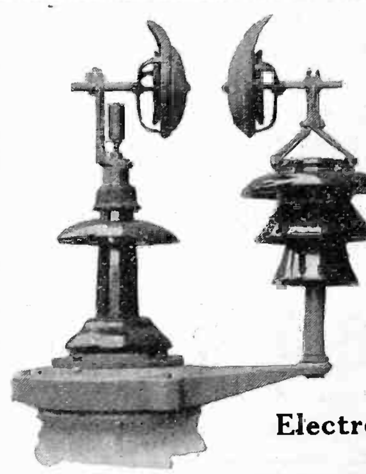


Write for Descriptive Sheet of Catalog No. 1009

THE R. THOMAS & SONS CO.

EAST LIVERPOOL, OHIO

New York Boston Chicago London



BENNETT

SURGE ARRESTERS

Ideal Protection

Ruggedness

Simplicity

Write for Bulletins and Questionnaire

Electro SERVICE Company

MARIETTA, GA.

COILS?

We are equipped to wind any kind you want.

Skilled winders always in attendance and raw materials produced in our own plant.

It will pay you to discuss your individual problems with our engineers.

Belden Manufacturing Company

Electrical Wire, Cable and Cordage

2300 South Western Avenue, Chicago

Eastern Office and Warehouse, Metuchen, N. J.

HEMINGRAY GLASS INSULATORS

The transparency of Hemingray Glass Insulators makes line inspection very simple. The lineman can tell at a glance whether the insulator is intact or not. Hemingray insulators are mechanically and dielectrically dependable, non-porous and uniform in structure. They defy moisture and age.

Send for Bulletin No. 1.

HEMINGRAY GLASS COMPANY

Muncie, Indiana

Extensively Used By the Country's Leading Power Companies

The T&M DISCONNECTING SWITCH

Test Values

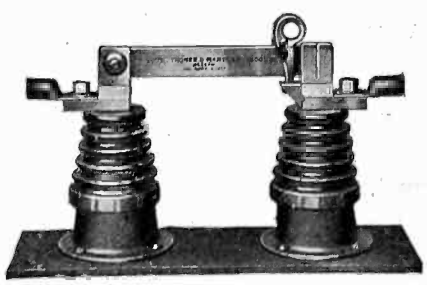
Flash-over 50,000 volt.

1 Minute 45,000 volt.

30 Minutes 30,000 volt.

Tensile Strength between Pillars 2200 lbs.

300 Amp.



15000 Volts

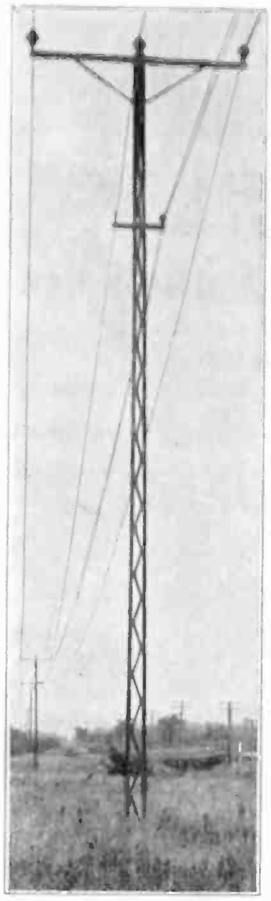
To Electrical Engineers

We invite correspondence on your switch requirements. Send us as complete data as possible and we will submit without obligation, sketches and costs.

Thoner & Martens, 463 Commercial St., Boston, Mass.

Specialists in Heavy Duty Switches—AC and DC

Bates Steel Poles



and Public Interest.

Do your installations favorably impress and interest the investing public?

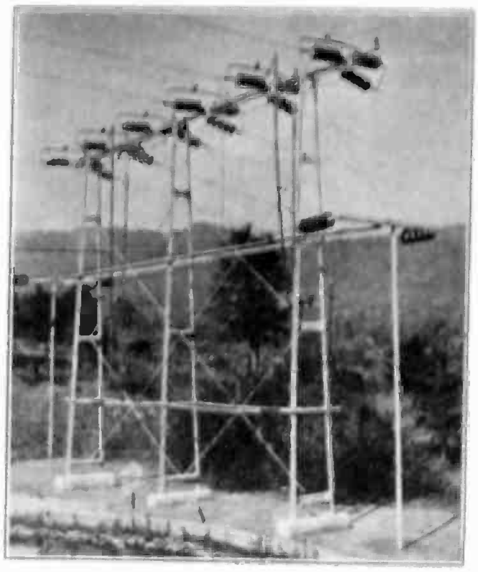
With Bates Poles as the ***backbone*** of your construction you can rest assured that the stability of your installation reflects the solidity of your organization.

Perhaps your line can be built on Bates Steel Poles, as numerous users have proven, with lower initial first costs per mile of completed line than if substitute poles are used.

Bates engineers will gladly co-operate with you in your planning.

Bates Expanded Steel Truss Co.

Illinois Merchants Bank Bldg.
CHICAGO, ILL.



Installation K-P-F 60 KV. Switches, San Joaquin Lt. & Pwr. Corpn., Calif.

Simpler— Stronger— Better—

K-P-F POLE TOP SWITCHES consist of fewer parts, are more rugged and require less labor and material for installation than any other.

Each pole becomes a self-contained unit. Switches are shipped ready to bolt on to crossarm in place of line insulator.

One crossarm supports it. Contacts are far removed from insulators and a unique device prevents sticking or freezing.

Send for bulletin K 105 containing full details.

K-P-F ELECTRIC CO.

855-859 Howard St. **San Francisco**

The Line that R. and I. E. Co. Builds!

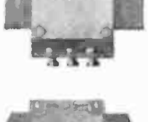
This is the

Mounting Clamp (pipe)—others for Flat, "I" Beam and "H" Section Mountings

That clamps the

R. & I. E. Interchangeable Insulator Units are mounted in any position that conforms with standard practice. Forged Steel Pins—Pressed Steel Caps. **No clamps, no screws.**

That supports the



Conductor Clamps made for all standard sizes of **round** and **rectangular** Conductors

That makes up the

R. & I. E. Interchangeable Insulator Unit Bus Supports and **Fittings** have been designed to obtain simplicity and flexibility. In addition to this they are **mechanically strong.** Bulletin 1200 shows several thousand combinations of various mountings

Interchangeable Unit Bus Support

that R. and I. E. Co. Builds

R. & I. E. Interchangeable Insulator Unit Equipment for outdoor service includes Bus Supports, Disconnecting Switches, Air Break Horn Gap Switches, Choke Coils, Fuse Holders, Lightning Arresters, Substation Combinations and Outdoor Steel Substations.

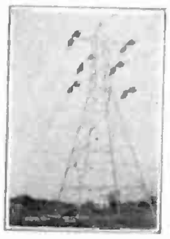
Manufactured by

Railway and Industrial Engineering Co.
Greensburg, Penna.

Sales Offices in · New York · Boston · Pittsburgh · Chicago · Cincinnati

2

LOCKE



The distribution of electrical energy is too vitally allied with the welfare of the nation to be guarded by any but the highest grade insulators.

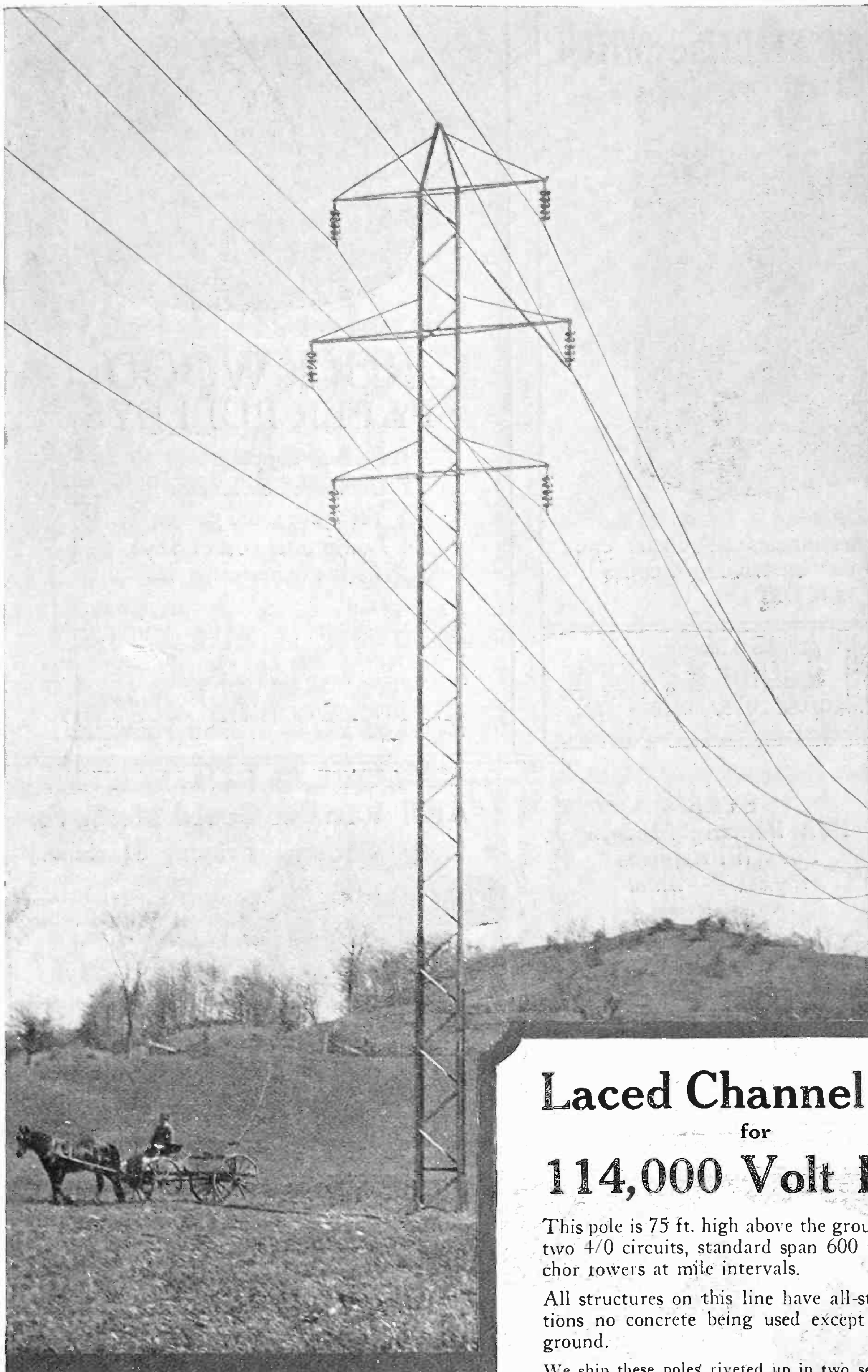
Locke Insulator Corporation
Victor, N. Y.

Over a quarter of a century manufacturers of electrical porcelain for high-tension electrical power transmission.

FACTORIES

Victor, N. Y. **Baltimore, Md.**

INSULATORS



Laced Channel Pole
for
114,000 Volt Lines

This pole is 75 ft. high above the ground carrying two 4/0 circuits, standard span 600 ft. with anchor towers at mile intervals.

All structures on this line have all-steel foundations no concrete being used except in swampy ground.

We ship these poles riveted up in two sections which telescope at splice. A conservative estimate of the saving in cost as compared with a similar line of square towers is at least $2,000.00 per mile due to the many practical advantages of the pole-type construction.

We would appreciate your inquiries.

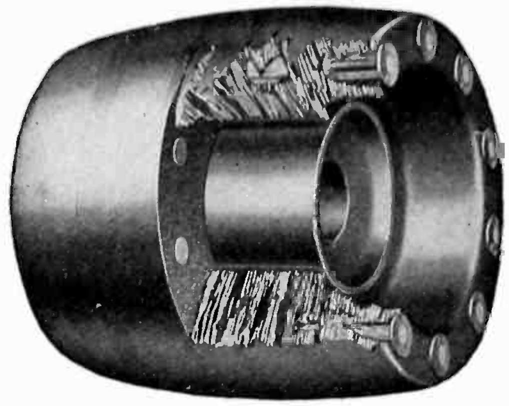
Archbold-Brady Co.
Syracuse, N. Y.

THE ROWAN A.C. STARTING SWITCH

PUSH BUTTON OPERATED
OIL IMMERSED

FOR
STARTING AND STOPPING SMALL SQUIRREL CAGE MOTORS THAT CAN BE THROWN ACROSS THE LINE

ROWAN CONTROL
THE ROWAN CONTROLLER CO., BALTIMORE, MD.



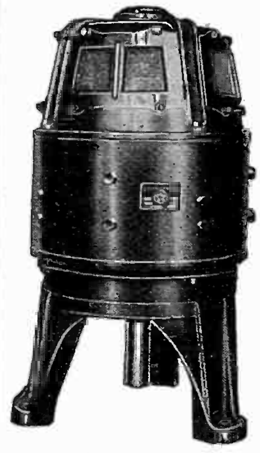
[Section removed to show construction]

ROCKWOOD
PAPER PULLEYS

1. Reduce slippage
2. Decrease belt tension
3. Transmit more power
4. Lower total cost of drive, due to narrower belts.

Whenever you buy a pulley for a motor, get a Rockwood Paper Pulley, the pulley that most every motor is equipped with when it leaves the factory. Rockwood is more than a pulley—*it is pulley service!* Order from your electrical dealer or direct from us.

THE ROCKWOOD MFG. COMPANY
1947 English Avenue INDIANAPOLIS, U.S.A.



STAR
Ball Bearing Motors For All Purposes

Horizontal–Vertical

D. C. Interpole Motors for hard usage—1 to 40 hp. Sparkless commutation at all times.

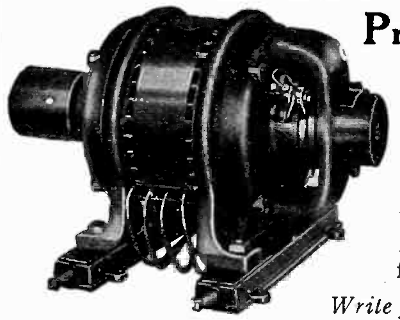
A. C. Polyphase Motors squirrel cage induction and slipring—all cycles, 1 to 40 hp., 110 to 550 volts.

A. C. and D. C. Generators and Motor-Generator Sets

Write for Bulletins.

Star Electric Motor Co.
Miller St. and N. J. R. R. Ave., Newark, N. J.

"AK" Variable Speed Motor for Printing Machinery



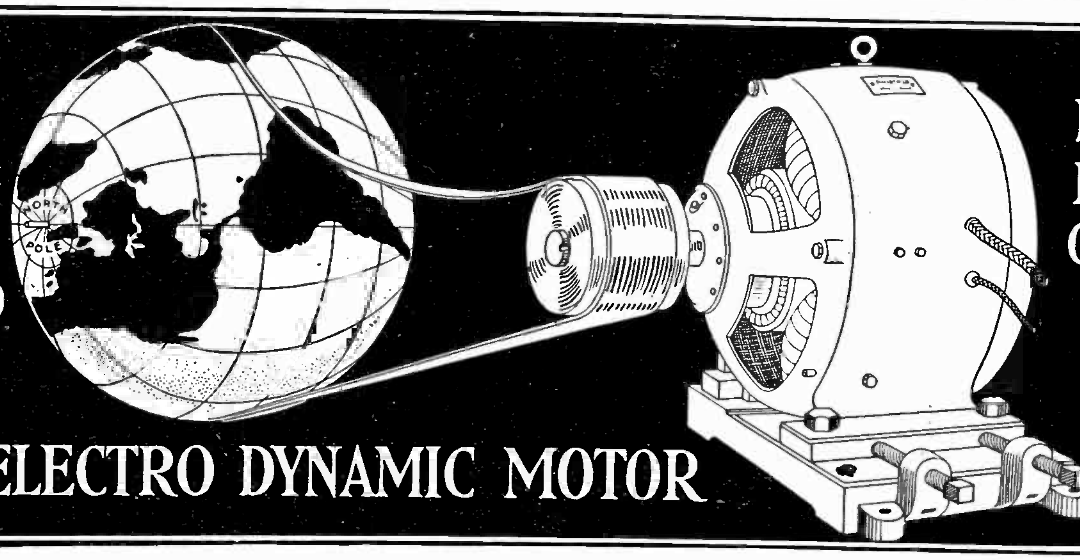
Highest efficiency under variable load. Wound for 25% overload. Push button control. For A. C. any cycles. In sizes 1/20 to 5 H. P.

Modern, safe equipment for job or cylinder press.

Write for complete information.

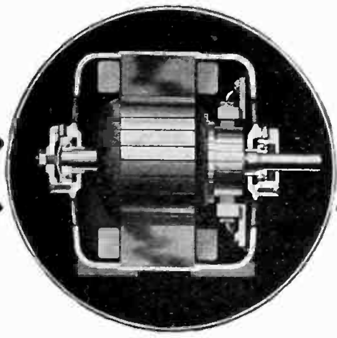
NORTHWESTERN ELECTRIC COMPANY
Also Mfrs. of the new "Martin" Rotary Converter.
409 So. Hoyne Avenue, Chicago, Ill.
Minneapolis—8 N. Sixth St. Kansas City, Mo.—1924 Grand Ave.
Toronto, Can.—308 Tyrrel Bldg., 95 King St., E.

THE WORLD CAN DEPEND ON



THE ELECTRO DYNAMIC MOTOR

ELECTRO DYNAMIC COMPANY
BAYONNE, N. J.
Sales offices in Principal cities



What Is the Life of Your Motor?

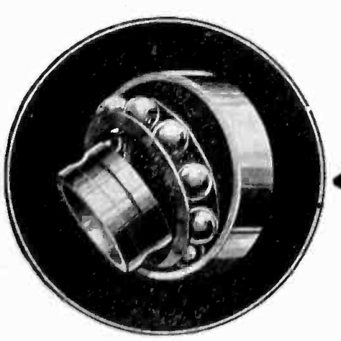
When its bearings fail, a motor fails—and its "life" is only the "life" of its bearings. It is a well known fact that—in small motors particularly—oiling is usually neglected. And most motor troubles are chargeable to inadequate or improper lubrication.

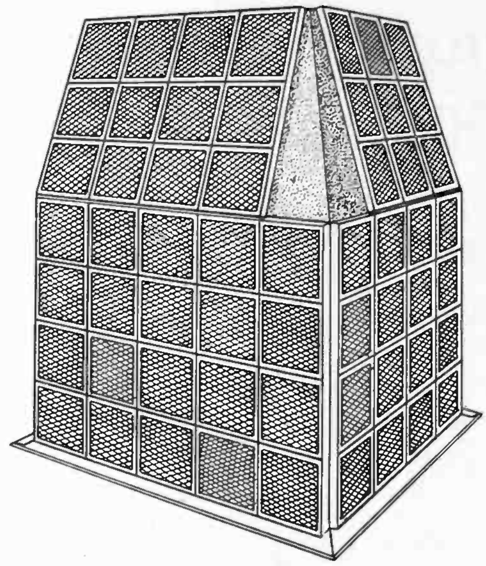
"NORMA" PRECISION BALL BEARINGS

In fractional hp. motors assure maximum "life," maximum usefulness—because all bearing wear comes on hardened steel surfaces completely and continuously oiled by the "magazine" lubrication that is a feature of "NORMA" mounting.

Let us send the booklet on making good motors better.

THE NORMA COMPANY OF AMERICA
Anable Avenue
Long Island City New York
BALL, ROLLER AND THRUST BEARINGS





All of the 400

and more large industrial plants using MIDWEST AIR FILTERS will testify to their high efficiency, low cost of operation and their permanence. In some plants **MIDWEST AIR FILTERS** insure continuous operation of sensitive machines (turbo generators, transformers, motors, compressors, etc.) thereby saving many thousands annually.

In others they have made vast improvements possible in the quality of the products (food factories, chemical works, paint shops, etc.)

In still others they are responsible for greatly increased production by providing clean air for the workmen. Wherever installed, they are *always on the job catching dust and germs.*

If you have any troubles from dust, kindly call on us for free cooperation, and in the meantime

Send for your Copy of Bulletin F-1

Midwest Steel and Supply Co., Inc.
Main Office: 100 E. 45th St, New York
Offices in Principal Cities

¶ Tantalum metal forms an electrolytic valve when used in a cell with another electrode. Tantalum is not attacked by acids or alkali solutions.

¶ Fansteel Products Company manufactures tantalum in sheets, wires and rods. Other metals manufactured by the same company which may help solve electrical difficulties are molybdenum in sheets, wires and special shapes or tungsten contact points.

¶ Fansteel tungsten contact points have been standard of quality for eight years.

FANSTEEL PRODUCTS COMPANY, INC.
North Chicago **Illinois**

The Highest Development of Vulcanized Cotton Fibre

It has taken nearly a half a century to produce Vul-Cot Fibre—a half century of study and experiment to produce material of exceeding toughness and hardness and that is not brittle.

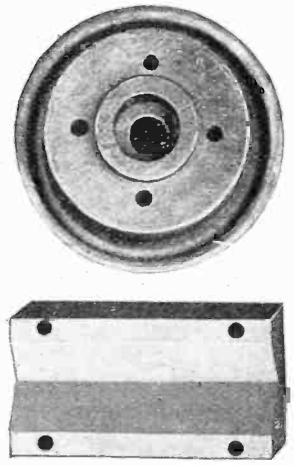
Every detail, every process in the manufacturing of Vul-Cot Fibre is performed in the three huge plants of the National Vulcanized Fibre Company.

The result is a Fibre that is three times as tough as leather. No ordinary force can crush, break, crack or split it. Its tensile strength is from 9,000 to 14,000 pounds per square inch, with a resistance to shearing up to 13,000 pounds per square inch, and an electrical rupture up to 400 volts per Mil.

If there is a place for fibre in the composition of your product—we will gladly place at your disposal the experience gained through years of making parts for the products of the host of manufacturers who use Vul-Cot Fibre.

National Vulcanized Fibre Company
Wilmington, Delaware

LAVA **LAVA**



INSULATORS

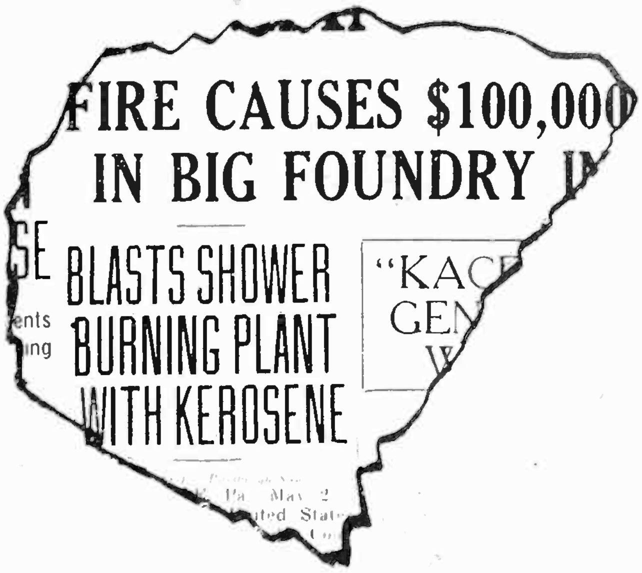
"Retained Dielectric Strength"

under high temperatures is one reason why electrical appliance manufacturers incorporate lava parts in their products.

Ask for Kruesi's Book "LAVA"

AMERICAN LAVA CORPORATION
27-67 Williamson Street
CHATTANOOGA, TENNESSEE
Manufacturers of Heat Resistant Insulators

"Fire Destroys Paint Shop of —— Company! Loss Estimated at $——000"



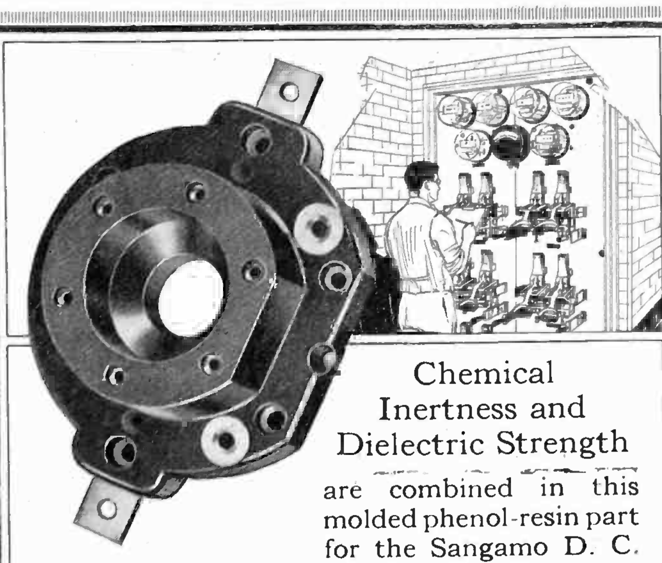
AVOID this description of your own paint shop by the use of Sterling non-inflammable insulating varnishes. The employment of a pure petroleum distillate solvent with flashpoint well over 100°F. reduces the danger encountered when gasoline is used to a minimum. These varnishes will not attack enamel wire. The name "Sterling" guarantees the quality.

These materials and many others are described in the Sterling Catalog No. 20. *Write for it.*

Our engineering department is always at your service for the solution of your insulation problems.

STERLING VARNISH

THE STERLING VARNISH COMPANY, PITTSBURGH, PA.



Chemical Inertness and Dielectric Strength are combined in this molded phenol-resin part for the Sangamo D. C. Watthour Meter.

Metal return plates and terminals were accurately and rigidly positioned during molding.

Phenol resin is obtainable only under the trade-marks Bakelite—Condensite—Redmanol.

Divisions of BAKELITE CORPORATION

BAKELITE
General Bakelite Co.
8 West 40th St. New York

Condensite
Condensite Co. of America
Bloomfield, N. J.

REDMANOL
Redmanol Chemical Products Co.
636-678 West 22nd St.
Chicago, Ill.

BAKELITE CORPORATION
Address the Divisions

The Material *of a* Thousand Uses

MINERALLAC

INSULATING COMPOUNDS

for over twenty years, have been in use as standard compounds by some of the largest Public Utilities in the country.

On 33,000 volt lines, Minerallac No. 78 is specially recommended for all Joint work. It cools rapidly but at the same time shows little shrinkage.

When a Cable Joint is properly made, the Compound fills all voids and minimizes danger of air pockets.

Self-healing, adhesive; has high Insulation Resistance.

MINERALLAC ELECTRIC COMPANY
1045 Washington Blvd. Chicago, Ill.

ROCKBESTOS

Asbestos Insulated Wires and Cables

ROCKBESTOS insulation will stand any degree of temperature. It is strictly and absolutely *non-burning*.

Hundreds of firms, by discontinuing the use of other makes of wire in favor of Rockbestos, have eliminated the cost of needless re-wiring.

Rockbestos Wire is insulated with pure, long-fibre asbestos and impregnated with a special moisture-proofing compound.

Write for any information you wish about the various forms of Rockbestos named below. Ask our Engineering Department for assistance on any of your wiring problems. This advisory service doesn't cost you a cent nor does it obligate you in any way.

Heater Cord — Magnet Wire
Fixture Wire — Stove Wire
Switchboard Wire — Motion Picture Cable

Also Improved
Radio Head Set Cords

ROCKBESTOS PRODUCTS CORPORATION
Sales Promotion Department G
NEW HAVEN, CONN.

Syracuse gets *Tested Meters*

With eight double STATES meter test tables, the Syracuse Lighting & Power Co. is enabled to carefully test each meter regularly and their customers know that their meters are correct.

Send for Cat. No. 1, Section 3, all about STATES Meter Test Tables.

THE STATES COMPANY
74 Francis Avenue Hartford, Conn.

DUNCAN MODEL M2.

An A. C. Watthour meter that for accuracy, efficiency and low cost up-keep is without a peer. Its design represents perfection in every detail and central stations are loud in their praises concerning its dependability.

DUNCAN ELECTRIC MFG. CO.
Lafayette, Ind.

Diamond-F

Use Diamond Fibre

Wherever the job in hand demands a tough, service-giving material of great strength, light weight and high dielectric qualities, use Diamond Fibre. We produce this remarkable raw material in easy-to-handle

SHEETS - RODS - TUBES

ready for all machining processes or fully machined to your own specifications. Write for samples and full information.

Diamond State Fibre Company
Bridgeport (near Philadelphia), **Pa.**
In Canada: Diamond State Fibre Company of Canada, Limited, 245 Carlaw Ave., Toronto, Ont.

PENNSYLVANIA ELECTRICAL SLATE

for
Switchboards, Panelboards, Fuse Blocks, Bus Bar Supports, etc.

THE STRUCTURAL SLATE CO.
Pen Argyl, Penna.
Comprehensive Data on Electrical, Chemical and Physical Properties of Pennsylvania Slate sent on request

PUMPS

INDUSTRIAL-AGRICULTURAL-MUNICIPAL-RESIDENTIAL
A TYPE FOR EVERY SERVICE
Bulletins on Request
THE GOULDS MANUFACTURING COMPANY
Seneca Falls, N. Y.
Agencies in all principal cities

GOULDS

STANDARDS

1922 Edition

Include standard definitions of electrical terms, technical data, standard performance, specifications for tests of electrical machinery, standard voltages and frequencies, and general recommendations, as adopted by the Standards Committee and approved by the Board of Directors of the A. I. E. E.

Flexible fabrikoid leather cover, 192 pp. Indexed. Price $2.00 per copy, with 25% discount to members of the A. I. E. E., and to dealers and purchasers of ten or more copies.

American Institute of Electrical Engineers
33 West 39th Street, New York

SANGAMO
DEMAND REGISTER

Service charges, based on maximum demand, can be determined by the Sangamo Demand Attachment, which may be applied to any Type H Sangamo Meter, either single-phase or polyphase. A pointer, moving over the scale at the top of the dial, indicates the maximum rate of power consumption for any given fixed time period since the last reading of the meter.

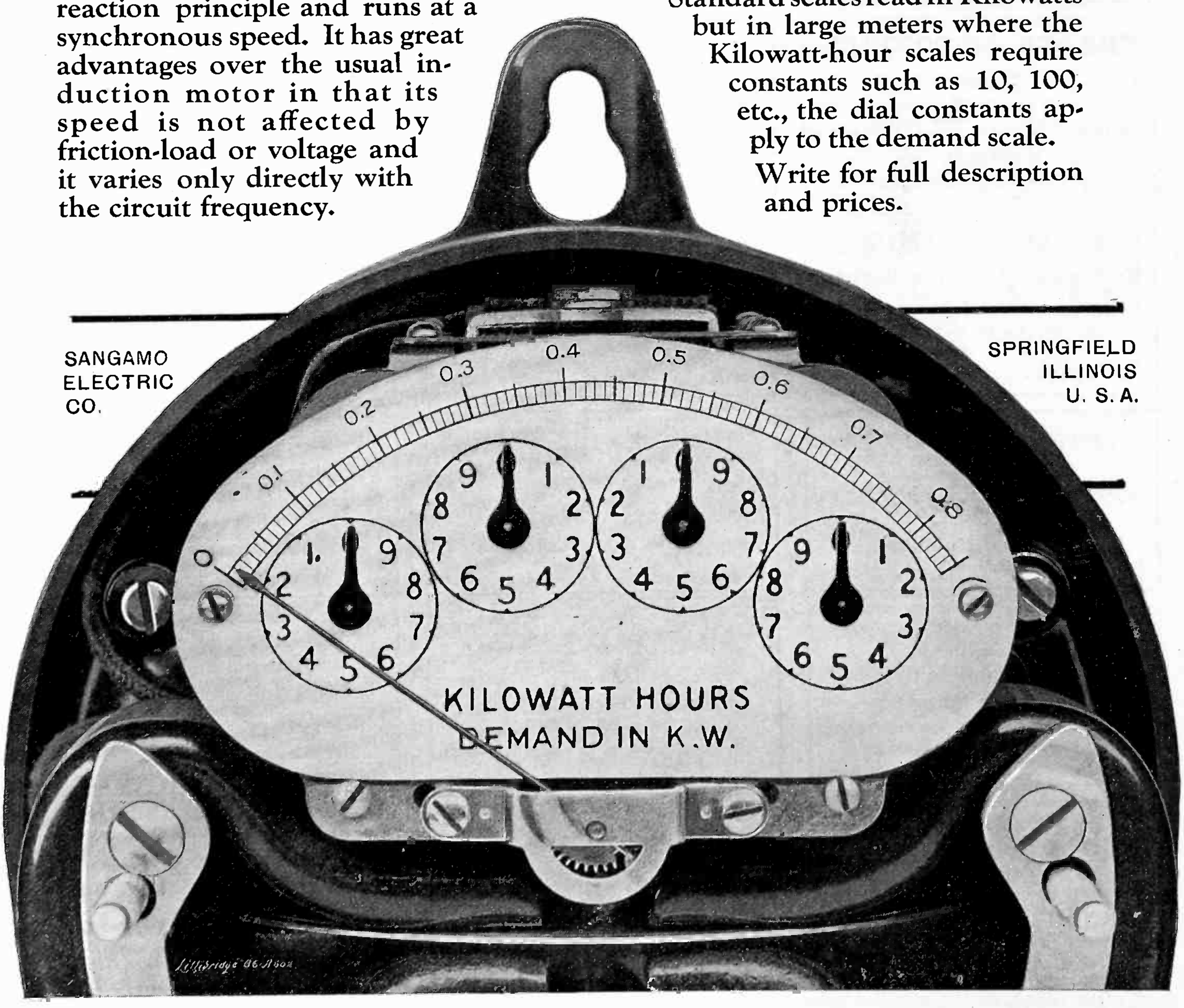
The timing is accomplished by a new type of motor that operates on the reaction principle and runs at a synchronous speed. It has great advantages over the usual induction motor in that its speed is not affected by friction-load or voltage and it varies only directly with the circuit frequency.

The function of the motor is to determine the time interval and reset the recording mechanism at the end of each interval. Standard intervals are 15, 30, 60 minutes.

Sangamo maximum demand dial with timing motor and all necessary mechanism can be used in place of the standard dial by substituting a new upper bearing screw, a bracket and a deeper cover which permits resetting the demand pointer from the outside.

Standard scales read in Kilowatts but in large meters where the Kilowatt-hour scales require constants such as 10, 100, etc., the dial constants apply to the demand scale.

Write for full description and prices.



SANGAMO
ELECTRIC
CO.

SPRINGFIELD
ILLINOIS
U. S. A.

PROFESSIONAL ENGINEERING DIRECTORY

For Consultants in the Fields of Engineering, and Related Arts and Sciences

Established 1857
ALEXANDER & DOWELL
Attorneys at Law
PATENT, TRADEMARK AND COPYRIGHT CASES
902 F Street, N. W. Washington, D. C.

AMBURSEN DAMS
Hydroelectric Developments
Water Supply and Irrigation Dams
DAMS ON DIFFICULT FOUNDATIONS
AMBURSEN CONSTRUCTION CO.
Incorporated
Grand Central Terminal, New York
Kansas City, Mo. Atlanta, Ga.

THE AMERICAN APPRAISAL CO.
Valuations and Reports
of
Public utility, industrial and all other properties
Rate Cases — Condemnation Suits
Reorganizations — Liquidations
NEW YORK — MILWAUKEE
1896 And Principal Cities 1922

THE ARNOLD COMPANY
Engineers
Constructors
Electrical - - Civil - - Mechanical
CHICAGO
105 So. La Salle St.

ROBERT BAHAMON
Mechanical and Electrical Engineer
Assoc., A. I. E. E.
Consulting, Contracts, Construction and Agencies
BOGOTA, COLOMBIA, S. A.

LESTER E. BARRETT
Patent Lawyer
Validity, Infringement and Preliminary Investigations
629 F Street, North West
Washington, D. C.

W. S. BARSTOW & CO.
Incorporated
Consulting and Construction Engineers
Public Service Properties
Financed and Managed
50 Pine St, New York.

BATTEY & KIPP
Incorporated
ENGINEERS
Complete Industrial Plants
Power Plants & Electrical Installations
Engineering Reports, Analyses & Appraisals
123 W. Madison Street CHICAGO

CHEYNEY AND WESCHLER
CONSULTING ENGINEERS
Electrical Utility Systems. Power Plants. Mechanical and Electrical Equipment of Buildings and Industrial Plants.
MILLS BLDG. WASHINGTON, D. C.

WALTER G. CLARK
Consulting Engineer
Electrical, Mining and Industrial Reports
Supervision of Organization and Arrangements for Financing
8 WEST 40th STREET NEW YORK

EDWARD E. CLEMENT
Fellow A. I. E. E.
Attorney and Expert in Patent Causes.
Soliciting, Consultation, Reports, Opinions.
McLachlen Bldg., 700 10th St., N. W. Washington, D. C.

DAY & ZIMMERMANN, Inc.
Engineers
Power Plants, Sub-Stations, Transmission Lines, Industrial Plants, Examinations and Reports, Valuations, Management of Public Utilities.
611 CHESTNUT ST., PHILADELPHIA
New York Chicago

ROBERT E. DENIKE, Inc.
Electrical Engineers and Constructors
NEW YORK CITY

Fellow A. I. E. E. Member A. S. M. E.
W. N. DICKINSON
Consulting Analyst
BUSINESS AND ENGINEERING PROJECTS ANALYZED
Aeolian Hall, 33 W. 42d St., New York City
Telephones:
Longacre 8196 *Longacre 8645*

CHARLES C. EGBERT
Engineer
Hydroelectric Power Development
Reports, Construction, Supervision
NIAGARA FALLS, N. Y.

DAVID V. FENNESSY
Consulting Power Engineer
MILLS BUILDING EL PASO, TEXAS

MONTAGUE FERRY
RADIO ENGINEERING
38 South Dearborn Street Chicago
50 Church Street New York

Edward F. Croker, Ex-Chief N. Y. Fire Dept. — Chas. W. Mitchell, Electrical Engineer
FIRE PROTECTION ENGINEERS
Fire Alarm Engineers & Contractors
Fire Drills, Fire Appliances and Equipment
22 W. 30th St. New York, N. Y.

FORD, BACON & DAVIS
Incorporated
ENGINEERS
115 Broadway, New York
Philadelphia Chicago San Francisco

FRANK F. FOWLE & CO.
Electrical and Mechanical Engineers
MONADNOCK BUILDING CHICAGO

FREYN, BRASSERT & COMPANY
Chicago Philadelphia
Consulting and Constructing Engineers
Gas, Steam and Hydro-Electric Power Plants
Electrification of Rolling Mills
Fuel, Oil, Tar, Gas Combustion Engineering
Design and Construction of Electric Furnace Installations

FULLER ENGINEERING COMPANY
Engineers and Constructors
Designs Estimates
PULVERIZED COAL PLANTS
and burning equipment for Steam Boilers, Locomotive Boilers and Industrial Furnaces
FULLERTON, PA.
50 Church Street New York

WILLIAM S. HIGBIE
Electrical Engineer
ENGINEERING AND PURCHASING SERVICE
Design—Manufacture—Construction
Own Shops
Own Yard for Handling
114 LIBERTY ST. NEW YORK CITY

Dugald C. Jackson
Edward L. Moreland
JACKSON & MORELAND
CONSULTING ENGINEERS
387 Washington St. Boston, Mass.

PROFESSIONAL ENGINEERING DIRECTORY

For Consultants in the Fields of Engineering, and Related Arts and Sciences

J. KAPPEYNE
Consulting Engineer
Valuations, Examinations and Reports.
Operating and Rate Investigations
909 Comstock Ave., SYRACUSE, N. Y.

OPHULS & HILL, Inc.
Formerly Ophuls, Hill & McCreery, Inc.
CONSULTING ENGINEERS
112-114 WEST 42d ST., NEW YORK CITY
Ice Making and Refrigeration
Investigations and Reports

SESSIONS ENGINEERING COMPANY
Engineers on
Power Plant Design & Industrial Betterments
Electrification
140 SO. DEARBORN ST. CHICAGO

E. S. LINCOLN, INC.
Consulting Electrical Engineers
Designs Investigations Reports
Electrical Research Laboratory
534 Congress St. PORTLAND, MAINE

I. S. PRENNER
of the Philadelphia Bar
Mem. A. I. E. E., S. A. M. E.
Technical Patent Expert
404 Penfield Bldg.
1328 Chestnut St. PHILADELPHIA

FREDERICK G. SIMPSON
Electrical Engineer
Reports, Designs, Specifications.
Electric Power
and
Industrial Developments.
RADIO COMMUNICATION SYSTEMS,
Telegraph and Telephone.
3301 L. C. Smith Bldg. Seattle, Wash.

J. N. MAHONEY
Consulting Engineer
Fellow A. I. E. E. Mem. Am. Soc. M. E.
Design, Supervision, Specifications, Reports
Specialist in Electrical Power Switching and Protective Equipment, Industrial and Railway Control and Brake Equipment
615-77th STREET BROOKLYN, N. Y

PUBLIC SERVICE PRODUCTION COMPANY
Engineers and Constructors
Design and Construction of Power Plants, Substations and Industrial Plants.
Examinations and Reports, Valuation and Management of Public Utilities.
80 PARK PLACE NEWARK, N. J.

SPRAY ENGINEERING CO.
Engineers and Manufacturers
Spray Cooling Systems - Irrigation Systems
Aerating Reservoirs - Air Conditioning
Gas Washing Pneumatic Paint Spraying
Spray Problems of All Kinds
Consulting Laboratory
60 HIGH STREET BOSTON

McCLELLAN & JUNKERSFELD
Incorporated
Engineering and Construction
New York
45 William St.
Philadelphia
112 South 16th St.

RICHARDSON & GAY
CONSULTING ENGINEERS
220 Devonshire Street BOSTON
Steam, Electrical, Hydraulic, Industrial Developments—Building Equipment—Investigations—Reports.
Edward B. Richardson Harry Gay

JOHN A. STEVENS, Engineer
Power Plants
Transmission Lines — Sub-stations
Hydro-electric Stations
Consultation — Analysis — Design
Supervision of Construction
Purchased Power Contracts Negotiated
LOWELL, MASSACHUSETTS
Cleveland Fall River

W. E. MOORE & CO.
Engineers
Plans and Specifications for
Hydroelectric and Steam Power Plants
Industrial Plants and Electric Furnaces
Union Bank Building Pittsburgh, Pa.

DWIGHT P. ROBINSON & COMPANY
Incorporated
Design and Construction of
Power Developments, Electric Railways, Industrial Plants
125 East 46th Street, New York
Chicago Youngstown Philadelphia
Los Angeles Montreal Rio de Janiero

William M. Stockbridge Victor D. Borst
STOCKBRIDGE & BORST
Patent Lawyers
41 PARK ROW NEW YORK CITY

N. J. NEALL
Consulting Engineer
for
Electrical and Industrial Properties
12 PEARL STREET BOSTON, MASS.

SANDERSON & PORTER
Engineers
Reports Designs
Construction Management
Hydro-electric Developments
Railway, Light and Power Properties
Chicago New York San Francisco

STONE & WEBSTER
Incorporated
Examinations Reports Appraisals
on
Industrial and Public Service Properties
NEW YORK BOSTON CHICAGO

NEILER, RICH & CO.
Electrical and Mechanical Engineers
Consulting, Designing and Supervising
Manhattan Building - - - Chicago

SARGENT & LUNDY
Incorporated
Mechanical and Electrical Engineers
1412 Edison Bldg., 72 West Adams Street
CHICAGO, ILLINOIS

PERCY H. THOMAS
Consulting Engineer
ELECTRIC POWER
Generation - Transmission
Applications
120 BROADWAY NEW YORK

EFFECTIVE ADVERTISING
——Your Card in This Directory
SMALL COST
——$40 per year—12 insertions

ADOLF P. C. SCHRAMM, E.E.
Mem. S. A. E. Assoc. A. I. E. E.
Consulting Engineer
Fractional Horse Power Motors
Designs
Manufacturing Methods and Processes
Labor Saving Devices
ADRIAN, MICHIGAN

UNITED GAS & ELECTRIC ENGINEERING CORPORATION
Engineers Management
Construction Appraisals
Reports, Estimates and Specifications
Now supervising the Engineering and Operation of 32 Public Utility Properties located in 12 states
61 BROADWAY NEW YORK CITY

(Cards continued on next page)

PROFESSIONAL ENGINEERING DIRECTORY

For Consultants in the Fields of Engineering and Related Arts and Sciences

VIELE, BLACKWELL & BUCK
Engineers
Designs and Construction
Hydroelectric and Steam Power Plants
Transmission Systems Industrial Plants
Reports Appraisals
49 WALL STREET NEW YORK

GARDNER S. WILLIAMS
Mem. Am. Inst. Cons. Eng. Mem. Am. S. C. E
Consulting Engineer
Hydroelectric Developments
Investigations and Reports
Cornwell Bldg. ANN ARBOR, MICH

EUGENE C. WOODRUFF, Ph.D
Member A.I.E.E. and A.E.R.A.
Fellow A.A.A.S.
Electric Railway Engineering
Automobile Engineering
STATE COLLEGE PENNSYLVANIA

THE J. G. WHITE ENGINEERING CORPORATION
Engineers—Constructors
Industrial Plants, Buildings, Steam Power Plants, Water Powers, Gas Plants, Steam & Electric Railroads, Transmission Systems.
43 EXCHANGE PLACE NEW YORK

WOODMANSEE-DAVIDSON ENGINEERING COMPANY
Consulting Engineers
784 Continental & Commercial Bank Bldg
CHICAGO, ILL.

J. G. WRAY & CO.
Engineers
J. G. Wray, Fellow A.I.E.E. Cyrus G. Hill
Utilities and Industrial Properties
Appraisals Construction Rate Surveys
Plans Organization Estimates
Financial Investigations Management
1217 First National Bank Bldg., Chicago

ENGINEERING FOUNDATION

Established 1914

Joint Research Instrumentality of the American Societies of

Civil, Mechanical, Electrical, Mining & Metallurgical Engineers

is

First: A body of educated men associated with the intent of applying "for the good of mankind," the sciences related to Engineering;

Second: An endowment fund held in perpetuity by United Engineering Society, as trustee for the Founder Societies;

Third: The department of United Engineering Society based upon the mental resources of the member societies and the endowment fund,—comprising men, means and activities.

Increase of income through additions to endowment or current contributions is desired in order to increase resources for aiding the Founder Societies in research work.

Annual Report for Eighth Year and Other Information may be had upon request addressed to

ENGINEERING FOUNDATION
29 West 39th Street, New York.

Is your name on our mailing list for bulletins and catalog?

Morganite Brushes

Morganite Brush Co., Inc.
519 W. 38th St.
New York

Progress

Proof that Columbia Pyramid Brushes progress with the industry

Our Development of Grade No. 259

marks the greatest advancement in the improvement of commutator and turbo-alternator collector ring brushes that has been made in many years.

This brush has met with unprecedented success and approval.

The continuous research and development work of the Union Carbide & Carbon Research Laboratories, Inc., assures the advancement of brush quality with the requirements of the industry.

Information on any of our products gladly sent upon request

NATIONAL CARBON COMPANY, INC.

Cleveland, Ohio San Francisco, Cal.

Please mention the JOURNAL of the A. I. E. E. when writing to advertisers.

Classified Advertiser's Index for Buyers

Manufacturers and agents for machinery and supplies used in the electrical and allied industries.

Note: For reference to the advertisements see the Alphabetical List of Advertisers on page 50

AIR COMPRESSORS
- Allis-Chalmers Mfg. Co., Milwaukee, Wis.
- General Electric Co., Schenectady, N. Y.
- Western Electric Co., All Principal Cities

AIR CONDITIONING EQUIPMENT
- Midwest Steel & Supply Co., Inc., New York.
- Spray Engineering Co., Boston.

AMMETERS, VOLTMETERS
- (See INSTRUMENTS, ELECTRICAL)

BATTERY CHARGING APPARATUS
- Cutler-Hammer Mfg. Co., Milwaukee
- General Electric Co., Schenectady, N. Y.
- Western Electric Co., All Principal Cities
- Westinghouse Elec. & Mfg. Co., E. Pittsburgh

BEADS, INSULATING
- Martindale Electric Co., The, Cleveland

BEARINGS, BALL
- New Departure Mfg. Co., The, Bristol, Conn.
- Norma Co. of America, L. I. City, N. Y.
- S K F Industries, New York

BOXES, FUSE
- General Electric Co., Schenectady, N. Y.
- Metropolitan Device Corp., Brooklyn, N. Y.
- Western Electric Co., All Principal Cities
- Westinghouse Elec. & Mfg. Co., E. Pittsburgh

BOXES, JUNCTION
- G & W Elec. Specialty Co., Chicago
- Metropolitan Device Corp., Brooklyn, N. Y.
- Standard Underground Cable Co., Pittsburgh

BRAKES CAR
- Allis-Chalmers Mfg. Co., Milwaukee, Wis.
- General Electric Co., Schenectady, N. Y.

BRUSHES, COMMUTATOR

Carbon
- Morganite Brush Co. Inc., New York
- National Carbon Co., Inc., Cleveland
- Westinghouse Elec. & Mfg. Co., E. Pittsburgh

Copper Graphite
- Morganite Brush Co. Inc., New York
- National Carbon Co., Inc., Cleveland
- Westinghouse Elec. & Mfg. Co., E. Pittsburgh

BUS BAR FITTINGS
- General Electric Co., Schenectady, N. Y.
- Westinghouse Elec. & Mfg. Co., E. Pittsburgh,

CABLE ACCESSORIES
- Dossert & Co., New York
- G & W Electric Specialty Co., Chicago, Ill.
- General Electric Co., Schenectady, N. Y.
- Minerallac Electric Co., Chicago
- Standard Underground Cable Co., Pittsburgh
- Western Electric Co., All Principal Cities

CABLES
- (See WIRES AND CABLES)

CABLEWAYS
- Roebling's Sons Co., John A., Trenton, N. J.

CAMBRIC, VARNISHED
- Irvington Varnish & Ins. Co., Irvington, N. J.

CARBON BRUSHES
- (See BRUSHES COMMUTATOR)

CIRCUIT BREAKERS
- Condit Electrical Mfg. Co., So. Boston, Mass.
- Cutter Company, The, Philadelphia
- General Electric Co., Schenectady, N. Y.
- Roller-Smith Co., New York
- Western Electric Co., All Principal Cities
- Westinghouse Elec. & Mfg. Co., E. Pittsburgh

CLUTCHES-MAGNETIC
- Cutler-Hammer Mfg. Co., Milwaukee

COILS, MAGNET
- Acme Wire Co., New Haven, Conn.
- Belden Mfg. Co., Chicago, Ill.
- Dudlo Mfg. Co., Ft. Wayne, Ind.
- General Electric Co., Schenectady, N. Y.
- Westinghouse Elec. & Mfg. Co., E. Pittsburgh

CONDENSATION PRODUCTS
- Bakelite Corporation, New York
- Condensite Co. of America, Bloomfield, N. J.
- General Bakelite Co., New York
- Redmanol Chemical Products Co., Chicago

CONDENSERS
- Allis-Chalmers Mfg. Co., Milwaukee
- General Electric Co., Schenectady, N. Y.
- Westinghouse Elec. & Mfg. Co., E. Pittsburgh

CONDUIT, UNDERGROUND FIBRE
- Western Electric Co., All Principal Cities

CONNECTORS, SOLDERLESS
- Dossert & Co., New York, N. Y.
- Western Electric Co., All Principal Cities
- Westinghouse Elec. & Mfg. Co., E. Pittsburgh

CONNECTORS AND TERMINALS
- Dossert & Co., New York
- G & W Electric Specialty Co., Chicago, Ill.
- Western Electric Co., All Principal Cities
- Westinghouse Elec. & Mfg. Co., E. Pittsburgh

CONTACTS TUNGSTEN
- Fansteel Products Co., Inc., North Chicago, Ill.
- General Electric Co., Schenectady, N. Y.

CONTROLLERS
- Cutler-Hammer Mfg. Co., Milwaukee
- General Electric Co., Schenectady, N. Y.
- Rowan Controller Co., Baltimore
- Western Electric Co., All Principal Cities
- Westinghouse Elec. & Mfg. Co., E. Pittsburgh

CONVERTERS
- Allis-Chalmers Mfg. Co., Milwaukee
- Northwestern Electric Co., Chicago
- Westinghouse Elec. & Mfg. Co., E. Pittsburgh

COOLING PONDS
- Spray Engineering Co., Boston

COPPER CLAD WIRE
- Copper Clad Steel Co., Rankin, Pa.
- Standard Underground Cable Co., Pittsburgh
- Western Electric Co., All Principal Cities

CUT-OUTS
- Condit Electrical Mfg. Co., S. Boston, Mass.
- General Electric Co., Schenectady, N. Y.
- G & W Elec. Spec. Co., Chicago
- Metropolitan Device Corp., Brooklyn, N. Y.
- Thoner & Martens, Boston
- Western Electric Co., All Principal Cities
- Westinghouse Elec. & Mfg. Co., E. Pittsburgh

DRAWING MATERIALS
- Keuffel & Esser Company, Hoboken, N. J.

DYNAMOS
- (See GENERATORS AND MOTORS)

ELECTRIFICATION SUPPLIES, STEAM ROAD
- General Electric Co., Schenectady, N. Y.
- Ohio Brass Co., Mansfield, Ohio
- Westinghouse Elec. & Mfg. Co., E. Pittsburgh

ENGINEERS, CONSULTING AND CONTRACTING
- Stone & Webster, Inc., Boston
- J. G. White Engg. Corp., New York
- (See also PROFESSIONAL ENGINEERING DIRECTORY)

ENGINES

Gas & Gasoline
- Allis-Chalmers Mfg. Co., Milwaukee

Oil
- Allis-Chalmers Mfg. Co., Milwaukee

Steam
- Allis-Chalmers Mfg. Co., Milwaukee

FANS, MOTOR
- Century Electric Co., St. Louis
- General Electric Co., Schenectady, N. Y.
- Star Electric Motor Co., Newark, N. J.
- Western Electric Co., All Principal Cities
- Westinghouse Elec. & Mfg. Co., E. Pittsburgh

FARM LIGHTING GENERATORS
- Western Electric Co., All Principal Cities
- Westinghouse Elec. & Mfg. Co., E. Pittsburgh

FIBRE
- Diamond State Fibre Co., Bridgeport, Pa.
- National Vulcanized Fibre Co., Wilmington, Del.

FURNACES, ELECTRIC
- General Electric Co., Schenectady, N. Y.
- Westinghouse Elec. & Mfg. Co., E. Pittsburgh

FUSES

Enclosed Refillable
- General Electric Co., Schenectady, N. Y.
- Western Electric Co., All Principal Cities
- Westinghouse Elec. & Mfg. Co., E. Pittsburgh

Enclosed Non-Refillable
- General Electric Co., Schenectady, N. Y.
- Western Electric Co., All Principal Cities

Open Link
- General Electric Co., Schenectady, N. Y.
- Metropolitan Device Corp., Brooklyn, N. Y.
- Western Electric Co., All Principal Cities

High Tension
- Metropolitan Device Corp., Brooklyn, N. Y.
- Railway & Industrial Engg. Co., Greensburg, Pa.
- Western Electric Co., All Principal Cities

GEARS, FIBRE
- Diamond State Fibre Co., Bridgeport, Conn.
- General Electric Co., Schenectady, N. Y.

GENERATORS AND MOTORS
- Allis-Chalmers Mfg. Co., Milwaukee, Wis.
- Century Electric Co., St. Louis, Mo.
- Electro-Dynamic Co., Bayonne, N. J.
- General Electric Co., Schenectady, N. Y.
- Northwestern Electric Co., Chicago
- Star Electric Motor Co., Newark, N. J.
- Wagner Electric Corp., St. Louis
- Western Electric Co., All Principal Cities
- Westinghouse Elec. & Mfg. Co., E. Pittsburgh

GENERATING STATION EQUIPMENT
- Allis-Chalmers Mfg. Co., Milwaukee
- General Electric Co., Schenectady, N. Y.
- Western Electric Co., All Principal Cities
- Westinghouse Elec. & Mfg. Co., E. Pittsburgh

GRINDERS, COMMUTATOR
- Martindale Electric Co., The, Cleveland

GROUND RODS
- Copper Clad Steel Co., Rankin, Pa.
- Western Electric Co., All Principal Cities

HEADLIGHTS
- Ohio Brass Co., Mansfield, O.

HEAD SETS, RADIO
- Brandes, Inc., New York

HEATERS, INDUSTRIAL
- Cutler-Hammer Mfg. Co., Milwaukee
- Western Electric Co., All Principal Cities
- Westinghouse Elec. & Mfg. Co., E. Pittsburgh

HEATING ELEMENTS
- General Electric Co., Schenectady, N. Y.

INDICATORS, SPEED
- Biddle, James G., Philadelphia
- Roller-Smith Co., New York

INSTRUMENTS, ELECTRICAL

Graphic
- Biddle, James G., Philadelphia
- Bristol Co., The, Waterbury, Conn.
- Ferranti, Ltd., London, Eng.
- General Electric Co., Schenectady, N. Y.
- Westinghouse Elec. & Mfg. Co., E. Pittsburgh

Indicating
- Ferranti, Ltd., London, Eng.
- General Electric Co., Schenectady, N. Y.
- Roller-Smith Co., New York
- Westinghouse Elec. & Mfg. Co., E. Pittsburgh

Integrating
- Biddle, James G., Philadelphia
- Duncan, Elec. Mfg. Co., Lafayette, Ind.
- Ferranti, Ltd., London, Eng.
- General Electric Co., Schenectady, N. Y.
- Roller-Smith Co., New York
- Sangamo Elec. Co., Springfield, Ill.
- States Co., The, Hartford, Conn.
- Western Electric Co., All Principal Cities
- Westinghouse Elec. & Mfg. Co., E. Pittsburgh

Repairing and Testing
- Electrical Testing Laboratories, New York

Scientific, Laboratory, Testing
- Biddle, James G., Philadelphia
- Foote-Pierson & Co., Inc., New York
- General Electric Co., Schenectady, N. Y.
- Leeds & Northrup Co., Philadelphia
- Metropolitan Device Corp., Brooklyn, N. Y.
- Roller-Smith Co., New York
- States Co., The, Hartford, Conn.
- Western Electric Co., All Principal Cities
- Westinghouse Elec. & Mfg. Co., E. Pittsburgh

Telegraph
- Foote, Pierson & Co., Inc., New York
- Western Electric Co., All Principal Cities

Wireless
- Acme Apparatus Co., Cambridge, Mass.
- General Radio Co., Cambridge, Mass.

INSULATING MATERIALS

Cloth
- Irvington Varnish & Ins. Co., Irvington, N. J.
- Minerallac Electric Co., Chicago
- Westinghouse Elec. & Mfg. Co., E. Pittsburgh

Composition
- American Insulator Corp., New Freedom, Pa.
- Bakelite Corporation, New York
- Belden Mfg. Co., Chicago
- Condensite Co. of America, Bloomfield, N. J.
- Cutler-Hammer Mfg. Co., Milwaukee
- General Bakelite Co., New York
- Redmanol Chemical Products Co., Chicago
- Westinghouse Elec. & Mfg. Co., E. Pittsburgh

Compounds
- Minerallac Electric Co., Chicago
- Standard Underground Cable Co., Pittsburgh
- Sterling Varnish Co., Pittsburgh
- Western Electric Co., All Principal Cities

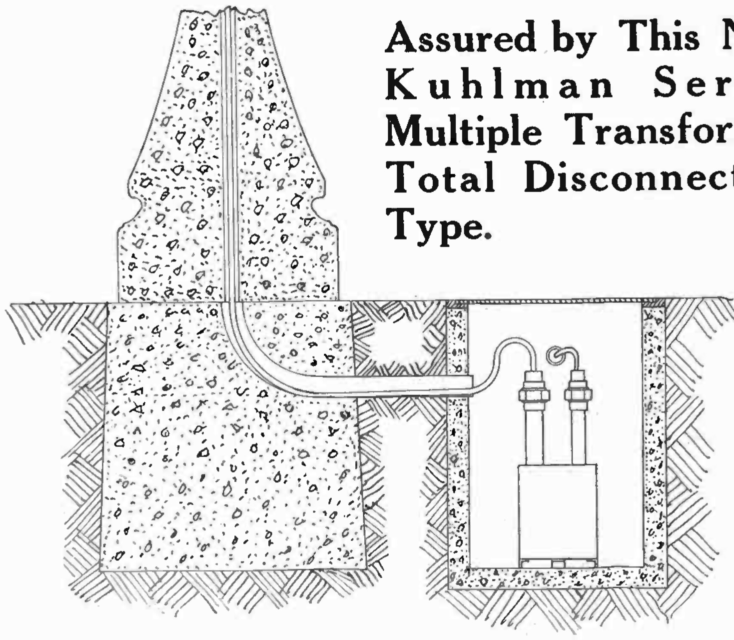
Fibre
- Diamond State Fibre Co., Bridgeport, Pa.
- National Vulcanized Fibre Co., Wilmington Del.

Lava
- American Lava Co., Chattanooga, Tenn.

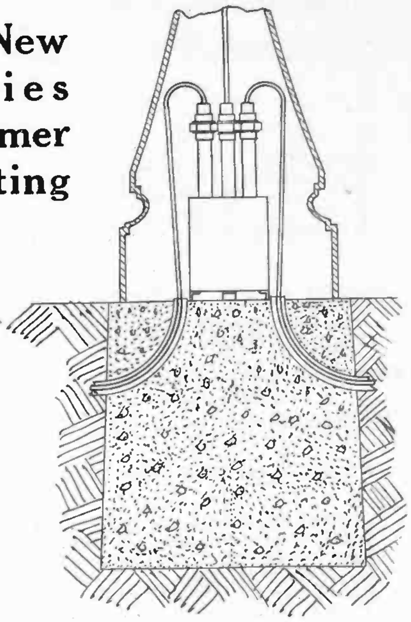
Uninterrupted Service in Lighting Circuits

Reconnecting Sleeve absolutely watertight.

Assured by This New Kuhlman Series Multiple Transformer Total Disconnecting Type.



Showing installation in manhole.



Installation in base of pole.

THE new Kuhlman Series Multiple Transformer is particularly adapted for use in underground systems of street lighting circuits, as shown in the illustrations.

Expressly designed to withstand the severest tests under all conditions of practical use, the advantages of these units include small installation cost with upkeep negligible; non-splice connections which may be made or broken in three minutes; absolutely waterproof, may be placed anywhere, under or above ground; and each unit can be quickly isolated, without interfering with the rest of the circuit.

These transformers automatically adjust themselves to lamp resistance and maintain normal current flow, independent of lamp outages, up to a point where 25% of lamps may be out.

They are highly efficient—a complete circuit of these units and lamps will have a power factor of better than 98%, or practically unity, and transformer losses are kept very low so that the efficiency will be not less than 92%.

Descriptive Bulletins No. 110 and 113 will be forwarded on request.

KUHLMAN ELECTRIC COMPANY, Bay City, Michigan

DISTRICT OFFICES:

Buffalo, 280 Carolina St.
Philadelphia, 1301 Vine St.
Cleveland, 511 Hippodrome Bldg.
Milwaukee, 453 E. Water St.
Minneapolis, 917-A Marquette Ave.
St. Louis, Federal Reserve Bank Bldg.
Los Angeles, 406 American Bank Bldg.
Denver, Franklin Sales Co., Denham Blg.
Detroit, 205 Kresge Bldg.
Kansas City, 505 Interstate Bldg.
San Francisco, Call Bldg.
Seattle, 1401 L. C. Smith Bldg.

DISTRIBUTORS:

Boston, New England Elec. Equip. Co., 164 Federal St. Duluth, Duluth Electrical Supplies Company

KUHLMAN TRANSFORMERS

1893 - 1923

Classified Advertiser's Index for Buyers—*Continued.*

INSULATING MATERIALS—*Continued*

Paper

Irvington Varnish & Ins. Co., Irvington, N. J

Silk

Irvington Varnish & Ins. Co., Irvington, N. J.

Slate

Structural Slate Co., The, Pen Argyl, Pa.

Tape

Belden Mfg. Co., Chicago
Minerallac Electric Co., Chicago
Okonite Co., The, New York
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

Varnishes

General Electric Co., Schenectady, N. Y.
Irvington Varnish & Ins. Co., Irvington, N. J.
Minerallac Electric Co., Chicago
Sterling Varnish Co., Pittsburgh

INSULATORS, HIGH TENSION

Composition

General Electric Co., Schenectady, N. Y.

Glass

Hemingray Glass Co., Muncie, Ind.

Porcelain

General Electric Co.. Schenectadv. N. Y.
Jeffery-Dewitt Insulator Co., Kenova, W.Va.
Lapp Insulator Co., Inc., LeRoy, N. Y.
Locke Insulator Mfg. Co., Victor, N. Y.
Ohio Brass Co., Mansfield, O.
Thomas & Sons Co., R. East Liverpool, O.
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

INSULATORS. TELEPHONE & TELEGRAPH
Hemingray Glass Co., Muncie, Ind.
Western Electric Co., All Principal Cities

LAMP GUARDS
Western Electric Co., All Principal Cities

LAVA
American Lava Corp., Chattanooga, Tenn.

LIGHTNING ARRESTERS
Electro Service Co., Marietta, Ga.
General Electric Co., Schenectady, N. Y.
Railway & Industrial Engg. Co., Greensburg, Pa.
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

LOCOMOTIVES ELECTRIC
General Electric Co., Schenectady, N. Y.
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

LUBRICANTS
Texas Co., The, New York

MAGNET WIRE
Acme Wire Co., New Haven, Conn.
Belden Mfg. Co., Chicago
Dudlo Mfg. Co., Ft. Wayne, Ind.
Roebling's Sons Co., J. A., Trenton, N. J.
Western Electric Co., All Principal Cities

METERS, ELECTRICAL
(See INSTRUMENTS, ELECTRICAL)

METER LOADING DEVICES
States Co., The, Hartford, Conn.

MOLDED INSULATION
Bakelite Corporation, New York
Belden Mfg. Co., Chicago
Condensite Co. of America, Bloomfield. N. J.
Cutler-Hammer Mfg. Co., Milwaukee
General Bakelite Co., New York
Redmanol Chemical Products Co., Chicago
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

MOLYBDENUM
Fansteel Products Co., Inc., North Chicago, Ill.

MOTORS
(See GENERATORS AND MOTORS)

PANEL BOARDS
(See SWITCHBOARDS)

PATENT ATTORNEYS
(See PROFESSIONAL ENGINEERING DIRECTORY)

PHASE MODIFYING APPARATUS
States Co., The, Hartford, Conn.

PHOTOMETERS—SPHERES
Foote, Pierson & Co., Inc., New York

PLUGS
Cutler-Hammer Mfg. Co., Milwaukee
General Electric Co., Schenectady, N. Y.
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

POLES, STEEL
Archbold-Brady Co., Syracuse, N. Y.
Bates Expanded Steel Truss Co., Chicago
Western Electric Co., All Principal Cities

POLES—TIES, WOOD
MacGillis & Gibbs Co., Milwaukee, Wis.
Page & Hill Co., Minneapolis, Minn.
Partridge Lumber Co., T. M., Minneapolis
Western Electric Co., All Principal Cities

POTHEADS
G & W Electric Specialty Co., Chicago
Standard Underground Cable Co., Pittsburgh
Thoner & Martens, Boston
Western Electric Co., All Principal Cities

PROTECTIVE DEVICES
Metropolitan Device Corp., Brooklyn, N. Y.
Western Electric Co., All Principal Cities

PULLEYS, PAPER
Rockwood Mfg. Co., The, Indianapolis

PUMPS
Allis-Chalmers Mfg. Co., Milwaukee
Goulds Mfg. Co., Seneca Falls, N. Y.

PUMPS, SPIRAL
Cramp & Sons Ship & Eng. Bldg. Co., The Wm., Philadelphia

PYROMETERS
Leeds & Northrup Co., Philadelphia

RADIO LABORATORY APPARATUS
Acme Apparatus Co., Cambridge, Mass.
General Radio Co., Cambridge, Mass.
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

RAILWAY SUPPLIES, ELECTRIC
General Electric Co., Schenectady, N. Y.
Ohio Brass Co., Mansfield, O.
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

REACTANCE COILS
Metropolitan Device Corp., Brooklyn, N. Y.

RECTIFIERS
General Electric Co., Schenectady, N. Y.
Wagner Electric Corp., St. Louis
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

REGULATORS, VOLTAGE
General Electric Co., Schenectady, N. Y.
States Co., The, Hartford, Conn.
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

RESISTANCE ELEMENTS
Cutler-Hammer Mfg. Co., Milwaukee
General Electric Co., Schenectady, N. Y.

RHEOSTATS
Biddle, James G., Philadelphia, Pa.
Cutler-Hammer Mfg. Co., Milwaukee
General Electric Co., Schenectady, N. Y.
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

ROPE, WIRE
Roebling's Sons Co., John A., Trenton, N. J.

SEARCHLIGHTS
General Electric Co., Schenectady, N. Y.
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

SLATE
Structural Slate Co., The, Pen Argyl, Pa.

SLOTTING EQUIPMENT, COMMUTATOR

Hand and Motor Driven

Martindale Electric Co., The, Cleveland

SOCKETS AND RECEPTACLES
Cutler-Hammer Mfg. Co., Milwaukee
General Electric Co., Schenectady, N. Y.
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

SOLENOIDS
Acme Wire Co., New Haven, Conn.
Belden Mfg. Co., Chicago
Cutler-Hammer Mfg. Co., Milwaukee
Dudlo Mfg. Co., Ft. Wayne, Ind.
General Electric Co., Schenectady, N. Y.
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

STOKERS, MECHANICAL
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

STONES, COMMUTATOR
Martindale Electric Co., The, Cleveland

SUB-STATIONS
Electro Service Co., Marietta, Ga.
General Electric Co., Schenectady, N. Y.
Railway & Industrial Engg. Co., Greensburgh, Pa.
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

SWITCHBOARDS
Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Condit Electrical Mfg. Co., So. Boston, Mass.
General Electric Co., Schenectady, N. Y.
Metropolitan Device Corp., Brooklyn, N. Y.
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

SWITCHES

Automatic Time

Ferranti, Ltd., London, Eng
General Electric Co., Schenectady, N. Y.
Minerallac Electric Co., Chicago
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

Disconnecting

Condit Electrical Mfg. Co., So. Boston
GeneralElectric Co., Schenectady, N. Y
K-P-F Electric Co., San Francisco
Pacific Electric Mfg. Co., San Francisco
Railway & Ind. Engg. Co., Greensburg, Pa.
Thoner & Martens, Boston

Fuse

General Electric Co., Schenectady, N. Y.
Metropolitan Device Corp., Brooklyn, N. Y.
Thoner & Martens, Boston

Knife

Condit Electrical Mfg. Co., So. Boston
Cutter Company, The, Philadelphia
General Electric Co., Schenectady, N. Y.
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

Oil

Condit Electrical Mfg. Co., So. Boston
General Electric Co., Schenectady, N. Y.
Pacific Electric Mfg. Co., San Francisco
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

Remote Control

Condit Electrical Mfg. Co., So. Boston
Cutler-Hammer Mfg. Co., Milwaukee
General Electric Co., Schenectady, N. Y.
Railway & Ind. Engg. Co., Greensburg, Pa.
Rowan Controller Co., Baltimore
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

TACHOMETERS
Biddle, James G., Philadelphia

TANTALUM
Fansteel Products Co., Inc., North Chicago, Ill.

TELEGRAPH APPARATUS
Foote, Pierson & Co., Inc., New York
Western Electric Co., All Principal Cities

TELEPHONE EQUIPMENT
Western Electric Co., All Principal Cities

TESTING LABORATORIES
Electrical Testing Labs., New York

TOWERS, TRANSMISSION
Archbold-Brady Co., Syracuse, N. Y.
Bates Expanded Steel Truss Co., Chicago
Western Electric Co., All Principal Cities

TRANSFORMERS
Acme Apparatus Co., Cambridge, Mass.
Allis-Chalmers Mfg. Co., Milwaukee, Wis.
American Transformer Co., Newark, N. J.
Duncan Elec. Mfg. Co., Lafayette, Ind.
Ferranti, Ltd., London, Eng.
General Electric Co., Schenectady, N. Y.
Kuhlman Electric Co., Bay City, Mich.
Moloney Electric Co., St. Louis
Pittsburgh Transformer Co., Pittsburgh
Wagner Electric Corp., St. Louis
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

Factory

American Transformer Co., Newark, N. J.
Kuhlman Electric Co., Bay City, Mich.
Moloney Electric Co., St. Louis, Mo.
Pittsburgh Transformer Co., Pittsburgh
Wagner Electric Corp., St. Louis
Western Electric Co., All Principal Cities

Furnace

Allis-Chalmers Mfg. Co., Milwaukee
American Transformer Co., Newark, N. J.
Moloney Electric Co., St. Louis
Pittsburgh Transformer Co., Pittsburgh

Metering

American Transformer Co., Newark, N. J.
Ferranti, Ltd., London, Eng.
Pittsburgh Transformer Co., Pittsburgh, Pa

Mill Type

Pittsburgh Transformer Co , Pittsburgh

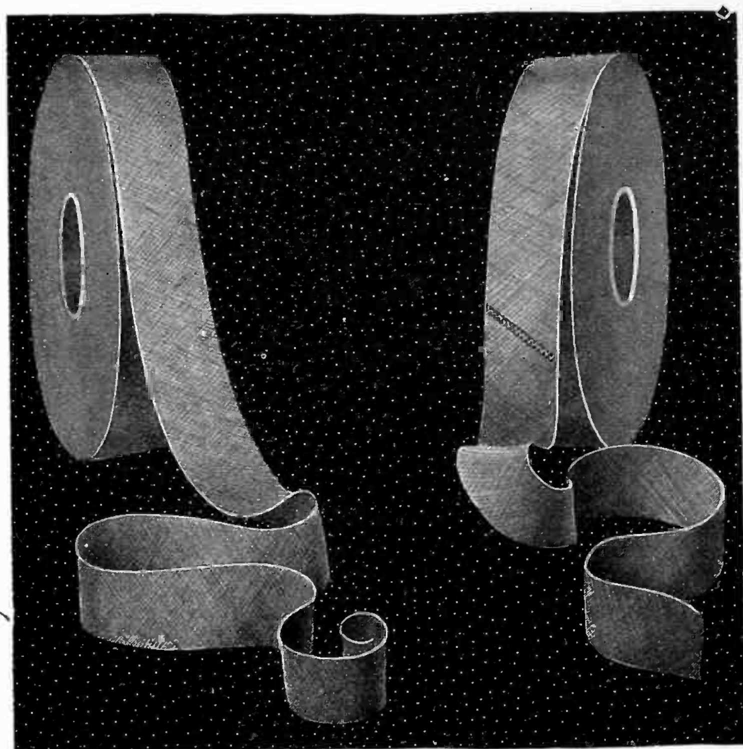
Radio

Acme Apparatus Co., Cambridge, Mass.
American Transformer Co., Newark, N. J.

Street Lighting

Kuhlman Electric Co., Bay City, Mich.
Western Electric Co., All Principal Cities

New Seamless Bias Tape



Sewed Bias Tape

COMPARE THESE TWO TAPES!
IRVINGTON SEAMLESS BIAS TAPE

Irvington Seamless Bias Tape is the better because every inch is effective insulation of uniform thickness. It gives you a direct gain in productive labor. It makes smooth windings, and it can be applied with taping machines. There is a minimum of air pockets and a minimum requirement of impregnating varnish.

Furnished in Yellow and Black .005 in. to .015 in. thick, ½ in. to 36 in. wide, on paper cores ⅜ or 1½ in. hole, standard length rolls, 72 yards.

Order some for trial and you will be sure to re-order.

What is lost in a 72 yard roll?

With the old type sewed bias tape, there is a loss of 63 inches of material by seam cut-outs; a loss of fifteen minutes productive labor; sixty three open or lumpy splices in the windings; maximum chance for air pockets or loose windings and a maximum requirement of insulating varnish.

Write nearest distributor.

IRVINGTON VARNISH & INSULATOR CO.
Irvington, New Jersey.

Established 1905

Sales Representatives:

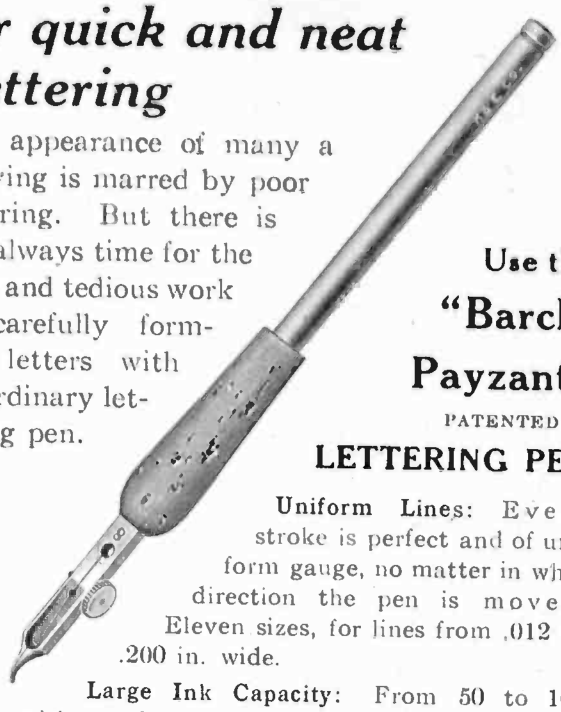
Mitchell-Rand Mfg. Co., New York
T. C. White Electric Supply Co., St. Louis
E. M. Wolcott, Rochester
L. L. Fleig & Co., Chicago
Consumers Rubber Co., Cleveland
Clapp & Lamoree, Los Angeles
F. G. Scofield, Toronto

Seven Factors of Quality

High Dielectric Strength
High Resistance
Flexibility
Non Hygroscopic
Heat Resisting
Chemically Neutral
Maximum Elasticity

for quick and neat Lettering

The appearance of many a drawing is marred by poor lettering. But there is not always time for the slow and tedious work of carefully forming letters with an ordinary lettering pen.



Use the "Barch-Payzant" PATENTED **LETTERING PEN**

Uniform Lines: Every stroke is perfect and of uniform gauge, no matter in what direction the pen is moved. Eleven sizes, for lines from .012 to .200 in. wide.

Large Ink Capacity: From 50 to 100 letters with one filling of the pen.

Pens for very fine work have aluminum handle and cork grip. Those for heavy lettering black wooden handles.

Send for circular

KEUFFEL & ESSER CO.

NEW YORK, 127 Fulton Street, General Office and Factories, HOBOKEN, N. J.

CHICAGO 516-20 S. Dearborn St. | ST. LOUIS 817 Locust St. | SAN FRANCISCO 30-34 Second St. | MONTREAL 5 Notre Dame St. W.

Drawing Materials, Mathematical and Surveying Instruments, Measuring Tapes

The World's Most Famous Pencil

VENUS PENCILS

The largest selling Quality pencil in the world

First in the estimation of engineers because of the dependable smoothness, firmness and uniformity of the leads.

17 Black Degrees 3 Copying

For bold, heavy lines . . 6B-5B-4B-3B
For writing, sketching . 2B-B-HB-F-H
For clean, fine lines . 2H-3H-4H-5H-6H
For delicate, thin lines . . . 7H-8H-9H

Plain Ends, per doz. . $1.00
Rubber Ends, per doz. . 1.20

At Stationers and Stores throughout the World

American Lead Pencil Co.
204 Fifth Ave., New York
also London, Eng.

Classified Advertiser's Index for Buyers—*Continued.*

TROLLEY LINE MATERIALS
General Electric Co., Schenectady, N. Y.
Ohio Brass Co., Mansfield, O.
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

TURBINES, HYDRAULIC
Allis-Chalmers Mfg. Co., Milwaukee
Cramp & Sons Ship & Eng. Bldg. Co., The Wm., Philadelphia.

TURBINES, STEAM
Allis-Chalmers Mfg. Co., Milwaukee, Wis.
General Electric Co., Schenectady, N. Y.
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

TURBO-GENERATORS
Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

VALVES
Johnson Hydraulic
Cramp & Sons Ship & Eng. Bldg. Co., The Wm., Philadelphia

VARNISHES, INSULATING
General Electric Co., Schenectady, N. Y.
Irvington Varnish & Ins. Co., Irvington, N. J.
Minerallac Electric Co., Chicago
Sterling Varnish Co., Pittsburgh
Westinghouse Elec. & Mfg. Co., E. Pittsburg, Pa.

WELDING EQUIPMENT, ELECTRICAL
General Electric Co., Schenectady, N. Y.
Ohio Brass Co., Mansfield, O.
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

WIRELESS APPARATUS
Acme Apparatus Co., Cambridge, Mass.
General Radio Co., Cambridge, Mass.
Pacent Electric Co., New York
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

WIRES AND CABLES
Armored Cable
Belden Mfg. Co., Chicago
Boston Ins. Wire & Cable Co., Boston
General Electric Co., Schenectady, N. Y.
Kerite Ins. Wire & Cable Co., New York
Okonite Company, The, Passaic, N. J.
Roebling's Sons Co., John A., Trenton, N. J.
Standard Underground Cable Co., Pittsburgh
Western Electric Co., All Principal Cities

Asbestos Covered
Belden Mfg Co., Chicago
General Electric Co., Schenectady, N. Y.
Rockbestos Products Corp., New Haven, Conn.

Auto
Belden Mfg. Co., Chicago
Boston Ins. Wire & Cable Co., Boston
General Electric Co., Schenectady, N. Y.
Kerite Ins. Wire & Cable Co., New York
Roebling's Sons Co., John A., Trenton, N. J.
Standard Underground Cable Co., Pittsburgh
Western Electric Co., All Principal Cities

Bare Copper
American Ins. Wire & Cable Co., Chicago
Anaconda Copper Mining Co., Chicago
Belden Mfg. Co., Chicago
Copper Clad Steel Co., Rankin, Pa.
Roebling's Sons Co., John A., Trenton, N. J.
Standard Underground Cable Co., Pittsburgh
Western Electric Co., All Principal Cities

Copper Clad
Copper Clad Steel Co., Rankin, Pa.
Standard Underground Cable Co., Pittsburgh
Western Electric Co., All Principal Cities

Flexible Cord
Belden Mfg. Co., Chicago
Boston Ins. Wire & Cable Co., Boston
General Electric Co., Schenectady, N. Y.
Okonite Company, The, Passaic, N. J.
Roebling's Sons Co., John A., Trenton, N. J.
Standard Underground Cable Co., Pittsburgh
Western Electric Co., All Principal Cities

Fuse
General Electric Co., Schenectady, N. Y.
Roebling's Sons Co., John A., Trenton, N. J.
Western Electric Co., All Principal Cities

Lead Covered (Paper and varnished cambric insulated)
Atlantic Ins. Wire & Cable Co., New York
General Electric Co., Schenectady, N. Y.
Kerite Ins. Wire & Cable Co., New York
Okonite Company, The, Passaic, N. J.
Roebling's Sons Co., John A., Trenton, N. J.
Simplex Wire & Cable Co., Boston
Standard Underground Cable Co., Pittsburgh
Western Electric Co., All Principal Cities

Magnet
Acme Wire Co., New Haven, Conn.
Belden Mfg. Co., Chicago
Dudlo Mfg. Co., Fort Wayne, Ind.
General Electric Co., Schenectady, N. Y.
Rockbestos Products Corp., New Haven, Conn.
Roebling's Sons Co., John A., Trenton, N. J.
Standard Underground Cable Co., Pittsburgh
Western Electric Co., All Principal Cities

Rubber Insulated
Atlantic Ins. Wire & Cable Co., New York
Belden Mfg. Co., Chicago
Boston Ins. Wire & Cable Co., Boston
General Electric Co., Schenectady, N. Y.
Kerite Ins. Wire & Cable Co., New York
Okonite Company, The, Passaic, N. J.
Roebling's Sons Co., John A. Trenton, N. J.
Simplex Wire & Cable Co., Boston
Standard Underground Cable Co., Pittsburgh
Western Electric Co., All Principal Cities

Trolley
Anaconda Copper Mining Co., Chicago
Copper Clad Steel Co., Rankin, Pa.
Roebling's Sons Co., John A. Trenton, N. J.
Standard Underground Cable Co., Pittsburgh
Western Electric Co., All Principal Cities

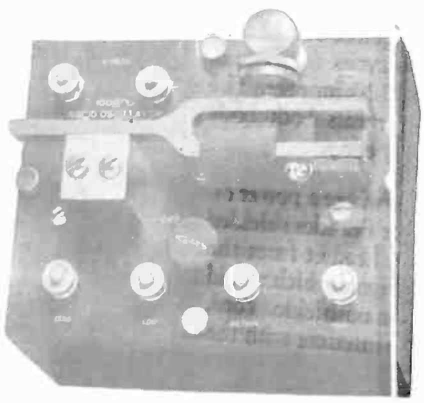
Weatherproof
American Ins. Wire & Cable Co., Chicago
Copper Clad Steel Co., Rankin, Pa.
General Electric Co., Schenectady, N. Y.
Kerite Ins. Wire & Cable Co., New York
Okonite Company, The, Passaic, N. J.
Roebling's Sons Co., John A., Trenton, N. J.
Simplex Wire & Cable Co., Boston, Mass.
Standard Underground Cable Co., Pittsburgh
Western Electric Co., All Principal Cities

Pacent
RADIO ESSENTALS

Every Pacent Product is bsed on years of radio experienceınd sound engineering princiles. These well known Essentıals, ·cent Universal Plug, Trin-ıpter, Multijack, Audiofoıer, Duolateral Coils and others ·ere made to meet perfectly defiite radio needs. Bulletins givin full description of Pacent Procıcts ı relative technical datawill .. sent upon request.

This trade mark is alway an assurance of radio satisfactın.

PACENT ELECTRIC COMPAıY, Inc.
Executive Offices, 22 Park Place, ıew York



TYPE 213

0 CYCLE OSCILLıTOR

A 1000 cycle alternating current supply so·ce for bridge and similar measurement work. Its wave form· remarkably free from harmonics, a very important feature · most alternating current bridge work.

Provision is made for output voltages of 0.5, 5 and 5 with corresponding currents of 100, 40 and 12 m iamperes respectively. It will operate successfully with in·t voltages of from 4 to 8. Since it is self starting, it may placed in a sound proof box or located at some distant point ıd controlled from the place where the measurements are beiı made. This is important where balances are indicated by th null method.

Particularly adapted for college laborator where continuous operation without attention or adjustmıt is desired.

Circuit Diagram and Complete Description in Bulletin 706E

PRICE $32.00

GENERAL RADIO C·.
Manufacturers of
ELECTRICAL AND RADIO LABORATORY PPARATUS
Massachusetts Avenue and Winds· Street
CAMBRIDGE MASSAıHUSETTS

5370

Brandes
— In the Laboratory

WHERE headsets are used to detect radio-frequency currents, greater accuracy is obtained by using the Brandes shielded headset cord to prevent the changing capacity, caused by the varying relation between the cord and the testing apparatus, from affecting the receivers.

The Brandes Navy Type Radio Headset is very sensitive. The minimum current required for audible signals at 1000 cycles is approximately 1.6, 10-10 amperes. The shielded cord prevents both body and cord capacity effect.

In audibility tests where a power oscillator is used the Brandes shielded cord protects the headset from the audio-frequency signal which would be picked up by an unshielded cord, and be allowed to interfere with the tests.

Distributors in Australia and New Zealand
International Electric Co., Wellington, N. Z.

Made in Canada and England by
Canadian Brandes Ltd., Toronto and London.

Distributed in Canada by Perkins Electric Ltd.,
Toronto—MONTREAL—Winnipeg

C. BRANDES, INC.
237 Lafayette St., N. Y.

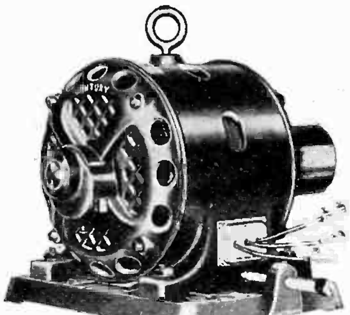
Matched Tone
TRADE MARK REG. U.S. PAT. OFF.
Radio Headsets

OVERMOTORING IS UNNECESSARY

with

Century

Type "A. S." Induction POLYPHASE MOTORS



A Motor of the correct horse-power rating for the running load usually produces sufficient static torque (not less than 180% of full load value) to meet the heavy starting demand of pumps, air compressors, refrigerating machinery, and other equipment producing a heavy inertia load.

They Keep-A-Running

½ to 60 H.P.

CENTURY ELECTRIC CO.

ST. LOUIS

Sales Offices and Stocks in Principal Cities

ALPHABETICAL LIST OF ADVERTISERS

(For classified list of Advertisers see Pages 44, 46 and 48)

1923 = 1919 + 1920 + 1921

UNDERGROUND CABLE

Over ~~About~~ two and one-half million feet of lead-covered paper insulated cable, made by six different manufacturers, will be ~~were~~ inspected and tested during ~~1919, 1920 and 1921~~ 1923.

Specially complete facilities for dielectric loss and other laboratory tests and investigations.

ELECTRICAL TESTING LABORATORIES
80th Street and East End Avenue
New York, N. Y.

Journal AIEE June 1922

Prominent Engineering Concerns

Specify and Purchase

SPRACO "VERTICAL"

Air Washing and Cooling Equipment

for the New Enclosed System of Ventilation for turbo-generators

(Stone & Webster,—Byllesby Engineering and Management Corp., and J. G. White Engineering Corp. are three of the prominent engineering concerns that have specified and purchased SPRACO Type "V" Air Washers for numerous installations)

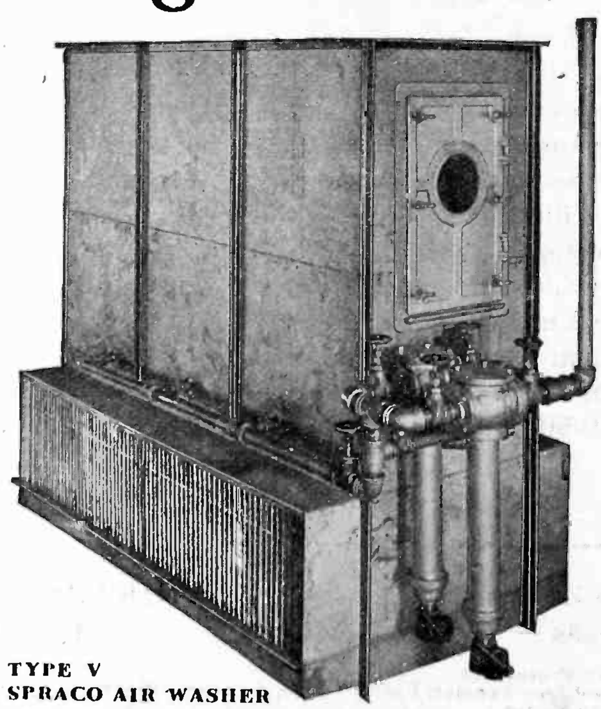
Our Engineering Department will submit, without obligation, recommendations, with proposal on a washer for the enclosed system of ventilation, on receipt of essential information. The Spray Engineering Company are also pioneer manufacturers of Horizontal Air Washers (non-recirculating air type) for conditioning the ventilating air for turbo-generators.

For full particulars
Write Dept. AW-69

Engineers for
Spray Cooling Systems
Irrigation Systems
Aerating Reservoirs
Air Conditioning
Gas Washing

SPRACO PRODUCTS

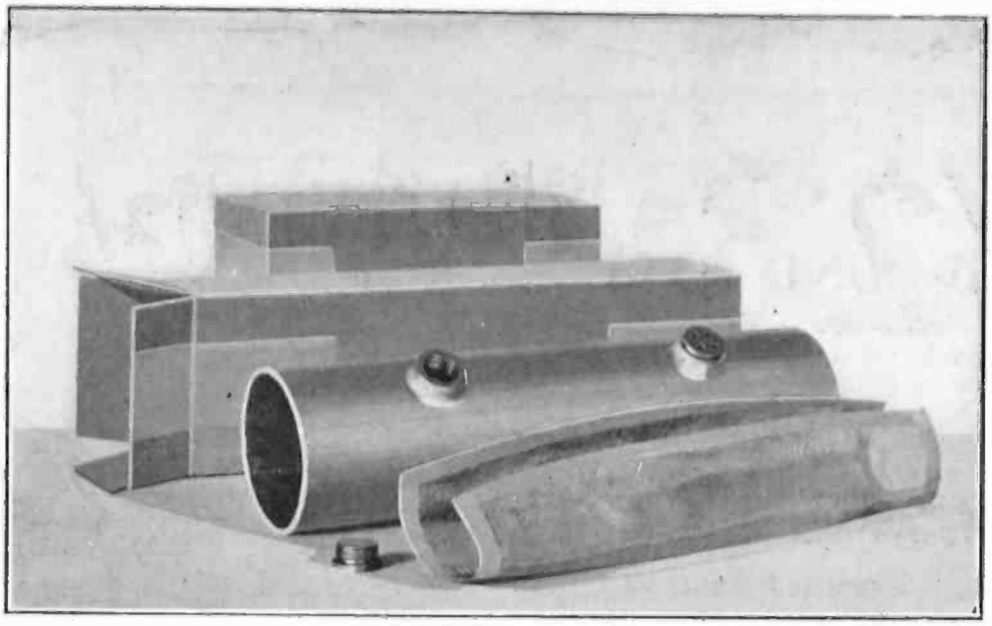
Manufacturers of
Air Washing Equipment
Spray Cooling Equipment
Paint Spraying Equipment
Flow Meters
Park Sprinklers
Self Cleaning Strainers



TYPE V
SPRACO AIR WASHER
Uses same air over—rewashing and recooling.
Enables generator to run indefinitely without cleaning.

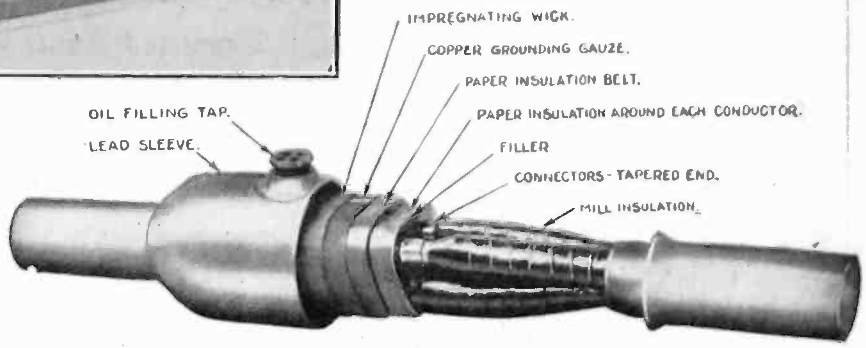
SPRAY ENGINEERING COMPANY

60 High Street, Boston, Mass.



Metropolitan Protective Devices (Murray Patents)

This standard package cable joint saves material. There is nothing to waste. It saves time. No trips need be made for materials forgotten. It saves money, being portable and easily installed.



Detailed View Metropolitan Oil-Filled Cable Joint

A New Standard Package Oil Filled Cable Joint that Requires No Vacuum Filler

Contents of Standard Package

Lead Sleeve
Sleeve Stocking
Compound
Paper Insulation
Impregnated Wicking
Rove Filler
Connectors
Emery Cloth
Waste Ends
Gummed Paper
Muslin
Bar 50-50 Solder

When the "OIL FILLED CABLE JOINT" was originally developed, the specifications for cables did not include bending tests, with the consequence that cables then produced were more susceptible to damage by bending than the modern cables built in accordance with the National Electric Light Association specifications, which call for two complete bending cycles, 180° and reverse, on a drum diameter 12 times that of the cable. The application of the vacuum with the "oil filled" cable joints caused the oil to travel a considerable distance into the cable at both sides of the joint, thereby healing any damage sustained at the cable ends by the bending and handling of these ends while splicing and racking the cable, or even in winding on the inner portion of the reel.

With modern, improved cables, we can now omit the vacuum process by using an improved grade of filling oil which gives practically as perfect penetration of the oil from the joint into the cable as formerly with the old type of oil, with vacuum. Our new oil, without vacuum, insures perfect uniformity of saturation between joint and cable ends, superior to any other type of joint filling compound. Therefore, with the improved oil we have removed the necessity of applying the vacuum thereby greatly simplifying the use of the "OIL FILLED CABLE JOINTS" but still retaining all of the numerous advantages and many points of superiority of this type of joint.

Other Metropolitan Products

Network Protectors
High and Low Tension Fuses
Junction Boxes
Standardized Switches
High Tension Cable Joints
Primary Cutouts
Subway Sectionalizing Units
D.C. Cable Testing Ammeters
High Tension Cable Joints
Cable Racks

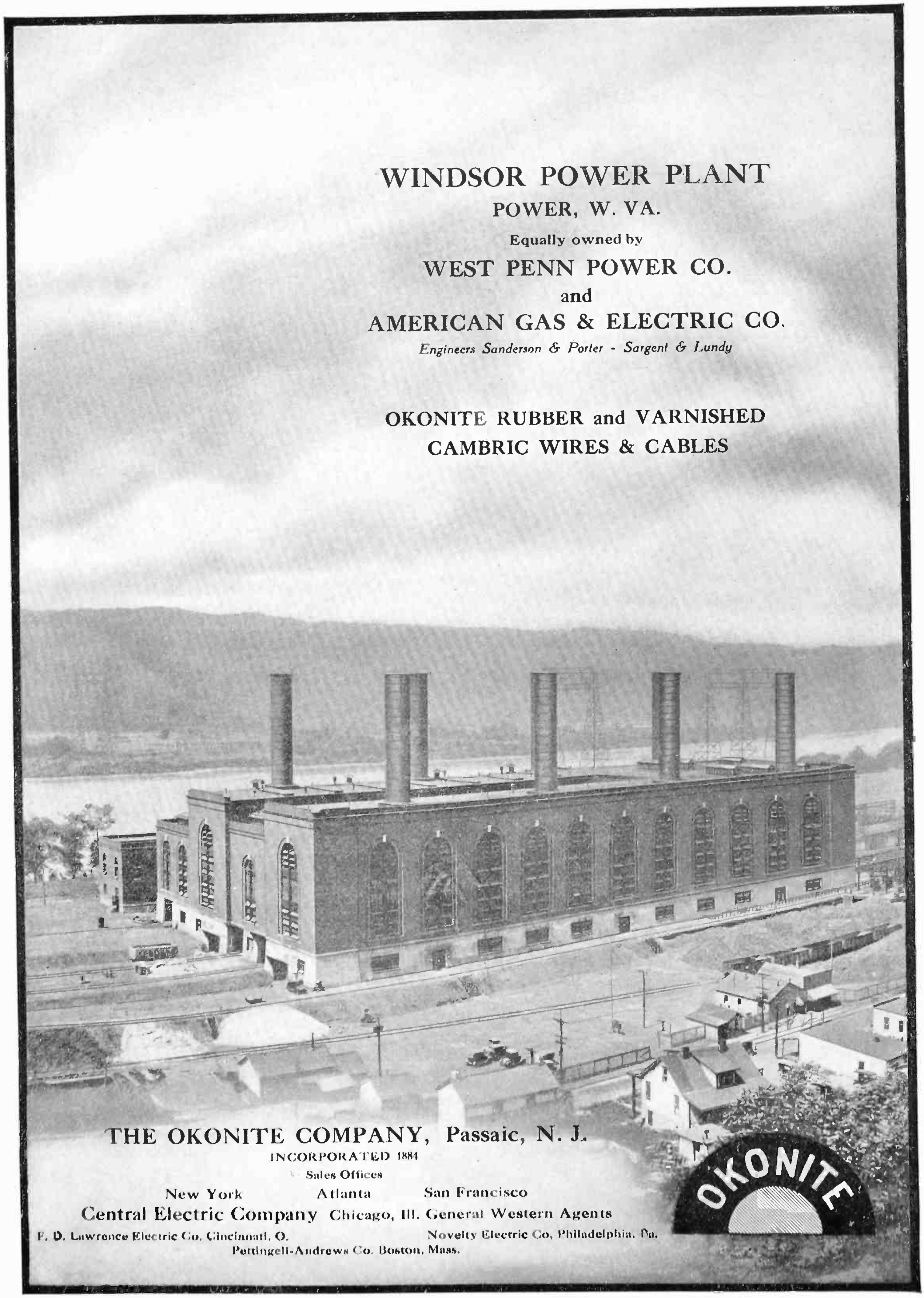
METROPOLITAN DEVICE CORPORATION
1250 Atlantic Avenue, Brooklyn, N. Y.

Gentlemen:—Please send full information on Metropolitan Standard Package Cable Joints.

Name.................................... Company....................................

Address.................................... Title....................................

And kindly check any of the items at the left on which you desire information.


WINDSOR POWER PLANT
POWER, W. VA.
Equally owned by
WEST PENN POWER CO.
and
AMERICAN GAS & ELECTRIC CO.
Engineers Sanderson & Porter - Sargent & Lundy
OKONITE RUBBER and VARNISHED
CAMBRIC WIRES & CABLES
THE OKONITE COMPANY, Passaic, N. J.
INCORPORATED 1884
Sales Offices
New York
Atlanta
San Francisco
Central Electric Company Chicago, Ill. General Western Agents
F. D. Lawrence Electric Co. Cincinnati, O.
Novelty Electric Co. Philadelphia, Pa.
Pettingell-Andrews Co. Boston, Mass.
OKONITE

1¼ Million Horse Power

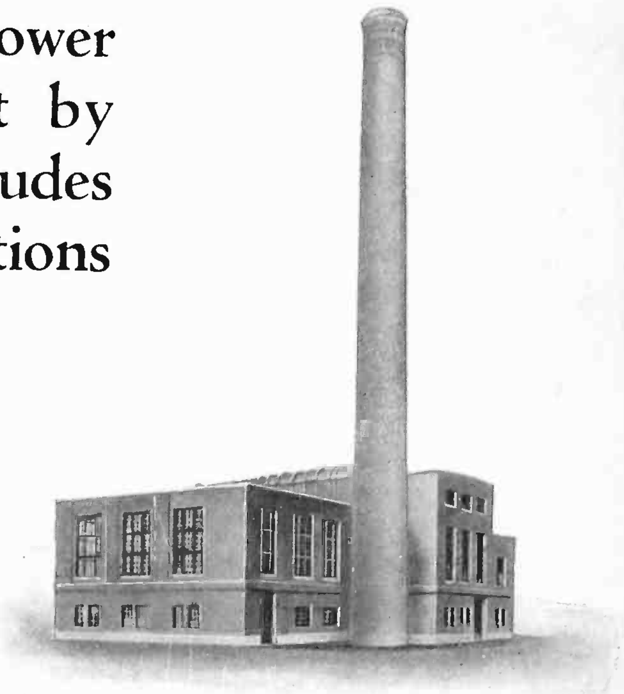
is the capacity of steam power stations designed and built by Stone & Webster. This includes ¼ million horse power in stations now under construction.

STONE & WEBSTER

INCORPORATED

BOSTON
CHICAGO
SAN FRANCISCO

NEW YORK
PITTSBURGH
PHILADELPHIA



BATON ROUGE
1,500 kw.

HARTFORD
130,000 kw.