BELL LABORATORIES RECORD

DIFFRACTION OF ELECTRONS
L. H. GERMER

TRANSMISSION AND NOISE MEASURING
F. H. BEST—R. S. TUCKER

SOUND SYSTEM FOR PROGRAM USE
W. A. MacNAIR

MARCH 1936 Vol. XIV No. 7

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BELL LABORATORIES RECORD

Published Monthly by BELL TELEPHONE LABORATORIES, INC.

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CLARKSON COLLEGE OF TECHNOLOGY
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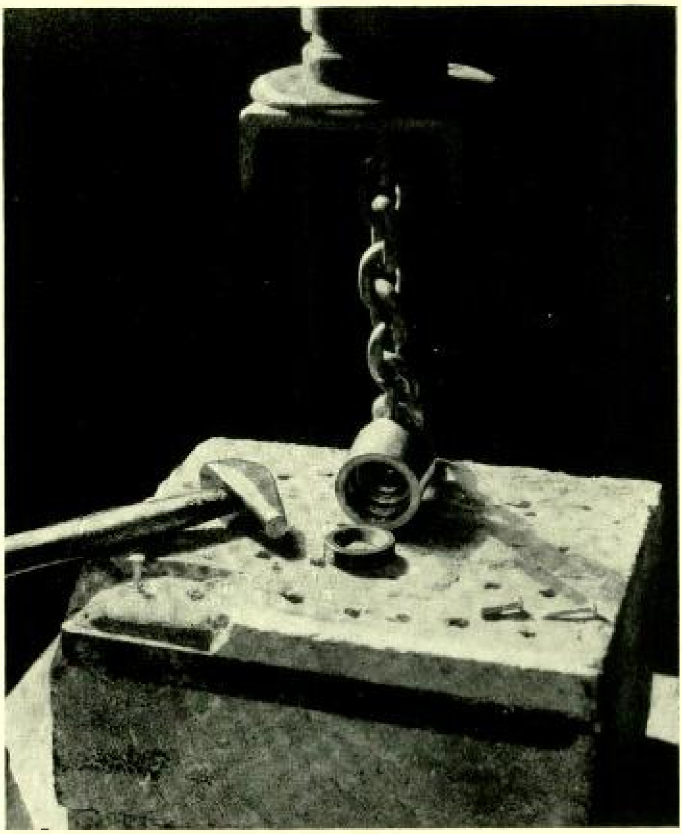

Laboratory test for masonry anchors

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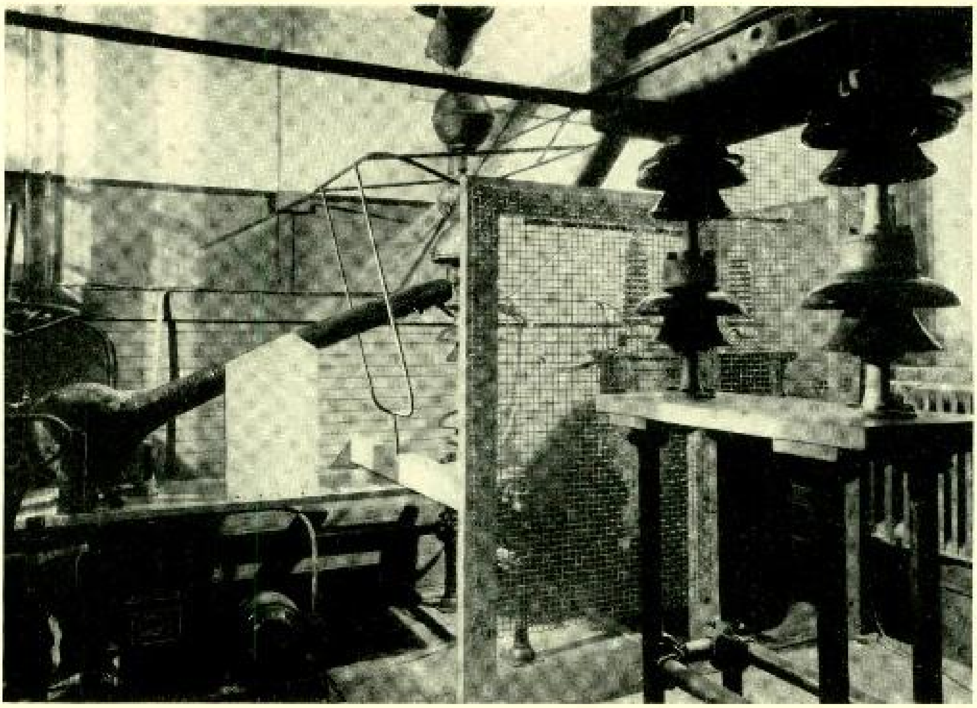

Electron Diffraction Analysis

By L. H. GERMER
Physical Research

WHEN a stream of electrons falls upon a crystalline material, most of the electrons are scattered in certain definite directions as sharply defined beams, or cones, or plane sheets. If one intercepts the scattered electrons by a photographic plate a pattern is recorded which consists of spots, or curves, or straight lines, or of combinations of these. This phenomenon, which was discovered about nine years ago,* is explained by assuming that beams of electrons have the properties of trains of waves. The waves of the incident train are scattered by the regularly arranged atoms in the crystals of the target, and the beams and cones which issue from the target are formed by constructive interference among the secondary scattered wavelets.

It was probably fortunate for those who discovered this phenomenon that the diffraction of X-rays by crystals had been discovered fifteen years earlier. The characteristic features of crystal diffraction were recognized at once in the patterns produced by electrons, and there was at hand a vast amount of information concerning the arrangements of atoms in crystals, which X-ray analysis supplied, and which could be used to test the hypothesis that electrons are waves and to determine their wave-lengths. From another point of view the earlier discovery of X-ray diffraction by crystals might be regarded as unfortunate for those studying electron diffraction

*RECORD, *April*, 1927, *p.* 257.

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and seeking ways of employing it, since most of the easy problems in crystal analysis had been solved during the fifteen years which elapsed between the two discoveries.

It happens, however, that the analysis of crystal structures by X-ray and by electron diffraction are not just two means of getting the same information. The field in which electron studies are useful is to a large extent different from that in which X-rays can be applied. Because of the well-known penetrating power of X-rays they are suitable for investigating the crystalline state of rather bulky specimens. Such specimens are, in fact, required because the great penetrating power is associated naturally with feeble scattering. Unless the specimen is rather thick the diffraction pattern is so excessively weak that it is useless. With electrons conditions are quite different, because they are a million times more strongly scattered than X-rays. It turns out that they are of no use for studying the interior of thick specimens, but are preeminently suited to the investigation of very thin foils or of very thin layers upon the surfaces of bulky materials. Neither of these can be investigated by X-ray methods. At the present time many problems of surface chemistry are being studied by electron diffraction, among which are problems in catalysis and in the corrosion of metals.

Although the technique of electron diffraction analysis is not as yet very well standardized, certain features of the experimental method are in fairly general use. Electrons from the cathode of a gas discharge tube or from a hot tungsten filament are accelerated by a potential difference of several tens of kilovolts. The crystalline material under investigation is bombarded by these electrons, and those scattered from it strike a photographic plate and record the diffraction pattern directly upon it. The technique differs from that of X-ray diffraction chiefly on account of the necessary vacuum. In the case of X-rays the beam has its origin in vacuum but is diffracted in air, whereas with electrons the beam is diffracted and the pattern is recorded in the same evacuated chamber in

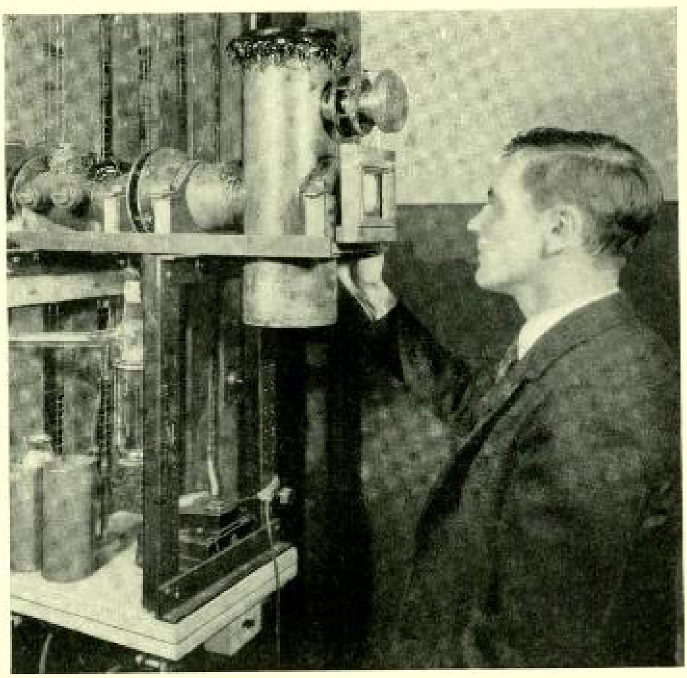

Fig. 1—K. H. Storks of the Research Department adjusting the camera preparatory to making a photographic record of an electron diffraction pattern

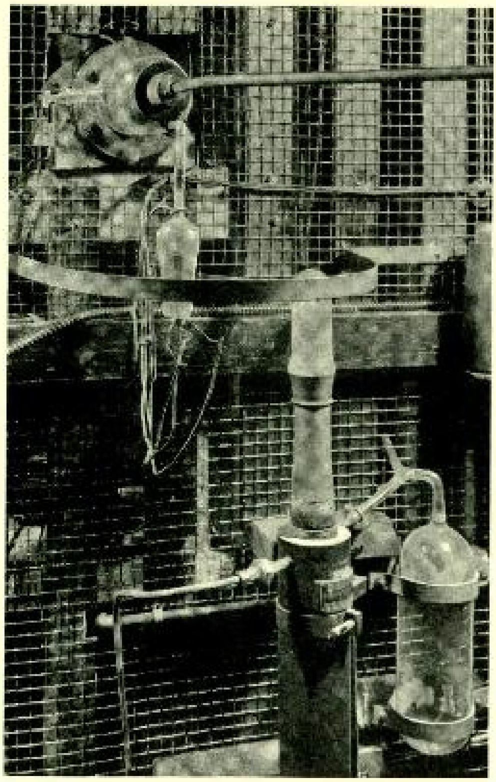

Fig. 2—The filament end of the camera. The filament is maintained at a potential of 50 or 60 kilovolts negative to ground. The transformer, rectifier, and filter which supply the high negative potential to the filament are shown in the headpiece

which the electrons are generated. The entire apparatus in which this is carried out may be appropriately termed "an electron diffraction camera" and is shown in Figures 1 and 2.

The drawing (Figure 4) represents a cross-section of the camera which is at present in use in these laboratories. It is contained in a large exhausted chamber made up of copper tubings which are soldered and bolted together. During operation this chamber is exhausted continuously by means of a mercury diffusion pump. Within the chamber is a tungsten filament, A, which serves as the source of electrons. These are accelerated by a potential difference of fifty or sixty kilovolts before reaching the small openings, B and B′, which define the electron beam sharply. Also, within the chamber, is an adjustable holder, C, for the material which is studied, and finally the photographic plate, D, upon which the diffraction record is formed. This plate can be raised and lowered so that several exposures can be made on it, and the plate can also be moved entirely out of the way. In this latter position the electrons strike a fluorescent screen, E, which seals one end of the chamber and is used to adjust the apparatus preparatory to taking a photographic record.

The various parts are adjusted within the exhausted chamber as indicated in Figure 4. Most of the adjustments are made through flexible copper bellows of the type used in steam pressure gauges and in high grade vent valves and shut-off valves. Through these so-called sylphon bellows one is able to transmit mechanical motions to movable parts within the apparatus, without the danger of air leakage. The pinholes, B and B′, each about 0.1 mm. in diameter, are adjustable both horizontally and vertically by means of such bellows. Another bellows enables the operator to rotate the specimen holder C about a vertical axis, and still another is used in moving the photographic plate.

Examples of diffraction patterns produced in this camera, and chosen to show widely different types of pattern, are exhibited in Figure 5. The first seven of these photographs were produced by single crystals. Numbers eight and nine are patterns from single crystals upon the surface of each of which there exists some poly-crystalline material. The last three were produced by masses of small crystals. In

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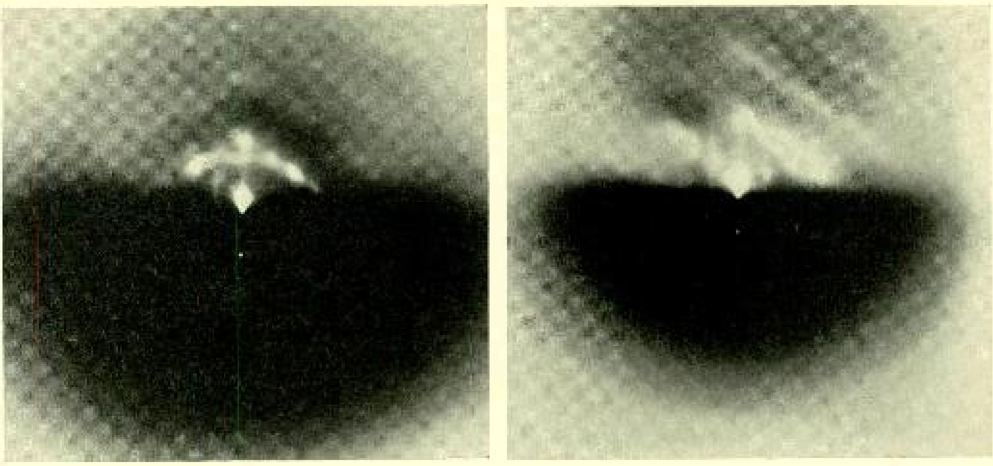

Fig. 3—Diffraction patterns from oriented layers of stearic acid molecules

all cases the electron wave-length was about 5.4×10^{-10} cm.

The prints of Figure 5 illustrate some of the complexities of electron diffraction phenomena. For example, prints 1 and 2 were both produced by electrons passing through thin crystals of mica, the only significant experimental difference being in the thickness of the crystal. The crystal from which print 2 was obtained is several times thicker than that which produced print 1. Prints 3 and 4 were made by electrons scattered from the surfaces of single crystals of copper oxide, the only important difference being in the orientation of the crystal. Polycrystalline sheets of this same substance gave the patterns of prints 10, 11 and 12. In 10 the crystals are randomly oriented. In 11 the surface has become largely covered by crystals of a new sort which have very marked preferential orientations. In 12 the surface consists of relatively few crystals, and these are disposed so that they exaggerate the effect of another phenomenon which is very

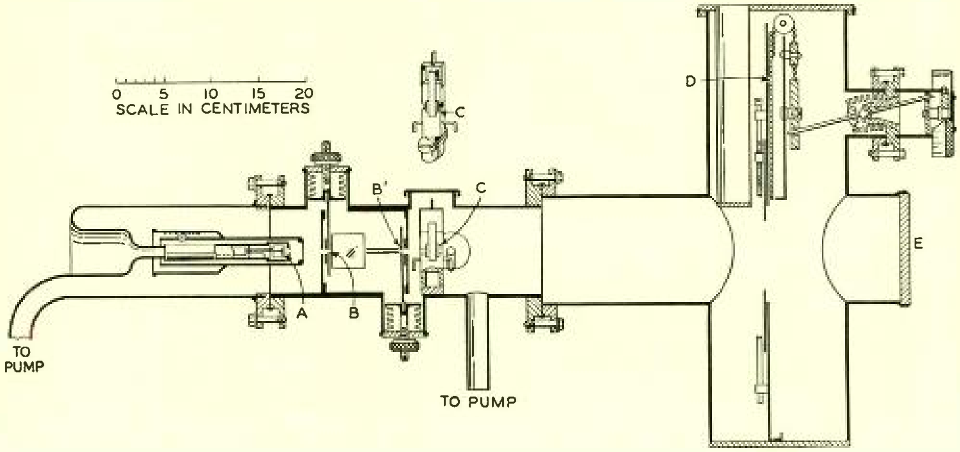

Fig. 4—Longitudinal cross-section of the electron diffraction camera

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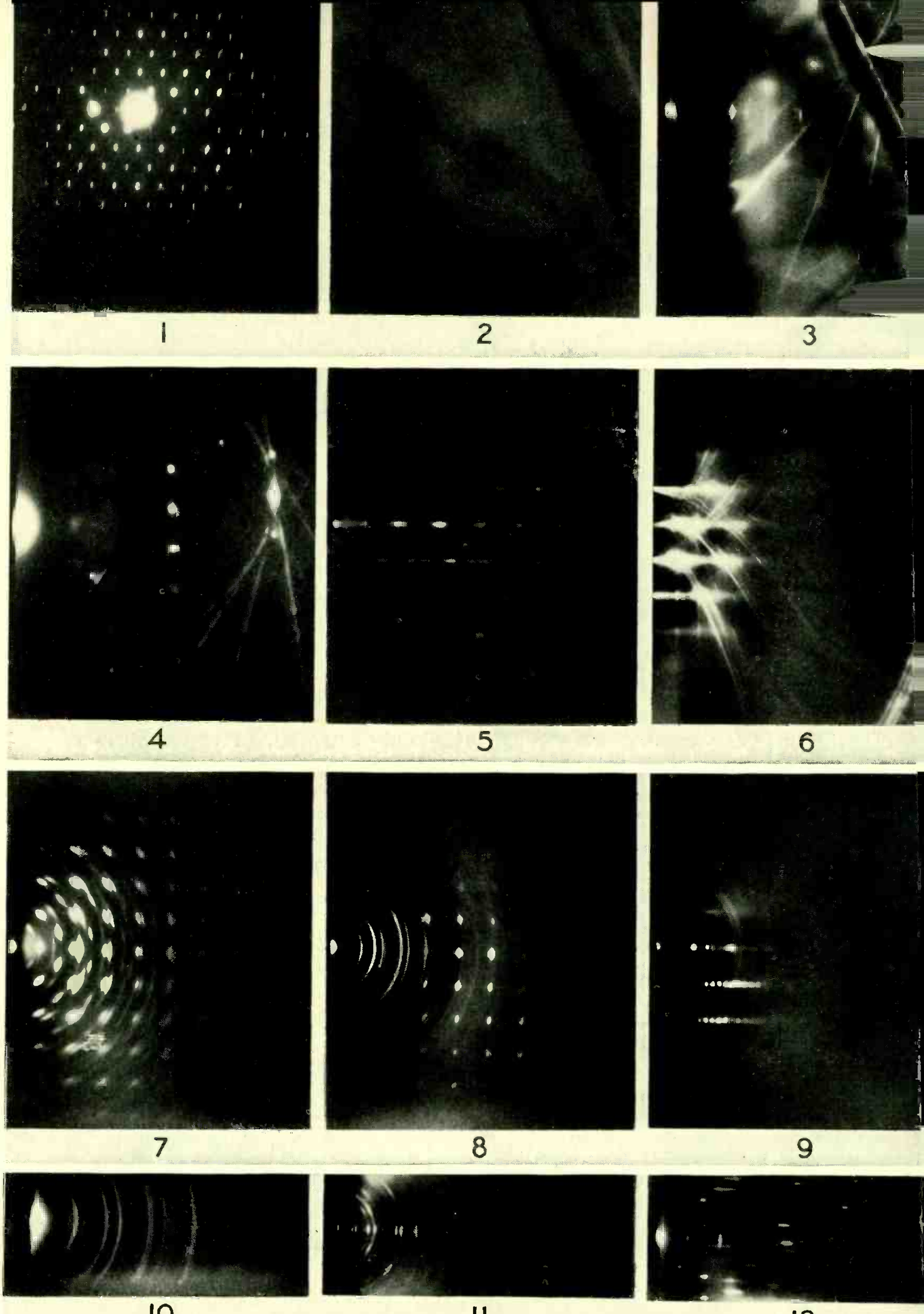

Fig. 5—Examples of electron diffraction patterns

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similar to optical refraction. Prints 5, 6 and 9 were produced by a crystal of carborundum. In 9 we see the pattern of randomly oriented crystals of a different sort superposed upon the carborundum pattern. The entire patterns of prints 7 and 8 are due to the mineral galena. The former shows the effect of extreme "imperfection" of orientation of the surface layer of the galena crystal. The crystal which produced the latter had been roughened in such a way that a very thin layer of randomly oriented galena crystals was superposed upon the underlying single crystal. The print shows the pattern of these randomly oriented crystals as well as the pattern of the single underlying crystal.

To one familiar with X-ray diffraction, print 10 has a thoroughly familiar appearance, as have portions of prints 8 and 9. The sort of preferential orientation indicated by print 11 is well known in X-ray studies, but the marked perfection of orientation shown here is quite new. Straight lines in some of the other prints show vague similarities to the results of experiments with gamma rays performed by Rutherford and Andrade in 1914 and to later experiments with X-rays. For the most part, however, the phenomena exhibited by these prints have no accurate counterparts in X-ray investigations. The electron phenomena are much more complex, and in most cases the interpretation is more difficult; but the amount of information which it is possible to obtain by means of electron diffraction is more extensive, and as a result is likely to be of greater importance both to technology and to science.

The Franklin Gold Medal has been awarded by The Franklin Institute to Dr. F. B. Jewett, President of Bell Telephone Laboratories, "In recognition of his many important contributions to the art of telephony, which have made conversation possible not only from coast to coast, but from this country to the other side of the world—contributions of which some were made by him alone, and some by him in collaboration with other workers in the great laboratory of research which he organized and which he has directed with such signal success."

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Paint Films of Controlled Thickness

By H. G. ARLT
Chemical Laboratories

IN the preparation of paint films for test purposes control of the thickness and uniformity of the coatings applied to the test panels is of extreme importance since the value of the results of exposure, corrosion, and physical property tests depends so largely on the duplicability of the films and their relation to the coatings applied in actual use.

Studies in the Laboratories show that coatings prepared by brushing may vary in thickness several hundred per cent under the same conditions and as much as one hundred per cent over a single surface even when applied by an experienced operator. Hand spraying gives somewhat more uniform results but still shows objectionable variations in thickness and uniformity. To obtain improved control the Laboratories has recently developed an automatic spraying device which may be used to apply organic coatings of all types.

It has been the custom in the past to prepare panels intended for exposure or other tests largely by brushing and spraying. More recently such test panels have been made by spinning. The procedure in this case is to pour the coating material on a panel which is rotated rapidly in a horizontal plane. By controlling the speed and time of rotation, and the consistency of the finishing material, coatings which are uniform within 0.0001 inch over the entire area except within perhaps 0.25 inch of the edge of the panel can be obtained. This method of application is limited to single coats except for materials in which the solvent action of the second coat does not

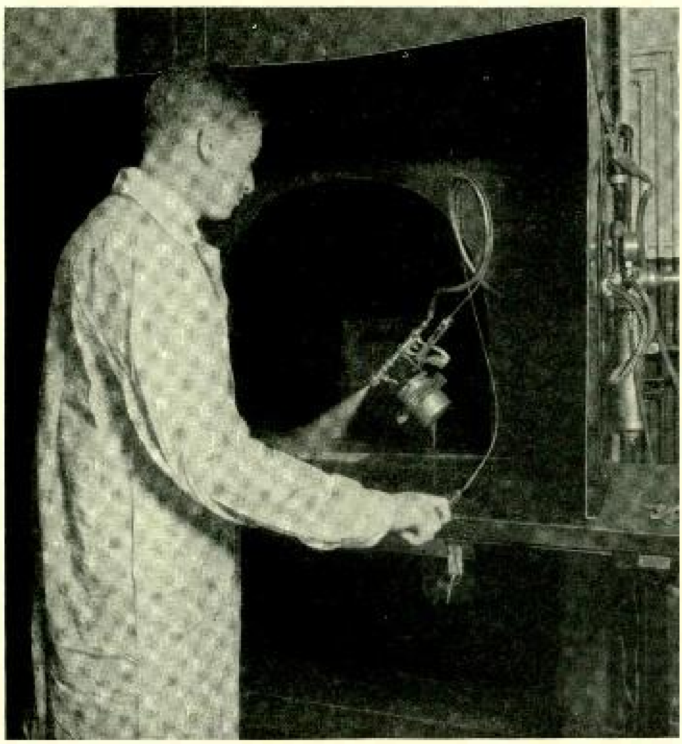

Fig. 1—The spray gun is moved automatically at a uniform rate over the panel to be finished. H. C. Theuerer is the operator

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soften the first coat and cause a secondary flow. Also, it is not possible by this procedure to produce uniform coatings of finishing materials which contain heavy pigments since radial striations usually occur in the film as a result of the centrifugal forces that are exerted by spinning on the heavy pigment particles.

Fig. 2—Several panels can be sprayed simultaneously

The automatic spraying machine developed by the Laboratories overcomes these limitations. It employs a spray gun of standard type which is mounted so that it moves at a uniform rate past the panel to be finished. The panel lies on a levelled horizontal surface and the spray gun travels back and forth above it on a reciprocating carriage which is motor driven. The width of spray emanating from the gun is set at about five inches at the panel level by adjusting the vertical arm on which the gun is mounted, but only the central three-inch portion of this spray fan is ordinarily used. The speed of travel of the gun can be changed easily and quickly by changing gears. The entire arrangement is mounted on a portable table so that it may be located in front of a spray hood to remove objectionable fumes.

There is a straight line relation between film thickness and the speed of travel of the spray gun with given spray conditions and consistency of material. The usual procedure is to depend on changes of gun speed to control the thickness of the film. The selection of the speed of travel required to give the film thickness desired within 0.0001 or 0.0002 inch can be found by making a single preliminary trial to determine the thickness of deposit obtained at a known speed.

The automatic spraying machine is constructed so that a number of panels can be sprayed at the same time. This is of particular advantage in cases where it is desired to prepare a series of panels with coatings of different thicknesses of the same finishing material. In such cases, it is customary to spray a row of panels and remove one after each pass of the gun.

The development of the automatic spray device for preparing uniform organic films for test purposes has not only been of value in facilitating studies of finishes with respect to thickness but has decreased the expense of preparing test films by approximately seventy-five per cent.

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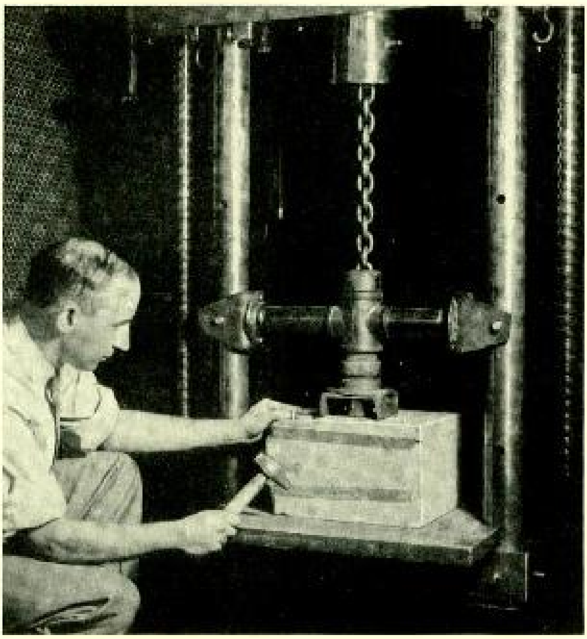

Testing Problems in Outside Plant Development

By O. B. COOK
Outside Plant Development

TO guard against failures in service, the materials used in the construction of aerial and underground telephone plant must be subjected in their development stages to thorough mechanical tests which are designed to reproduce as far as possible the conditions to be encountered in service. Because of the varied shapes and sizes of outside plant materials and the conditions of their use, such testing presents many problems.

The first consideration in testing outside plant materials is the provision of adequate equipment to obtain the required data on articles which range in size from small nails to assemblies of structural shapes. It has been found that most of the testing can be done in the laboratory on an Amsler hydraulic testing machine of 30,000 pounds capacity. In some instances, however, it is impossible, due either to limitations of size or to complexity of attachments, to reproduce the required loading conditions in this machine. For such work the field laboratory at Chester, New Jersey, furnishes facilities for simulating service construction and loading to whatever degree of accuracy is desired. In other cases the utility of a material depends upon its performance over a period of time so that testing takes the form of trial service in the plants of the Operating Companies.

Storm guy straps are products which can be put to realistic test on an

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Amsler machine. These straps are used in guying the poles of open-wire lines in areas exposed to heavy storms. They are metal straps which are attached to the pole by a bolt at the bottom and a screw at the top. The pull of the guy strand on the strap tends to bend the bolt and screw and to crush the timber under them. To measure the effect of the pull, it is necessary to approximate the field loading by mounting a pole section in the Amsler machine at the minimum angle to be expected (Figure 1).

A similar set-up is used for testing the attachments which support aerial

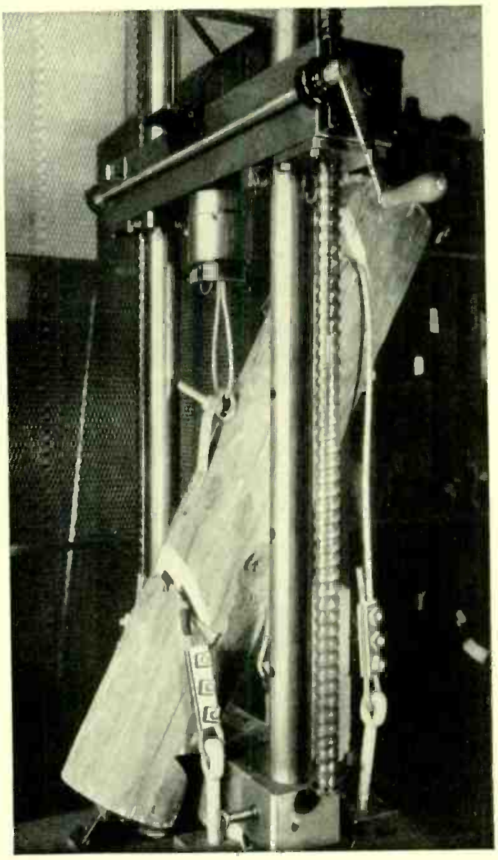

Fig. 1—Storm guy straps used on telephone poles are tested under service load conditions by mounting them on a section of a pole held at an angle in an Amsler testing machine

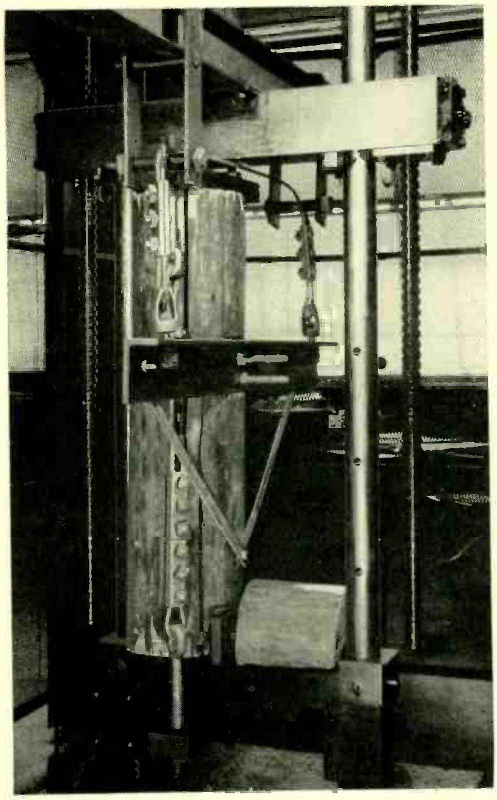

Fig. 2—The strengths of steel crossarms and attaching bolts are determined by mounting them on a pole section in the Amsler machine. The braces are removed before testing

cable where there is a change in direction and the resultant of the weight of the cable and the pull of the suspension strand is at an oblique angle to the pole.

Steel crossarms are used for supporting four cables on poles. They and their attachment to the pole must withstand the total weight of the cable and the ice which forms on it in severe storms. How the testing machine is set up to determine both the resistance of the crossarms to bending and the strength of the attaching bolts when subjected to this vertical load is shown in Figure 2.

The transposition of open-wire lines at regular intervals to provide satis-

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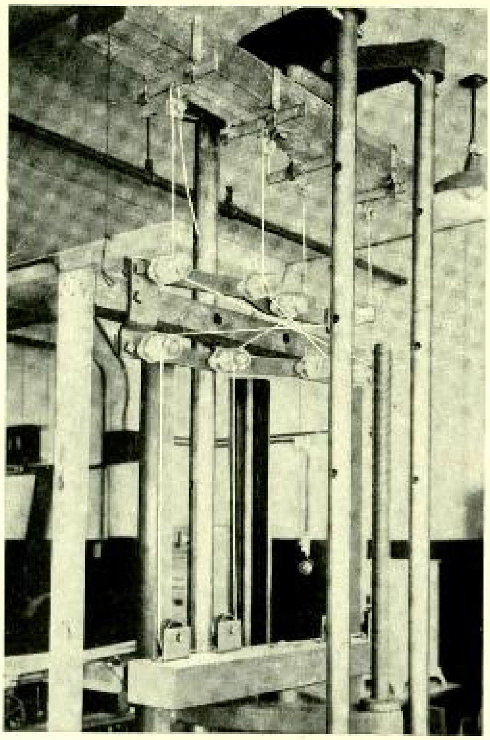

Fig. 3—The effect of the complex load applied to transposition brackets, used where open-wire lines are transposed, is determined by reproducing the entire field installation in the testing machine

factory transmission requires brackets, one type of which is of particular interest from a testing standpoint. This is the "point phantom transposition bracket," which permits at one pole crossovers for the wires of two pairs in any of the four possible ways. These transpositions place eight differently directed loads on the bracket and the only feasible way to determine their total effect is to reproduce the entire field installation of wires in the testing machine. This method is shown in Figure 3.

The ordinary telephone subscriber probably does not ever see or realize the presence of two small devices which play a vital part in bringing his line to him and maintaining its position. These are masonry anchors which consist merely of a nail or screw and an expanding shell. They are used in securing to brick and masonry walls other devices which in turn carry the wire. The expansion shell is set in a drilled hole; and then driving the nail into it or turning the screw in its soft metal expands it and develops frictional resistance against removal. Comprehensive tests must be made on these anchors in all types of brick and masonry to insure their satisfactory performance; and again the Amsler machine supplies this information. The problem involves mounting in the machine, as shown in

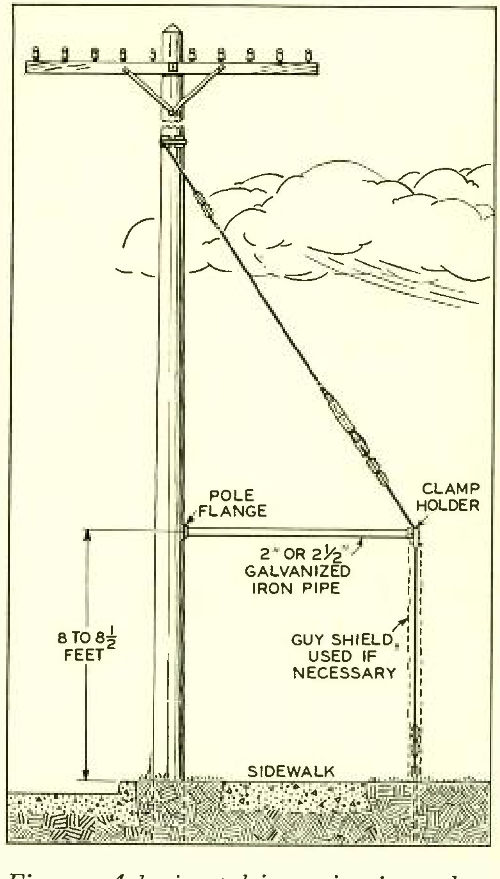

Fig. 4—A horizontal iron pipe is used to prevent the guy strand from interfering with the right-of-way

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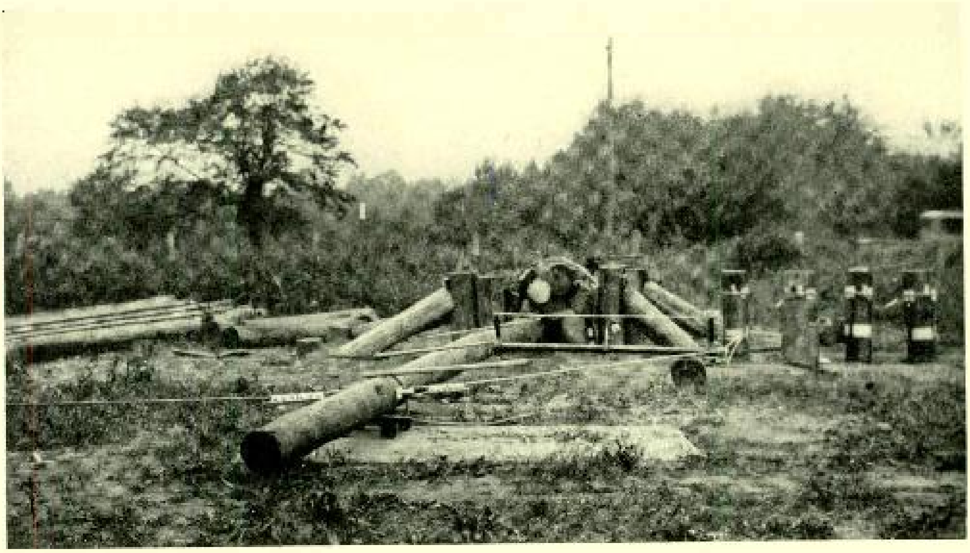

Fig. 5—Sidewalk guy fixtures, used where clearance above sidewalks is required, are tested at the Chester field laboratory by mounting them on poles supported horizontally close to the ground for convenience of measurement

the illustration at the beginning of this article, blocks of brick and masonry, representing walls of sufficient surface area to permit a number of individual tests to be made on each block. A special gripping device was designed for applying a pull to the head of the nail or of the screw. The grip attaches to the chain shown in the picture. In some instances where the article to be attached pulls at an angle upon the expansion anchor, the assembly is tested with the load applied as in service.

Masonry screw anchors as well as wood screws require a muscular effort to install them which must not be beyond the capability of the installer. It is therefore necessary to determine just what torques are involved before approving such articles. The device employed for obtaining this information is illustrative of the special tools which must sometimes be developed for outside plant testing. It consists of a long screw-driver, the elastic deformation of which in torsion is measured on a dial gauge. As the screw is turned in, the dial gauge is read; and the values obtained are converted by calibration into pounds-feet of turning effort.

The guying of overhead lines to balance the forces acting on them at corners and at dead-ends cannot always be accomplished in the customary manner by running guy strand from the top of the pole directly to an earth anchor in the ground. Where insufficient space or right-of-way difficulties necessitate, the strand is brought down from the top of the pole to the outer end of a steel pipe and thence vertically downward to an earth anchor, thus maintaining the desired clear space between pole and anchor. This assembly, however, must have the same strength as the usual construction. Since the length of pipe (Figure 4) required may be as much as twelve feet, it is not feasible to set up a pole, a pipe and the strand assembly in the Amsler machine. Such a set-up requires a field laboratory. At Chester,

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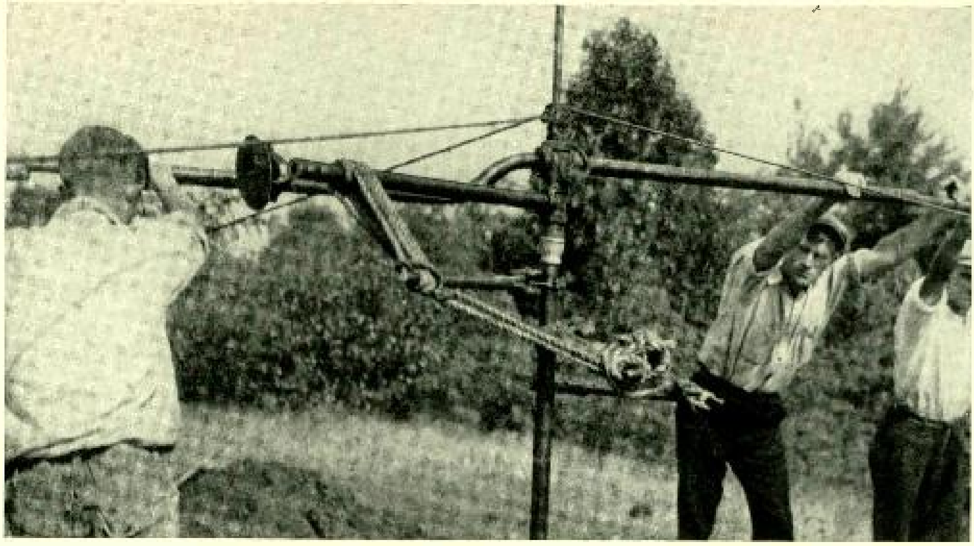

Fig. 6—Earth anchors of the screw type used in guying poles in sand and swamp land are tested by measuring the torque required to force them into the ground

therefore, tests are made on these "sidewalk-guyed" poles to determine the effects on the various parts of the assembly. To simplify the equipment and minimize labor the plane of the pole-pipe assembly is set horizontally. The butt of the pole is supported in a crib and force is applied to its top. In its motion the top of the pole is carried on a trolley which runs on a wooden platform. Figure 5 shows the essential features and the device for measuring the bow of the pipe under compression.

Since neither end of the pipe is fixed with respect to the crib, it is impossible to measure the deflection by an instrument set on the ground. Further, the direction in which the pipe will deflect cannot be predicted. Accordingly, a pair of wires held taut by springs is arranged to extend between iron brackets at the ends of the pipe and to be parallel to the pipe if it is not deformed. A rod joined to the wires at the center of the pipe carries an index point which is accurately centered on a circular target fastened to the pipe. Deflection of the pipe under load is then readily determined by observing the movement of the target under the index point.

The rings used to support cable on suspension strand afford another illustration of the testing work which can be readily accomplished at the Chester Laboratory. In service, the assembly of cable, rings, and strand is subjected to the action of wind and other forces which combine to produce a vibratory motion of low frequency that may ultimately result in the cable sheath wearing or cutting at the rings. This "ring-cutting," if allowed to become excessive, entails considerable maintenance expense on the cable. An accelerated test on two spans of cable at a time was set up at Chester. The cables were swayed by an electric motor acting through a walking-beam and a fabric strap which embraced the cables. Inspection of the cables from day to day yielded information on the comparative merits of various types of rings designed for this purpose.

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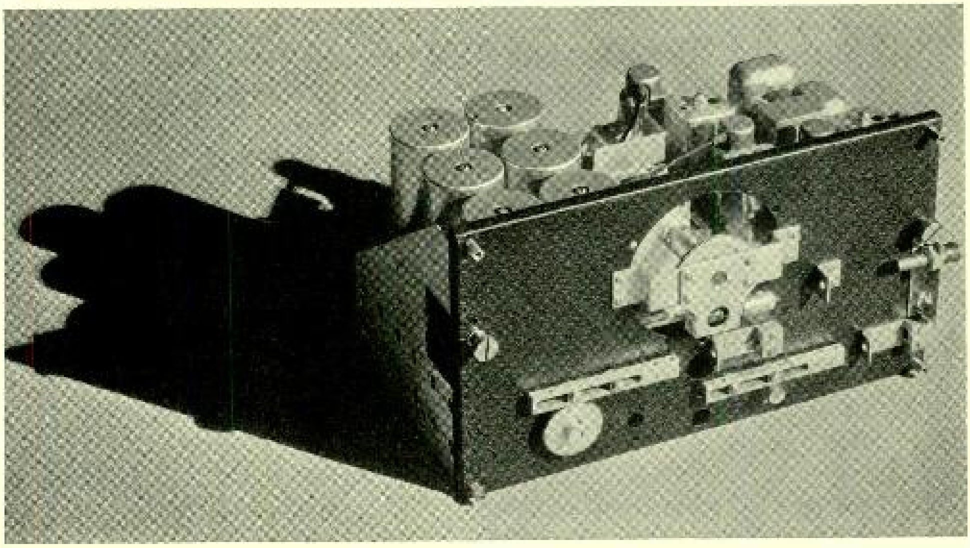
The earth anchors used in guying pole lines represent a type of product most satisfactorily tested under actual service conditions. Anchors are tested in the type of soil in which they are to be used; and a location is usually selected which has soil of minimum holding power. Recently, tests have been made on anchors of the screw type which are used in sandy soil or in swamp land where it is impossible to dig a hole. These consist of one turn of a helix mounted on a rod or length of pipe, and are turned into the ground by means of a suitable wrench. In testing them there are determined the torque required to screw them into the ground and their ultimate strength in torsion. The device shown in Figure 6 was developed for this purpose; it consists of an arm attached to the anchor pipe and connected through a series dynamometer to other arms on which the turning load is applied by hand. With the aid of this measuring instrument, comparative data which suggested improvements in design and method of installation were obtained on a variety of makes of anchors.

All the tests which have been described in this article are concerned with mechanical and structural problems of outside plant equipment and particularly with the simulation of conditions encountered in service. Coordinated with such tests are all the considerations of design and of chemical, metallurgical, and electrical aspects of the equipment in the study of which the Outside Plant Department has the benefit of the coöperation and advice of the other departments of the Laboratories.



Western Electric 20-type radio receiver developed by the Laboratories to provide a light, compact set of extreme selectivity for use in small aircraft. The receiver is designed for either remote (shown above) or local control and is provided with four frequency bands covering a range from 200 kilocycles to 10,000 kilocycles

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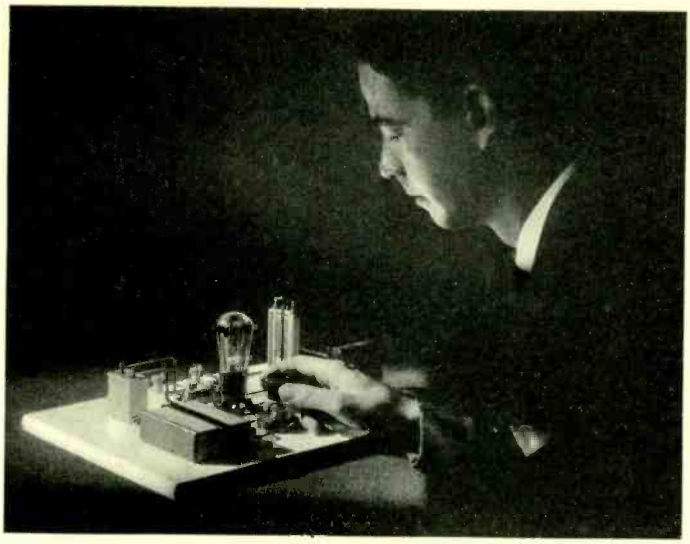

Direction of Motion of Oscilloscope Spot

By J. R. HAYNES
Physical Research

THE moving spot of light which generates the characteristic fluorescent patterns in a cathode ray oscilloscope is usually vibrating so rapidly that it is impossible for the eye to detect its instantaneous direction of motion. It is sometimes important, however, in experimental work that this direction be definitely known. This was the case recently in a study of mechanical hysteresis in microphone transmitters and on account of the special conditions which had to be met it was found necessary to devise a new method for determining such directions of motion.

A simple gas tube relaxation oscillator like that shown diagrammatically in Figure 1 was constructed. This operates by gradually building up a potential difference across the condenser C until the critical breakdown voltage of the tube is reached at which time the condenser discharges. By properly choosing the values of R and C the condenser can be made to charge and discharge at rates varying from one to 20,000 times per second. If the output of such an oscillator is connected to one axis of a cathode ray oscilloscope and the other axis is made a time sweep circuit a saw-toothed wave like that shown in Figure 2 results. The saw teeth which are caused by the sudden increase of voltage across R when the condenser C dis-

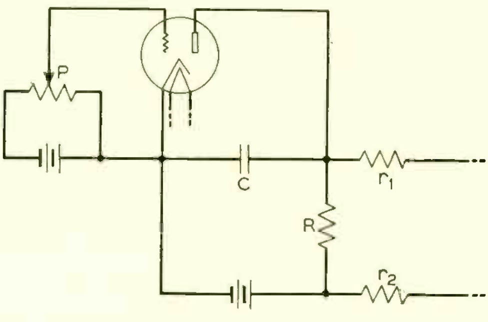

Fig. 1—A gas tube relaxation oscillator, shown here diagrammatically, is used to provide a rapid succession of timed pulses

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charges and the subsequent slow decrease as it charges again may be thought of as arrows pointing in the direction of motion of the spot. Thus if it is desired to measure the direction of motion of the cathode ray spot in any cathode ray oscilloscope figure it is only necessary to connect the relaxation oscillator, tuned to the appropriate frequency, through suitable high resistance leads r_1 and r_2, Figure 1, and superpose the saw tooth wave

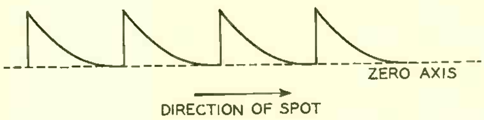

Fig. 2—A saw-toothed wave-form is obtained when the output of the oscillator is connected to a cathode ray oscilloscope with a time sweep axis. The serrations point in the direction of motion of the oscilloscope spot

on the figure in question. It has been found that a Western Electric 256A vacuum tube used with a capacity of 0.0005 mf. and a resistance of one megohm will cover the desired frequency range of from seven hundred to eight thousand cycles per second.

The appearance of an oscilloscope pattern without and with the relaxation oscillator is illustrated in Figure

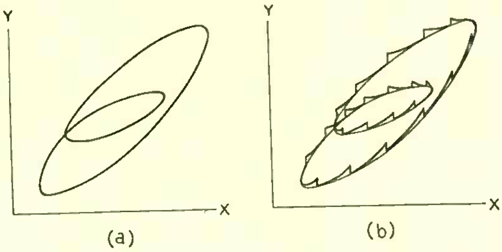

Fig. 3—The oscilloscope pattern (a) is changed to that shown at (b) when the relaxation oscillator is applied, thus indicating in this case that the oscilloscope spot is actually rotating in a clockwise direction

3a and 3b, respectively. The direction of motion of the spot in this particular case was clockwise.

Because of its simplicity and adaptability it is felt that this method of determining the direction of motion of a cathode ray oscilloscope spot may be applicable to a wide variety of circuits.

Texas Centennial Exposition

This Exposition, to be held in Dallas from June 6 to November 29, will commemorate the hundredth anniversary of Texan independence. Arrangements for a Bell Telephone System exhibit have been made by the American Telephone and Telegraph Company. Operative exhibits of apparatus are being prepared in Bell Telephone Laboratories. The Southwestern Bell Telephone Company will be responsible for the operation of the exhibit.

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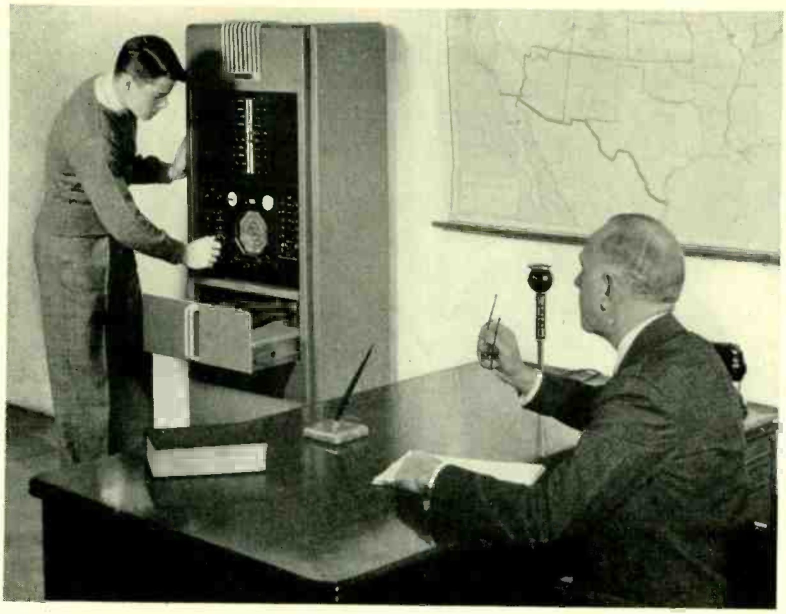

Sound System for Program Distribution

By W. A. MacNAIR
Special Products Department

PROGRAM sound systems are now installed in many modern hotels and schools as well as in industrial plants to provide facilities for distributing speech and music, radio broadcasts, and phonograph records throughout the building from some central location. For convenient and effective control of such installations a compact integrated unit is required. This need is fulfilled in the new program sound system recently developed by the Laboratories. It comprises a radio receiver, a disc phonograph for lateral-cut records, and three microphone input circuits. These are all housed in a single cabinet with amplifiers, a monitoring loud speaker and the necessary control switches to distribute the program to any one or more of sixty loud speakers located in different parts of the building. One key panel with twenty room switches is shown in the illustration but the system is designed to accommodate three such banks of keys. Two amplifiers are normally provided so that two independent programs can be handled simultaneously, but if only a single program channel is desired one amplifier will suffice.

Signals from any of the above mentioned sources may be connected to the input of either or both amplifiers. The loud speaker in any room may be connected to the output of either amplifier or turned off by means of a three-position key on the switching panel. All of the small room loud speakers can be thrown onto the output of one amplifier by a switch on the control panel for emergency announcements. This changeover is effective for all of the small speakers regardless

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of whether they are connected to one or the other channel or turned off. If desired, all of the loud speakers in large rooms, or auditorium speakers in the case of a school installation, may be connected to the output of the amplifier used for emergency announcements regardless of the position of the room keys associated with them.* A talk-back feature has also been included in this equipment so that by throwing the talk-back switch the school principal may monitor the educational program being pursued in any classroom. To do this the loud speaker in the classroom is used as a microphone and the sound is heard

*About one minute is required to heat the tubes after the system has been turned on but if instantaneous response is required this can be had by leaving the power on the amplifier continuously.

Fig. 1—The new program sound system comprises a radio receiver, a phonograph and three microphone input circuits

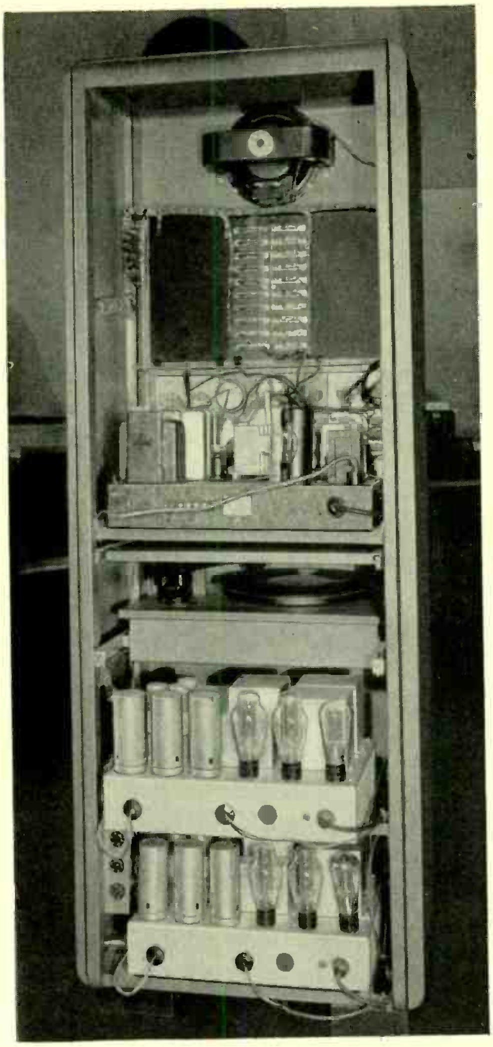

Fig. 2—The two amplifiers, and radio set are mounted on shelves which slide out from the back of the cabinet for adjustments

from the monitoring speaker in the cabinet. By equalization this talk-back circuit has been made to give good speech quality. The monitoring loud speaker in the cabinet may also be used as a microphone, and is equalized for this purpose when announcements are made from the cabinet in cases where it is not desired to take the time to attach a high quality microphone to the system.

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A front and a rear view of the equipment are shown in the illustrations. The monitoring loud speaker is located behind the grill at the top of the cabinet. Directly below are the room loud speaker keys. The input switches and gain controls associated with both channels are shown at the right of the dial of the radio receiver which is in the middle of the panel. Below the dial are the five knobs for the radio receiver adjustments and above it is the radio tuning meter which is used to adjust for maximum signal reception. To the right of the tuning meter is a volume indicator meter and to the left is the emergency call key. On the left-hand side of the control panel are the power switches and pilot light, a switch to put the monitoring loud speaker on either channel and a gain control for this speaker, another switch to connect the volume indicator to either channel and other switches for special functions. Below the control panel is a slide to provide desk space for the use of the operator.

The radio receiver is a high-fidelity superheterodyne of new design with band-width adjustment in the intermediate stages and tone control. Provision is also made to receive short-wave signals for foreign reception or from police and aircraft radio and amateur stations. The receiver is mounted on runners so that it can be pulled out readily from the rear of the cabinet.

The disc reproducing equipment has a phonograph turntable and pick-up of commercial design. It is equipped with a two-speed hysteresis type motor and rotates at the rate of either 78 or 33 r.p.m. so that both ordinary and theatre sound records can be reproduced. This phonograph is located in a drawer which can be pulled out from the front of the cabinet.

The system is designed for the new Western Electric non-directional microphone* but any good quality transmitter with low impedance which does not require a separate current supply can be used.

The two amplifiers are housed in the space below the drawer which holds the phonograph reproducer and are mounted on shelves which can be withdrawn from the rear of the cabinet on runners like the radio set to replace tubes and make adjustments. They were developed specially for this system, each having about 105 db gain and a nominal power output capacity of 20 watts, but a maximum output of 30 watts can be attained with some distortion. The total output of 60 watts from the two amplifiers will ordinarily not be required, but the large reserved power available will be useful on occasions such as for athletic-field announcements.

The loud speakers in the small rooms have permanent magnet fields which are an advantage when they serve as microphones for the talk-back feature. The auditorium loud speakers employed are of the electromagnetic type.

The convenience and versatility of the program sound system will recommend its use not only in places which have at present no reproducing system but for many schools, hotels, department stores and industrial plants now incompletely equipped with one or more of the features which it incorporates.

*Record, *October*, 1935, *p.* 34.

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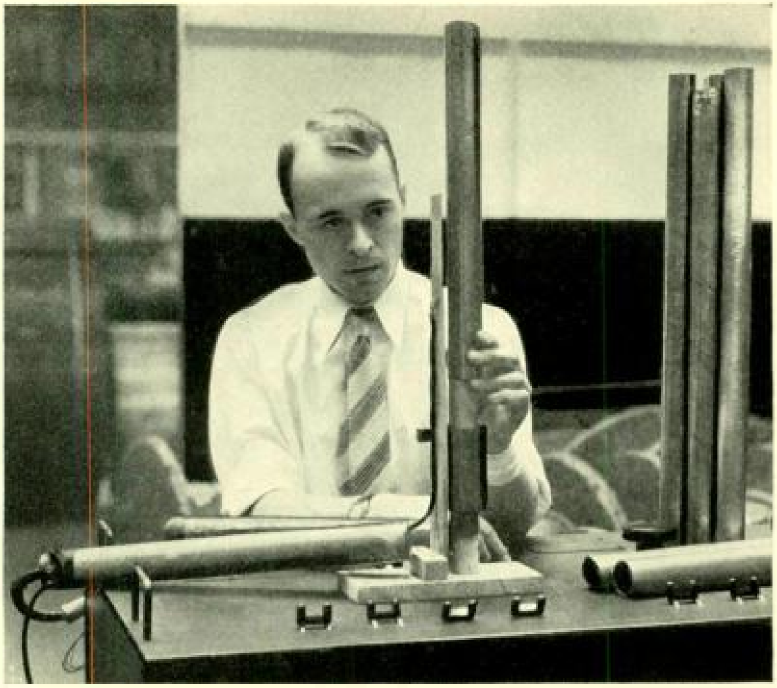

A Theory of Shielding

By S. A. SCHELKUNOFF

AMONG the important and often perplexing factors encountered in the design of communication lines are interference and cross-talk. Although any efficient transmission line keeps most of its energy to itself and under any circumstances gives up only small amounts to the neighboring lines, yet these small energy transfers while not affecting appreciably the efficiency of the line may prove very annoying as interference. In ordinary telephony these troubles are usually overcome by "transposing" at intervals the wires of the communication lines, thereby cancelling most of the induction effects; but in carrier telephony the frequency may be so high as to render this method insufficient and necessitate the use of shields.

The problem of shielding is comparatively simple in principle but efforts to express the concepts involved in quantitative form have long been fraught with difficulties. A method of approach applicable to solid shields is presented here which it is hoped may be helpful, particularly to those accustomed to think in terms of electrical transmission problems. It is based upon the fact that the movement of energy at right angles to communication wires, which is the cause of interference and cross-talk, follows the same basic laws which govern the transfer of energy along a transmission line. From this point of view an electromagnetic disturbance starts from the wires and spreads radially outward through the dielectric surrounding them which constitutes the first section of the radial

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transmission line. At the shield the electrical characteristics of this line suddenly change and another similar abrupt change occurs when the shield terminates. Outside of the shield the radial transmission line extends indefinitely into space but very little

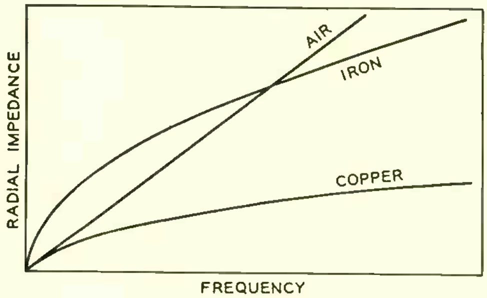

Fig. 1—Radial impedance of all materials increases with frequency: the graph for air and other dielectrics is a straight line; the graphs for magnetic materials, of which only one is shown, are curves which have values greater than those of air for lower frequencies, and less for higher frequencies. The radial impedance of copper and other non-magnetic materials is always less than the value found for air

energy is able to reach this section and cause interference if the shield is correctly constructed.

Before applying these ideas to the propagation of energy radially let us consider the behavior of an ordinary transmission line. The voltage and the current in this line are in general attenuated on account of energy dissipation. If the line is infinitely long the voltage-current ratio is the same at all points; this ratio is called the characteristic impedance. Let us suppose that beyond a certain point the given line is replaced by a section with a different characteristic impedance. A reflection will take place at the junction between the two lines. In other words, when a wave traveling along the line encounters a sudden change in the medium of transmission, a wave in the backward direction originates at the point of discontinuity. The only time when there is no reflection is when the characteristic impedance of the second line equals that of the first line, that is, when the impedances are matched. Under all other circumstances there will be a reflection and the reflection coefficient can then be easily calculated from the ratio of the two impedances.

Although the behavior of an electromagnetic wave traveling along a transmission line is usually described in terms of the voltage and current, it could also be expressed as a function of the electric intensity E and the magnetic intensity H. The measurements of voltage and current are so easily made, however, compared with those of E and H, that the former are used exclusively in practice; but when we have to deal with radial transmission lines which have no wires to carry the conduction current, the variation of E and H along a radius is all that is available to measure.

Returning then to a consideration of the radial transmission line the electromagnetic disturbance may be thought of as originating in a pair of wires and spreading radially outwards. This actual source can be replaced without introducing serious errors by a line source midway between the wires. The outward progress of the radial wave originating from this line source can be fully described by an electric intensity E parallel to the wires and by a magnetic intensity H perpendicular to both the wires and the radius from the line source to the point under consideration. The ratio of E to H may be called the radial impedance.

In a dielectric the radial impedance at a point whose distance from the axis is ρ is $i\omega\mu\rho$ ohms, provided ρ is

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Table 1—Experimental data on shielding obtained by W. E. Mougey and his associates in the Cable Development group. The last two columns show the remarkable agreement between the calculated and experimental values

Material	Thickness	Frequency	Calculated Loss			Measured
			Attenuation	Reflection	Total	Loss
	mils	*kc*	*db*	*db*	*db*	*db*
Copper	16	80	15.1	27.6	42.7	43.7
		150	20.7	31.3	52.0	52.1
Aluminum	18	80	13.3	26.5	39.8	39.8
		150	18.2	29.2	47.4	47.6
Zinc	18	80	9.3	23.4	32.7	32.0
		150	12.7	26.1	38.8	38.5
Lead	86	80	22.5	17.5	40.0	40.3
		150	30.8	22.0	52.8	52.3

short in comparison with the wavelength. In metals on the other hand it is equal to $\sqrt{i\omega\mu/g}$ ohms*, unless the frequency is very low. At low frequencies the radial impedance of metals is also $i\omega\mu\rho$ ohms. The variation of radial impedances with the frequency is shown in Figure 1.

In their progress through metallic substances radial electromagnetic waves are attenuated at the rate $\alpha = \sqrt{\pi\mu f g}$ nepers/cm. This attenuation is caused by transformation of electric energy into heat and is so great, except at very low frequencies, as to mask altogether the slight attenuation due to the divergence of the waves.† In copper $\mu = 1.257\ (10^{-8})$ and $g = 5.80\ (10^{-5})$ so that the attenuation constant at 10,000 cycles is about 15 nepers or 130 db/cm.

The effectiveness of a shield is due in part to this rapid attenuation and in part to the reflection occurring at the boundaries of the shield because of the difference in radial impedances of the shield and adjacent dielectric. Comparing the expressions for impedances, we see that the reflection loss between two metals or two dielectrics is independent of the frequency, but it is not so between a metal and a dielectric. As shown in Figure 1, the radial impedance of copper is very much lower than that of air, while the radial impedance of iron is at one frequency equal in magnitude to that of air.* This means that while at a certain frequency there is practically no reflection between iron and air, there will be a very large reflection between copper and air. Hence, for sufficiently thin shields the higher attenuation loss of iron, as computed by the formula $\alpha = \sqrt{\pi\mu f g}$, may be more than offset by the greater reflection loss at copper-air boundaries.

An interesting and at first sight curious phenomenon is explained by the ratios between the impedances of different substances. If a composite shield is made of alternate layers of copper and iron the effectiveness of the shield is very much greater when

*The quantity $i = \sqrt{-1}$, ω is $2\pi \times$ the frequency f, and μ is the permeability in henries/cm. In vacuum $\mu = 4\pi 10^{-9}$ henries/cm $= 1.257\ (10^{-8})$ henries/cm. The quantity g is the conductivity in mhos/cm.

†In perfect dielectrics "attenuation" is due entirely to the divergence of the waves.

*The phases of the two impedances are different, however, so that at this point the reflection loss is not quite zero as it otherwise would be if the impedances were exactly equal.

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the outside layers are made of copper. This is because of the higher reflection loss between copper and air, the attenuation loss being independent of the arrangement of layers.

Another interesting fact is that while non-magnetic shields become increasingly effective with increase of frequency this is not always true with magnetic shields. At low frequencies magnetic shields are very efficient. As the frequency increases they sometimes become less effective but ultimately reach a minimum beyond which they improve again so that at sufficiently high frequencies they are always better than non-magnetic shields. These characteristics are due to the manner in which the impedances mismatch, as previously explained. In the case of non-magnetic shields the impedances of the shield and dielectric are always mismatched except for zero frequency and by an amount which increases with the frequency as shown in Figure 1. For magnetic shields the mismatch is large at low and high frequencies but is small at certain intermediate points.

The method of explaining inductive interference and shielding effects in terms of the impedance characteristics of a radial transmission line as here outlined has been tested by extensive experiments on shielding carried out at the Laboratories by W. E. Mougey and his associates. The results show a remarkable agreement between the calculated and experimental values as is shown in the accompanying table.

Radio Telephone Scores Another Rescue

Radio telephone apparatus, first made available to vessels off the New England coast during the latter part of 1932, *has already taken an important part in a number of rescues—the most recent being that of the crew of the* Gertrude M. Fauci *on February* 12 *of this year. This auxiliary schooner is one of several fishing vessels owned and operated by Charles M. Fauci, all of which are equipped with the Western Electric marine telephone.*

The Gertrude M. Fauci *sprung a bad leak off Nova Scotia, and her master, Captain Patrick McHugh, called the shore station of the New England Telephone and Telegraph Company at Green Harbor over the radio telephone, reporting his position and asking for immediate assistance. Albert F. Coleman, marine Technical Operator at Green Harbor, saw from his chart that none of the other vessels equipped with radio telephone were in that vicinity, and therefore had a general telegraphic SOS sent out through Coast Guard headquarters.*

Within a few hours, the trawler Lemberg *of Halifax was standing by ready to take off the crew of the* Fauci. *Captain McHugh placed a final call on Green Harbor, reporting the arrival of the* Lemberg *and that they were about to abandon the ship, which was in immediate danger of sinking. During this last conversation he was standing in two feet of salt water and the batteries were partly submerged, but his words still came clearly across some 400 miles of the icy North Atlantic.*

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Measurements of Noise on Program Circuits

By R. S. TUCKER
Noise Prevention Department

IF undesirable noise were allowed to appear on a telephone circuit, not only would the quality of the reception be marred but the range of volume that could be transmitted would be reduced. Studies are constantly being made, therefore, of means for keeping telephone circuits free from appreciable noise. Noise measurements are commonly made when a circuit is originally set up, and from time to time thereafter.

Apparatus for measuring noise on ordinary telephone circuits has been available for some time, but it is not specifically suited for measurements on program circuits. The frequency range required to clearly reproduce intelligible speech is narrower than that required for program circuits, which must meet the more severe requirements of transmitting music sufficiently unimpaired in quality to retain its aesthetic appeal. As a result of this difference in the width of the frequency band, apparatus suitable for measuring noise on message circuits is not in general applicable to noise measurements on program circuits. The Laboratories, therefore, has recently developed apparatus particularly designed for measuring noise on program circuits. For use in telephone test rooms, panel-mounted apparatus has been developed, while a portable noise measuring set has been arranged for use in other places.

A combination of amplifier, weighting network, rectifier, and indicating meter is generally employed for noise measurements. Without the weighting network, such an arrangement would indicate the power in the noise currents. If currents of many frequencies were present, each frequency component would contribute to the total reading in proportion to its own power content. The same power at different frequencies does not, however, result in the same disturbing effect. Consequently any noise measuring apparatus should include some means of "weighting" the different frequency components so that their contribution to the meter reading will be in proportion to the disturbing effect they produce on reception. This "weighting" is ordinarily done by a network which has an attenuation characteristic that is complementary to the relative effects of the same amount of power at the various frequencies.

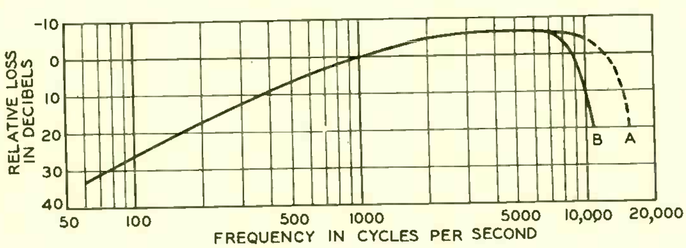

Fig. 1—Frequency weighting curve for program circuit noise. Curve A for circuits transmitting all audible frequencies up to fifteen thousand cycles and Curve B for those cutting off at eight thousand cycles

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Fig. 2—A. V. Wurmser measures program noise with the new apparatus

American Telephone and Telegraph Company. Each observer in turn was seated in a room arranged to simulate listening conditions in a relatively quiet home, and asked to adjust his mental attitude to that of a listener to a radio broadcast program. The program to which he listened carried a small amount of line noise which could be varied in volume, and he was asked to adjust this noise until it just failed to interfere appreciably with his enjoyment of the radio program.

Before the test each observer's hearing was tested to make sure that it was normal. Special attention was given to the hearing at high frequencies, since variations in the hearing ability of individuals are greater at high than at low frequencies. In general, the high frequency hearing of the observers employed was representative of the hearing of young people rather than of older people, as the hearing ability of the latter in this particular frequency range is generally poorer.

Program noise measuring apparatus, used heretofore on a limited scale, has employed a weighting network based on estimated values of the relative interfering effects. Before standardizing apparatus for use by the operating companies, however, it was thought best to make a careful investigation supplemented by a series of tests to determine just what were the relative interfering effects of noises of different frequencies on a typical person who might be listening in to a radio broadcast program.

These tests were carried out in 1932-1933 by the Laboratories in co-operation with the then Department of Development and Research of the

To obtain data applying not only to the best present commercial program transmission, but also to experimental circuits covering a broader frequency range such as the auditory-perspective system,* the frequency range covered by the observations was extended to about 15,000 cycles. Within this range observations were made with single-frequency noises, with noises covering a narrow band width, with combinations of single frequencies, and with bands of cross-induction from speech translated in

*Record, *May*, 1933, *p.* 254.

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frequency so as to be unintelligible. It seemed likely that the effect of the noise would depend somewhat on the type of program. The effects of various types of noises were, therefore, investigated on four types of program material: high-grade orchestral music, high-grade violin and piano music, jazz, and speech. High-grade music was found to have the strictest requirements, and therefore only noise data for programs of this type were used to establish the weighting curve. A few tests were also made in the small hours of the morning when the room was quieter, to get an indication of the effects of room noise.

From the results of all these tests the frequency-weighting curve shown in Figure 1 was derived. Two branches of the curve are shown for the higher frequencies. That marked B is for program circuits cutting off at 8000 cycles, while that marked A applies to circuits transmitting all audible frequencies. The section of this latter curve above 10,000 cycles is shown dotted because the data over this range were not determined to as high a degree of accuracy as that below 10,000 cycles.

A circuit that will attenuate in conformance with curve B has been developed by the Laboratories and a schematic of it is shown in Figure 3. The unit is designed for use with transmission measuring apparatus suitable for testing program circuits which is already available in the plant.

The network, which is designated the J64004B Program Frequency Weighting Network, has been made as inexpensive as possible by building it mainly of elements already standard. Since the previous use of some of these parts did not require as exacting performance as was needed for the weighting network, it was necessary to provide two adjustable elements so that each weighting network could be made to approximate closely the frequency characteristic desired. An adjustable resistance is used for low-frequency adjustments and an adjustable capacity for high. Their position in the circuit is evident in Figure 3.

To make a measurement of noise, an amplifier is required in addition to the weighting network and the transmission measuring device, because the noise currents are materially smaller than the program currents normally transmitted. A high-grade amplifier, known as the J64006B, has been developed for this purpose. Where the purchase of this amplifier may not be warranted because of the small number of noise measurements to be made, one of the standard line amplifiers used in Bell System program circuits may be employed with some sacrifice in the range and accuracy of the measurements. By properly setting the adjustable resistance and capacity already referred to, and by short-circuiting the input resistance shown in Figure 3 when a standard line amplifier is used, the 4B weighting network may be used with either type of amplifier.

Models of the 6B amplifier and 4B weighting network are shown in Figure 2. The amplifier is the top apparatus unit on the bay; the small panel below it is the network; below

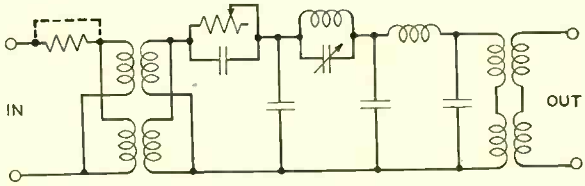

Fig. 3—Circuit schematic of frequency-weighting network for program circuit noise measurement

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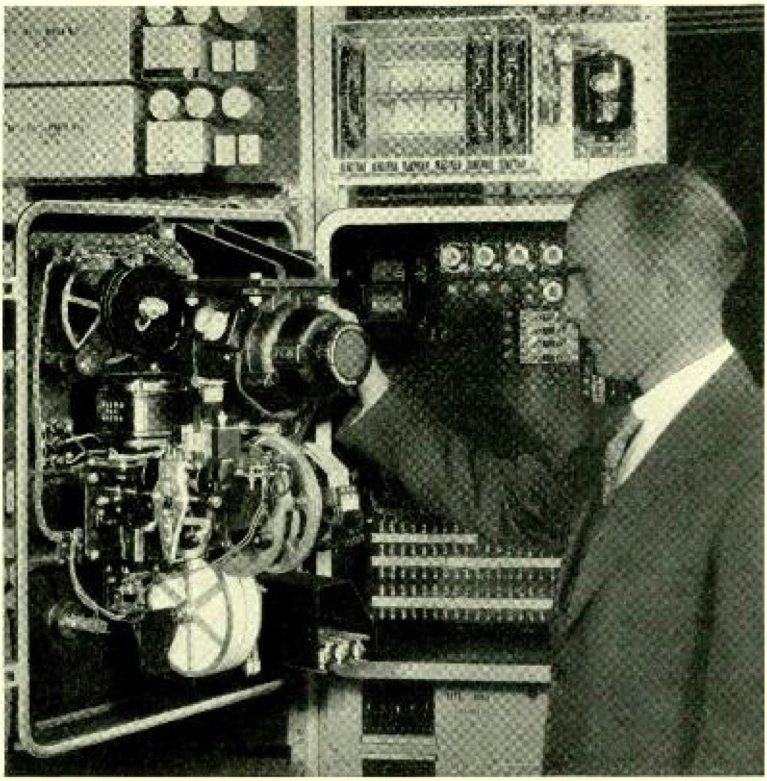
this is a 1A amplifier-rectifier used as an indicating device.

In addition to this panel-mounted apparatus, a circuit for measuring program noise has been included in a recently developed portable noise-measuring set of the visual indicating type, designated the 2-A Noise Measuring Set. This set is complete in itself and does not require the use of any amplifier or transmission measuring set. The frequency weighting is obtained largely from the characteristic of the amplifier in the noise measuring set, so that only a small amount of shaping is required in the supplementary network used to obtain program weighting. This arrangement has other advantages, such as ability to measure a wide range of noises, and high balance to ground as a safeguard against effects of voltages between ground and the metallic circuit on which the noise is being measured.



V. E. Rosene of the Systems Development Department displays the inner mechanism of the pilot-wire controller used for transmission twist regulation on cable-carrier telephone circuits. This equipment corrects for the change in attenuation in a frequency band caused by temperature variations of the cable. An associated equalizer switch box is shown above the controller

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Improved Transmission-Measuring System

By F. H. BEST
Toll Transmission Development

THE Bell System ideal, that satisfactory conversation be possible at all times between any two telephones in the system, requires that every part of the plant be maintained continuously at high transmission standards. To assure this condition, routine transmission measurements of both local and toll circuits have been carried out as a regular part of plant maintenance work for a number of years. These tests are made by applying a known amount of power at one end of a telephone circuit and measuring the power received at the other end.

Heretofore the circuits of the local plant and the shorter toll circuits, which do not require very frequent checking, have been tested at intervals by travelling transmission testing forces, while the toll plant, with its large groups of long and complex circuits which demand more attention, has been handled chiefly from transmission test boards installed in terminal and intermediate offices. The development of a new and relatively inexpensive transmission-measuring system will now make it practicable to place the local plant and the small toll office on the same basis as the large toll installations. A further advantage of the new system is that tests on interoffice trunks can be made by an attendant in one office without calling for the special assistance formerly required from the office at the other end of the circuit.

The new system resembles other modern transmission-measuring systems in general principles. Measurements of the transmission loss caused by a telephone circuit are made by

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supplying the standard testing power of one milliwatt at 1000 cycles to one end of the circuit and measuring the power received at the other end. The transmission loss is indicated on a meter at the receiving end in terms of the ratio, expressed in decibels, of the power received to that sent out. The novel feature of this new system consists in having the testing power applied to the sending end of the circuit by direction of the tester at the receiving end who simply calls or dials a designated number over the circuit to be tested. The testing power is cut off at the sending end when the connection is broken at the receiving end. Tests can also be made in the same manner from private branch exchanges and subscriber stations without a charge being registered against the subscriber.

Testing power is generated by a permanent-magnet inductor-alternator which is driven by an induction motor from the commercial 60-cycle power supply. This unit is shown in Figure 1. The generator output is connected to terminals at one or more points in an office through a distributing circuit which supplies one milliwatt to each point up to a total of 150. The load on the generator is maintained constant by having each testing point normally terminated by a resistance approximately equal to the impedance of the circuit. This resistance is removed during a test. The motor speed changes slightly with changes in power-line voltage and frequency, thus causing a corresponding change in both the generated test frequency and power, but for practical speed changes the power supply to all testing points can be maintained effectively constant. The motor-generator is mounted on a relay-rack panel, which contains the distributing circuit and a relay for remote starting and stopping of the motor. When no tests are being made the motor-generator is not in operation, so that power is consumed only when testing. The circuit arrangements for connecting the testing power to interoffice trunks, subscribers' loops, switchboard cords, etc., are installed on two small panels called the cord test line unit and the trunk test line unit.

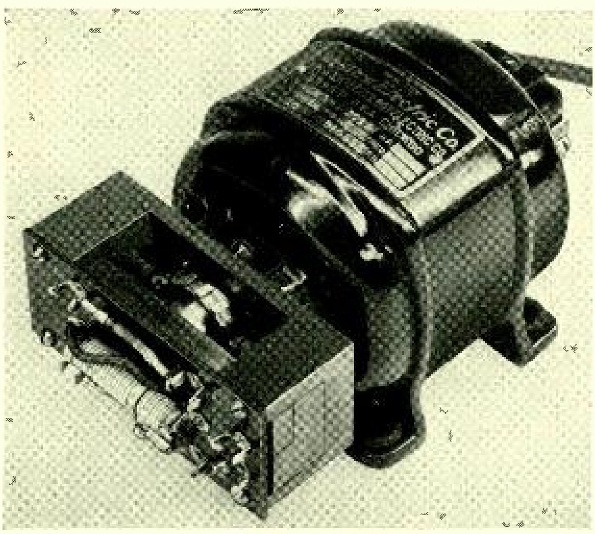

Fig. 1—Current for transmission tests on telephone circuits is generated by a small permanent-magnet inductor-alternator driven by a motor which is directly connected to the 60-cycle power supply

Two transmission-measuring sets have been developed for use at the receiving end. One is intended for large offices and the other primarily for subscriber stations, private branch exchanges, and other small offices where the expense of the larger set cannot be justified. The larger set is shown in the photograph at the head of this article, with H. L. Weisler observing the meter. This set has a transmis-

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sion range of 25 decibels and a frequency range from 300 to 4000 cycles. It is equipped with an amplifier and rectifier which operate on the 60-cycle commercial power supply but it can also be arranged to operate on direct current when alternating current is not available. Jacks are provided for conveniently connecting cord circuits and trunks for test and also for plugging in a dial in order that the generator at the sending end may be added to the circuit by dialing from the measuring set.

The smaller receiving set, shown in Figure 2, whose total weight is only 28 ounces, has no amplifier and consequently requires no external power supply for its operation. The transmission range is 10 db and the accuracy of measurement is somewhat less than that of the larger set, but the frequency range is the same. A copper-oxide rectifier is provided to convert the alternating current used in testing to direct current since the meter is a sensitive d-c instrument. A transformer mounted inside of the carrying case serves as a holding coil for operating supervisory signals.

The development of this new low-cost transmission measuring system will be of greatest benefit to the local plant and small toll office by placing at their disposal transmission-measuring facilities previously available only to the large toll plants.

Fig. 2—A small receiving set has been developed to measure the transmission loss of subscribers' lines. By calling a designated number, P. F. Jones has automatically connected the 1000*-cycle generator to the other end of the line and is about to read the meter*

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An Inexpensive Thousand-Cycle Generator

By R. D. de KAY
Equipment Development

ALTERNATING current of small but constant output and relatively constant frequency is required in transmission tests which are made at regular intervals on telephone lines to assure that they are functioning properly. The standard testing power for this purpose is one milliwatt at a frequency of one thousand cycles per second. It is supplied in large toll offices by panel mounted oscillators requiring storage batteries for operation; but this arrangement will not operate from the power available in local offices and the development of a small portable magneto driven by a 115-volt 60-cycle alternating current motor which would be easily attachable to commercial power lines was therefore undertaken.

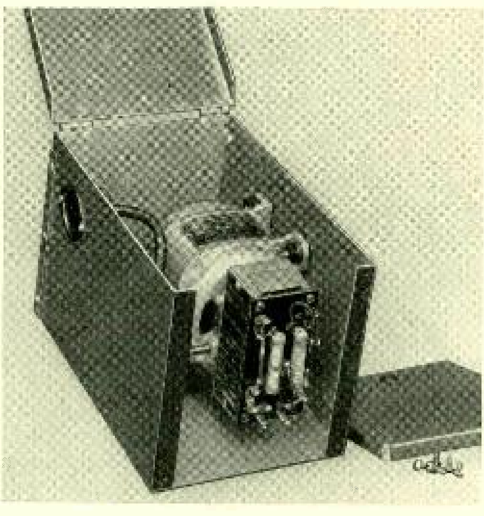

Fig. 1—The thousand-cycle generator is a permanent-magnet inductor-alternator

The machine in practical form is shown in Figures 1 and 2. It consists essentially of a permanent-magnet inductor alternator, which is attached to the end shield of a self-starting induction motor of the two-pole split-phase type. The alternator is housed in a rectangular structure which contains permanently magnetized bars of cobalt steel mounted in a composition cage. Projecting into the center space of this structure are pole pieces on which are mounted the coils in which the thousand-cycle output of the alternator is induced. Between these coils and mounted on the shaft extension of the motor is a laminated iron rotor on the periphery of which are cut seventeen scallops or teeth. When two opposite teeth are in line with the poles the air gap is a minimum and the flux through the coils is a maximum. As the rotor moves, the space between teeth comes in line with the pole pieces, thereby increasing the air gaps and reducing the flux. It is this periodic change in flux through the coils which develops the alternating current. The frequency is determined by the speed of the motor and the number of teeth on the rotor. The leads from the coils, which are connected in series, are brought out through an insulating terminal block attached to the magnet structure. Resistor pads are provided so that either the full load, which is approximately one-half watt, can be used, or the output can be limited to the one milliwatt required in transmission testing.

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The frequency of one thousand cycles per second is obtained when the motor runs at about fifty-nine revolutions per second. Unwanted harmonics are relatively small in amount. Variations in the output with speed changes in the driving motor due to fluctuations of line voltage are so small that no rheostat or other adjusting device is required. The size and power of the motor are dictated by the torque required to overcome the magnetic pull between the teeth of the rotor and the pole pieces of the permanent magnet rather than by the output of the alternator. The input, however, is only 35 watts.

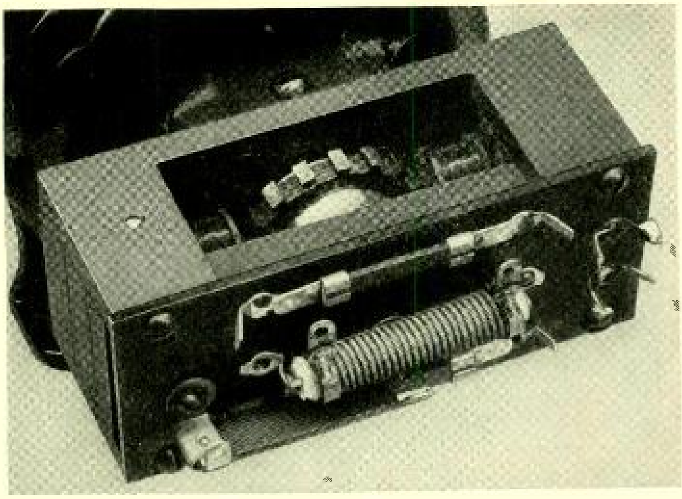

Fig. 2—Between the inductor coils, which are mounted in a rectangular structure on the end of the inductor-alternator, is a laminated iron rotor with seventeen teeth

The machine itself weighs less than ten pounds. It is furnished, if desired, in a carrying case about six inches square and nine inches long with a removable front and equipped with a handle on a hinged top. A motor lead receptacle base is provided into which a portable cord extension, furnished with the carrying case, can be plugged. Soft rubber grommets placed in holes on the motor feet provided cushions to damp out vibration.

It is expected that the use of this simple thousand-cycle generator may be extended to many other applications besides that of testing the transmission of telephone lines.

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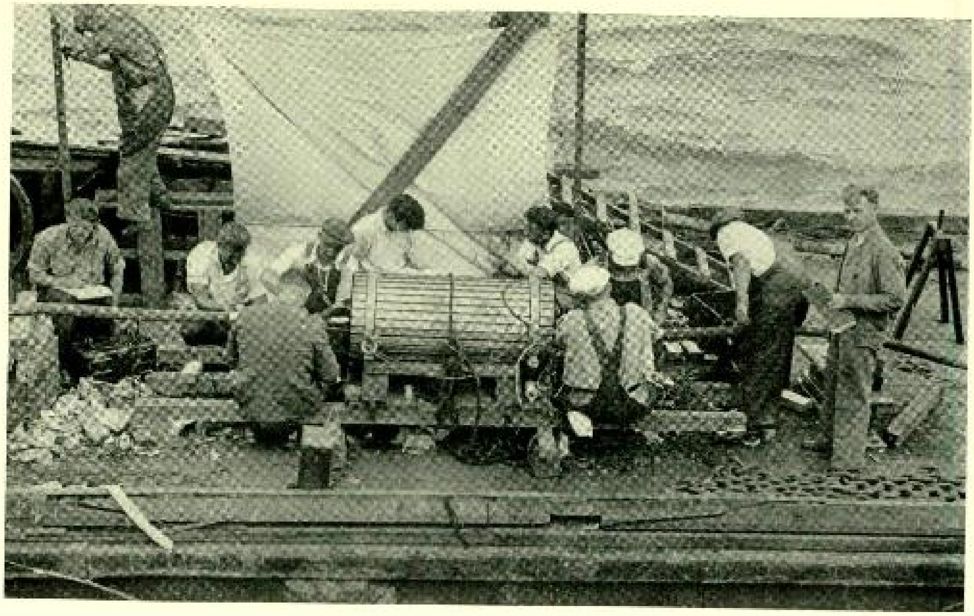

A Submarine Loading Case

By J. R. BARDSLEY
Telephone Apparatus Development

LEAD-covered telephone cables are usually carried along pole lines or in underground ducts, and their loading-coil cases are either mounted on poles or installed in manholes. Occasionally, however, loaded cables must cross wide rivers or bays, and as a result there is a need for submarine loading-coil cases. A suitable case was designed about 1915, and in the years immediately following a number of them were installed in various parts of the country—two of them in the Hudson River on a cable running from Tarrytown to Nyack, which connects central offices in the New York metropolitan area to those in Rockland County. As shown in the map, Figure 1, the river widens at this point to about three miles, and is known as the Tappan Zee. Some time ago, one of the ferryboats which run from Tarrytown to Nyack apparently got off her course and damaged the cable so that extensive repairs became necessary.

Since these loading-coil cases were designed, loading coils have been improved and their size decreased. In addition, the construction of land cases has been considerably modified as already discussed in the RECORD*, so that it seemed desirable to take advantage of the necessity of raising the cable to replace the loading units with others of more recent design and with better transmission characteristics, and also to provide cases of more recent design.

The Tarrytown-Nyack cable has thirty-seven loaded quads of sixteen-gauge paper-insulated conductors and twelve pairs of twenty-two gauge, which are not loaded. Each quad has a phantom and two side-circuit load-

*RECORD, *July*, 1931, *p*. 517.

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ing coils, which form a loading unit. In the original loading-coil cases, which have now been replaced, the loading units were mounted on four spindles and placed within a steel shell. End plates, riveted to the shell, had holes at the centers through which stub cables carrying the connections to the coils were passed. A large lead sleeve was slipped over the steel container, and lead end-plates were lead-burned both to the lead sleeve and to the lead sheath of the stub cable to form an impervious inner barrier against the entrance of water. As further protection against water, a second lead sleeve was slipped over the first, with a separating layer of canvas, and similar end-plates were lead-burned to the sleeve and cable sheath. This assembly was then covered with wood strips and enclosed by split sections of a heavy iron casting.

The completed case, including terminating sections covering the splices between stub cables and main cables, is shown in Figure 2. Besides providing space for the splice, the terminating sections provided means for securing the steel armoring wires. This arrangement is shown in the cross-section of Figure 4. The armor wires are bent over a cone-shaped casting which in turn is drawn into the tapered end of the terminating casting. Before shipment by the manufacturer, the entire loading-coil compartment was filled with compound so that all circuit elements were immersed in compound and sealed. The completed case was sixteen feet long and weighed approximately five tons.

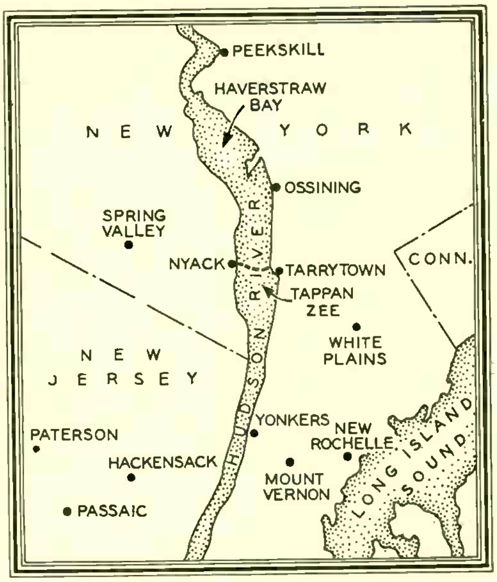

Fig. 1—Rockland County is the southernmost county of New York State, bordering the western shore of the Hudson River

The loading-coil case designed to replace the older type is shown in Figures 5 and 6. The loading coils, which have permalloy dust for the cores instead of the iron dust of the earlier coils, are assembled in small cans, each housing only the phantom and two side circuit coils forming a loading unit for one quad. Nine of these loading units are mounted on the face of each of four steel plates—thus providing loading for thirty-six

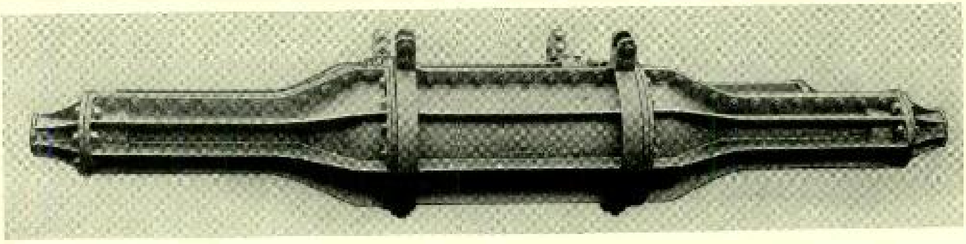

Fig. 2—The early loading coil case was sixteen feet long and weighed nearly five tons

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quads. The thirty-seventh quad as well as the twelve pairs are carried through the case unloaded. The supporting plates for the loading units are mounted on three steel rods rigidly fastened to two heavy steel head-plates. A steel sleeve slips over the plate assembly, and is welded to the two head-plates to form a water-tight housing. Nipples welded in the center of the head-plates serve as exits for the stub cables, to the sheaths of which they are soldered.

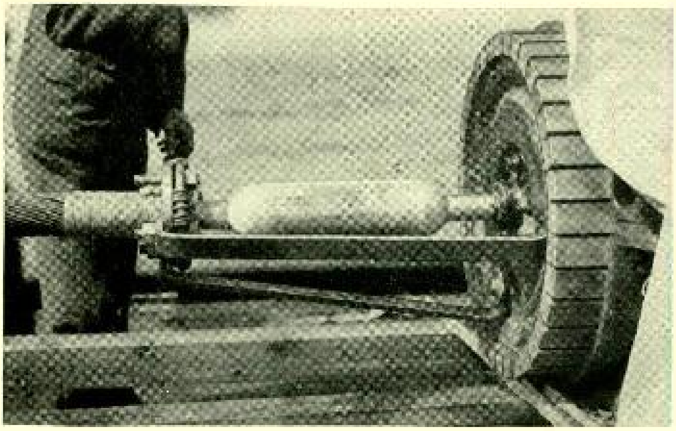

Fig. 3—Temporary spacing bars secure the clamping rings in the proper position until after the splice has been completed

The steel case itself is covered with layers of cloth and with the asphalt compound usual for underground cases, and over all is placed a covering of wood strips to protect the coating during transit and installation. This wood lagging is held in place by two steel bands, which also serve for lifting the case and lowering it in the river.

Terminating sections for housing the splices are also provided as for the earlier cases, and consist of steel cylinders with flanges welded on one end which bolt to the head plates of the main case. At the outer end of the terminating section a plate is provided which is welded to the cylinder. Two steel rings, just inside the end plate, clamp the armor wires and secure them rigidly to the loading case. Set screws are provided by which these clamping rings may be adjusted

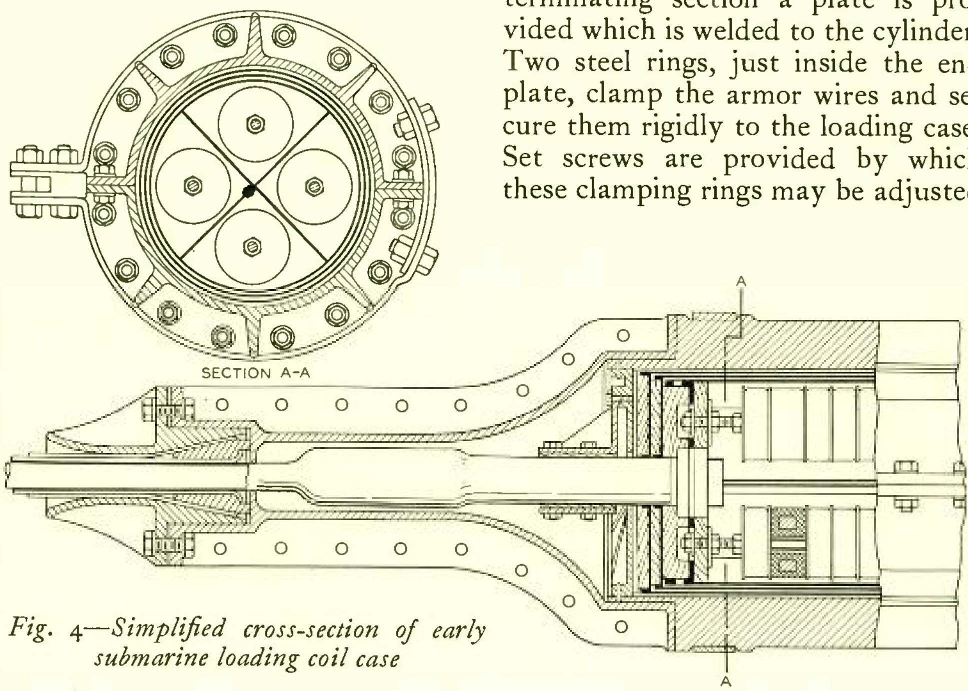

Fig. 4—Simplified cross-section of early submarine loading coil case

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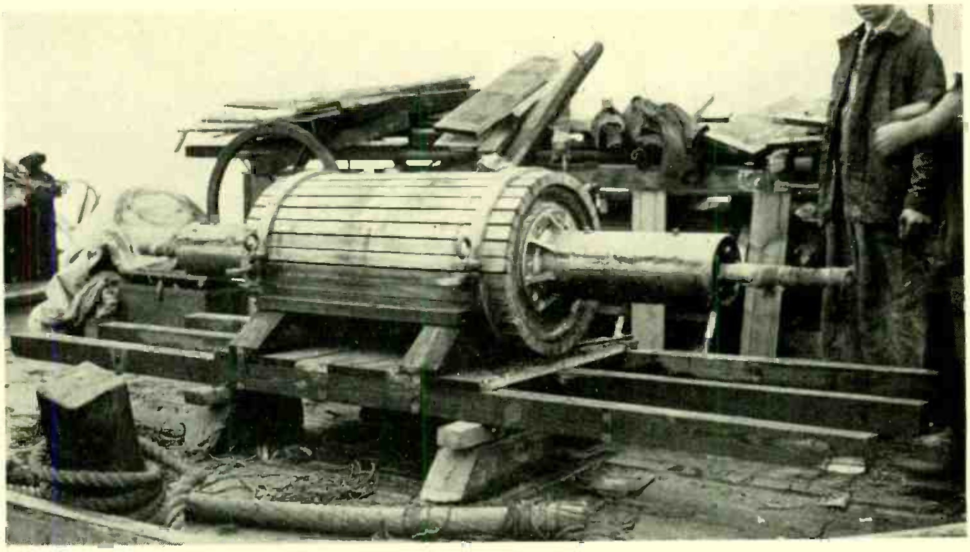

Fig. 5—The new submarine loading coil case ready for installation

in position with respect to the end of the splicing compartment so as to allow the tension, which is carried by the armoring, to be transmitted to the steel housing rather than to the lead cable and splice. This arrangement is shown in Figures 3 and 6. As the final step in assembly, the terminating section is filled with sealing compound, which flows around the armor clamping assembly and both completely seals the chamber and protects the iron wire from corrosion. The terminating section and other exposed details are heavily galvanized to prevent corrosion, but in addition they are covered with hot compound, before being lowered into the water, as a further protection.

The new cases are only about half as long as the earlier type, and in both weight and cost there is nearly an eighty per cent reduction. The two cases for the Nyack-Tarrytown project were installed in June of last year and their light weight and simplicity in design proved to be a great advantage in the work of installation.

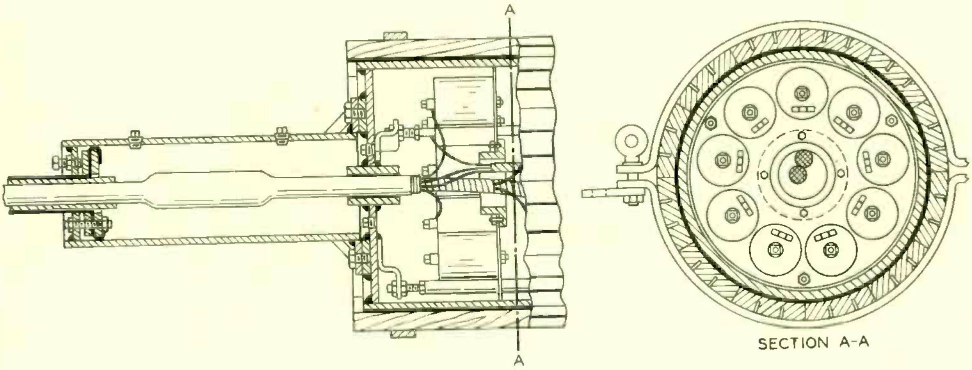

Fig. 6—Simplified cross-section of the new case

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Contributors to This Issue

R. S. Tucker received the B.S. degree in 1922 from the Harvard Engineering School, and after a year abroad joined the Development and Research Department of the American Telephone and Telegraph Company. His work there dealt with inductive coördination and other noise problems, particularly those relating to the evaluation of the effects of noise and the measurement of circuit noise and room noise. Recently his work has been concerned with the balance and shielding and the noise-producing characteristics of telephone equipment.

J. R. Bardsley joined the Apparatus Drafting Department in 1919 where he later served as a group supervisor. In 1924 he graduated from the Technical Assistants course, and the following year transferred to the Apparatus Specification Department, where he engaged chiefly in the preparation of loading coil case specifications. After two years with this department he became associated with the group developing retardation and loading coils, and in 1928 transferred to the group developing loading coil cases—at this time actively engaged in the development of welded steel cases. More recently he has been associated with the designs and development of welded steel cases for submarine applications.

After graduating from the United States Naval Academy in 1918, R. D. de Kay served as assistant engineer officer and later as chief engineer officer in the Navy until 1922 when he joined the Bell Laboratories' technical staff. For the past twelve years he has been connected with the development of machines for supplying the signalling current used to ring telephone bells and the associated equipment, also battery charging equipment and rectifier design. As parallel developments he has been concerned with machines for signalling over toll lines of which the one described in the present issue of the Record is an example.

F. H. Best joined the Engineering Department of the American Telephone and Telegraph Company in 1911 immediately after graduating in Electrical Engineering from Cornell University. He was trans-

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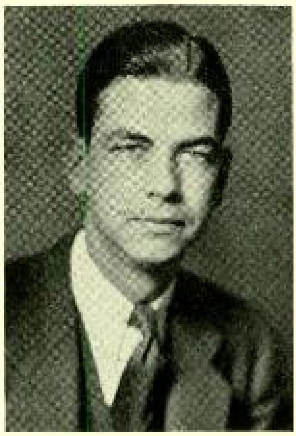
ferred to the Department of Development and Research upon its formation in 1919 and became a member of our Technical Staff when the organizations were consolidated. Mr. Best has been engaged principally in the development of testing methods and arrangements used in transmission maintenance work.



J. R. Haynes

After graduating from Stevens Institute of Technology with the degree of M.E. in 1923, H. G. Arlt joined the Laboratories. He spent two years writing specifications for apparatus, after which he transferred to the physical laboratory where he conducted life tests, mechanical analysis and precision measurements on apparatus. He has specialized in the engineering of finishes and now has charge of finishes as well as chemical requirements for a variety of organic materials.

W. A. MacNair joined the Laboratories Staff in 1929. For several years he was in charge of a group investigating acoustical problems in sound recording and reproduction. Recently he has been concerned with the development of sound program systems. Prior to coming to the Laboratories, he was instructor in Mathematics and Physics at the Michigan College of Mines, Assistant and Associate Physicist at the National Bureau of Standards and with the Research Department of the Victor Talking Machine Company. He received the degree of B.S. from Colgate in 1920 and from Johns Hopkins the M.S. in 1924 and Ph.D. in Physics in 1925. He held a National Research Council Fellowship for two years which were spent on studies in atomic structure at Johns Hopkins University and the Bureau of Standards.

J. R. Haynes has been engaged in fundamental research relating to microphonic action since he joined the Laboratories in 1930. In these studies the cathode ray oscilloscope has proven an important aid for the analysis of complex cyclic currents. The determination of the direction of motion of the cathode ray spot has also been found necessary in these investigations and Mr. Haynes devised for this purpose the simple means described in this issue of the Record. He received the degree of B.S. in Physics at the University of Kentucky in 1930.

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S. A. Schelkunoff

L. H. Germer

O. B. Cook

Sergei A. Schelkunoff came to the Laboratories in 1929. Since that time he has been concerned with applications of the classical electromagnetic theory to various problems in the communication art. Interference and cross-talk studies represent one phase of his work. Prior to 1929 he was an instructor and then an assistant professor at the State College of Washington. His B.A. and M.A. were received at the State College of Washington in 1923 and Ph.D. at Columbia in 1928.

L. H. Germer joined the Engineering Department of the Western Electric Company in 1917. From August of that year until the spring of 1919 he served with the United States Army in this country and in France. Since 1919 he has been engaged in research work in thermionics and electron physics, the last several years having been spent in pioneer work in applying the methods of electron diffraction to the study of surface layers. Dr. Germer was graduated from Cornell in 1917 and holds the degrees of A.M. and Ph.D. from Columbia University.

O. B. Cook received the B.A. degree from Columbia University in 1925 and remained at the Engineering School until 1927 to complete courses leading to an M.E. degree. He then joined the Outside Plant Development Department of the Laboratories where he has been engaged in the development and testing of metal products used in the aerial and underground telephone plant.

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