ELL LABORATORIES RECORD

Photograph by John Mills, Jr.

A visitor checks her hearing-test card at the Telephone Exhibit, New York World's Fair

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Sorption of Water by Organic Insulating Materials

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WHEN insulating materials like rubber and phenol plastics are immersed in water or exposed to humid air large changes may occur in their resistivity, dielectric constant, and power factor. These changes are caused by water which condenses on the surface, adsorbs in the interstices of the material, or is absorbed by soluble impurities. Laboratory studies of these effects help to predict the behavior of such materials in service.

Initially, the rate of sorption* is comparatively rapid whether the substance is immersed in water or water vapor; in most cases the amount of water taken up increases as the square root of the time of exposure. Characteristic sorption curves are shown in Figure 1 for soft vulcanized rubber and phenol plastic in distilled water. The phenol plastic reaches a state of equilibrium where sorption ceases, but the rubber, which is elastic, may continue to take up water until it disintegrates and is dispersed throughout the liquid. This is illustrated by the logarithmic graphs of Figure 2. At vapor pressures less than saturation, equilibrium is reached by both phenol plastic and soft vulcanized rubber but the rate of sorption and final water content are less.

Several factors will cause sorption curves to deviate from straight lines before the point of equilibrium is reached. Among these are changes during the test in temperature or in relative vapor pressure. Leaching of water-soluble materials decreases the

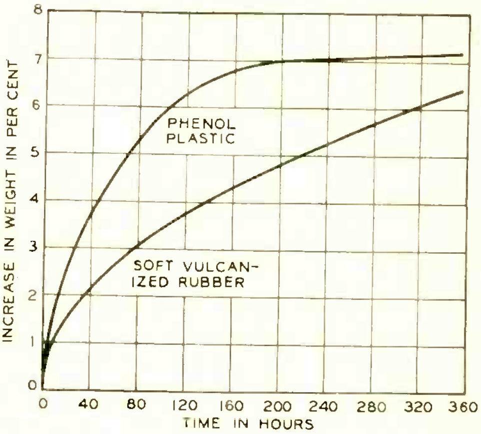

Fig. 1—Sorption of water by thin sheets of insulating materials that are immersed in distilled water

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*Sorption is used in conformity with current phraseology to signify the combined effect of adsorption and absorption.

slopes of the curves; and the formation of additional water-soluble materials by oxidation shifts the curves upward. The latter is of particular significance because it is a measure of the deterioration of materials when they come in contact with water.

The straight-line logarithmic plot of Figure 2 can be used to predict the water content of materials exposed to water for a given length of time, if fixed conditions of temperature and relative vapor pressure are maintained. A rubber piece-part which, for example, sorbs 0.1 per cent water in one day will, in accordance with this straight-line relation, contain about six per cent water after ten years.

In the early stages of sorption the percentage increase in weight of sheet materials when exposed to water varies nearly inversely with the thickness of the sheet, provided its area is large in comparison with its thickness. Since the rate of sorption is given by the slope of a curve showing the increase in weight plotted against the square root of time, the slope for a sample of unit thickness will serve as a sorption coefficient to compare different materials. At room temperature the sorption coefficient for a phenol plastic is about 0.026; for soft rubber, 0.015 and for ebonite, 0.0024. The coefficient describes the rate at which a material takes up water, and is not a measure of the final water content of the material.

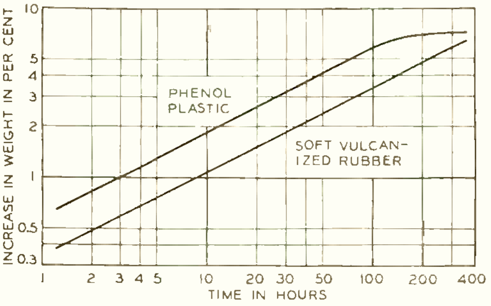

Fig. 2—A logarithmic plot of the sorption of water shows the attainment of equilibrium by the rigid material

It has been demonstrated experimentally for rubber that the logarithm of the sorption coefficient is inversely proportional to the absolute temperature. By using this straight-line relation it is possible to calculate from short-time test data obtained at one temperature the water content of such materials after an extended period of immersion at some different temperature.

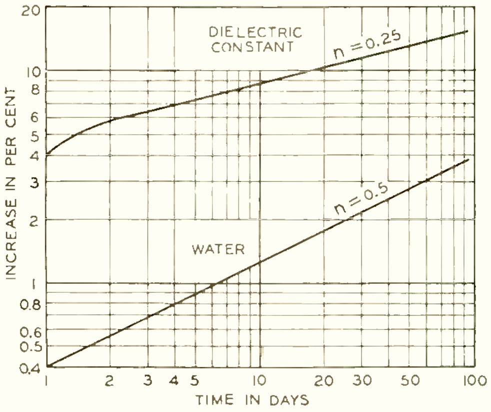

Fig. 3—In distilled water both the water content and dielectric constant of a rubber sheet increase

An important practical application of sorption data is predicting the changes in dielectric constant which accompany the sorption of water. When sheets of soft vulcanized rubber are immersed in distilled water at constant temperature, the increase in weight is proportional to the square root of time, but the accompanying increase in dielectric constant of the material is proportional to the fourth root of time.

These relations are illustrated in Figure 3. There is, however, an initial

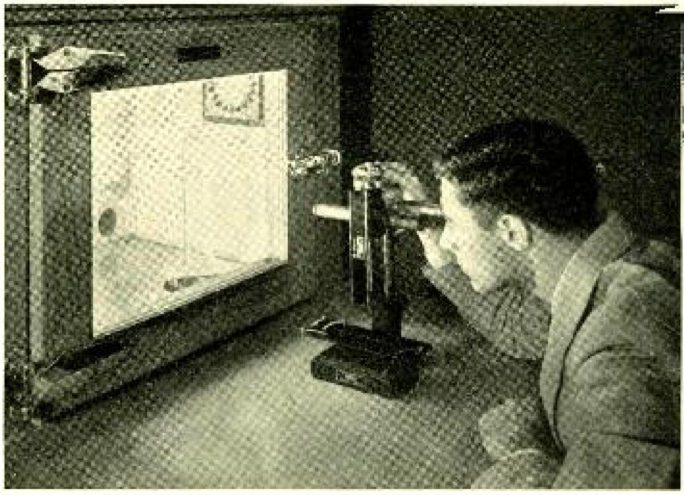

Fig. 5—F. J. Biondi measuring the absorption characteristics of a plastic by suspending it from a spiral quartz spring and observing the rate at which the spring elongates

period when the dielectric constant increases rather rapidly and during which the power factor reaches a peak. The rapid increase in dielectric constant is believed to result from water adsorbed on the inner structure of the material and the slow increase thereafter mainly to water absorbed by water-soluble substances that are in the material.

From the relationships of the preceding paragraph, it is evident that the increase in dielectric constant is proportional to the square root of the water content. A curve illustrating this is shown in Figure 4. Although different materials differ in the amounts of water they sorb and in the effect of this water on the dielectric constant, when the relation between dielectric constant and water content is known, a measurement of dielectric constant alone suffices to describe the water-sorbing characteristics of many materials.

Before equilibrium is reached, water sorbed by a homogeneous material such as soft vulcanized rubber does not distribute itself evenly throughout the material but concentrates largely in the outer layers and decreases exponentially toward the center. In many practical cases this exponential distribution proves advantageous; for example, sorption by the insulation on rubber-covered wire. In this case the rubber next to the conductor may remain relatively dry although the amount of water sorbed by the insulator as a whole is appreciable. Wire insulation which has sorbed water in this manner should be considered as graded rather than homogeneous. Curves may be plotted to show the distribution of water in insulation of various kinds and shapes. These curves, with others of the type shown in Figure 4, may be used to calculate the dielectric properties of this type of continuously graded insulation. Information of this character is of practical interest in the telephone plant because of the increasing use of buried wire and the installation of circuits in locations exposed to high humidity.

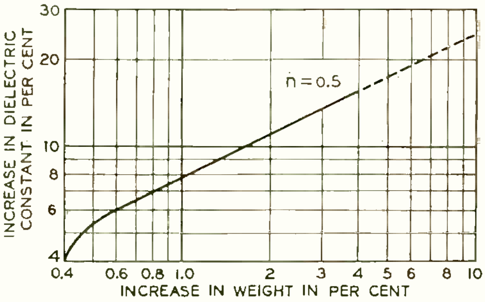

Fig. 4—Dependence of the dielectric constant of rubber sheets on the water content

Terminating Markers: Busy Testing and Line-Choice Selection

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BY OPERATIONS described in a previous article,* the terminating marker decodes the number transmitted to it by the terminating sender, and operates a block relay in one of the number groups. Forty block relays with their cross-connection banks, which permit the assignment of any line number to any line switch in the office, are mounted in a bay as shown in Figure 1. Since each block relay represents twenty line numbers, each bay represents 800 line numbers, and a sufficient number of bays are installed to take care of all the lines in the office. The operation of a block relay closes sixty contacts—three for each of the twenty subscriber numbers associated with it. Over one of these three leads, the marker will test the called line to determine whether or not it is busy. If the line is in use, the marker will cause a busy signal to be returned to the subscriber. If the line is idle, however, relays will be operated over the other two leads to direct the marker to the particular crossbar switch to which the line is connected, so that a path may be found between it and the incoming trunk. The lead used for the busy test will then be used to operate the hold magnet of the line called.

Each of the sixty moving contact springs of a block relay is strapped to the corresponding springs of all other block relays of the number group, and is then carried through the number-group connector to the marker. Here they are distributed and connected

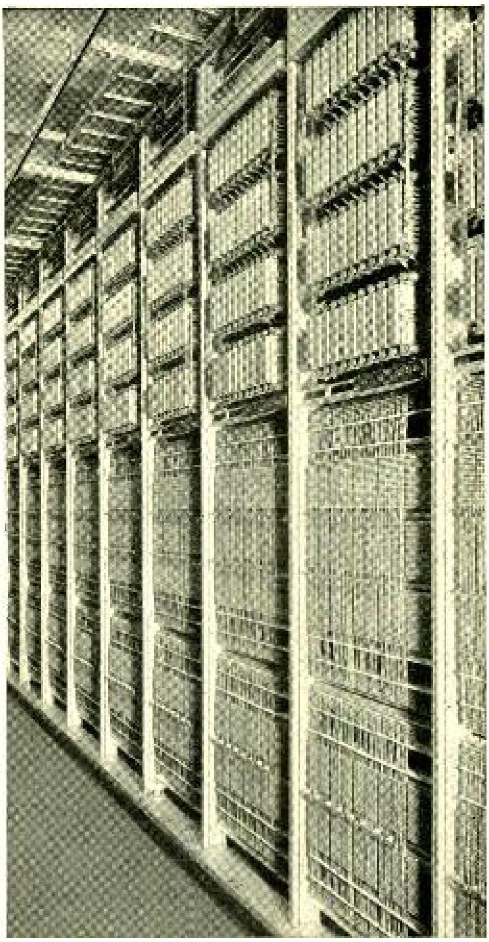

Fig. 1—Block relay bays, each with forty block relays above, and line cross-connecting terminals for their NC *and* NF *leads below*

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*Record, *July*, 1939, *p.* 356.

to three moving spring contacts of twenty L relays as shown in Figure 2. The three leads for each line are marked NC, NF, and NS, followed in each case by a number from 0 to 19 to designate the twenty lines of the block relay. The L relays are also numbered from 0 to 19.

The leads from the front contacts of the block relays run to terminal strips—all the NC leads to one set, the NF to another, and the NS to another. The terminal strips for the NC and NF leads are mounted on the frames beneath the block relays as illustrated in Figure 1. These terminal strips are five terminals high and ten wide, and ten of them are mounted in a row across the frames. One such row for the NF leads is shown immediately beneath the block relays. Below it are three banks of multiple-terminal strips, each twenty terminals high. These multiple-terminal banks—somewhat like the banks of a panel selector in appearance—are built up of insulated horizontal metal strips with soldering terminals projecting in line with each terminal of the upper set of terminal strips. Below these is another row of terminal strips for NF terminals like the one above. Two strips—one above and one below the multiple-terminal banks—take care of the NF terminals from the five block relays controlled by one hundred-block relay. Eight pairs of fifty-terminal strips across the bay thus provide for all the block relays on the bay. The ninth and tenth pairs of terminal strips are used for other purposes. Below these cross-connection terminals for the NF leads is a similar set for the NC leads, the main difference being that there are only two banks of multiple terminals for the NC leads instead of the three provided for the NF terminals. Figure 3 shows the arrangement for one twenty-block relay only.

The twenty leads from each of the three multiple-terminal banks associated with the NF terminals are marked TF, HF, and RF, respectively, and numbered 0 to 19 inclusive. They are all carried through the number-group connector to the marker. Cross-connecting jumpers are run from each NF terminal to one of the terminals in one of the multiple-terminal banks. For individual and party lines, the jumper runs to either the TF or RF banks, depending on whether the called station is rung over the "tip" or "ring" conductor, while trunks to a PBX are cross-connected to the HF bank, except the last trunk in a group to any one PBX, which is cross-connected to the RF bank.

The terminals for the NS leads are on the line distributing frame. The terminals to which they are cross-connected on this latter frame are connected to one side of the hold magnets of the primary switches on the line-link frames, and there is thus one terminal for each equipped line in the office. Cross-connecting jumpers are run to associate each NS lead with the hold magnet with which the corresponding line is associated at the line switch. If the line is busy, its NS lead will be found grounded through the sleeve lead of the line. Thus when a block relay is operated, the twenty NS leads brought to the marker will be either grounded or not grounded depending on whether the lines are busy or idle.

As may be seen from Figure 2, the NS leads are extended through back contacts on the L relays—which are unoperated at this point—to the windings of S relays, and the S relays connected to busy lines will be operated by the ground on their NS leads, while those of idle lines will be left unoperated. The number dialed is indicated by a gound placed on one of twenty leads coming from the unit-digits group of recording relays. These twenty leads follow through a chain of contacts as in the thousands, hundreds, and tens groups of recording relays, only the chain for the unit group relays includes two additional relays, one marked "tens even" and the other "tens odd." This is necessary because a twenty-block includes two sets of ten digits: in the 0 twenty-group for example, are digits 0-19; the first ten, 0-9, are called the even group, and the second, 10-19, the odd group. Similarly 20-29 is an even group and 30-39 an odd group, the term even and odd referring to the tens digit, and this indication is given by contacts on the "tens even" or "tens odd" relays. These "even" and "odd" relays, in turn, are operated by a chain through relays of the tens group, the "tens even" being operated if the tens digit is even, and the "tens odd" if it is odd.

These tweny leads from the units register relays run to the moving spring contacts of the twenty S relays, and one of them will be grounded. If the relay to which this grounded lead is connected is operated, indicating a busy line, the ground will be carried through a front contact on the S relay, and a back contact on the associated HT relay, to a line-busy relay, which causes relays in the incoming trunk to operate and return a busy tone to the calling subscriber. If the line is not busy, the S relay will not operate,

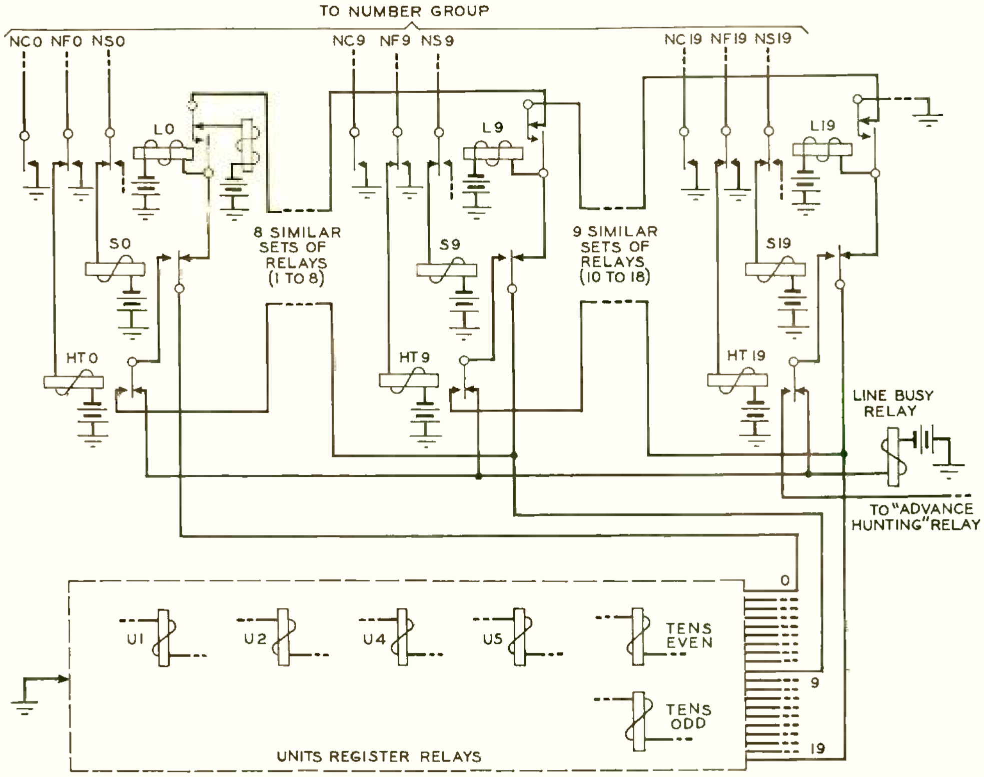

Fig. 2—Simplified schematic of the busy-test circuit of the terminating marker

and the ground will be carried through a back contact of the S relay to operate the associated L relay.

After the number has been registered in the marker a relay is operated that grounds the twenty HF leads brought to it through the number-group connector. This relay remains operated until an L relay operates. If any of the lines of the twenty block are any but the last of a group of PBX trunks, the corresponding NF terminals will be cross-connected to the HF bank, and the ground on these latter leads will thus be carried through the block relay, the number-group connector, and back contacts on the corresponding L relays in the marker, and will operate the corresponding HT relays. All HT relays corresponding to PBX trunks, except the last, will thus be operated. This switches the leads connected to the front contacts of the S relays from the "line-busy" relay to the moving contact of the next S relay, so that instead of returning a busy signal if the first trunk is busy, the ground from the register relays will operate the L relay of the first idle trunk.

Suppose, to take a simple example, that the first trunk of the PBX had 10 as its last two digits and that there were ten trunks in the group—running from 10 to 19. Since the number dialed has 10 as its last two digits, a ground would appear on the 10 lead from the units register. This ground would be carried to the moving contact of the S10 relay, and if this trunk were busy, would be extended through front contacts of S10 and HT10 to the moving contact of S11. If this trunk also is busy the ground will be simi-

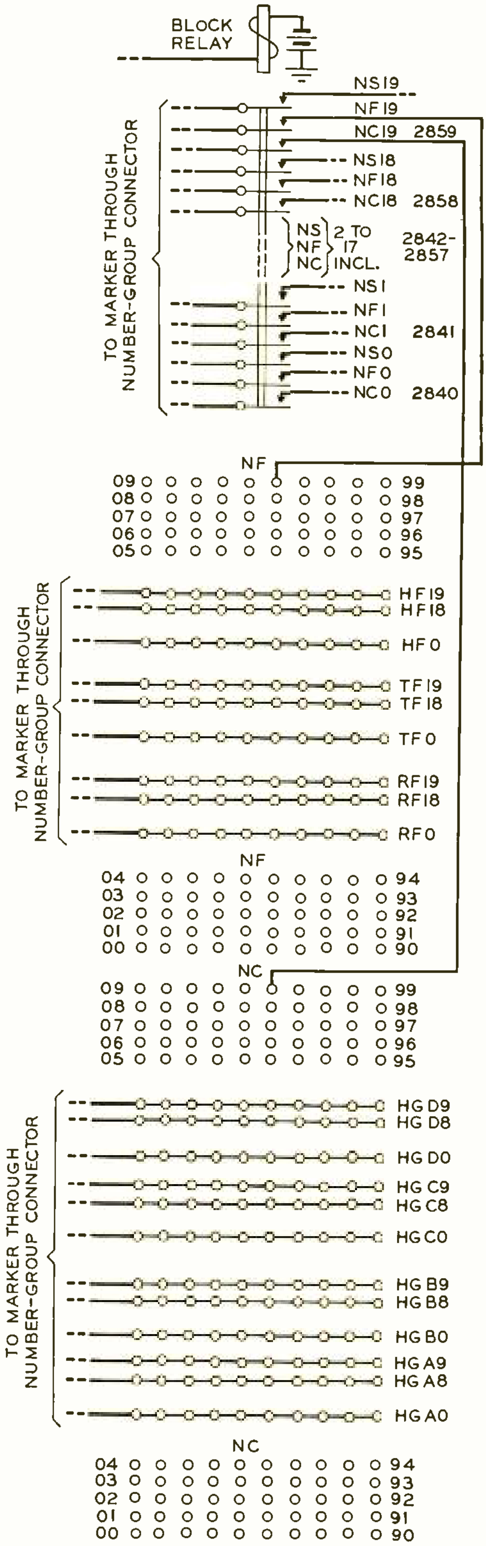

Fig. 3—Simplified schematic of cross-connecting terminals for five block relays, with one of the block relays shown above

larly extended to S12, and so on until an idle trunk is reached, when the ground would be extended through the back contact of that S relay to operate the corresponding L relay. It should be noted, however, that this testing does not pass from one trunk to the next in sequence, but that since all the S and HT relays that are to operate are operated together by the closure of the block relay—the L relay of the first idle line is also operated immediately after the block relay has operated.

If the PBX had been a large one, there would very likely be more than twenty trunks, so that they could not all be reached through a single block relay even if they started with the first line of that block. This situation is taken care of by running the lead from the front contact of the last HT relay to an "advance hunting" relay, which is associated with a group of "hunting progress" relays through which pass the leads from the tens group register relays on their way to the windings of the block relays. If all the trunks in the first block were busy, the ground from the units group of register relays would be carried through the front contact of HT19 to operate the advance hunting relay. This relay would release the block relay already operated, and bring in the block relay with the next group of trunks to the PBX called. At the same time the ground would be removed from the 10 lead from the units register relays and placed on the 0 lead. The leads from the second block relay would now be connected to the marker, and this group would be busy tested in exactly the same manner. By this same method it is possible to test large trunk groups, bringing in one block relay after another as all the trunks of one block are found busy. Should all the trunks in the group be busy, the ground would be extended to the line-busy relay through the back contact of the last HT relay, which will not be operated since the last trunk of a group is connected to the RF rather than to the HF lead.

The operation of an L relay, when a line or trunk is found idle, grounds both the NF and NC leads, and connects the NS lead to relays in the marker that will be used later for "closing through" the talking path. The grounds on the NC and NF leads are carried back through the number-group connector and the block relay to the NC and NF cross-connecting terminals. As already pointed out, the NF leads are cross-connected to one of the terminals of one of these multiple banks—to the RF or TF banks if it is an individual or a party line, and to the HF if it is a PBX trunk. Each multiple bank, however, has twenty rows of terminals, one for each of twenty possible line-link frames, and the cross-connection made will depend on which primary line-link frame the line is connected to.

For convenience in controlling the completion of calls, the line-link frames are divided into groups of four, called "line-choices," and the control leads from only one line-choice at a time are brought to the marker through a line-choice connector. This arrangement parallels that of the number group and number-group connector. There may be as many as twenty line-choices in an office, and the twenty horizontal strips in each of the multiple banks associated with the NF terminals are assigned to the twenty possible line-choices. The cross-connection from any NF lead is thus run to the particular multiple strip that corresponds to the line-choice in which that line is located.

Leads from these multiple banks run to the marker through the number-group connector, and when an L relay operates, the group placed on the NF lead will pass over the cross-connection to the multiple strip—in either the TF, HF, or RF bank—for the line choice on which that line or PBX trunk appears, and will operate a relay in the marker that will bring in the proper line-choice connector.

It is necessary further for the marker to know which particular line-link frame of the line-choice the line is connected to, and the particular row of switches in that frame, so that it can proceed to find an idle path between the incoming trunk and the line. This information is obtained by the cross-connection of the NC lead. As pointed out above there are only two multiple banks associated with the NC leads, but each is divided horizontally into two groups, so that there is the equivalent of four multiple banks, each ten terminals high. Each of these banks represents one of the four line frames of a line-choice, and the ten strips in each group represent the ten rows of switches on each frame. These banks are marked A, B, C, D, rather than by actual frame numbers since they represent different frames depending on the line-choice selected. The jumper from the NC terminal is thus run to the particular level in the A, B, C, or D bank that corresponds to the location of the line on the line-link frame.

The leads from these multiple banks also run back to the marker through the number-group connector. Ground appearing on one of them, from a front contact on the L relay, operates relays that allow the marker to test for idle paths from the incoming trunk to that particular row of switches, and also to operate the proper select and hold magnets to connect the line through.

THE MORRIS LIEBMANN MEMORIAL PRIZE

for 1939 *has been awarded to H. T. Friis by the Institute of Radio Engineers in recognition of "his investigations in radio transmission including the development of methods of measuring signals and noise and the creation of a receiving system for mitigating selective fading and noise interference." The award will be presented to Mr. Friis at the Fourteenth Annual Convention of the Institute that will be held in New York in September. Previous Laboratories recipients of this medal are R. A. Heising, J. R. Carson, Ralph Bown, Edmond Bruce, F. B. Llewellyn, W. H. Doherty and G. C. Southworth.*

Time Characteristics of the U-Type Relay

By P. W. SWENSON
Switching Development Department

ON A local call between two subscribers in a crossbar office, nearly a thousand relays are involved. Their sequence of operation and release is determined chiefly by the circuit arrangement, the action of each relay or group of relays depending on the operation or release of some other relay or circuit element before it. At many stages, however, it is essential that the operating or releasing times of certain relays be delayed or hastened to secure the required performance of the circuit. It is important, therefore, that the operating and releasing times of the relays be known and subject to control so that correct operation can be assured under all conditions. With the development of the U and Y-type relays,* therefore, studies were undertaken to determine the various factors affecting operating and releasing times and their range of values, so that curves and tables could be prepared which would enable the performance of these relays to be accurately predicted.

It is possible, of course, to measure the overall releasing or operating times of relays, and to use these results in designing the circuits, but this method has its disadvantages. The releasing time, for example, depends in general both on the number and type of contact springs, and on the height of the stop disk, which is used to provide a small airgap between the armature and core when the relay is operated. To secure releasing times by this purely experimental method, therefore, measurements would have to be made on many combinations of contact springs and of stop-disk heights. In addition, measurements would have to be made on a large number of relays for each combination of springs and disks to establish the minimum and maximum value for each. The more satisfactory procedure is to analyze the time into its various components, and to determine experimentally the range of delay caused by each. When this is done, it is always possible to combine the factors in any desired manner, and to determine the maximum and minimum limits under all conditions.

The releasing time of a relay may be divided into two components known as the electrical releasing time and the mechanical releasing time. The former extends from the time the winding circuit is opened to the time the armature begins to move. The latter is the time required for the armature to move from the operated position to that in which the contacts just open.

The electrical releasing time is really the time required for the flux to decrease from its value when the winding circuit is opened to its value when the pressure of the springs is just sufficient to overcome the pull on the armature. For a relay with no short-circuited winding, this time would be zero if it were not for the eddy currents induced in the mag-

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*Record, *May*, 1938, *p.* 300 *and p.* 310.

netic material. These currents exert a magnetomotive force tending to maintain the flux, and thus the electrical releasing time may be redefined as the time required for the magnetomotive force of the eddy currents to reduce from its maximum value to a value just small enough to permit the relay to release.

For a given magnetic structure and material, the flux is a definite function of the magnetomotive force maintaining it, and for the U-type relay the relationship is as shown in Figure 1, where the magnetomotive force is given in ampere turns. The form of the relationship between flux and ampere turns depends on whether the exciting current is increasing or decreasing. In the former case, the graph is called a magnetizing curve, and in the latter—which is the one shown—a demagnetizing curve. The major variable in the magnetic circuit of the U relays under operated conditions is the height of the stop disk. The curves of Figure 1 give the relationship for the two extreme limits of stop-disk heights; the lower one, for an 18-mil disk and 250 ampere turns initial magnetization, represents the conditions for establishing minimum release time; while the upper one, for a 5-mil disk and 500 ampere turns initial magnetization, represents the conditions for establishing maximum release time. For all intermediate values of disk height and magnetization, the curves would lie somewhere between these two.

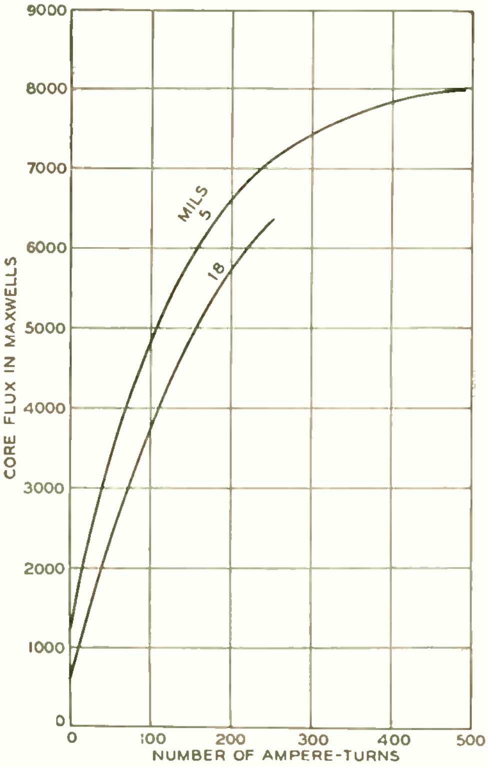

Fig. 1—Demagnetization curves of the U-type relay for 5-mil stop disks, above, and for 18-mil stop disks, below

The time required for the flux to decay over any interval along a demagnetization curve varies as the steepness, or slope, of the curve and as the logarithm of the ratio of the lower to the higher limit of the ampere turns over the interval. If the slope of the curve were the same at all points, that is if the curve were a diagonal straight line, the time would be the same over the interval from 500 to 250 ampere turns as it was from 100 to 50, since the ratio is the same for both intervals. Actually the slope decreases for the higher values of ampere turns, and approaches zero at 500 ampere turns.

As a result of this flattening, the amount of releasing time contributed by a reduction from 500 to 250 ampere turns is very small, so that the overall time depends primarily on the value of ampere turns at which the relay just releases, called releasing ampere turns, which is the lower limit of the interval. The slopes of the two curves, moreover, are very nearly the same, so that the decay time along

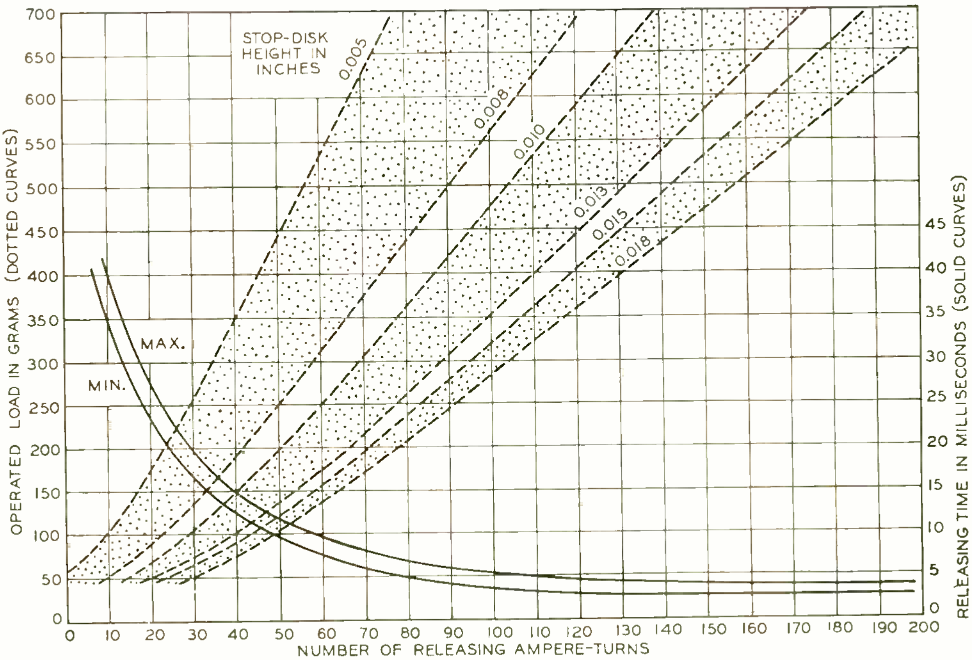

Fig. 2—Curves for the U-type relay showing relationship between releasing ampere turns and electrical releasing time with no short-circuited winding, solid curves, and against operated load for various stop-disk heights, dotted curves

the two curves also is nearly the same, that along the five-mil curve being slightly greater because of the contribution of the section of curve above 250 ampere turns.

It would be possible to calculate the releasing times from these curves if the characteristics of the circuit in which the maintaining current was flowing were known. When the magnetomotive force is due to eddy currents in the magnetic material, however, the current paths are too irregular to permit ready calculation. It is necessary, therefore, to measure the releasing time for various values of releasing ampere turns measured in the winding. Such a set of measured values is shown by the two solid curves of Figure 2. These curves represent the minimum and maximum values of releasing times for all values of releasing ampere turns. Actually, the curves include some mechanical time, since the armature had to move a small distance before opening the contact used to make the measurements. In general the upper curve corresponds to the 5-mil stop disk and 500 ampere turns initial magnetization, and the lower curve to the 18-mil stop disk and 250 ampere turns initial magnetization, but the two curves also cover the small variations from relay to relay. The lower curve is used, therefore, for estimating minimum releasing times, and the upper curve for estimating maximum times.

These time curves thus give the range of electrical releasing times for all U-type relays regardless of the combination of springs and of the height of the stop disks employed. They are not of much value by themselves, however, because they give release time in terms of releasing ampere turns. It is necessary to know in addition how the releasing ampere turns vary with various combinations of springs and stop-disk heights. Each spring load requires a definite flux to hold it, but the magnetomotive force or ampere turns required to produce this flux will vary with the height of the stop disk, because of the reluctance it introduces into the magnetic circuit. For each of the three nominal heights of stop disks provided, therefore, it is possible to determine experimentally the relationship between spring load and releasing ampere turns. Curves showing this relationship are also plotted on Figure 2, but because a certain amount of variation is unavoidable for a given nominal height of disk, curves for the two limiting values of each of the three nominal heights are shown. These limiting values are 5 and 8 mils for the smallest, 10 and 13 mils for the intermediate, and 15 and 18 mils for the largest stop-disk heights.

The releasing force of the relay depends on the number and types of springs, and tables are available giving the force in grams for each type. For any particular relay, therefore, it is necessary only to add up the loads for the various springs to determine the total load. If, for example, the total load were 300 grams on a relay with a five-mil stop disk, the electrical releasing time would be found by entering Figure 2 at 300 grams on the left-hand ordinate scale, running horizontally to the five-mil load curve, then vertically to the release time curves, and finally horizontally to the right-hand ordinate. Here the maximum time would be found to be some 17 milliseconds and the minimum time, 14 milliseconds. To this, from 1 to 5 milliseconds is added for the travel time. This travel time depends on the spring combination, but is small in any event, so that great precision is not required in determining it. With this set of curves, and tables giving the load of various types of springs and the time of travel from beginning of release to opening of the contacts, the release time may be readily determined for any U-type relay that does not have a short-circuited winding.

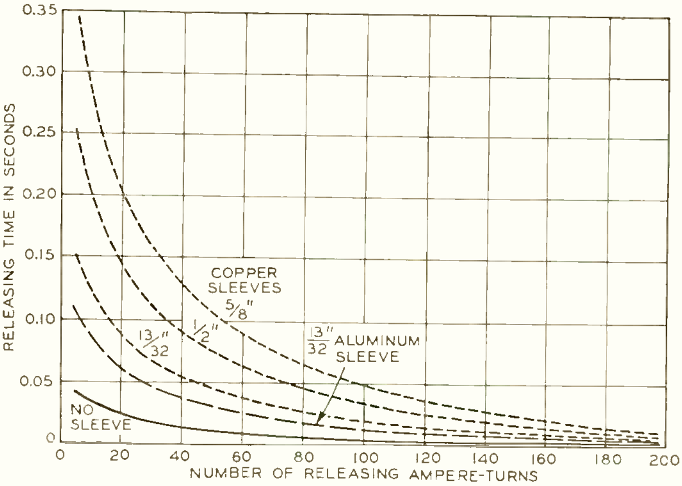

Fig. 3—Electrical releasing time of the U-type relay for various sizes of aluminum and copper sleeves over the core

To secure longer release times, a short-circuited winding is placed over the relay core. Such windings provide an additional circuit of much lower resistance for eddy currents. Moreover the time required for the current in this winding to decay may be calculated, since it depends on the ratio of inductance to resistance of the short-circuited winding, and the inductance may be calculated from the demagnetization curves of Figure 1.

In the example taken above, the number of releasing ampere turns, determined from Figure 2, was about 35, and this, as may be seen from Figure 1, corresponds to a flux of about 2700 maxwells for the upper curve. The determination of the delay caused by the short-circuited winding thus reduces to a determination of the time constant of the short-circuited winding as the flux decays from 8000 to 2700 maxwells, which corresponds to a decrease in magnetomotive force from 500 to 35 ampere turns. As already pointed out, this time is proportional to the ratio of the inductance to the resistance. The inductance, which varies with the slope of the demagnetization curve, can be calculated for any point along the curve, and the resistance, which remains essentially constant, can be calculated from the constants of the short-circuited winding. From these values the time for the current to decrease to the desired value may be determined. The total release time will then be that due to the short-circuited winding plus that due to the eddy currents in the magnetic material as given in Figure 2.

The short-circuited windings of the U-type relay usually take the form of a copper or aluminum sleeve placed directly over the core, and concentric with the energizing winding, and the minimum electrical release times for the four sleeves provided, computed as described above, are shown in Figure 3. The bottom curve, which gives the time when no short-circuited winding is used, corresponds to the minimum release-time curve of Figure 2.

Data for estimating the operate times of U-type relays have also been established. This time is mainly dependent on the time required for the current to build up in the operating winding to the value required to operate the relay. Eddy currents in the magnetic material have a less significant although not negligible effect on the operate time. If a short-circuited winding is used, the time constant of this winding will also enter. The longest operate time that can be insured with the U-type relay is around forty milliseconds, while the longest release time is some 125 milliseconds.

Both operate and release-time data are also available for the Y-type relay,* which differs from the U type chiefly in not employing a stop disk. Its armature makes an iron-to-iron contact with the core, and thus holds operated to much lower values of ampere turns. This does not appreciably affect the operate time, but release times as high as 330 milliseconds may be secured.

The data made available by these studies give the relay engineer all the information needed for determining operating and releasing times under all ordinary conditions. One of the valuable features is that it gives maximum and minimum values, and the circuits are always designed for whichever of these values is controlling. When this is done, the variations of individual relays that are employed in a system will not affect the correct operation of the circuit.

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*Record, *May*, 1938, *p*. 310.

HEARING TEST

Tests of hearing, using
tones, are available for vis
both the World's Fairs. The
listens through a telepho
ceiver to a musical tone w
hears in spurts—one, t
three at a time. Successive
sound farther and farther
He writes on his test blan
time how many tones he
This is then repeated for
pitches; the tones are 440
1760, 3520 *and* 7040 *cycl*
second. Upon completion t
card is held over a light wh
correct numbers appear th
the paper. Words "Impa
"Slightly Impaired" and
mal or Good" also appear th
the paper. The words oppos

incorrectly recorded numbers describe the condition of hearing. An attendant then places a check mark on the card signifying in private code the sex, color and approximate age of the visitor; and runs it through a photographic recording machine. The photographs so obtained are being used for a survey of hearing undertaken in the Research Department by Dr. J. C. Steinberg.

The photographs shown on this page were taken at the New York World's Fair. Top, the eight entrances to the special sound-proof rooms; center, inside of a room showing five of its seven booths; bottom, recording the test card. The frontispiece, page 369, *shows a visitor checking her test card*

Portable High-Frequency Transmission-Measuring Set

By F. R. DICKINSON
Toll Equipment Development

ONE of the essential requirements for the development and maintenance of long-distance lines is the provision of means for accurately measuring gains or losses in the component parts of the system. Transmission-measuring sets, as a result, have been made available to meet a variety of requirements. Until recently, however, the highest frequency employed has been about thirty kilocycles, used for the type-C carrier system. Transmission-measuring sets for these high frequencies have been of the bay-mounted type, and are permanently installed in terminal offices or in major repeater stations.

With the advent of the J and K carrier systems, it was necessary to design a new set because of the much higher range of frequencies to be measured—running up to 150 kc—and of the higher gains and losses involved. Moreover, the use of many additional small repeater stations, most of them maintained from main stations, made it desirable to make a portable set. As a result, the 30A transmission-measuring set has been developed. It is housed in a cabinet approximately twenty by twelve by six and one-half inches, and its total weight is only thirty-six pounds.

The general method of measurement is indicated in Figure 1. An external oscillator—the 17B* has been provided for the purpose—serves as a source of testing current; and a sensitive microammeter, connected across a thermocouple, acts as the indicating device. The set provides two paths between the oscillator and meter, in one of which are two adjustable attenuators, giving adjustment in 1-db steps from 0 to 60 db, and a fixed attenuator of 30 db. Either path may be selected by means of the "adjust-compare" key. When a unit having an unknown overall loss is to be measured, it is plugged into the jacks in the lower path. The loss in the attenuator is then adjusted to equal the unknown loss, comparative readings being taken through each branch of the set until the meter readings are the same.

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*Record, *May*, 1939, *p.* 291.

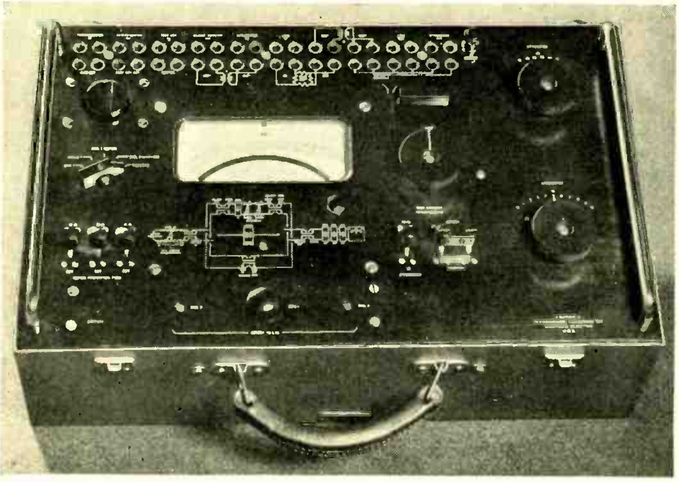

Fig. 2—Top view of test set with cover removed

When a unit having an overall gain is to be measured, it is inserted in the upper path at the output of the attenuator. Again, adjustments are made in the attenuator until the meter readings through both branches of the circuit are the same, which indicates that the net loss through the upper branch is zero. The unknown gain is then equal to the attenuator reading. Since the smallest unit of attenuator adjustment is 1 db, fractional parts of a db are read on the meter scale, which is marked in heavy lines over the range from −1 to +1 db. The 0-db reading in the center of the scale corresponds to one milliwatt, which is the reference level of the set. At this point the accuracy of the meter is one-quarter of one per cent.

Since the meter is of the thermocouple type, it may be calibrated on direct current, and a flashlight cell is included in the set for this purpose. The complete calibration is accomplished in three steps, using the five-position switch at the left center of the test set, shown in Figure 2. The switch is first turned to the position marked "dial 1," which establishes a circuit as shown in the upper part of Figure 3. The battery is connected across a high-resistance potentiometer, controlled by "dial 1," and across the potentiometer is connected a 135-ohm resistance through an ammeter shunt. Since the high-frequency carrier systems are designed for 135-ohm circuits, the test set is similarly designed, and is calibrated as a termination for circuits of this impedance. "Dial 1" is adjusted until the meter reads zero.

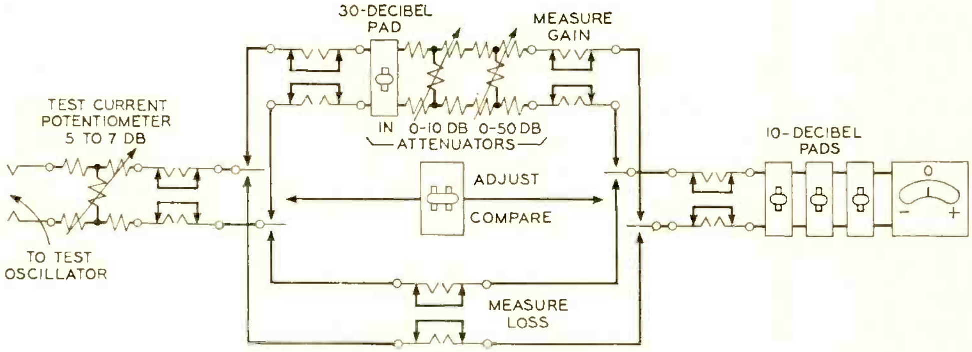

Fig. 1—Simplified schematic of the 30A transmission-measuring set

When connected to the shunt in this manner the meter will read zero with a current of 2.72 milliamperes, which is the current that is required for one milliwatt of power in the 135-ohm resistance.

Having thus adjusted the battery current to give an output of one milliwatt into a 135-ohm resistance, the switch is turned to the position marked "dial 2," which gives the connections shown in the middle of Figure 3. In this position, the 135-ohm resistance is replaced by the thermocouple in series with the resistance controlled by "dial 2," which is adjusted until the meter pointer again rests at the zero position. This adjusts the resistance of the thermocouple circuit to 135 ohms.

With this adjustment made, the switch is turned to "dial 3" position, which gives the connections shown in the lower diagram of Figure 3. This is the same as for the previous arrangement, except that the meter has been moved from the shunt to the thermocouple. "Dial 3" is adjusted until the meter pointer is again at zero. The thermocouple may give slightly different readings depending on the direction of current through them, and a fourth position is provided on the switch to reverse the current to the thermocouple. "Dial 3" is adjusted so that the meter gives equal deflections on both sides of the zero for the two directions of current flow. The thermocouple is in a separate replaceable unit, mounted just above the calibration switch, and, for extremely precise results, various thermocouples may be tried until one is found that has little or no directional effect. When this final step of the calibration is completed, the switch is turned to the fifth position, which disconnects the battery and connects the set so that it is ready for making measurements.

Although designed for measurements on 135-ohm circuits, the set may be used on 600-ohm circuits by inserting repeating coils, which are incorporated in the set. These introduce some loss, for which a correction must be made when precise measurements are desired. The correction per coil is less than ½ db over the frequency range from 100 to 150,000 cycles. A 10-db loss network is also provided for use when the 90 db provided for normal use is not sufficient. This network and the two repeating coils are connected to jacks along the upper part of the set, so that they may be patched into the circuit at any of the five jack positions indicated in Figure 1, these jacks also being mounted in the row along the

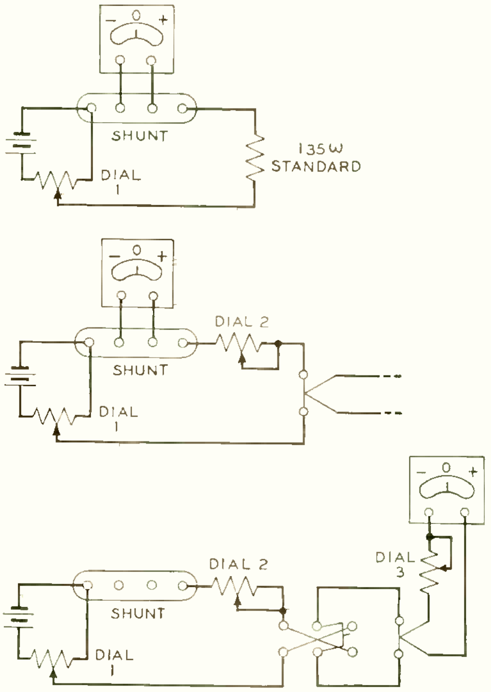

Fig. 3—Calibration of the 30A test set is accomplished in three steps shown in order above from top to bottom

top of the set. A set of three pairs of jacks is also provided, connected in parallel, which may be used when multiple connections are required. Three 10-db pads, controlled by keys at the lower left corner of the set, are provided in series with the meter to prevent damage from large current during the early stages of a measurement. These may be cut out, one at a time, by the keys and are all out for the final measurement.

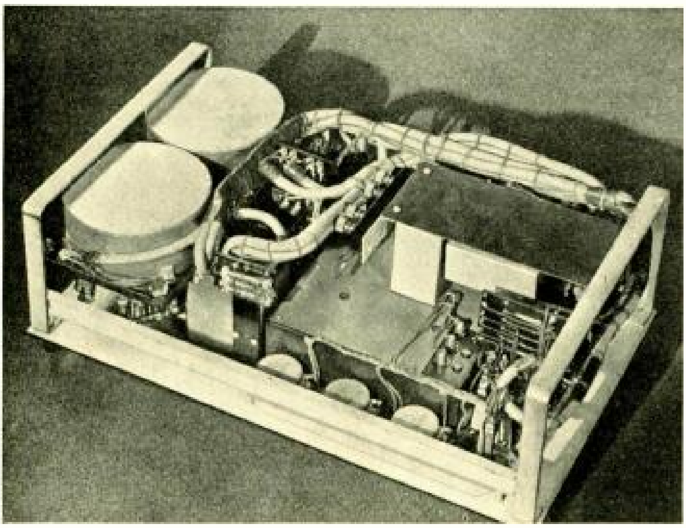

Fig. 4—Under side of the 30A test set when removed from case

Because of the high frequencies for which the set will be used, and the wide range in level, careful consideration had to be given to all parts of the design. All the keys except the adjust-compare key have twin contacts to increase their reliability. Side-wiping contacts are provided for the adjust-compare key for a similar reason. The attenuators all have silver wiping-contacts with non-inductive resistances and are accurate within 0.1 db. Internal shielding of the component parts is of prime importance. The row of jacks at the top of set is shielded by a structure resembling the ice tray of an electric refrigerator each pair of jacks being in one compartment. Within the row, the jacks are located so as to bring high differences in level as far apart as possible. The attenuators all have their overall shields, with separate shields for the resistances. The two halves of the "adjust-compare" key, where high differences of level occur, are completely boxed in by shields, and the operated position of the key that cuts in the 30-db attenuator is completely enclosed. Rubber-covered shielded wire is used to reduce crosstalk and capacity to ground. The two repeating coils have been placed at right angles to each other to reduce crosstalk effects observed when the coils are parallel. The metal top panel, when grounded, serves as a shield for the entire set, and all the jack sleeves are grounded through contact with it.

This top panel serves also as a mounting plate for all the apparatus, and is arranged for removal from the casing as shown in Figure 4. A cover, not shown in the photographs, protects the top of the set when not in use or during shipment. This cover, when in place, depresses a button just below the right-hand corner of the meter, which operates a short-circuiting switch on the moving coil of the meter to damp the movement and lessen the likelihood of damage when the instrument is in transit. The top panel is of heavy aluminum sheet, which is treated by a patented process known as alumiliting. This process, which includes a black aniline dye for color, gives the panel an aluminum oxide coating of sapphire hardness and extreme resistance to wear, with an appearance similar to that of phenol fibre. By means of a printing process from a photographically produced master plate, the name-plate, designations, and diagrams are etched through the oxidized surface to the bright aluminum beneath. With such a process, the number of designations placed on the plate has practically no effect on the cost, and it was therefore found desirable to include a simplified schematic diagram in the space below the meter. The designations on the apparatus together with the simplified schematic diagram make the set practically self-instructing. With only a limited knowledge of its operation a person wishing to make transmission measurements is able, in a very short time, to realize its full capabilities and be able to make any desired measurement.

Use in the field has proved this 30A transmission-measuring set a valuable unit of testing equipment. Its compact size and light weight make it convenient, and its high accuracy yields results equivalent to those ordinarily obtained in the laboratory.

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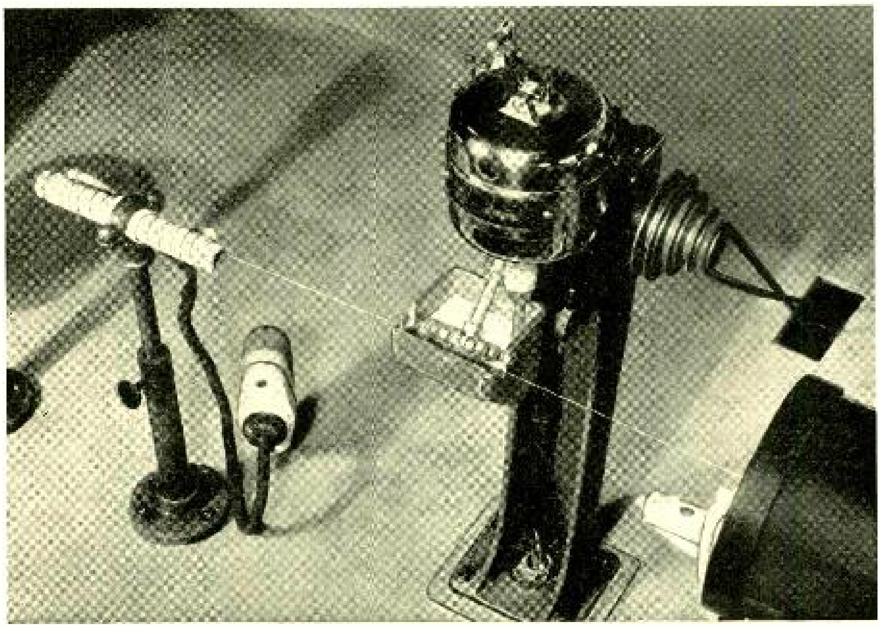

Apparatus developed by the Laboratories to coat vacuum-tube filaments automatically. The fine core-wire passes through coating baths and then through electric furnaces to dry the coating. The slotted wheel applies the coating mixture as it passes along a groove in the wheel. The mixture is stirred by a small motor-driven propeller

Simplifying the Adjustment of Antenna Arrays

By J. F. MORRISON
Radio Broadcast Development

IN RECENT years radio broadcasters have been extensively utilizing multiple-element antenna systems to make the most effective use of their licensed power. These antenna arrays, usually consisting of two or more vertical antennas, allow a directional control of the radiated power, thus permitting a reduction in interference with stations operating on the same or on an adjacent frequency and an increase in signal strength in densely populated areas where high noise conditions generally prevail. Two examples of such arrays have already been described in the RECORD.*

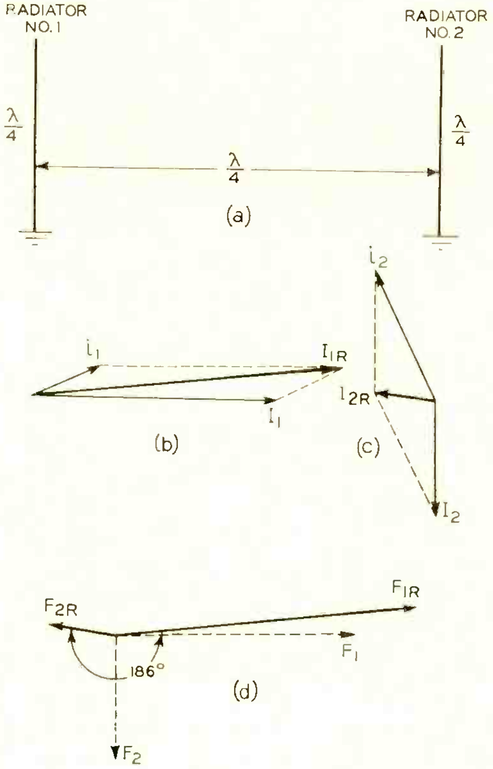

Fig. 1—Because of currents induced in each radiator by currents in the other, the resultant currents in each of the radiators differ considerably from those that would exist without the mutual effect

The radiation patterns obtained from such arrays depend upon the separation of the individual towers generally used for antennas, and on the relative magnitude and phase of the current in each of them. Once the desired radiation pattern has been agreed upon, and the spacing of the antennas settled, it is possible to calculate what the relative magnitude and phase of the current in each antenna should be. To secure these desired currents, however, is not simple. Line-branching and phase-shifting networks are provided to control the magnitude and phase of the current to each antenna, but how these networks should be adjusted to give the desired antenna currents cannot be predicted in advance because of the reaction of the current in each antenna on the current in the others.

Assume, for example, that two quarter-wavelength antennas spaced a quarter wavelength apart were to be employed to secure a particular pattern, and that the current in radiator 1 was required to be twice the magni-

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*RECORD, *April*, 1935, *p.* 232, and *September*, 1936, *p.* 17.

tude of that in radiator 2 and to lead it by 90 degrees. If the current in one radiator had no effect on that in the other, all that would be required would be to adjust line-branching and phase-adjusting networks so that the current flowing to radiator 1 would be twice that going to radiator 2 and would lead it by 90 degrees. The radiated fields from the two antennas are proportional to the respective currents, and the field in any direction would be the resultant of these two component fields, allowing for the phase difference caused by the quarter-wavelength separation of the two antennas.

Actually, however, the current in each radiator induces a current in the other, with the result that the net current in each is the vector sum of the current fed to the antenna from the transmitter and that induced in it by the current in the other radiator. The effect of this is shown vectorially in "b" and "c" of Figure 1, where I is the current supplied to the radiators from the transmitter, and *i* is the current induced in the radiator by the current in the adjacent radiator. In the diagram, subscripts 1 and 2 are employed to differentiate the currents in the two radiators. The resultant currents I_r are then a first approximation of the actual currents in the radiators.

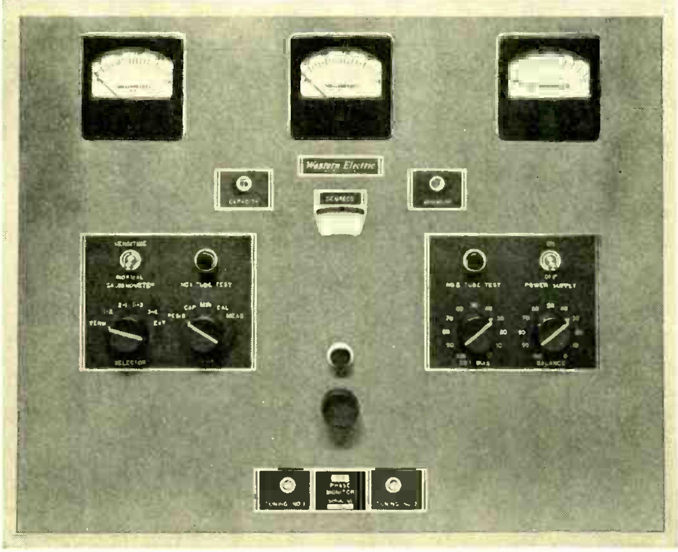


Fig. 2—The measuring apparatus is arranged on a 19-inch panel, which may be mounted on a relay rack if desired

The two radiated fields are in phase with the resultant current and are indicated at (d) on the diagram. The desired fields are indicated by the dotted vectors, and the wide divergence of the actual values—resulting from the induced currents in the radiators—is plainly evident. The effect of the induced currents on the resultant currents in the antenna as shown on Figure 1 indicates why the line-branching and phase-shifting networks cannot be set to produce the desired difference between the currents in the two radiators.

To obtain the currents to give the desired pattern it has been necessary in practice to make an approximate adjustment and then to make field intensity measurements around the array. From these measurements, the magnitude and phase of the current in the radiators can be calculated, and changes can then be made in the networks to produce more nearly the desired results. This process might have to be repeated a number of times, with the result that the adjustment of an array becomes a comparatively long and tedious process. Moreover the radiation pattern needs checking from time to time since the currents in the antennas may change because of variations in circuit characteristics. Thus it can be seen that some simpler means of determining the currents in the antennas of an array is highly desirable.

The 2A phase monitor has been developed to facilitate these original adjustments and to enable the station operator to restore or check them at any time. It consists of a panel, shown in Figure 2, connected to sampling loops on each tower by coaxial transmission lines as shown in Figure 3. The sampling loops consist of a single turn loop which is fastened to each antenna at a point sufficiently high above the ground to assure an accurate sample of the current flowing in the antenna. The dimensions of the loop as well as its points of attachment must be identical for both the antennas. The top of the loop is directly connected to the towers, while the bottom is insulated, and is connected to the center conductor of a coaxial line leading to the measuring equipment. The two transmission lines are made to have identical overall characteristics.

At the measuring equipment the lines are connected through radio-frequency thermal milliammeters, which indicate the magnitude of the two currents supplied to the input of a vacuum-tube galvanometer or voltmeter. Between the milliammeter M2 and the galvanometer on one of the lines, however, is a phase-shifting network which permits the phase of the current in that circuit to be shifted until it is the same as that supplied by the other line. The circuit is arranged so that when this condition is reached, the galvanometer will give a minimum reading, and the amount of phase shift required to bring the two currents into phase is indicated by the dial controlling the phase-shifting network. Since the magnitude and phase of the currents required to give the desired field distribution pattern are known, it is necessary only to adjust the line-branching and phase-shifting networks in the main

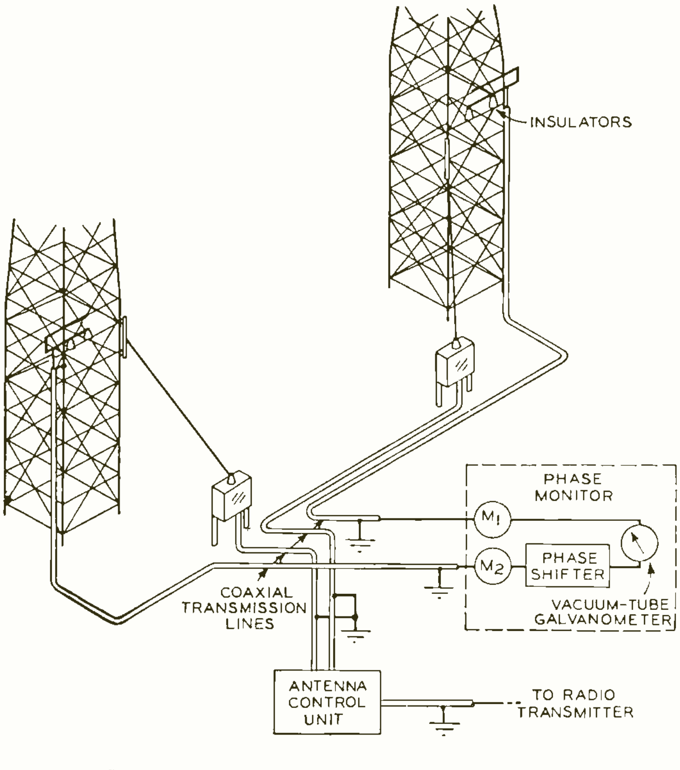


Fig. 3—Block schematic of method of directly measuring antenna currents by means of 2A phase monitor

lines to the antenna until those known values are indicated on the measuring equipment. The necessity of tedious field-strength measurements are thus unnecessary except as a final check.

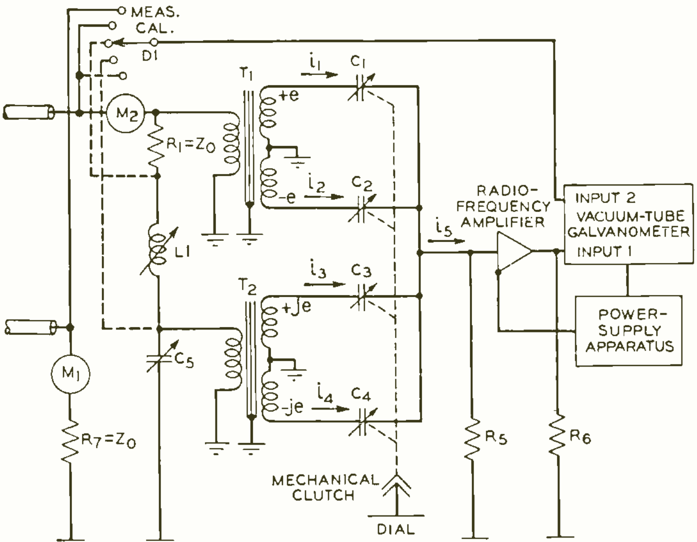


Fig. 4—Simplified schematic of the measuring circuit

The circuit of the measuring equipment is shown in schematic form in Figure 4. One of the coaxial transmission lines is connected through a radio-frequency milliammeter M2, a resistance R1, an inductance L1, and a capacity C5 to ground, the inductance and capacity each having impedances, at the carrier frequency, numerically equal to resistance R1, the characteristic impedance of the coaxial sampling line. Two identical high-impedance radio-frequency transformers with permalloy-dust cores, T1 and T2, are connected from the resistance to the ground and from the capacity to ground respectively, and thus produce on their secondary sides two potentials in quadrature with each other. The secondaries of these two transformers are grounded at their midpoints, with the result that the four potentials across the condensers C1, C2, C3 and C4 across the secondaries of the transformers are all in quadrature and may be represented as $+e$, $-e$, $+je$, and $-je$. The rotor plates of the four condensers are connected together electrically so that the output current, i_5, is the sum of the currents through the four condensers. This output current produces a voltage across R5 which is amplified to make up for the loss through the phase-shifting network and to adjust the output voltage to equal that across the other terminating resistance R7. The amplified voltage is then applied to the vacuum-tube galvanometer. The voltage developed across the terminating resistance R7 of the other line is also applied through switch D1 directly to the vacuum-tube galvanometer, which will give a minimum reading when the phase of the voltage at input 1 is the same as that of input 2 and the two voltages are equal.

If the rotors of the condensers were so positioned relative to the stators that the capacitances of the four condensers were always the same, the output current, i_5, would, of course, be zero, because four equal quadrature components sum up to zero. Actually, however, the stators and rotors of the four condensers are mounted as shown in Figure 5. There are four sets of stator plates but only two sets of rotor plates; one set of rotor plates

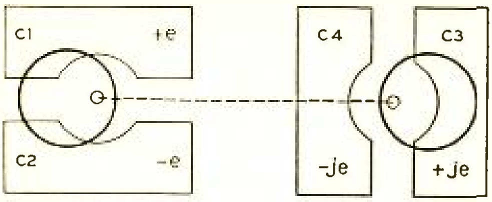


Fig. 5—Relative position of the stator and rotor plates of condensers c1, c2, c3 *and* c4

serving for c1 and c2, and the other for c3 and c4. The rotors are connected mechanically in the relative positions shown on the illustration, Figure 5, above, and are rotated together by a single dial.

In the position of the rotors indicated, the capacitances of c1 and c2 are alike and thus i_1 and i_2 flowing through the condensers are equal, but since they are of opposite phase, they cancel. The capacitance of c4, on the other hand, is zero and that of c3 is a maximum, so that i_4 is zero and i_3 is a maximum, and the resultant output, i_5, is equal to $+ji_3$, which applies a potential to the voltmeter proportional to $+je$. As the rotors are turned to the right, there is a progressive change in the magnitude of the four components, so that, after a 90-degree turn, i_2 is zero, i_1 is a maximum, and i_3 and i_4 are equal and opposite, so that the resultant current, i_5, becomes $+i$.

The values of the capacitances of the four condensers for various angular positions of the rotor are as indicated in the four graphs of Figure 6, and the component currents correspond to these capacitances. Since the currents flowing through c1 and c2 are always 180 degrees apart, they may be added algebraically to give the solid curve of Figure 7, which represents the real component of i_5. Likewise the currents flowing through condensers c3 and c4 may be added algebraically to give the dotted curve of Figure 7, which represents the imaginary component of i_5. The two components represented by these curves are the quadrature components of the resultant current and must be added vectorially to give i_5. The result of the vector addition is indicated for a number of angular positions of the rotor in Figure 8. It will be noted that for all angles of rotation of the plates, the magnitude of the resultant current, i_5, is the same and its phase angle is equal to the angle of rotation of the condenser rotors. Thus the voltage at the input of the voltmeter is always the same in magnitude but is shifted with respect to the

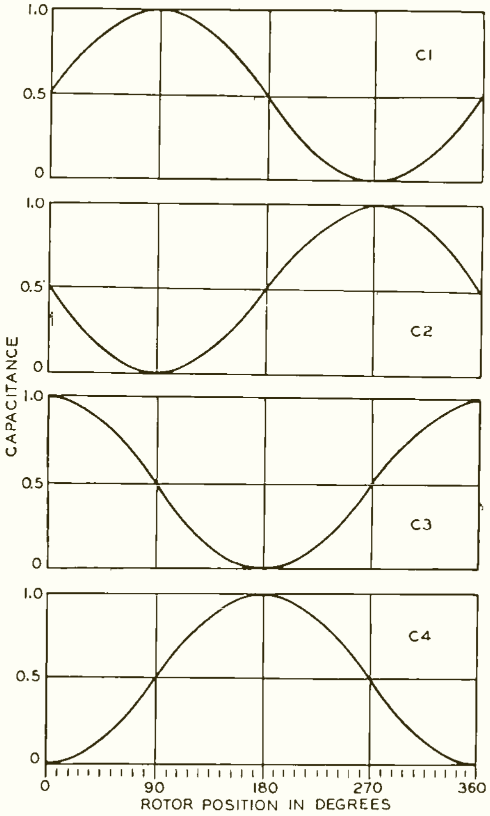


Fig. 6—Capacitance of the four phase-shifting condensers for various angular positions of the rotor

phase at the input to the phase-shifter by an amount equal to the rotation of the rotor plates.

The resistance and capacity network, R1 and C5, which provides the quadrature relationship required between the two transformers by the phase-measuring condensers, is adjusted by using the vacuum-tube galvanometer. Two contacts, in addition to the "CAL" and "MEAS" points, on the test switch D1 are provided as shown dotted in Figure 4 so that the voltage of condenser C5 to ground may be measured and the capacity adjusted until the voltage across it equals that of resistance R1 to ground. Another point on the switch enables inductance L1 to be adjusted so that its impedance is equal and opposite to that of condenser C5, as indicated by a minimum deflection upon the galvanometer. The proper adjustment of C5 and L1 may by this means be quickly established for any frequency and checked at any time without supplementary measuring equipment.

The vacuum-tube galvanometer, as already noted, gives a minimum reading when the potentials applied to its two inputs are in phase and equal in magnitude. Since one input is supplied directly from one of the transmission lines, and the other, from that of the other transmission line through the phase shifter, a minimum reading will be obtained when one input to the voltmeter has been shifted in phase sufficiently to bring it in phase with the other input, and the amount of phase shift necessary to bring this about is the original phase difference between the currents from the two transmission lines at the input to the measuring equipment.

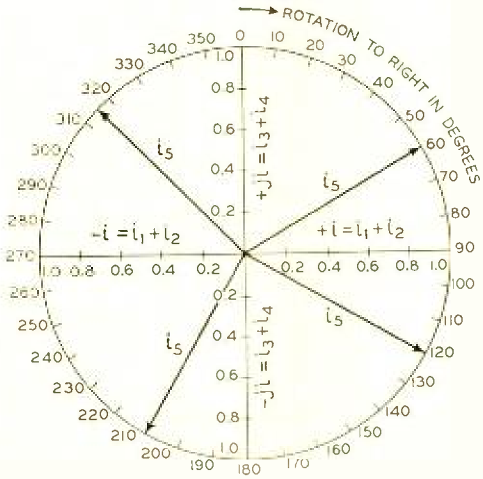


Fig. 8—Vector resultants of the curves of Figure 6 for various rotor positions

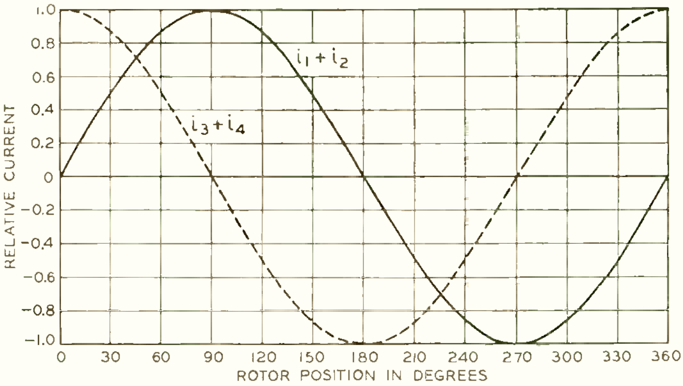


Fig. 7—Sum of i_1 *and* i_2*, solid curve, and of* i_3 *and* i_4*, dotted curve, for various angular positions of the rotor*

The relative magnitudes of the currents in the towers are determined directly from the readings of the radio-frequency thermal milliammeters M1 and M2. These meters are of the expanded-scale type having substantially linear scales from 50 to 250 milliamperes.

Terminations are provided for three sampling lines and a selector switch has been provided which is wired to enable the relative magnitude and phase to be determined for each of three towers.

Another feature is a provision for interchanging the connections between the monitor proper and two of the sampling lines which makes it possible to re-measure an angle using an adjacent quadrant of the phase-measuring condensers, thus obtaining a substantial check upon the accuracy of the original adjustments and measurement. The same interchange provision makes it possible to eliminate meter errors that might occur from the relative magnitude determination.

This new monitoring equipment is useful not only in adjusting the pattern when the station is first put in operation, but in checking the performance of the array from time to time. As a permanent part of the equipment of stations using antenna arrays to secure controlled radiation, the apparatus makes it possible to check the performance of the array periodically, and thus to avoid a changing of the pattern caused by variations that are likely to occur.

* * *

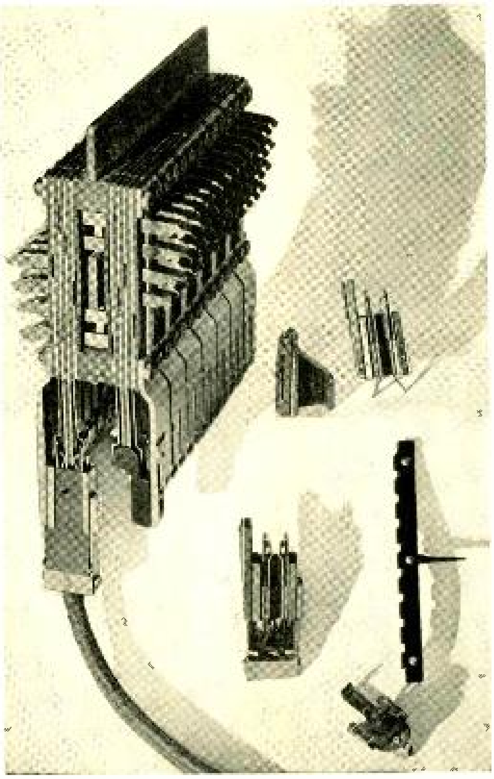
Mrs. Gilbert Grosvenor, daughter of Alexander Graham Bell, and Mr. Grosvenor (at the right) hear Mrs. Anna Mae Swenson operate the Voder in Mr. S. S. A. Watkins' office at the Bell System Exhibit at the New York World's Fair

Jacks for Main Distributing Frames

By J. E. SHAFER
Electro-Mechanical Development

IN METROPOLITAN areas, where telephone circuits are installed in cables entirely underground, as many as thirty thousand pairs of wires may enter a single central office. These wires all terminate at the main distributing frame. To conserve space at this location a jack arrangement has been developed to connect the cable pairs to the central-office circuits. It replaces the protector mounting which is not needed where the outside plant is entirely underground, since excessive voltages cannot ordinarily be impressed on the circuits. Twice as many circuits can be accommodated in the same space by the use of this jack arrangement without sacrificing any of the testing arrangements now generally used.

A group of the new jacks is shown in the illustration. Each jack has two pairs of spring contacts which normally close the tip and ring of a cable pair to the tip and ring of the associated central-office circuit. Each set of springs is opposite another set on the other side of the jack and each set serves one cable pair. The incoming cable pairs are soldered to terminals on one side of the jack and the cross-connecting jumpers to the other side. The outside wires usually remain connected during the life of the office but the jumper wires are frequently changed. The terminals for both the outside wires and jumpers are mounted forward in an accessible position. Precious-metal contacts assure greater freedom from circuit noise than protector mountings which have base-metal contacts. A guide is also provided to hold the plugs in position and to insure their proper insertion into the jack.

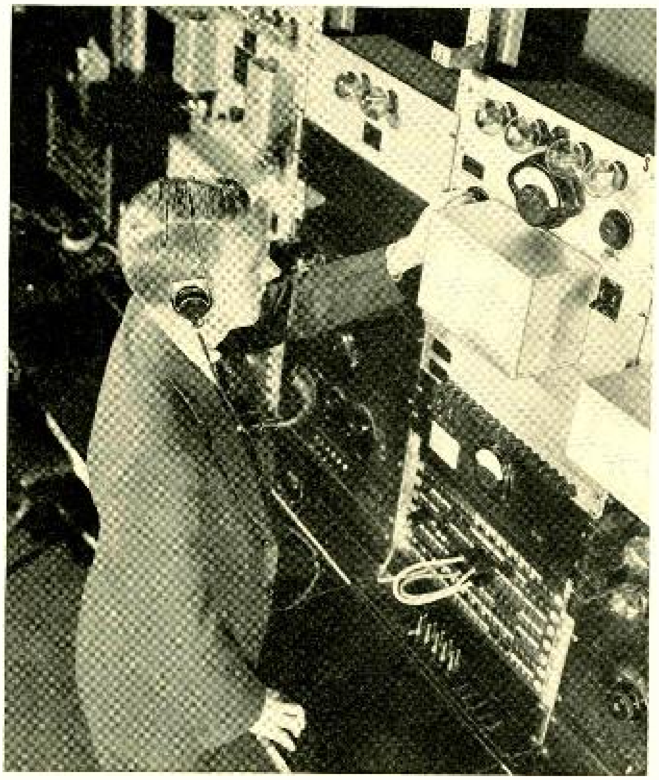


New plugs and shields have been developed for the new jack. A test plug and a dummy plug are shown in place in the illustration. The test plug has four springs which are connected to the tip and ring conductors of the cable and to the jumper pair. By this plug the central office and cable circuits can both be patched to a testing station. Inserting the dummy plug disconnects the cable pair from the inside circuit; and this is equivalent to removing heat coils or dummy heat coils from a protector mounting.

Several other attachments are shown in the photograph, some with their protective covers removed. Above at the right is a test plug which has terminals from the two inner springs only and is used to check cable pairs during installation or in case of cable failure. Below at the left is a reversing plug which reverses the tip and ring connection to the line. A guard, shown near the bottom of the photograph, serves as a marker for important circuits to prevent accidental insertion of a plug. The object nearest the jacks is a shield to cover completely the front end of a jack when extra protection is desired. The gang plug at the right opens ten pairs at a time and is used principally in case of cable failure.

Substituting the new jacks for protector mountings will reduce appreciably the floor space required where protector blocks are not needed. In some cases it will make unnecessary a double-sided protector frame, the cabling that is necessary between the protector frame and the main frame, and the additional mezzanine platform and lighting facilities.

* * *



Testing toll circuits with a return-loss set which measures the unbalance between a line impedance and a network impedance. When the return-loss is high the balance is good and this condition makes two-wire repeatered circuits operate most satisfactorily

Contributors to this Issue

P. W. Swenson graduated in 1927 from Worcester Polytechnic Institute with a B.S. degree in Electrical Engineering. He immediately entered the Systems Development Department of these Laboratories. After spending a year in the manual systems laboratory group, he transferred to the relay group where he has since been engaged in the application and development of relays for various central-office switching circuits.

J. W. Dehn joined the Engineering Department of the Western Electric Company in the fall of 1919, and at first engaged in laboratory testing and analysis of manual and panel telephone circuits. Subsequently he worked on the design of manual circuits and later of automatic testing circuits for panel offices. Since 1933 he has been engaged in the design of automatic testing circuits and marker circuits for the crossbar system. During this period, he has attended classes at the Polytechnic Institute of Brooklyn from which he received the degree of Electrical Engineer in 1932.

J. E. Shafer joined the Laboratories immediately after receiving his B.S. degree in Physics at Pennsylvania State College in 1919. For eight years he was engaged in research testing of magnetic materials, after which he transferred to the Apparatus Development Department. Here he worked on the design of relays, switches to control electrolysis and message registers. He is now primarily interested in polarized relays.

J. F. Morrison joined the Engineering Department of the Federal Telephone and Telegraph Company in 1923, where he engaged in the development and manufacture of the earlier broadcast receivers and transmitters. Previous to this time he had spent two years at the Electrical Vocational School, Buffalo, New York. In 1926 he left the Federal Company and joined the Long Lines Department of the American Telephone and Telegraph Company. The following year he was engaged as wireless operator by the Radio Corporation of America, and operated on Standard Oil Company ships between New York and South American ports. A year later he left to become Vice-President and Technical Director of the Buffalo Broadcasting Corporation which oper-

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ated Radio Broadcast stations WKBW, WGR, WMAK and WKEN. In 1929 Mr. Morrison joined the Radio Development Department of these Laboratories. His work in that department has included the supervising of radio broadcast transmitter installations, radio transmission studies, and broadcast antenna design.

F. R. DICKINSON graduated from Union College in 1927 with the B.S. degree in Electrical Engineering. He at once joined the Technical Staff of the Laboratories, where with the Trial Installation Department he took part in various trials at a number of places scattered around the country. In 1932 he left the Laboratories and was engaged in the development of electrical instruments and public address equipment. Returning to the Laboratories in 1936, he joined the Toll Equipment Department, where he has since been engaged in studies of automatic regulation of carrier-telephone systems for open-wire lines.

R. L. TAYLOR received the B.S. degree in Chemical Engineering from the State College of Washington in 1928 and an M.A. degree in Chemistry from Columbia University in 1939. He joined the Laboratories in 1928. His work has been concerned mainly with measurements of the dielectric properties of organic insulating materials and studies of their stability to water and sunlight.

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