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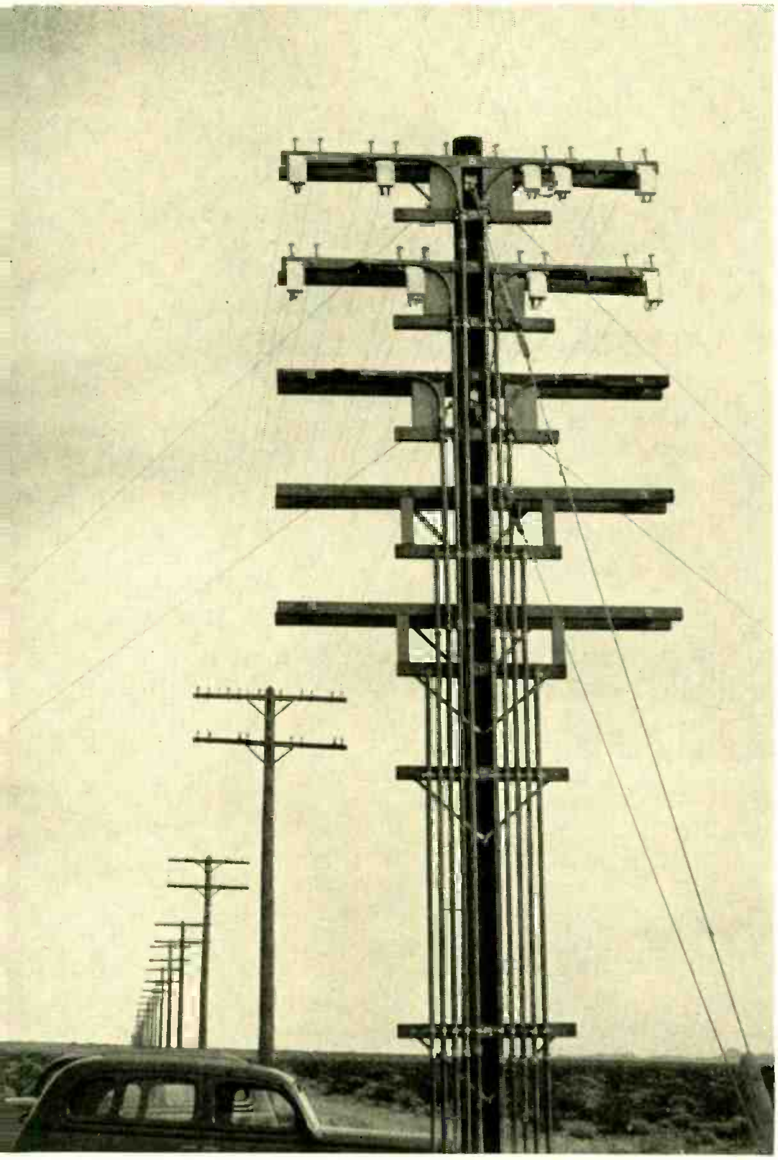

Photo by M. Kirkwood, A. T. & T.

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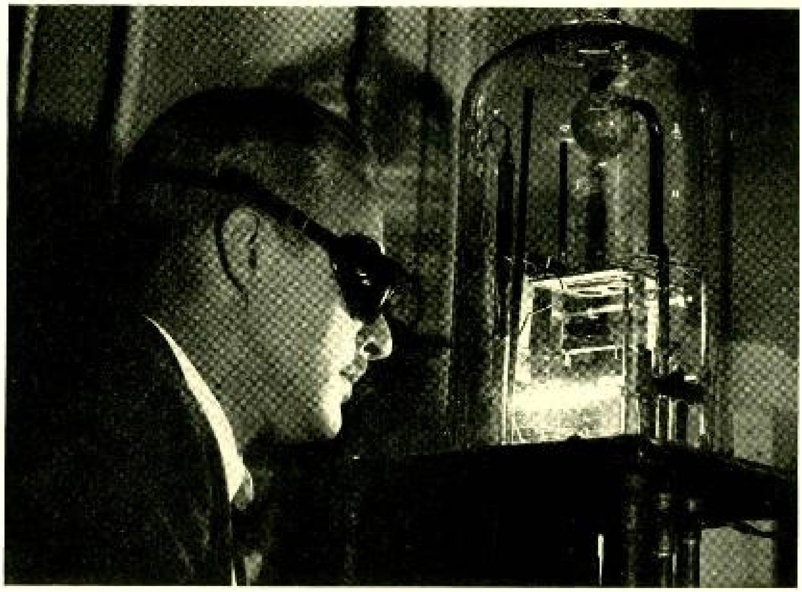
Where open wires connect to cables in the type-J carrier telephone system



Varistors: Their Characteristics and Uses

By J. A. BECKER
Physical Research

DURING the first four decades of the telephone industry, the only kind of conductors which were used followed Ohm's law; in these conductors or circuit elements the current increased proportionately to the voltage. The advent of the vacuum tube introduced a circuit element in which the current did not obey Ohm's law; furthermore it depended on the polarity of the voltage. These properties gave the vacuum tube its wide usefulness as a modulator and as a rectifier. In the last few years a class of solid non-ohmic conductors has been put to use in the fields of communication and electrical engineering; since their resistance is variable, they have come to be known as "varistors."

Varistors may be classed as rectifiers, such as the copper-oxide or selenium rectifier; symmetrical varistors, such as the silicon-carbide varistor or "thyrite"; and "thermistors" which change their resistance because of their large temperature coefficient. All three classes of varistors are in general made of semiconductors; that is, materials whose conductivity lies between that of conductors and insulators.

The copper-oxide rectifier consists of a washer or disc of sheet copper which has been oxidized so as to form on its surface a layer of red cuprous oxide. A film of conducting material is applied to the outer surface of this oxide, and this film is known as the "outer contact."

When a potential is applied between the copper and the outer contact, it is found that the current is not proportional to the applied potential and that it depends on the direction of the applied potential. In the conducting direction which corresponds to a negative potential on the copper, the current increases very rapidly with the applied potential. In the reverse direction the current is very much smaller than it is in the conducting direction. This is illustrated by the solid curve in Figure 1. The dashed curve shows the reverse current on a scale which is magnified a hundred fold. Because the currents cover such a large range of values, it has been found useful to plot the current-voltage curves on a logarithmic scale such as that in Figure 2. The curve OA is for the conducting direction while OB is for the reverse direction.

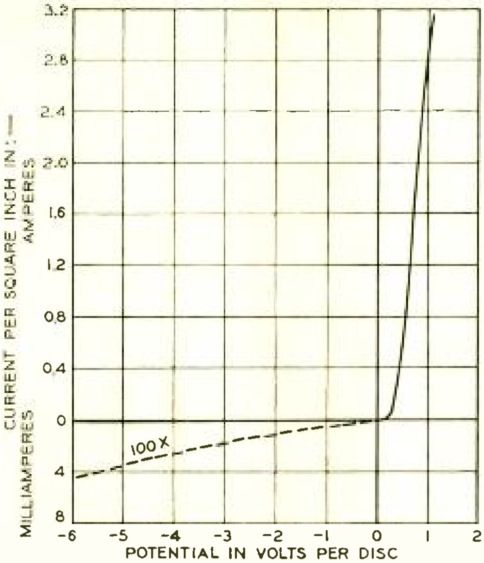


Fig. 1—Current-voltage relation for a copper-oxide rectifier

In passing from the copper to the outer contact, the current must cross the inner junction between the copper and the oxide, the body of the oxide, and the outer junction. Detailed experiments have shown that the conductivity in the body of the oxide and at the outer contact obeys Ohm's law and that the non-linearity in the current voltage relation is due to the peculiar nature of the conduction at the inner junction.

In the second type of varistor the current increases much more rapidly than proportional to the voltage, but it is the same for the two directions of the applied potential. Hence they are called symmetrical varistors. This type of varistor, of which Thyrite is an example, consists of a large number of granules of silicon carbide bonded together by a ceramic. Each silicon-carbide granule touches its neighbors in only a few small contact areas. The electrical characteristics are determined largely by the nature of these contacts. While any one contact may rectify to some extent, the overall characteristic shows practically no rectification because there are numerous contacts in series and in parallel.

At sufficiently low voltages the current approximately obeys Ohm's law. At higher voltages there is a considerable region in which the current-voltage relation is a straight line on a log-

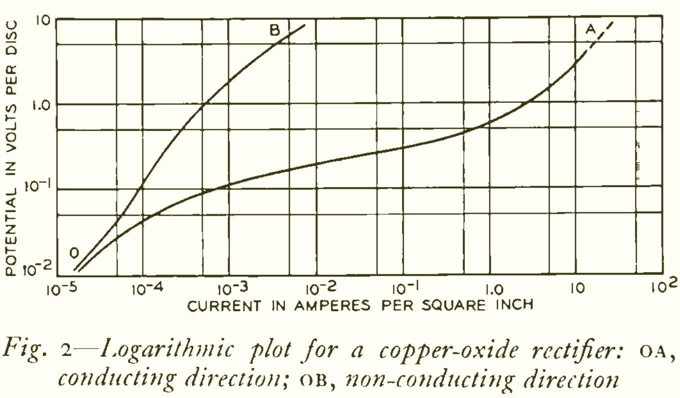


Fig. 2—Logarithmic plot for a copper-oxide rectifier: OA, *conducting direction;* OB, *non-conducting direction*

log plot. In this region the current increases as some power of the voltage; as high as the fifth, for some samples of material made at the Laboratories. Figure 3 shows such a log-log plot for two varistors whose thickness is 1 inch and .02 inch. For a given current per square inch, the voltage across the varistor is roughly proportional to the thickness. For higher voltages and currents than those shown in Figure 3, the conductivity approaches Ohm's law as a limit.

Another way of contrasting the characteristics of the two kinds of varistors is to plot the logarithm of the resistance as a function of the voltage. This has been done in Figure 4 for a standard copper-oxide unit and a one-inch-thick silicon-carbide varistor. The voltage scale for the silicon carbide is 1000 times as condensed as for the copper-oxide curve.

In comparing the characteristics of varistors made with silicon carbide and with copper oxide, respectively, it is interesting to note the following: The current through silicon-carbide varistors does not depend on the direction in which the voltage is applied. The ratio of the resistance at high and low voltages is between a hundred thousand and a million, which is about 100 times as great as for the standard copper-oxide varistor. On the other hand, the current through silicon carbide never varies as rapidly with voltage as it does for the most non-linear portion of the copper-oxide characteristic. Since the silicon-carbide varistors cannot be made indefinitely thin, there is a voltage below which the deviation from Ohm's law is no longer large enough to be useful. At the present time the lower limit of thickness which can be obtained commercially is about 0.015 inch and the lowest voltage at which these varistors deviate sufficiently from Ohm's law to be generally useful is about 1 volt.

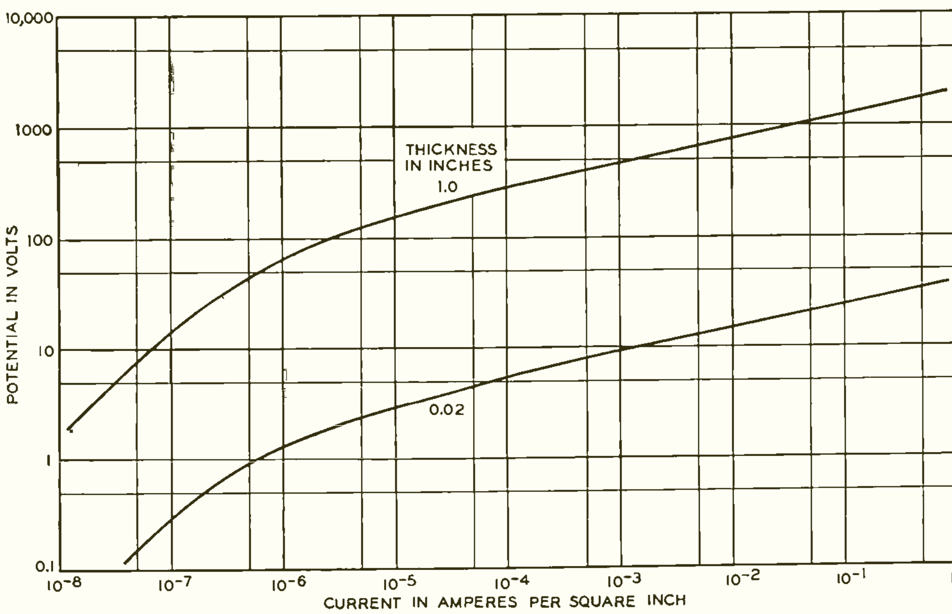


Fig. 3—Logarithmic plot for two silicon-carbide varistors

On the other hand, an inch-thick piece will momentarily withstand thousands of volts. Copper-oxide and silicon-carbide types thus supplement each other; the copper-oxide type is essentially a low-voltage varistor while the silicon-carbide type is essentially a high-voltage varistor.

In the third type of varistor, the resistance varies rapidly with temperature; hence the name "thermistor"; in nearly all cases the resistance decreases as the temperature increases, i.e., the temperature coefficient is negative. However, as long as the temperature of the thermistor is constant, Ohm's law is obeyed. As the power dissipated in the thermistor increases, its temperature rises and consequently the resistance decreases. If the power is increased still further, the resistance may be decreased by a factor of 1,000 or more. When the power is suddenly increased from one value to a higher value the resistance begins to decrease rapidly at first and then more and more slowly until it approaches its steady value. When a voltage is impressed across a thermistor in series with an ordinary low resistance the current starts out at a low value, builds up gradually at first, then more and more rapidly and finally approaches a steady value. There is thus introduced a time delay between the application of the voltage and the building up of the appropriate current. By a suitable design of thermistors and circuits it is possible to vary this time delay from something like milliseconds to several minutes.

A very interesting feature of thermistors is that over a certain range of their current voltage relation they act like a negative resistance, i.e., as the current through the thermistor increases the voltage across the thermistor decreases. This is brought out in Figure 5 which shows a plot of the logarithm of the voltage across the thermistor *vs.* the logarithm of the current through the thermistor. For each point sufficient time is allowed so that the voltage and resistance attain their final steady value. In order

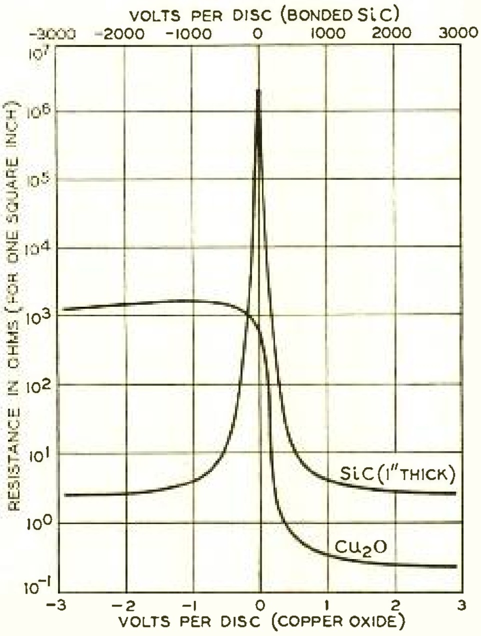


Fig. 4—Comparison of copper oxide and silicon carbide: logarithm of resistance vs. applied voltage

to obtain such a curve, it is necessary to put a stabilizing resistance in series with the thermistor and the source of the emf. For small currents the voltage is proportional to the current and the points fall on a straight line inclined at forty-five degrees. However, as the current increases the points for the steady-value voltage deviate more and more from this straight line. At some particular current the voltage attains a maximum value and for still larger currents the voltage actually decreases. This keeps up for a considerable range but at very large currents it increases with the current.

In a second type of thermistor, the temperature is raised by sending a current through a heating coil. Hence they are called indirectly heated thermistors. The resistance of the semi-conductor is controlled by the current through the heater.

Varistors are small, rather inexpensive, have no filament, need little servicing, have no moving parts, produce no noise, and have a comparatively long life. For these and other reasons, they are being used in the Bell System to an ever-increasing extent. Thermistors are so new in the art that their use in the system is still comparatively small.

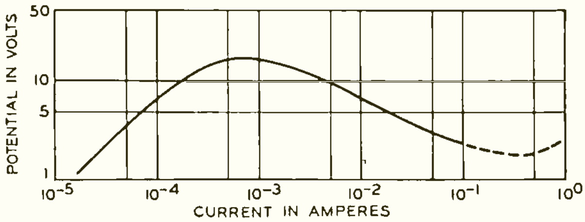


Fig. 5—Logarithmic plot for a directly heated bead-type thermistor

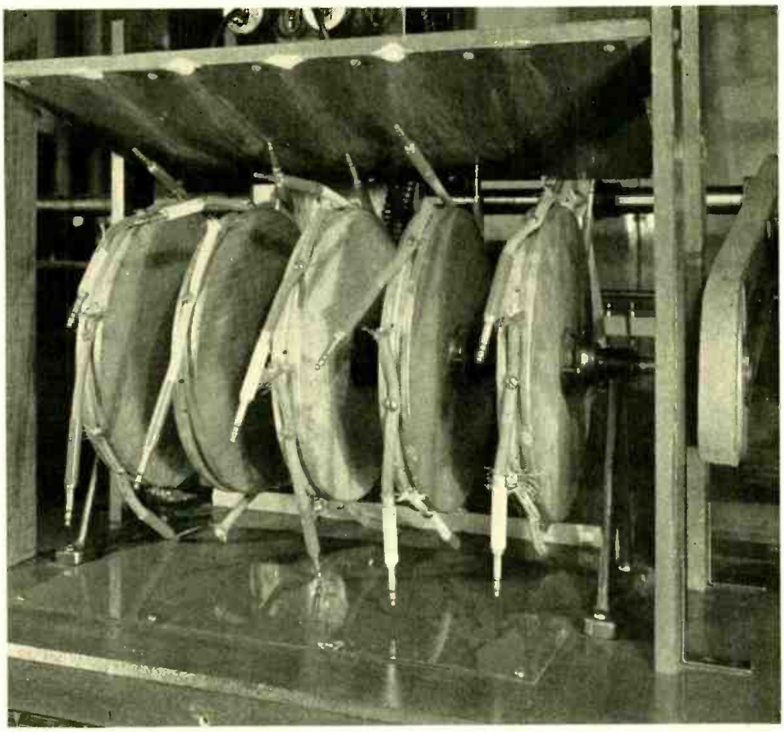
As the name implies, the copper-oxide rectifier is used primarily to rectify alternating current and convert it into direct current. This direct current may be used to charge storage batteries or to operate d-c devices. The rectifying property also finds use in measuring small alternating currents. The alternating current is first rectified and is then passed through a direct-current meter. In the cable carrier and coaxial cable projects the copper-oxide varistor plays an essential part in modulators and demodulators. Here the carrier frequency and voice frequencies are fed into a four-arm bridge, each arm containing one or more copper-oxide discs; because the current-voltage relation is non-linear, modulation products are obtained. Because the resistance decreases rapidly with voltage copper-oxide varistors can be used as low-voltage protective devices. For this purpose two sets of discs are oppositely poled and connected across the load. The number and size of the discs are so adjusted that under normal conditions the resistance of the varistor is large compared to that of the load and very little energy is shunted through it. Under abnormal conditions the resistance of the varistor is comparatively small and most of the energy is by-passed through it. Still another use is that of converting an ordinary relay to a polarized relay by placing a rectifier in series with the relay. In this way polarized message registers for party lines may be obtained.

Silicon-carbide varistors are more applicable where protection against the higher voltages is concerned. Field trials are being made of the silicon-carbide units in association with standard station protection with a view to supplementing the protective features of the carbon blocks in these protectors. Another use of the silicon-carbide varistor is that of shunting it across the terminals of the coil of an electromagnet and thus reducing the voltage induced when the circuit is opened.

Many uses have been suggested for thermistors. The one which is most imminent for large-scale use is that of preventing false operation of the ring-up relay in P.B.X. circuits. If the thermistor is put in series with the ring-up relay, surges on the line are prevented from operating the relay because the energy is absorbed in the thermistor, which under these conditions has a high resistance. When ringing voltage is applied to the line, the thermistor at first has a high resistance, but in a few tenths of a second its resistance is greatly reduced, and the ring-up relay operates.

The indirectly heated thermistor has been used successfully in trial installations as a regulator on type-K carrier on cable and on coaxial-cable circuits. In this case the temperature of the thermistor is controlled by the amplitude of the pilot signal. This temperature determines the resistance of the thermistor which is placed so as to control the gain of the line amplifier. Thermistors also show promise of use as time-delay devices, as sensitive power-measuring instruments at high frequencies, as minute sensitive thermometers and as simple oscillators for audio-frequencies.

The importance of these devices in the communication field has been appreciated for but a comparatively short time. As their possibilities become more widely known no doubt many new applications in the telephone system will suggest themselves.



Testing switchboard plugs for dependability of their inside cord connections by attaching them to rotating drums which cause them to strike violently against a plug shelf at each revolution, thus simulating blows received in service when the plug is dropped and allowed to slide back into the plug shelf

Cables for the J Carrier System

By C. KREISHER
Toll Cable Development

OPEN-WIRE telephone systems require a certain amount of cable for short sections where open-wire construction is not suitable. Cable, for example, is commonly employed for river crossings or other such locations that cannot be economically spanned with open wire. A more extensive use of cable, however, is to bring the open-wire circuits into the central offices or repeater stations when necessary through built-up sections of a city. The development of the J-type carrier system* for open-wire lines has placed very severe requirements on these intermediate and entrance cables because of the high frequencies employed—up to about 140 kc. Not only is the loss and cross-talk of ordinary toll cable high at such frequencies, but matching the impedance of the cable to the open-wire line over the wide frequency band becomes exceedingly difficult.

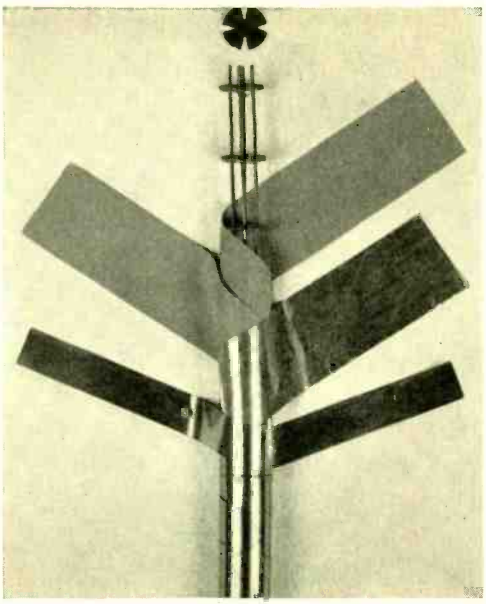


Fig. 1—Spiral-four unit, disc insulated and shielded, designed for short entrance cables

Existing cable, which generally has a capacitance of about 0.062 mf per pair mile, cannot be economically loaded for these high frequencies because the loading-coil spacing would be only about 200 feet, and for underground runs loading coils would have to be installed between existing manholes, which would be very expensive. When the cable circuits are not loaded, however, their impedance differs so greatly from that of open-wire circuits that no simple network can make them match over the whole frequency range. At repeater stations and terminals, however, filters are employed to separate the J carrier frequencies from lower frequencies employed by the C carrier, voice, and telegraph channels. In entrance-cable installations, therefore, it seemed desirable to move these filters to the open-wire end of the cables to effect the separation at that point, and then to use loaded pairs in the existing entrance cable for the low frequencies, and to use non-loaded pairs equipped at the terminals with impedance matching transformers for the J frequencies. To make this possible, filter huts are provided, at the junctions of the cable and open-wire line,

*Record, *April*, 1940, *p.* 226.

to house the filters that have been moved from the repeater station. Balancing panels are installed either in these huts or at some other convenient location to balance out the crosstalk between cable pairs, which without such provision would be severe. Even with these precautions only those pairs in the cable which have low crosstalk with respect to each other can be used, and this method is available only where there are spare pairs in the cable that can be used for the J channels.

For a short entrance cable the cost of a filter hut would become large relative to the cost of the cable, and for intermediate cable there would not only be the expense of two filter huts, but filters also would have to be provided, which means an additional expense that would not otherwise be required. By designing a special cable that would transmit all of the frequencies without filter separation, considerable economies could therefore be effected. Such cable would have to be loaded to match the impedance of the open-wire line, and economical loading at high frequencies calls for low cable capacitance.

For long cable runs, on the other hand, the attenuation with ordinary non-loaded cable pairs would be objectionable, and in extreme situations might be so great as to require the installation of an additional type-J repeater. Under these circumstances again, a special cable is indicated. To meet these new requirements, therefore, two new cables have been developed, one where low capacitance to permit economical loading is the primary requirement, and one where low attenuation of the non-loaded circuit is of principal importance.

To secure low capacitance in a cable, the conductors should be as far apart as possible and the insulation between them should have as low a dielectric constant as possible. With these requirements in mind, the conducting unit shown in Figure 1

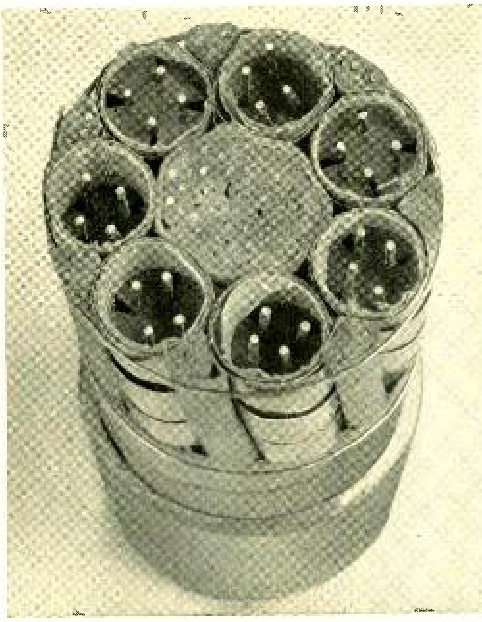


Fig. 2—Seven disc-insulated shielded units are stranded with a number of paper-insulated pairs to form a J system entrance cable

was designed. Four sixteen-gauge copper wires are held at equal distances apart by hard rubber discs like the one shown in the upper part of the photograph. Four radial slots, slightly narrower than the wires, lead to holes of the same diameter as the wire, so that when the wires are snapped into the holes, they are held there. This structure is then twisted so that the wires have a helical lay. The discs are spaced an inch apart, and two overlapping strips of paper are placed over them to form an insulating tube. A strip of thin copper is then wrapped over the paper; over the copper are two strips of thin steel.

With the rubber discs, most of the

dielectric between the conductors is gaseous, so that the dielectric constant is low. The paper serves as a firm base for the thin copper tape, and prevents accidental contact between it and the wires. The copper and steel both act as shields for the mitigation

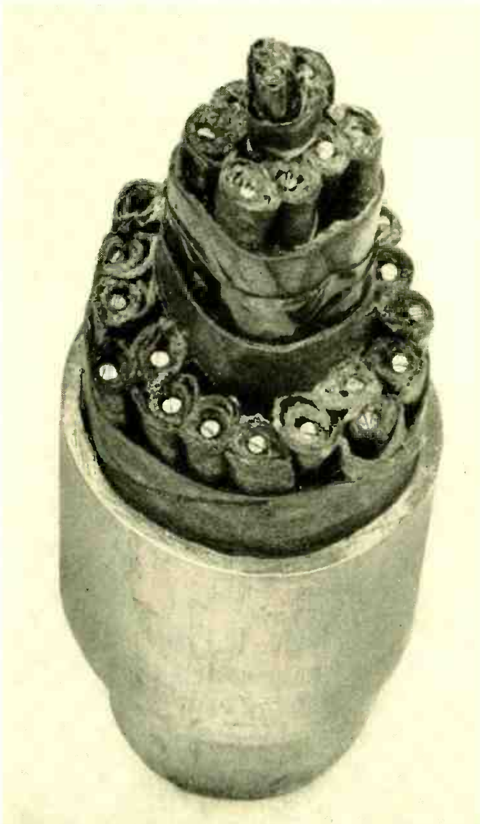


Fig. 3—Fourteen-pair paper-insulated cable used with the J carrier system

of crosstalk or other outside disturbances, and to give mechanical support to the structure. A shield performs its functions in two ways: by reflecting energy and by attenuating it. Copper is more effective in reflecting energy than any other common metal,* but only a relatively thin sheet is required to obtain its full reflecting benefit. The rest of the shielding is best done with steel, which gives a higher attenuation.

In a quad of this type, diagonally opposite wires are used as a pair, and the capacitance depends not only on the dielectric constant of the insulation but on the diameter of the conductors and the ratio of their spacing to the inside diameter of the shield. The smaller the wire the lower will be the capacitance, but the strength and stiffness of the wire is also a consideration. In this particular structure, a fifty per cent reduction in the cross-section of the conductor would result in a decrease in capacitance of only about sixteen per cent, however, and it was decided that this relatively small decrease did not warrant the use of conductors smaller than 16 gauge. To secure minimum capacitance, the ratio of conductor spacing to inside diameter of shield for a shielded quad is about 0.49, and this ratio was used in the design. A capacitance of 0.025 mf per mile was secured and, non-loaded, an attenuation of 1.9 db per mile at 140 kc, while for an ordinary 19-gauge toll cable, the capacitance is 0.062 mf—2 to 3 times as great—and attenuation at 140 kc is between 5 and 6 db.

The actual inside diameter of the quad was set at 0.66 inch, because this is the largest diameter that will permit seven quads and a group of paper-insulated circuits to be placed inside a full-sized cable, which has an inside sheath diameter of 2⅜ inches, as shown in Figure 2. Seven quads, or fourteen pairs, are required for the maximum number of J systems proposed for a single open-wire line. The paper-insulated group may be used for the non-J open-wire pairs. One-quad disc-insulated lead-covered cables are also used for lead-in cables

*Record, *March*, 1936, *p*. 229.

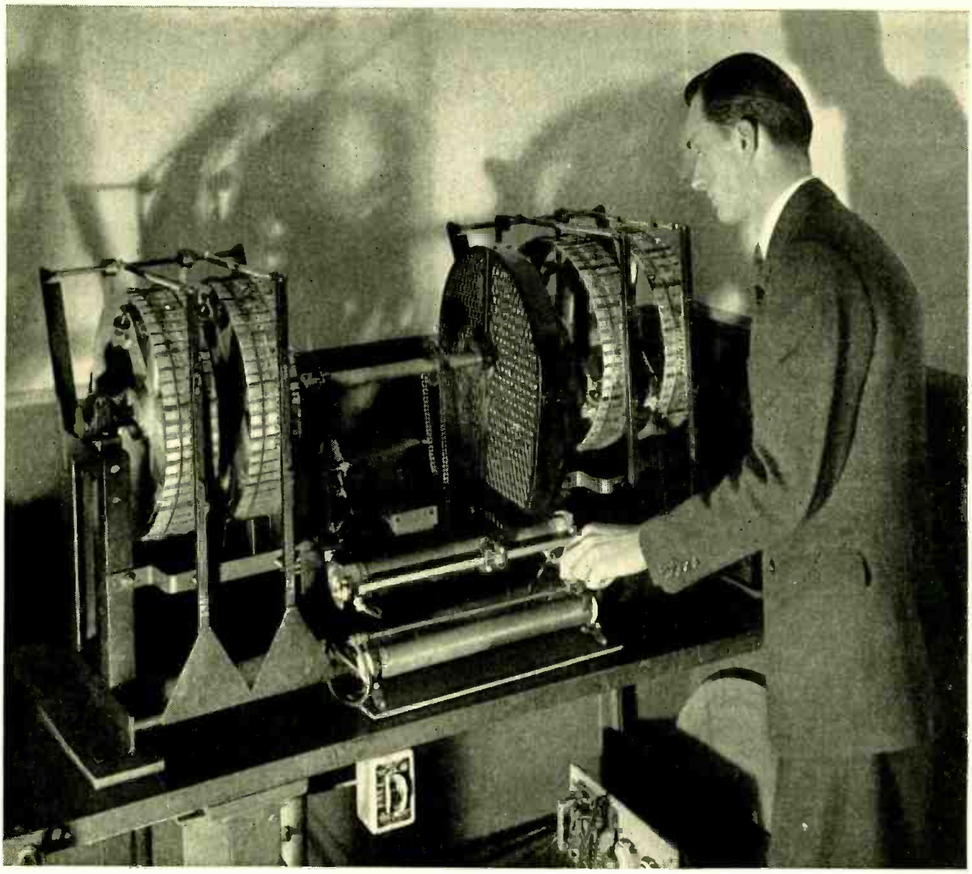
at auxiliary repeater stations. Here again loading is employed to match the open-wire impedance.

Although the electrical characteristics are controlling, the development of a radically new cable structure of this kind involves numerous mechanical problems, both in the manufacture of the cable and in adapting it to withstand the bending and handling of installation procedures. Many samples had to be tested, and finally trial lengths had to be manufactured and installed for final study and test before a satisfactory design was secured.

With a long entrance cable, it is generally more economical to use a filter hut at the junction with the open-wire line than to use disc-insulated loaded cable, particularly since suitably loaded pairs for the lower frequency services are usually available. Under these conditions, the capacitance of the cable used for the type-J entrance is not so important, but because of the length of the cable, it is desirable to keep the attenuation low. Shielding also is of less importance because the cost of installing and adjusting balancing units to balance out the crosstalk is small compared to the total cost of the installed cable. The requirements for a long entrance cable are thus considerably different from those for a short cable. The crosstalk should be low and the impedance uniform to simplify the crosstalk balancing, and the attenuation should be as low as can be economically obtained.

Studies indicated that for cable of this type, paper-insulated pairs without individual shields would be economical. The size of the conductor and diameter of insulation could not be calculated as readily as with the disc-insulated cable and were therefore determined empirically. As with the disc-insulated cable, it was desirable to get fourteen pairs within a standard full-size sheath, and this determined the space available per pair. From tests on a series of experimental cables of various gauges and capacitances, it was found that 10-gauge pairs insulated to occupy this space would best meet the requirements. To simplify the balancing, it is desirable to have the product of inductance and capacitance constant, which means that the characteristics of the cable should be uniform from length to length, and accordingly the insulation on each conductor must be firm to hold the inter-conductor spacing uniform. A special multi-strip insulation was developed for this purpose.

Four pairs are laid together in the center, and ten pairs are placed around them, as with any fourteen-pair cable, but a copper tape shield is used to separate the inner four from the outer ten pairs. This practically eliminates a great many of the crosstalk paths, and greatly simplifies the balancing. Although the attenuation of this cable, shown in Figure 3, is slightly greater than that of the disc-insulated cable, its cost is considerably less. Having both types of cable available makes it possible for the engineer, in planning applications of the J carrier system, to select at each point where cable is required the type best adapted to the local conditions.



Improvements in Drop Wire

By F. F. FARNSWORTH
Outside Plant Development

DROP wire is usually the last connecting link to be installed between the central office and the subscriber. The more permanent parts of the distribution system, such as underground and aerial cable or possibly open wire, have all been placed before the familiar "drop" is run from pole to house. Where possible, the drop is installed in the clear but contacts with trees or other objects are not always avoided, particularly when the wire sways in the wind. The drop is exposed at all times directly to the weather and to mechanical damage of widely varying nature. There are over eleven million such drops now in use in the Bell System, and their average overall length is about 190 feet.

The service life of a station drop is considerably shorter than that of the permanent distribution plant because of continuing migration of subscribers and service changes. Approximately 300 million feet of drop wire are added each year as new wire. Drop wire must, therefore, remain a relatively low-cost item, in spite of the severe service conditions to which it is subjected. It must also be strong and rugged while kept down in size and weight to facilitate installation.

The first drop wire supplied as a single unit to replace open-wire drops was a 14-gauge twisted pair of hard drawn copper conductors to provide the mechanical strength for installation in spans. Each conductor was separately insulated with a heavy wall (.040 inch) of rubber compound braided and weatherproofed. This large and relatively expensive wire was used exclusively for drops until 1910 and is still in considerable demand for special purposes such as for storm repairs, very long drops, and emergency circuits for toll open-wire lines. From 1910 to 1931, drop wire evolved through several stages and emerged finally as a duplex-extruded type with two parallel wires of 17-gauge, 1¾ per cent tin-bronze under a common braid. During this period a much smaller, better appearing drop wire which had mechanical strength equal to that of its bulkier predecessors was developed by using small high-strength conductors, first of copper-clad steel and later of tin-bronze, with thinner walled (.028 inch) and greatly improved rubber insulating compounds. The substitution of more durable weatherproofing compounds for the waxy materials formerly employed also added greatly to the weather resistance of the new wire. For nine years this parallel type 17-gauge "BP" drop wire has remained the Bell System's standard except for severe tree conditions where specially designed wires with greater resistance to abrasion are required.

As field reports become available relating to failures which can be traced to certain features of wire design, the emphasis on development effort is shifted to correct these faults. Several years ago, the crushing strength and stability of the insulating compounds required major attention to minimize insulation failures at points where the wire was tightly squeezed in clamps or at other attachments. Such failures have now been largely eliminated but three types of drop wire service failures still result in annual maintenance charges which bulk uncomfortably large. Tree abrasion failures account for more than one-third of all maintenance expense, while loss of adhesion between insulation and the conductor and the cracking of insulation by sunlight penetrating through openings in the braid also contribute to a lesser extent.

Development work directed toward minimizing drop wire failures from these three sources has made possible the introduction of a new standard drop wire. Fortunately, since first cost must continue to play a part in determining the suitability of the product, advances in the technique of non-ferrous metal casting and wire drawing made available a three per cent tin-bronze conductor as strong in 18-gauge size as was the previously used 1¾ per cent bronze in 17-gauge, and with electrical conductivity adequate for its use in drop wire. The cost advantages which result from this saving in metal have played a large part in building into this newcomer its greater durability at no increase in price.

In the new drop wire, designated TP, to differentiate it from the former standard BP wire, the hot dip tin coating usually applied to the conductor has been replaced by a new composite

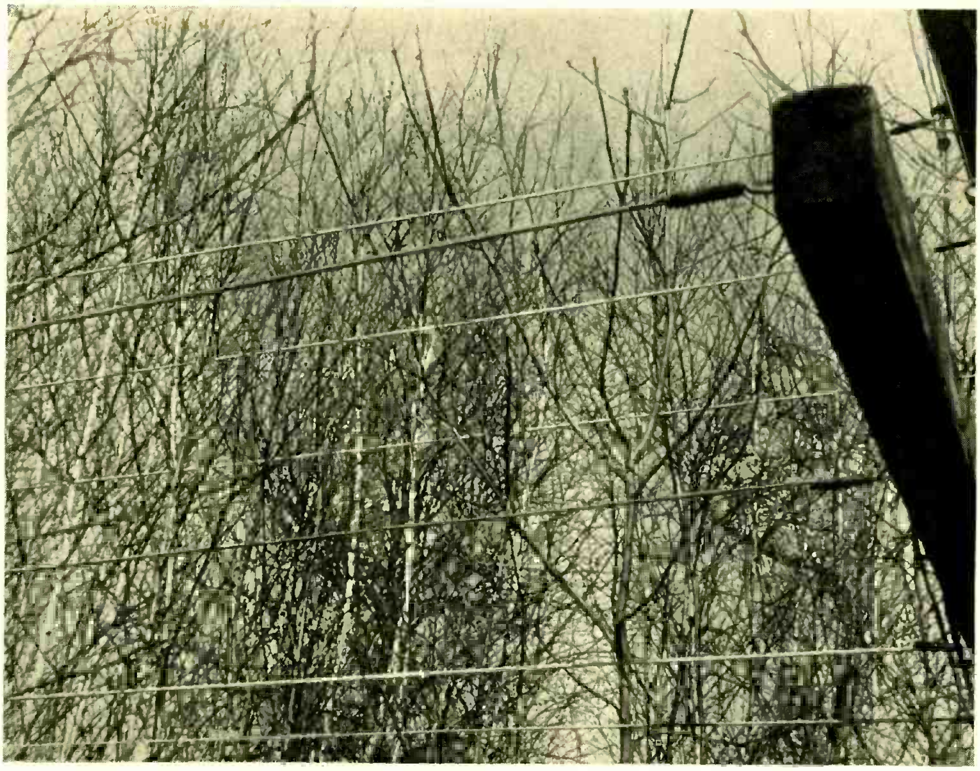


Fig. 1—Drop wire is tested for resistance to abrasion by running it through birch thickets at the Chester Field Laboratory

coating. This new conductor coating was developed to serve the double purpose of providing an inert barrier between the conductor and the rubber compounds and of presenting to the insulation a surface to which rubber will adhere firmly over long periods of time. Experience with the tin coatings showed them to give satisfactorily high initial adhesion but this dropped to unsatisfactorily low levels, particularly in warm humid weather. In marked contrast, the composite coatings now standard have exhibited steadily increasing adhesion over a considerable period of time. This enduring adhesion adds to the performance of the completed drop wire at clamps and other attachments, improves the crushing strength of the insulation, facilitates precise skinning at terminations and permits the re-use of wire which otherwise might have become unsuitable because of loss of adhesion.

Compressive strength and aging characteristics of the rubber insulation have been improved so that a somewhat thinner insulating wall than that standard for BP could be employed on the new TP wire with no sacrifice in those properties. The reduction in size of conductor from 17 to 18 gauge and the slight reduction in insulation thickness permitted the use of a cotton braid almost twice as heavy as was previously employed without increasing the size of the finished wire. The introduction of a new wire of overall size or shape different from the old standard would have complicated field installation practices, particularly so long as much of the older design remains in service in the plant.

Resistance to cracking of the insulation when exposed to sunlight has been greatly increased. The insulation of BP drop wire will crack through to the conductor in a relatively short time if the braid is removed and the insulated conductor wound about itself into a small helix, or otherwise sharply bent, and exposed to summer sunlight, but the new insulation under similar severe exposures exhibits only slight surface attack over long periods. Field experience to date, particularly in coastal areas, has shown the greater ability of the insulation to withstand sunlight without cracking to be particularly helpful in minimizing drop wire failures which result from electrolytic corrosion of the conductors at points where cracks in the insulation have occurred.

Another important improvement incorporated in the new drop wire is the cotton covering and weatherproofing applied over the insulated wire to provide protection from sun and rain and tree abrasion. The new cotton braid is nearly twice as heavy, in pounds of cotton per thousand feet of finished wire, as the braid of the 17-gauge drop wire and the amounts of asphalt saturant and stearine pitch finish taken up by the heavier braid are increased. The savings realized from the use of the smaller conductor have permitted these important steps to be taken without any price increase.

The performance characteristics of the new wire have been determined in the laboratory, checked under severe tree conditions at the Chester Field Laboratory, and checked further by general service trials. In the laboratory, the resistance to abrasion of short samples of the finished wire is determined by the abrasion machine shown in the headpiece. Here the wires are mounted in slots on the periphery of the rotating drums and rubbed against slotted hardened steel abraders until braid failures occur. A large number of wires of both types were also installed in birch thickets on the grounds of the Chester Field Laboratory under exposure conditions as severe as are likely to be encountered in service. The multitude of tree contacts provided by these thickets and the severe wind conditions in this area made possible quite satisfactory confirmation of laboratory results. These tests demonstrated that the new TP drop wire was roughly two and a half times more resistant to tree abrasion than its predecessor.

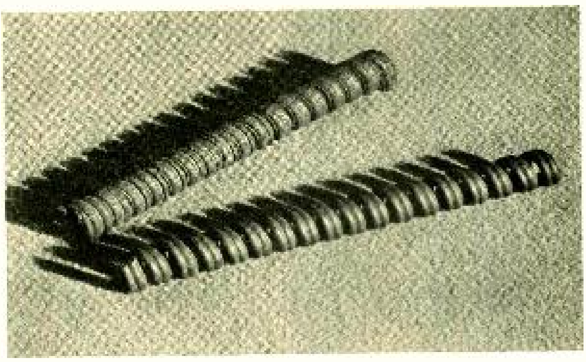


Fig. 2—The new TP *drop wire is much more resistant to cracking, due to sunlight, than the* BP *type formerly used*

Apart from their greater abrasion resistance, the heavier braid and the greater quantities of weatherproofing materials taken up by it have increased the weather protection offered to the underlying insulation in approximately direct proportion. Where wires are sharply bent, the heavy braid shows less tendency to open and expose the insulation to sunlight. It has been anticipated that this latter improvement, together with the more light-stable insulation, will be reflected in improved performance of drop wire in coastal areas to a degree comparable to that already discussed for areas where tree abrasion constitutes the major hazard.

Recent rapid strides in the development of knitted cotton covers as replacements for braid and of a wide variety of new and promising synthetic insulating and weatherproofing materials point toward drop wire designs which promise to achieve even more in resistance to abrasion and to weathering than has been realized in the new TP drop wire.

Television for National Republican Convention

THE National Broadcasting Company broadcast television scenes from the National Republican Convention in Philadelphia beginning June 24. The television signals from the pickup apparatus in Convention Hall in Philadelphia were transmitted over cable circuits to the NBC television studio in Radio City, New York. The Bell System provided facilities for this cable transmission.

For the major part of the distance, from the Long Lines testroom in the Bourse Building in Philadelphia to Bell Telephone Laboratories in New York City, the coaxial cable was used. This cable was equipped by the Laboratories for transmitting television signals, including those used by the National Broadcasting Company. This required the provision of amplifiers at five-mile intervals that transmit frequencies up to about three million cycles, and equalizers that maintain proper strength of all the frequencies within this very wide band as well as equal times of arrival within a small fraction of a millionth of a second.

Besides equipping the coaxial cable, it was necessary to arrange for transmission between Convention Hall and the Bourse Building in Philadelphia, and between the Laboratories and Radio City in New York. For these shorter distances regular cable pairs were used, as was done for recent television transmission from Madison Square Garden to Radio City. Such circuits do not transmit television signals as readily as does the coaxial cable, and amplifiers are needed at approximately one-mile intervals. In New York City a new type of cable was installed to link the Laboratories with Radio City. This new cable has the advantage of requiring no intermediate amplifiers for the distance involved.

For the two cable runs at each end of the coaxial cable, it was simplest to transmit the signals just as received from the television camera, the so-called video signals, extending from a few cycles per second up to several million. For most satisfactory transmission over the long length of coaxial cable, however, it was desirable to eliminate the lower range of frequencies, and to accomplish this, special equipment was provided at Philadelphia to raise the frequency band by about 300,000 cycles. Corresponding equipment was provided at the Laboratories to bring the signals back to the video range.

A Signalling System for Intertoll Dialing

By H. A. SHEPPARD
Toll Facilities Department

UNTIL recently most long-distance traffic has been handled over what are known as ringdown trunks. At each end these terminate in jacks at the toll board, and either operator may signal the other by sending a spurt of alternating current over the trunk by operation of a ringing key. With the usual operating practice, the outward operator plugs into a trunk going to the desired point, and operates her ringing key to attract the attention of the inward operator. When the inward operator answers, the outward operator passes the called number to her, and then listens on the line until the connection has been completed so that she can begin timing the call. Each operator receives a disconnect signal when the subscriber at her end of the line hangs up, and each then pulls out her plug. Although signals can pass in either direction over the line, there is no occasion for them to pass in both directions at the same time, and if signals should be started in both directions simultaneously,

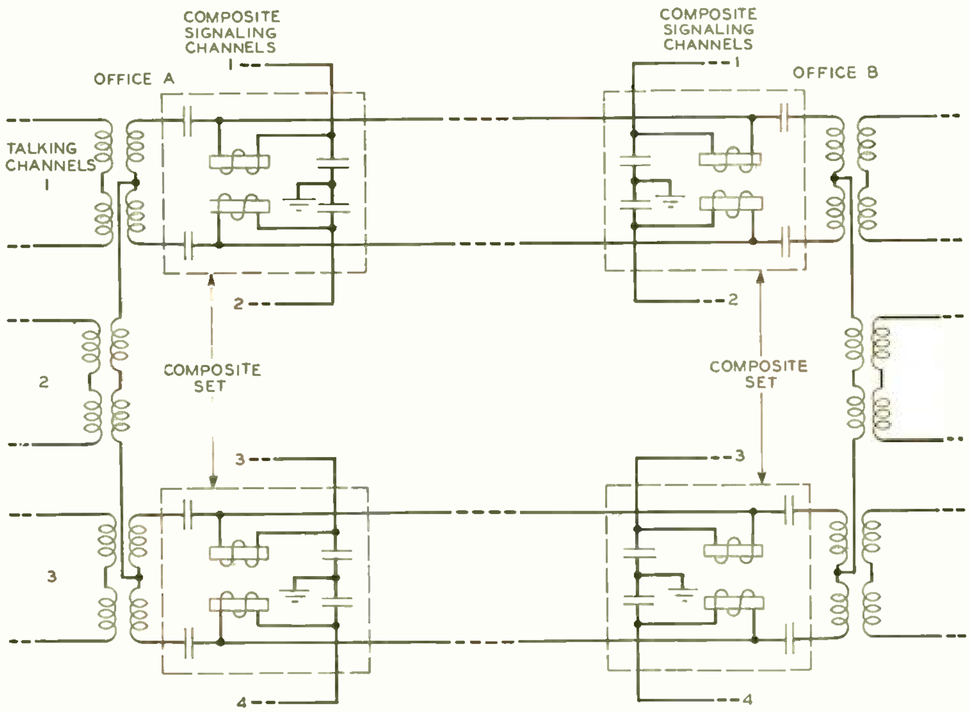


Fig. 1—Simplified schematic of a composited phantom group, showing the derivation of four signalling channels

they would probably interfere with each other.

When these trunks are to be arranged so that the outward operator may dial over them, and select a dial subscriber at the distant end without the aid of an inward operator, as described in an earlier article,* this simple signalling system is not adequate. In the first place the ringdown signalling system is too slow to transmit dial pulses and supervisory flashes because of the use of slow relays, which have been found necessary to protect the system against false operations on voice and interference. Moreover, it is necessary to make the system fully duplex, that is, so that signals may be sent in both directions simultaneously.

Since most of the toll lines operate over phantom groups, each two physical circuits providing a third—or phantom—circuit, it seemed desirable to provide signalling channels by compositing, which is the method used to apply d-c telegraph circuits to such phantom groups. D-c signalling circuits capable of operating over such channels are already in use with certain short-haul dial tandem trunks, and also for some grounded telegraph, and these were studied with possible adaptation in view. For one reason or another, however, none of them was suitable for our purposes, and a new system was developed.

The arrangement which permits d-c signalling on a composited phantom group is as shown in Figure 1. The two physical circuits, known as the side circuits, have repeating coils at each end, and the third, or phantom circuit, is derived by connecting the third repeating coil at the mid-points of the repeating coils of the two side circuits. The composite set derives four d-c signalling channels from the two side circuits by sets of retard coils and condensers. These form a filter to keep the d-c and low frequencies out of the voice circuits, and the voice out of the signalling channels, but d-c signals may be transmitted independently over each wire of the physical circuits. In this way four d-c signalling channels are derived for each

*Record, *May*, 1940, *p.* 266.

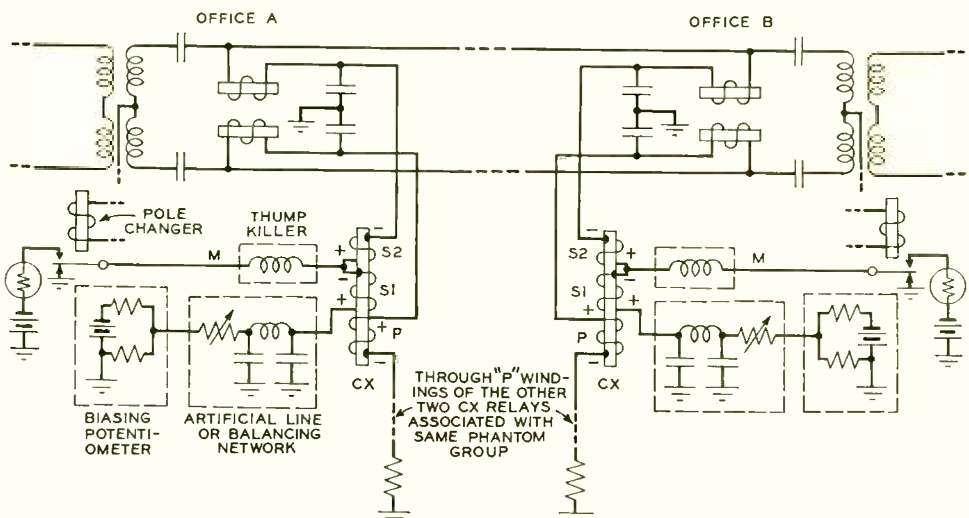


Fig. 2—Arrangement of composited signalling circuit for one voice circuit

phantom group. This gives a signalling channel for each side circuit and the phantom, and a fourth that may be used to neutralize differences in ground potential at the two ends of the line.

For signalling and pulsing purposes, each circuit of the phantom group is provided with a CX relay at each end of the line, arranged as shown in Figure 2. These relays have three windings, but one of them is employed for ground-potential compensation and need not be considered in the explanation of the signalling circuit itself. The two signalling windings S1 and S2 have the same number of turns and are connected differentially. One is connected to the composite signalling channel and the other to a biasing potentiometer through an artificial line, which has characteristics approximately the same as the line itself, so that current builds up and decays in the two windings at the same rate. The other ends of the two windings are connected together and to a lead, marked M, to the armature of the pole-changing relay, which is used for signalling and pulsing. The

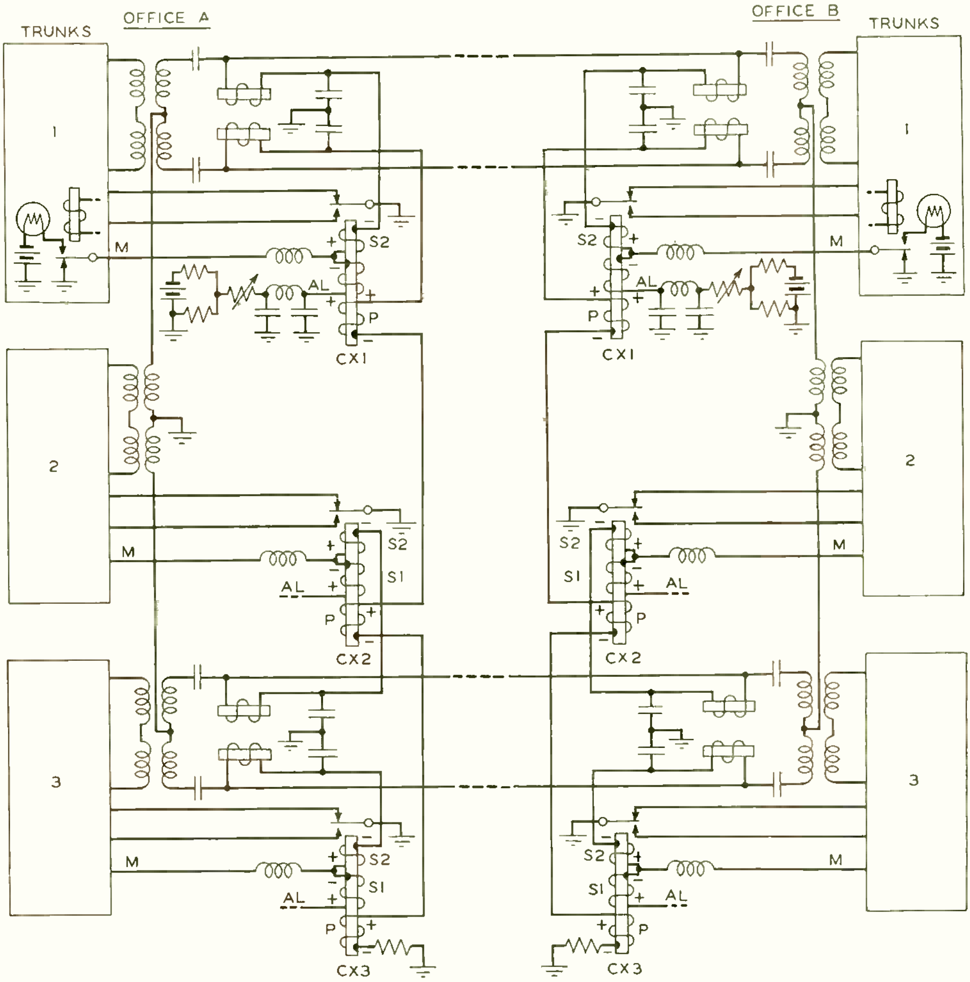


Fig. 3—Composited signalling and pulsing circuit for a complete phantom group

"thump killer" shown in the M lead in the diagram prevents the signal and dial pulses from affecting the telephone circuit.

Suppose, now, that a call is made from office A. Before the operator plugs into the intertoll trunk, current flows from the biasing potentiometer through the artificial line and the S1 winding to ground at the pole-changing relay. This biases the CX relays to their released positions. When the operator plugs into the intertoll trunk at office A, current flows through her pole-changing relay and operates it. This causes current to flow in the S1 winding of her CX relay in the opposite direction and tends to operate the relay. It also flows in the S2 winding, tending to release the relay; and because the voltage at the biasing potentiometer is higher than ground, the current through S2 is enough greater than that through S1 to hold the relay released. The current in the S2 relay flows out over the upper wire of the line, however, and through the S2 winding of the CX relay at office B. Here, because of its greater value, it overpowers the effect of the current in the S1 winding, and operates the relay. The operation of the relay, in turn, causes other relays not shown to prepare the selector for dialing.

When the operator starts to dial, her dial alternately makes and breaks the current to her pole-changing relay. Whether the pole-changing relay at office A is released or operated, the CX relay at this office will remain released, in one case because of the current in S1, and in the other because the current in S2 is greater than that in S1. The CX relay at office B, however, will operate and release with the pole-changing relay at office A as already described. This operates the selectors at office B and selects the desired line.

The full duplex action of this signalling system can now be illustrated

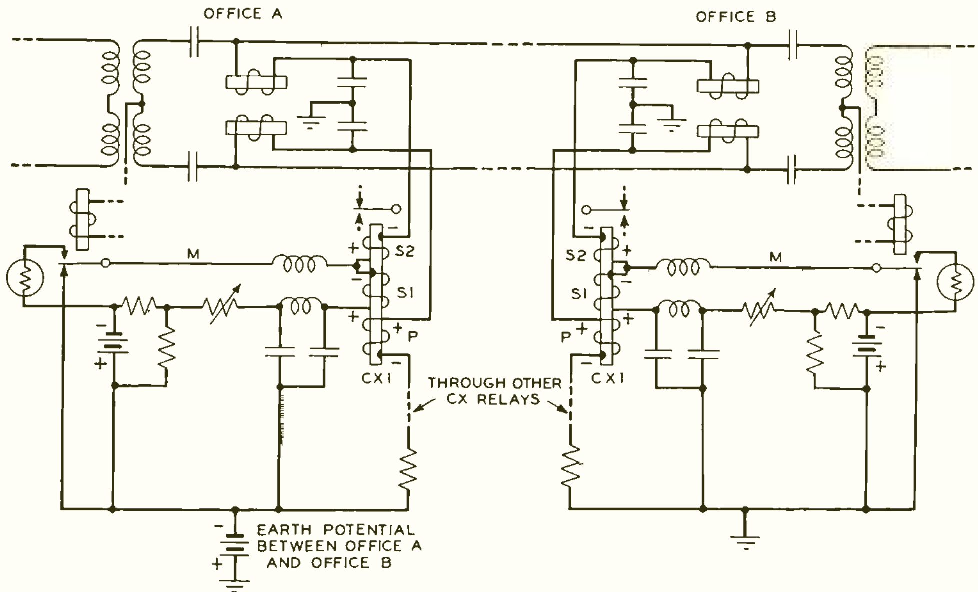


Fig. 4—Simplified schematic showing the effect of a ground potential difference on the signalling circuit

by the subscriber-answer signal returning against the correct signal, which continues to be applied at office A as long as the plug is in the jack. When the subscriber answers, a signal is returned by office B, which requires the operation of the cx relay at office A without releasing the cx relay at office B. The answer signal at office B will operate the pole-changing relay there, causing an operating current to flow in its s1 winding. Since the two s2 windings are now in series to battery at each end of the line, no current will flow in them. The cx relay at office A thus operates by the current through its s1 winding, and the cx relay at office B remains operated, the operating current in s1 taking the place of the previous operating current in s2. Another illustration of full duplex operation over the system would be on a disconnect against a flashing busy signal.

The connections for the complete phantom group are shown in Figure 3. Trunk 1 uses the upper wire of the upper physical pair for signalling. The phantom trunk uses the upper wire of the lower physical circuit, and the third trunk uses the lower wire of the lower pair. This leaves the lower wire of the upper pair available for ground potential compensation. The connection from this wire is carried in series through the third, or P, winding of each of the cx relays to ground. The P winding has the same number of turns as the s2 winding, but is oppositely poled and has only 1/3 its resistance. The three P windings together thus have the same resistance as an s2 winding. The effect of a difference in ground potential at the two ends of the line is the same as inserting a battery between the ground terminals and ground at one end of the line.

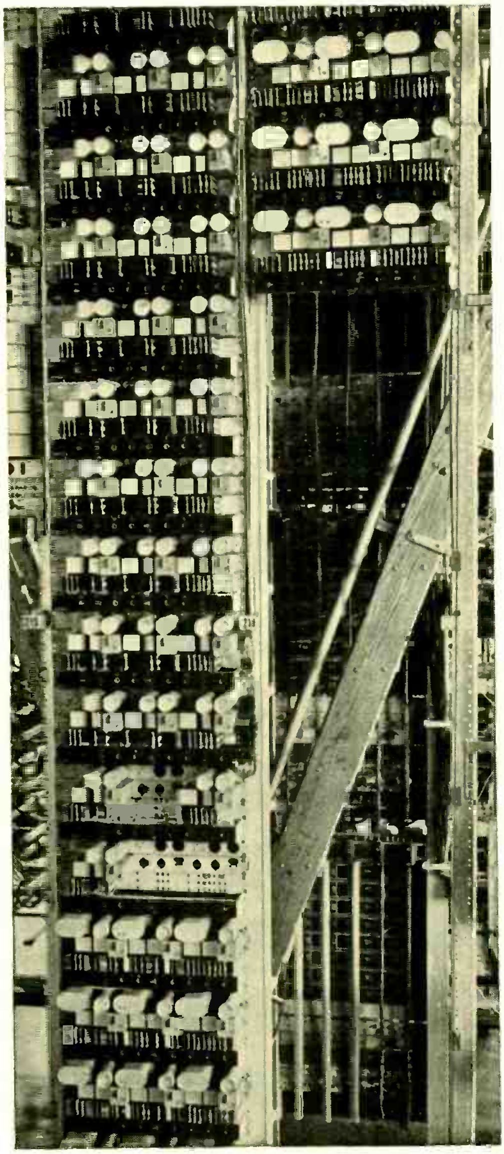


Fig. 5—Composite signalling units in Springfield, Ohio

This is illustrated in Figure 4, where a battery is shown in the ground lead to represent the difference in ground potentials between the two offices. First consider what would happen with the added ground potential difference if there were no P winding on the cx relay. With a potential as shown in Figure 4, the current through the S1 windings at both offices would be unaffected because the added potential is outside of these circuits. A current however, which did not exist before would flow through the S2 winding via lead M and the line. This current would bias the CX relay at office A further in the release direction but since this relay is already released, no false signal occurs at office A. At office B this is an operating current, and if great enough would overpower the S1 winding and operate the relay, causing a false signal. Had the voltage been in the opposite direction, there would be no false signal created at office B, but one would occur at office A.

With the P windings in the circuit, however, the effect of the added current flowing through the S2 windings and the line would be offset by that flowing through the P windings, since these windings are equal in number of turns and oppositely poled to the S2 windings. The P circuit uses the lower wire of the upper pair of Figure 3, and thus has the same line resistance as the S2 winding, and each of the P windings has ⅓ the resistance of the S2 winding so that the total winding resistance in each circuit is the same. The current through the P and S2 windings due to this ground potential difference is thus the same, and since their effects are opposite, there is no net result. Under ideal conditions this arrangement is effective regardless of the value of the ground potential difference. Since on an actual line there may be differences in the leakage to ground of the different wires, however, effective differences in potentials might exist. As a result, this compensating circuit may not be satisfactory where very high ground potentials may exist.

Since some of the trunks that may be used for intertoll dialing are already equipped with composite sets, to provide telegraph channels as needed, the signalling unit itself is built up to include only the CX relays and the various condensers and resistances needed. These units are assembled and wired in the shop on panels arranged for relay-rack mounting, and each includes the equipment for one phantom group. A group of units installed in Springfield, Ohio, is shown in Figure 5. The strip of jacks at the bottom of each unit is for testing and maintenance purposes.

While the features of the new composite signalling circuits have been described only in connection with intertoll dialing, it should be understood that their use is by no means limited to this field. As a matter of fact many of them are now operating on community dial office trunks.

F. J. Scudder and J. N. Reynolds Receive Award

For the paper entitled Crossbar Dial Telephone Switching System, *F. J. Scudder and J. N. Reynolds have been awarded the* 1939 *prize for "Best Paper in Engineering Practice" by the American Institute of Electrical Engineers. The paper was presented at the* 1939 *winter convention of the Institute. A paper by B. W. Kendall and H. A. Affel,* A 12-Channel Carrier-Telephone System, *also presented at the same convention, received honorable mention.*

Sound Tests of Telephone Ringers and Dials

By N. R. STRYKER
Electromechanical Development

A TELEPHONE, like a good servant, should always be ready to serve but never intrude; the sound of the ringer ought to be just loud enough to arrest attention and the dial should operate with little noise. These requirements make it desirable to have testing means which are more accurate and reliable than the human ear. The test equipment must measure correctly the total sound energy radiated from the set and the results must not be influenced by noises in the laboratory or factory where the tests are to be made.

To meet these needs the Laboratories has developed an apparatus for testing combined telephone sets. The set is located inside and at one end of an irregularly shaped box, none of whose walls are parallel but which are sound insulating and acoustically hard. At the other end of the box there is a microphone and between them are a group of irregularly shaped vanes on a rotating plate. These vanes and the irregular walls of the box insure many reflections which reduce the effects of variations in the sound radiated by the set from moment to moment. They also tend to equalize the effects of the different frequencies that are obtained with the various ringers.

The microphone output is rectified after amplification and read on a meter. The amplifier with its graduated attenuator measures a wide range of sound levels. It also responds uniformly to frequencies from 1,000 to 10,000 cycles or more, to cover the range of the ringer. A high-pass filter which cuts off at 1,000 cycles is included in the circuit to eliminate

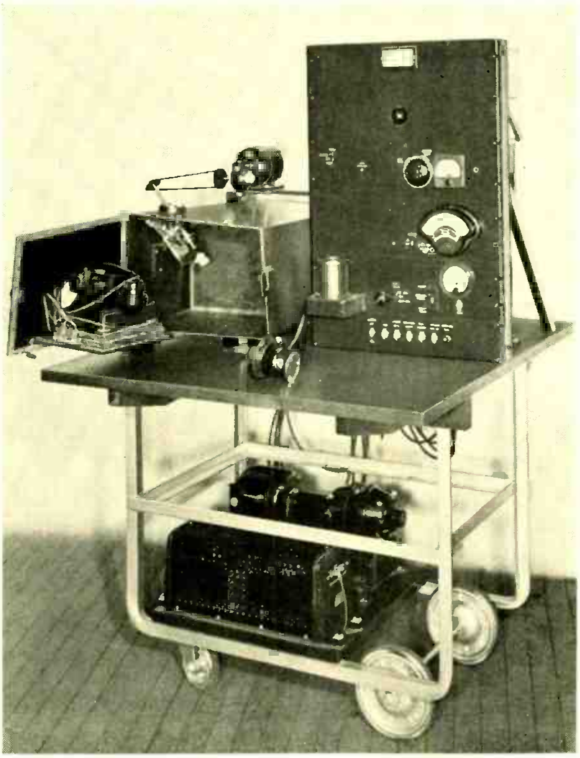


Fig. 1—The sound of ringers and dials is measured by operating them in a soundproof box which encloses a microphone. To make the sound field more uniform vanes are rotated in the box and the box is so designed that no two of its walls are parallel

sounds of low frequency not originating in the telephone set. The amplifier operates from alternating-current service mains through a voltage regulator to prevent variation in sensitivity of the measuring equipment.

The telephone set is mounted on a shelf attached to the door of the box, shown in Figure 1, to make it accessible when the door opens. The microphone, shown in the foreground, is mounted at the rear of the box when in use. On the rack at the right is the rest of the measuring apparatus; the oscillator panel with the microphone calibrating chamber is immediately above the switching panel and the amplifier, meters and attenuators are mounted above the oscillator. A motor generator set on the lower shelf supplies ringing current and a voltage regulator to control the alternating voltage supplied to the amplifier and oscillator.

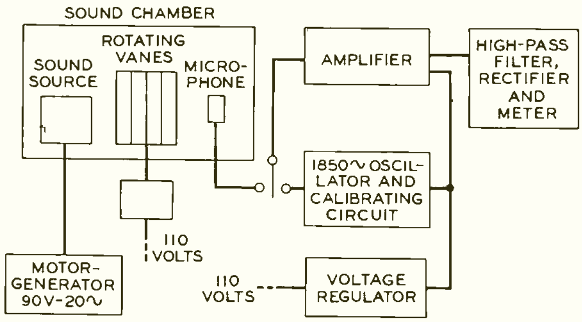


Fig. 2—Diagram of the apparatus used in making sound tests on telephone ringers and dials

To measure dial noise the apparatus is equipped with an automatic dial-winding mechanism, shown at the upper left side of the box. This mechanism has a shaft with a rubber ring on the end, which is coaxial with the dial when the door of the box is closed. A cam arrangement presses the rubber ring against the face of the dial long enough to permit winding; then the shaft retracts and allows the dial to return to normal. This winding and retracting operation is repeated automatically by the motor on top of the box. The operator determines when the dial is being wound and unwound by the sounds in a telephone receiver in the amplifier circuit and thus associates these operations with the noise indicated on the meter. For testing dials whose sounds are considerably lower in intensity than those of ringers, the box is mounted in a sound-attenuating housing to further exclude outside noise.

To check the sensitivity of the microphone, the amplifier, and the meter, a fixed-frequency oscillator operated from the alternating-current mains supplies 1850-cycle current. The apparatus is calibrated by coupling the microphone to a calibrated telephone receiver located at the bottom of the cylindrical box at the left of the oscillator panel.

Test sets like the one described here have been used to measure the performance of telephone dials and ringers in the Western Electric shops as well as in the Laboratories. They have been helpful in arriving at the final design of the combined-set housing and base and in working out modifications of the ringer to insure sufficient sound output. These measuring sets are also used in investigating methods of generating ringer sounds, in improving ringer gongs and ringer motor mechanisms, and as a guide in modifying telephone dials to reduce dial noise. In the factory they have been found useful in locating imperfections of manufacture and in checking the performance of ringers and dials to assure uniformity.

Photo by H. Kahl

Alarm System for Auxiliary Repeater Stations

By V. E. ROSENE
Switching Development

OVER the existing network of long-distance telephone cables, conversations are transmitted at audio frequencies and repeaters are provided at about fifty-mile intervals. Much higher frequencies are used in the type-K Carrier Systems* designed for use over the same cables, and hence repeaters are required at shorter intervals. Usually between each of the existing stations two repeaters are required; they have been designed for unattended operation with maintenance by men sent out from a nearby station.

Adequate provision had to be made, therefore, for giving alarms at a main repeater station, where a maintenance force would be always available, whenever situations that threatened continuity of service arose in the auxiliary stations. Repeater stations of the auxiliary type had already been used in a few instances on voice-frequency cables, and an alarm system to protect them had been developed. With the more extensive use of such a system that the advent of the K carrier foreshadowed, it seemed desirable to modify the existing system so that it could be used for either voice or K carrier channels. When work started on the J carrier system for open-wire lines, which would also use auxiliary repeater stations, the requirements of this system were also considered, and the alarm circuit was arranged so that it could be used with minor modifications wherever auxiliary repeater stations were required.

This new alarm system divides all types of trouble into not more than ten classes, and gives a distinctive

*RECORD, *April*, 1938, *p.* 260.

alarm for each class. This division into classes is based on the type of action and promptness of attention needed. It enables the maintenance force to know whether immediate attention is necessary. When power fails at the auxiliary station, for example, the load can be carried for some time by the battery alone. Failure of power, therefore, would not require any action at the moment, but the subsequent dropping of the battery voltage below some established value would require immediate attention.

The alarm equipment and the method of operation is essentially the same whether the station is for voice-frequency or J or K carrier channels, but the method of transmitting the alarm over the line differs. With the cable system, the signals are ordinarily transmitted over the two wires of a 19-gauge pair. The range of transmission is about sixty miles, but this distance may be extended by paralleling pairs to reduce the resistance of the line circuit. On the open-wire lines, because of the need of the d-c facilities for telegraph use, a single wire and ground are used to transmit the signals. Since the open-wire conductors are much larger than the cable conductors, the range of the alarm system is greater, varying from 150 to 250 miles depending on the gauge of the conductor.

At both main and auxiliary stations the alarm system employs a ten-point rotary selector with two banks of contacts to permit indication of the class of trouble. Both of these selectors are operated by an interrupter circuit at the main station, and each step of one bank of both selectors is associated with a lamp to indicate the class of trouble. Occurrence of trouble at the auxiliary station grounds a circuit that puts the alarm circuit in operation. The selectors at both stations start to rotate, and as soon as they reach the point corresponding to the class of trouble, a lamp at the main station lights and a circuit to a corresponding lamp is set up at the auxiliary station, but the lamp is not lighted until the maintenance man arrives and presses a key. This avoids unnecessary drain on the battery at the auxiliary station, which might be of importance under some conditions. Control of the selectors from one end only insures that they are always in step; and with this control located in the main station, there is no danger of signals being transmitted over the wires before the receiving apparatus at the main station is ready to receive them.

Such a system requires that signals be sent both from the auxiliary to the main station, and from the main to the auxiliary station. When an alarm condition arises at the auxiliary station, a signal is sent to the main station to start the interrupter circuit, and also to give an audible signal to indicate that trouble has arisen. The main station then sends signals back to the auxiliary station to rotate the selector there, and at the same time it rotates its own selector. When the selector at the auxiliary station reaches the point corresponding to the class of trouble that has arisen, a signal is sent to light the individual indicating lamp at the main station. At the same time a circuit is established to the corresponding lamp at the auxiliary station. This does not interrupt the return of signals to the auxiliary station to control the rotation of the selector, which continues until all ten steps have been passed over. If more than one class of trouble has arisen, each will be signalled to the main station as that step of the selector is reached. At the eleventh pulse from the main station, the selectors at both stations are released, and at the breaking of the pulse the circuits are reëstablished in their normal condition except that the indicating lamp remains lighted.

The individual indicating lamps used for the ten classes of trouble may be of various colors, and each will have a designation to indicate the classification more precisely. The lamps are located at some place where they can be easily seen by the maintenance force, but the rest of the equipment — both at the main and auxiliary station — is mounted on a relay rack panel, which may be mounted in any convenient place. The panel for an auxiliary station is shown in Figure 1.

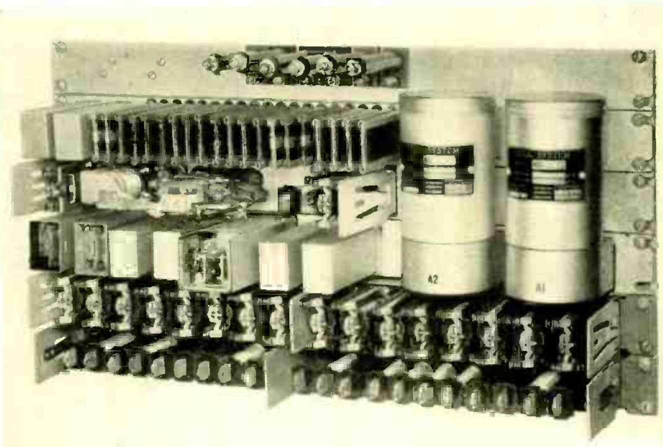


Fig. 1—Alarm unit used at auxiliary stations for the type-J carrier-telephone system

The circuit as arranged for the type-K system is shown in simplified form in Figure 2. Under normal conditions current flows continuously around the loop connecting the two stations, and holds the relay P1 at the auxiliary station operated. Resistance R2 is adjusted so that L1, which is a marginal relay, will not operate. Signals are transmitted from the auxiliary to the main station by short-circuiting resistance R1, which allows enough current to flow to operate L1. Return signals to the auxiliary station for operating the selector are sent by operating relay P, which in turn releases P1.

Once the interrupter circuit has been started at the main station, relays P, P1, and P2 are operated and released eleven times by the interrupter circuit at the main station. This latter circuit is started, and signals are transmitted for operating the indicating lamps, by operating relay L at the auxiliary station. Operation of L short-circuits the resistance R1, thus allowing L1 to operate and to release L2. The indicating lamps are controlled by ten "A" relays at the auxiliary station and ten "B" relays at the main station, which are operated through contacts on the selectors through back contacts of P2 and P. The first signal from the auxiliary to the main station is used to start the alarm circuit, while subsequent signals—up to the time the selectors have been restored to normal—are used to operate one or more of the "B" relays. The transfer of the signals at the main station from the interrupter and alarm to the "B" relays is accomplished by the TR relay, which switches the effect of a release of L2 from the interrupter and audible alarm relays to the selector, whence it is distributed to the "B" relays.

The appearance of trouble at the

auxiliary station places a ground on the lead to one of the "A" relays, and through a back contact on the relay operates S1, which in turn operates L, thus sending the original signal to the main station. For this initial signal, L is operated on ground through the off-normal contact of the selector. For subsequent signals—to bring in the indicating lamp—it will be operated in series with an "A" relay through the selector from the ground placed on the lead to that "A" relay by the trouble condition.

The operation of the circuit, relay by relay, for a trouble placing a ground on the lead to the No. 3 "A" relay is shown in Figure 3. The relays are indicated as in Figure 2; the letter designations are in bold-face type when the relay is operated, and in light face when it releases. Time flows down the page from top to bottom, those operations occurring at approximately the same time being indicated on the same line. The left side of the column represents actions at the auxiliary station, and the right side, those at the main station. Underlineation of an operated relay indicates that the relay holds itself operated. The action of the interrupter circuit in alternately applying and removing ground from the lead to the P relay is indicated by short horizontal lines—bold face when ground is connected, and light face when it is removed. Actually, the interrupter action is at uniform intervals, but they are unequally spaced on the tabulation because of the greater number of operations during some periods than in others.

A relay, which has been omitted from Figure 2 for the sake of simplicity, is connected to the line at the main station to give an alarm if the connecting loop becomes open-cir-

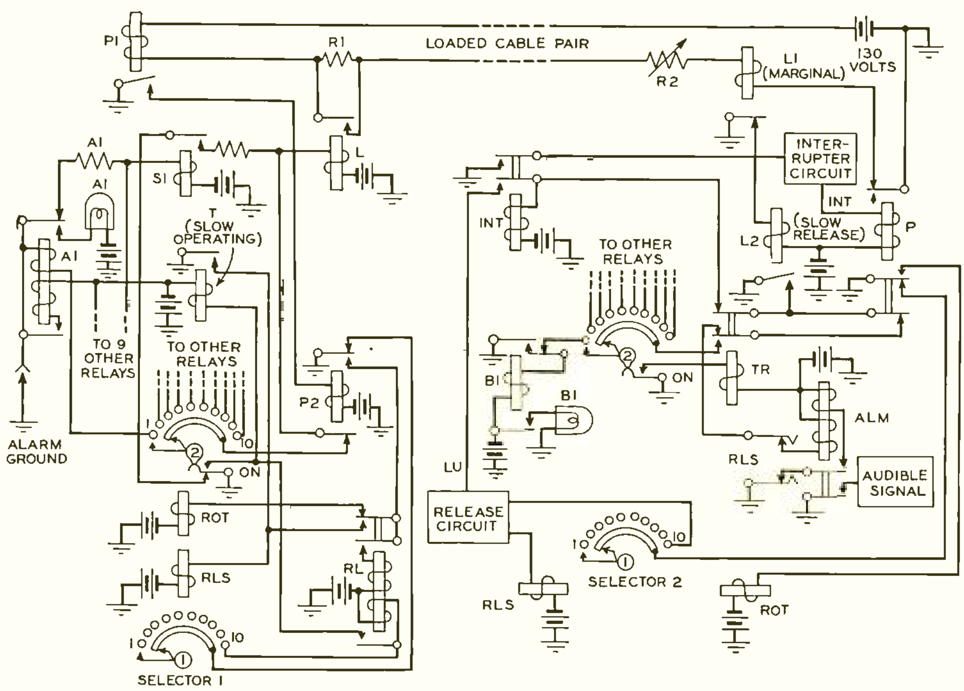


Fig. 2—Simplified schematic of alarm circuit used with the K carrier system

cuited. Since such an open circuit would release P1, and thus operate P2 and rotate the selector at the auxiliary station to the first step, relay T is installed, which—operated when the selector moves off normal — will release the selector in approximately three minutes. The operating cycle of the alarm circuit, from the occurrence of an alarm at the auxiliary station to the final release of the selector, requires only a little over half a minute and thus relay T will not release the circuit under ordinary operating conditions.

A remote-control recheck feature is provided to permit a verification of the indicated trouble. This recheck feature is controlled from the main station and releases the "A" and "B" relays and main station indicating lamps. This starts the alarm circuit operating again and if the trouble condition is still present in the auxiliary station, and was properly indicated before, the same "A" and "B" relays will operate again and light the corresponding indicating lamps.

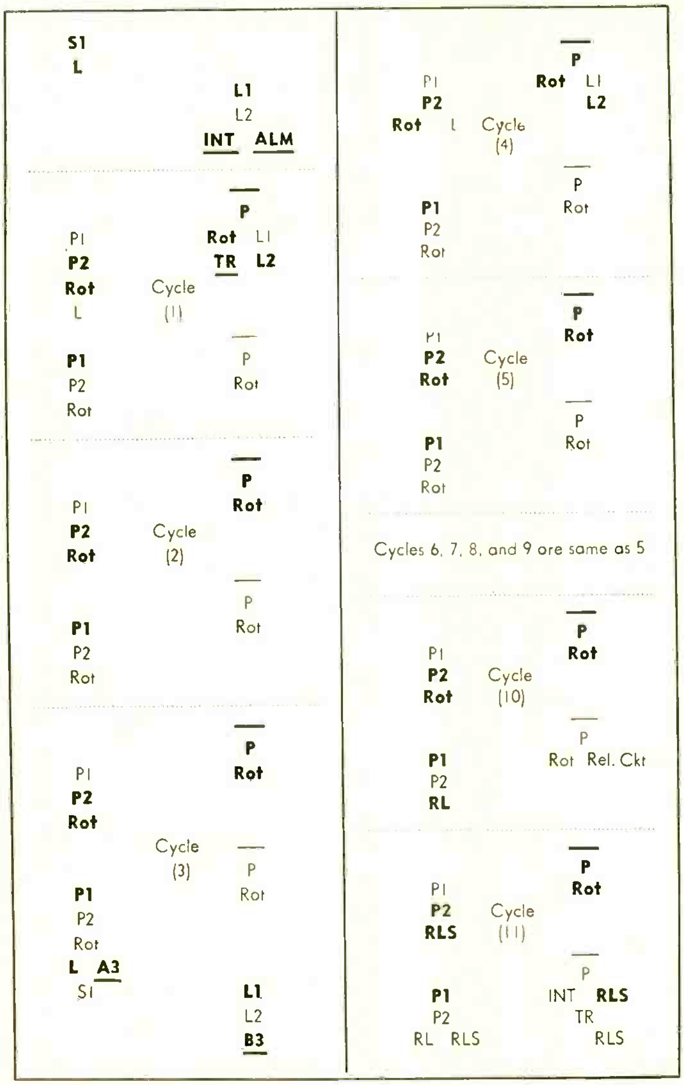


Fig. 3—Operation chart for alarm circuit. Designations on left side of both columns represent apparatus at the auxiliary station (at the left of Figure 2) and those on the right side of both columns represent apparatus at the main station (at the right of Figure 2). The sequence of operations begins at the top of the left column and runs to the bottom of the right column. Bold-face type represents operation of a relay, and light face, its release. Bold- and light-face dashes in the right-hand side of the two columns represent a ground and interruption, respectively, placed on the INT lead by the interrupter. Action is started by the appearance of an "alarm ground" on the leads to one of the ten relays at the auxiliary station

The circuit used for transmitting the signals with the J system is shown in Figure 4. Current normally flows over the single line conductor through the differentially wound polar relay P1—which remains unoperated—and the L1 relay, which is held operated by it. As with the K system, signals are sent to the main station by an operation of L at the auxiliary station. This operates S2, which releases L1 at the main station, P1 at the auxiliary station being unoperated. Signals to the auxiliary station are sent by operating P, thus operating RE which in turn operates P1. The operation of the circuit is thus essentially the same as for the K system, shown in Figure 2, except that the actions of P1 and L1 are reversed—operating in the J system when they are released in the K and vice versa.

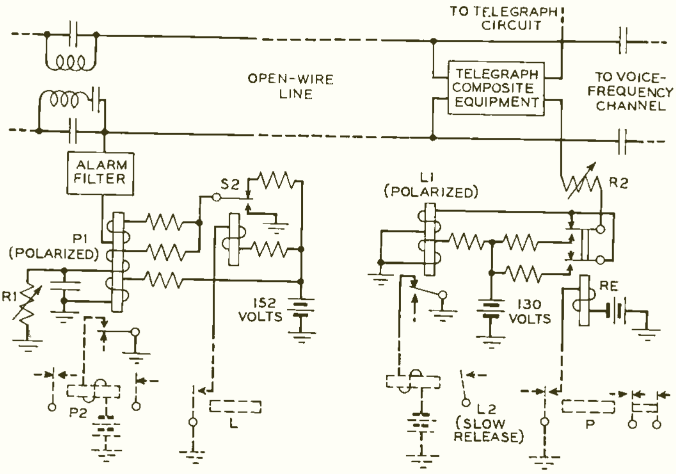


Fig. 4—Simplified schematic of the signalling loop circuit for the J carrier system

Contributors to this Issue

F. F. Farnsworth graduated from Albion College with an A.B. degree in Chemistry in 1914. He did graduate work at the University of Illinois while Assistant there in Physical and Electro-Chemistry and received an M.S. degree in Chemistry from that university in 1916. Mr. Farnsworth left Illinois in 1918 to join the Army. After the war, he spent two and one-half years with the American Lead Pencil Company as research electrochemist where he studied the design of electric furnaces for firing ceramic bodies. In 1921 Mr. Farnsworth joined the Chemical Research Department of the Laboratories and was assigned to studies of electroplating, metals corrosion, and electrolytic condensers. He transferred to the Outside Plant Development Department in 1928 where he engaged in development projects relating to glass and porcelain insulators, automotive fleet painting procedures, insulated wires and cables for outside distributing and station use. More recently he has been concerned with cable splicing methods, solders, first aid and miscellaneous materials such as body belts and safety straps.

J. A. Becker received his bachelor's degree from Cornell in 1918 and after spending some time with the Bureau of Standards in Washington, the Research Laboratory of the Westinghouse Company in East Pittsburgh, and with Bell Telephone Laboratories, he returned to Cornell as an Instructor and received his Ph.D. in 1922. For the next two years he was a National Research Fellow at California Institute of Technology where he worked with Professor Millikan. For the summer of 1924 he was Acting Assistant Professor at Stanford University, and in the fall returned to the Laboratories. His work here has been on thermionic emission from coated filaments, and from thoriated and caesiated tungsten, and on adsorption, electron conduction in solids, and surface phenomena in general.

H. A. Sheppard graduated from the Virginia Polytechnic Institute in 1922 with the B.S. degree in Electrical Engineering and immediately entered the Engineering Department of the Western Electric Company. Here he associated with the Systems Development Department, and for the first few years was en-

F. F. Farnsworth

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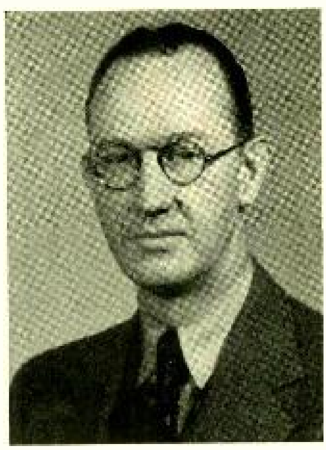

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N. R. Stryker

gaged in laboratory testing of circuits for manual and dial offices. He then transferred to the circuit analysis group where he was concerned with the current engineering problems of the various telephone companies. In 1935 he transferred to the Toll Facilities Department where he has been concerned with signalling problems associated with intertoll dialing.

V. E. Rosene studied electrical and mechanical engineering at Lowell Institute while working with the Wireless Specialty Apparatus Company in Boston. He continued this work after his graduation in 1921 and during the next nine years he worked also with the Peerless Radio Corporation and the Selsian Motor Company. In 1930 he joined the Toll System Department of the Laboratories. Here, with the toll-switching group, he has been engaged in a number of switching projects during the last decade. He worked on both 20 and 135-cycle ringing, and on pilot-wire regulating circuits for voice and carrier-cable circuits. He also engaged in the development of voice-frequency terminating circuits for carrier systems, and in alarm and control circuits. More recently he has worked on line and balancing circuits for telephone repeater stations.

C. Kreisher graduated from the State College of Washington in 1921 with the degree of B.S. in Electrical Engineering. Shortly after, he joined the Western Electric Company at Hawthorne and was assigned to what is now the Cable Branch of the Outside Plant Development Department of the Laboratories. He has been continuously associated with this work ever since. In 1929 he was in charge of a group engaged in the development of voice-frequency toll cable. In 1932 he transferred to the Point Breeze factory, where he has been engaged principally in the design of cable for carrier transmission. Mr. Kreisher had a prominent part in the development work that led up to the design used for the experimental coaxial cable between New York and Philadelphia.

N. R. Stryker graduated from the University of Illinois in 1921 with the degree of B.S. in Electrical Engineering, and then joined the Western Electric Company. Here he was engaged until 1928 in high-quality transmitter development and the application of electroacoustic testing methods to high-quality microphones. From 1928 to 1935 he was concerned with development and testing methods applicable to sound picture recording and reproducing equipment and quality studies of sound picture systems. Since 1935 Mr. Stryker has been interested in the electromechanical analysis of coin collectors and applying the principles of acoustics to the design and construction of sound-testing equipment for the combined telephone set.