BELL LABORATORIES RECORD

SECRETARIAL TELEPHONE SERVICE
H. M. HAGLAND

TELEPHOTOGRAPH LINE
PIERRE MERTZ

LOCATING FAULTS IN TOLL CABLE
C. E. CLUTTS

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The Telephotograph Line

By PIERRE MERTZ
Toll Transmission Development

THE development of a complete system of telephotography demands, in addition to the construction of sending and receiving apparatus for the terminals, the solution of the problem of transmitting the signals from one station to the other. The immediately obvious possibility is to use telephone circuits for this service. Telephone and telephotograph signals, however, have certain inherent differences, and a careful consideration of these differences reveals that a line designed for telephone transmission, even though better in certain characteristics than would be required for telephotography, may yet not give satisfactory transmission.

One of these differences in the use of circuits for the transmission of telephotograph signals is that a time factor appears in a form that cannot be considered when the circuits are employed for telephone transmission. A telephone conversation must be transmitted syllable by syllable as it is spoken; a group of words requiring three minutes for their delivery must be transmitted in exactly three minutes. A picture need not meet any such requirements; the rate at which it is transmitted has no inherent limitations, and may be as long or short as other conditions warrant or demand. A very short transmission time will require a very wide frequency band for satisfactory results, while a long time will permit the use of a narrow band. The type of circuit that must be employed depends in turn on the width of the frequency band, so that the shorter the transmission time, the higher the grade of circuit that must be used. Conversely, of course, the picture apparatus can be adapted to use frequency bands that can be transmitted by circuits which are already in existence in the telephone plant.

Another way in which the circuit required for telephotography differs from that required for telephony is that with the former, the successive portions of the signal are spread out side by side and all seen by the eye at the same time, whereas the ear hears these successive portions one after the other. This spreading out in space greatly amplifies the sensitivity with which an incorrect time sequence in the component parts of the signal can be distinguished. Considerable care must therefore be taken to prevent the circuit from distorting the time sequence of the parts of the signal. This requirement holds whether the received picture is permanently recorded or not, as evidenced by the

Fig. 1—The result of transmitting the photograph shown at the head of this article over a toll line not specially arranged for telephotograph transmission

Fig. 2—A properly equipped line results in a picture nearly as good as the original

fact that it is generally as important for television as for telephotography.

Still a third way in which the type of circuit required for telephotography differs from that required for telephony, depends upon the fact that a permanent record is kept of a received picture, but not of a telephone conversation. Thus during a conversation, disturbances may blur over or mar certain sounds, but if they are not bad enough to destroy intelligibility or cause annoyance, they are soon forgotten if noticed at all. In a telephotograph, on the other hand, each disturbance remains on the print as a record for all time and can never be forgotten.

These and other differences between telephone and telephotograph transmission require in general a different treatment of the line. An ordinary toll line is designed for transmitting telephone messages, and while a picture can be transmitted over it successfully if the speed of transmission is slow enough and all other conditions are favorable, nevertheless to insure at all times continuous transmission of pictures that are faithful reproductions of the originals, requires a modification of the circuits and usually more elaborate facilities.

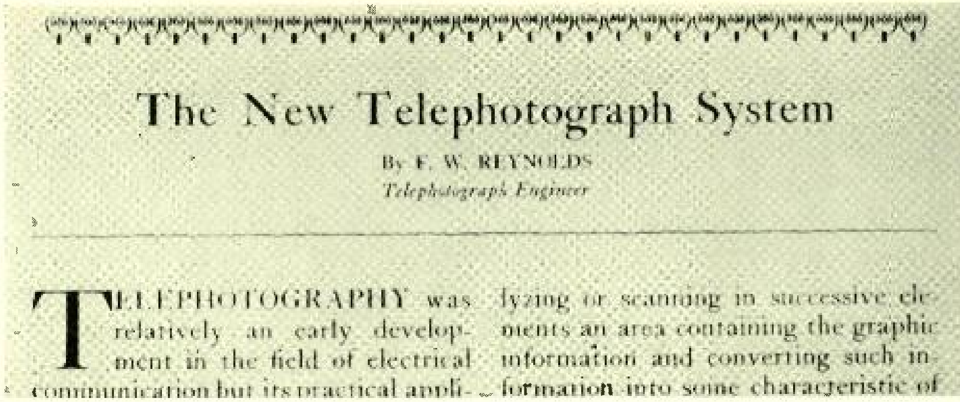
A distinguishing feature of the new Western Electric telephotograph system is the carrier transmission of the signal by single sideband. Although this is common practice in carrier telephony, it has been difficult to apply to telephotography because of the lack of separation between the upper and lower sidebands. The lower frequency of the voice band is about 200 cycles, and this frequency when modulated with a carrier of frequency C gives sideband frequencies of C+200 and C−200. Between these two frequencies there is a separation of 400 cycles, which is ample to allow the band-pass filters to remove one sideband for single-sideband transmission. In the telephotograph system, however, the original signal band begins at zero frequency, and the modulation products extend continuously in both directions from the carrier, leaving no unused space whatever. Any practical filter, however, has a sloping characteristic in the cut-off region, and since this region covers the ends of both sidebands adjacent to the carrier, some of the signal energy in the wanted sideband is attenuated.

This energy can be restored to the ultimate signal by arranging the filter to pass a suitable amount of signal energy from the other sideband in the correct phase. In the demodulation process these two bands combine to give uniform transmission. This process permits the use of single-sideband transmission for a commercial telephotograph system for the first time. The frequency range of the lower sideband runs from 1200 cycles to the carrier at 2400 cycles, and a little of the upper sideband, up to 2600 cycles, must be transmitted. So far as the frequency band required by the telephotograph signal is concerned, therefore, there is little difficulty in using a telephone circuit for its transmission.

In regard to delay distortion, however, as has been already intimated, some difficulty may be anticipated. For satisfactory reception over a telephone circuit, it is desirable to have the middle and upper frequency components of the signal received not more than about 20 milliseconds out from their correct time sequence, more distortion being permitted for the low frequency components. Where music is concerned, and a higher artistic standard imposed, as in program circuits, this figure is reduced to 5 or 10 milliseconds. When a picture is transmitted with the new system over a circuit just satisfying the 20-millisecond limit, a sharp edge between light and shade in the original is broadened into a streak, or series of streaks, covering something like a third of an inch in width. This impairment obviously cannot be tolerated, and in practice the blurring permitted is only about one fortieth as much. To put the matter in other words, the envelope delay* at any two frequencies within the band, over the greatest length of circuit that is employed in joining any two stations, must not differ by more than about half a millisecond. Because of the general severity of this requirement and the great lengths of line involved, the meeting of it constituted one of the major problems in setting up a nationwide telephotograph circuit.

An illustration of the distortion caused in a picture transmitted over a high grade telephone circuit, in which, however, the delay varies too much for telephotographic use, is shown in Figure 1. The original is reproduced at the head of this article, and the result when the delay of the line is specially equalized for picture transmission is illustrated in Figure 2. This is still not quite as sharp as in the headpiece, because the lines along which it is scanned are coarse compared to the fine half-tone pattern used here. If they were reproduced with a coarse screen such as used in

*See page 193 of this issue.


The New Telephotograph System

By F. W. Reynolds

Telephotograph Engineer

TELEPHOTOGRAPHY was relatively an early development in the field of electrical communication but its practical appli- lyzing or scanning in successive elements an area containing the graphic information and converting such information into some characteristic of

Fig. 3—A sample of typography, taken from Bell Laboratories Record, *transmitted over a specially equalized telephotograph line*

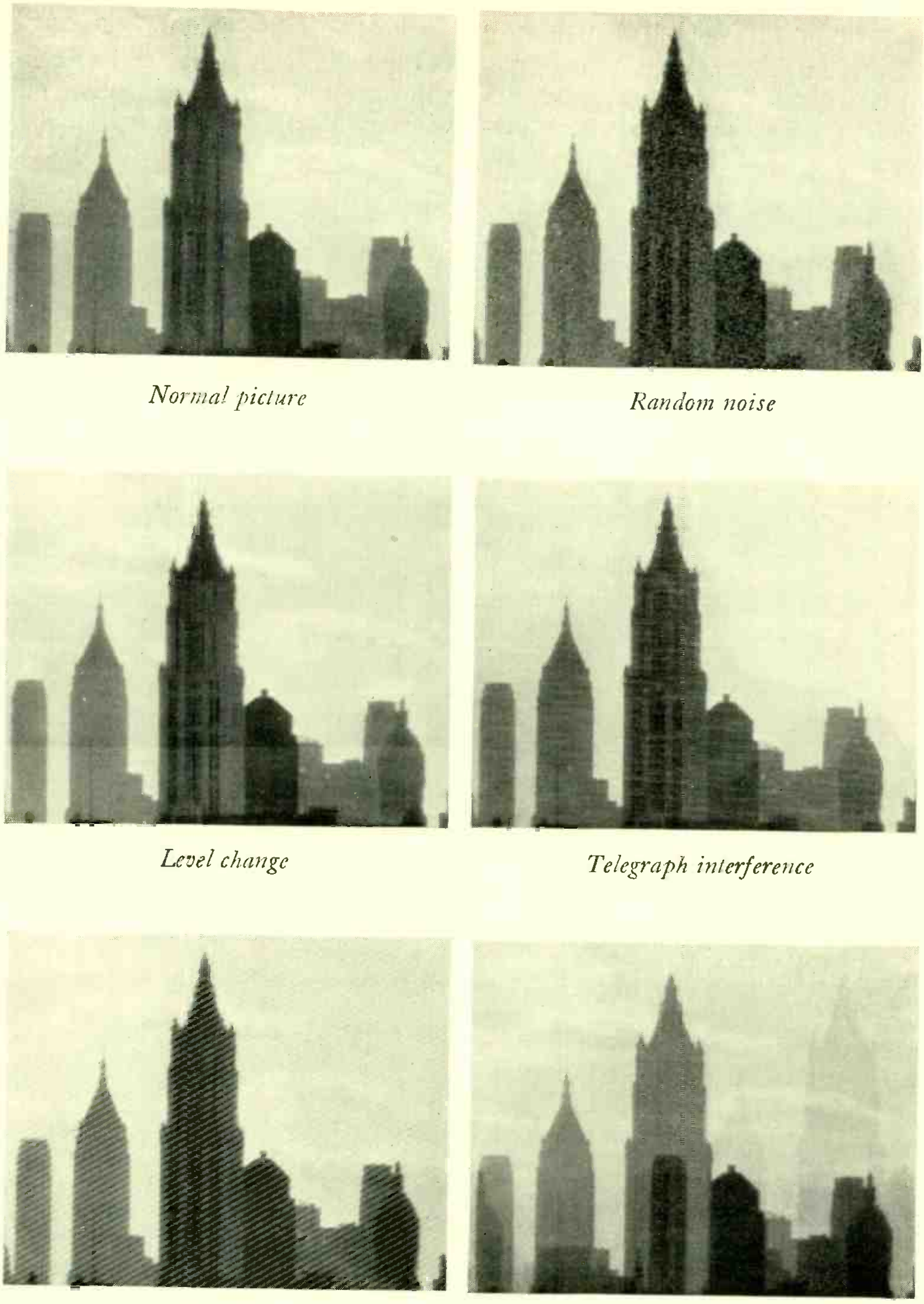
newspaper work the difference between the two would be much less.

The equalization of delay is achieved by the use of networks in much the same manner as is the attenuation distortion on these same circuits. The equalizing networks delay certain frequency components of the signal more than others, in such a manner that with the networks in tandem with the line, the overall circuit has the same envelope delay, to within the requirement imposed, for all frequencies within the transmitted frequency band. The degree of equalization required, as well as the extent of the frequency band over which it must hold, depends upon the speed at which the picture is transmitted. Thus with an untreated circuit good results might still be obtained, at the expense of patience and the inefficient use of the circuit, merely by allowing a considerably longer time for the transmission of a given picture.

As has been mentioned, a further major difference between graphical and audible reception depends upon the fact that the former leaves a permanent record. A small sudden disturbance in the circuit, such for example as a small change in level, is almost entirely unobjectionable in a telephone conversation. Such a level change in a photograph, however, results in a streak which not only gives some possibility of misinterpreting the picture but produces an unpleasing effect. A telephone circuit, before it can be used to transmit telephotograph signals, must therefore be very carefully gone over to remove, as far as possible, all possibilities of sudden disturbances such as level changes and very short interruptions, and also noise—especially of a character to show distinct patterns.

This is of particular importance because of the method now used in practice to compensate for variation in attenuation of cable circuits caused by temperature changes. This compensation* is effected automatically by adjustable networks in some of the repeaters, which change their gain to meet the changed cable loss in steps of about one-half db. The sudden changes in the net loss of the line occurring when the switch is moved from one step to the next are entirely imperceptible to the ear but are quite inadmissible in a picture circuit. To avoid this effect, the regulating net-

*Record, *January*, 1929, *p.* 183.



Normal picture — *Random noise*

Level change — *Telegraph interference*

High-frequency noise — *Echo*

Fig. 4—Various forms of distortion that may occur on a line not arranged for telephotograph transmission

work circuit is arranged to be locked up during the transmission of a picture. By this arrangement, the sudden changes in the transmission equivalent of a circuit can occur only between pictures, and the effects of the gradual changes that take place during a picture transmission period are practically imperceptible.

"Compositing," or any superimposing of d-c telegraph signals on telephone circuits, causes a somewhat related effect sometimes called "Morse flutter." Here the sudden changes in transmission loss, while perhaps not quite so large as caused by regulators, are more frequent, and produce a grained effect rather than streaks in the picture. It is thus necessary to remove composited d-c telegraph from circuits used for telephotography.

The removal of telegraph leaves the d-c channel vacant, and in the new nationwide system recently established advantage is taken of this vacant channel for the transmission of special signals to lock up the regulating networks during the transmission of a picture. This signal is sent only before or after a picture and thus has no effect on it.

Another characteristic of telephone circuits to be considered when adapting them to picture transmission is what is called "echo," or the propagation of a delayed and usually attenuated replica of the main signal. While a small amount of echo in a telephotograph circuit does not generally show in a picture, long circuits with open-wire sections containing many two-wire repeaters furnish a large number of possible echo sources and can give a serious cumulative effect. The d-c channel, which has been made available by the removal of d-c telegraph, also provides a means to effect the necessary switching to cut the entire wire network to a one-way condition during the transmission of a picture, thereby completely eliminating the possibility of echoes.

An illustration of the impairment in a picture caused by the various effects just discussed is shown in Figure 4. With this class of defects, contrary to the case of delay distortion, no substantial improvement can be obtained by slowing down the transmission of the picture.

The telephone circuit connecting the telephotograph stations of the new network is arranged so that when not used for the transmission of pictures, it may be used to pass orders and information relative to the picture transmission. This means that the modifications made in it to satisfy the picture transmission must not prevent its use for telephony. In particular, it must, when not in the picture condition, be usable as a two-way conference circuit, in which each of a number of stations connected to the system can talk to all the others and hear the reply from any of them.

New Carrier Loading Equipment for Entrance Cables

By E. C. HAGEMANN
Telephone Apparatus Development

CARRIER transmission in the Bell System is at present employed chiefly on non-loaded open-wire lines. A small amount of cable is generally unavoidable, however, at terminal and intermediate repeater points, to bring the circuits through built-up districts into the telephone building. These incidental cables, if more than a few hundred feet long, are usually loaded to make them match the open-wire impedance, and thus to minimize reflections at the junction of the cable and open-wire line. This loading also reduces the transmission losses in the cable itself. A number of loading systems, differing with respect to impedance and transmission-band width, are required to satisfy the range of requirements imposed by the different types of open-wire lines and carrier systems superimposed upon these lines.

Gradual development over a period of years has led to the use of longer carrier systems, and as a result it has been necessary to reduce the permissible cross-talk per unit length of circuit. In the open-wire lines themselves this reduction in cross-talk has been accomplished by a number of changes in pole-line construction and in transposition practices. Cross-talk improvements in the associated loaded cables have been secured by means of the improved types of carrier loading apparatus, described in this article, and by design improvements in the cables.

In respect to cross-talk, non-phantomed open-wire pairs are much more satisfactory for carrier operation than side circuits of phantom groups when a large number of carrier systems are worked over the same pole line. Under certain conditions, however, side circuits of phantom groups are satisfactory, but the associated phantoms

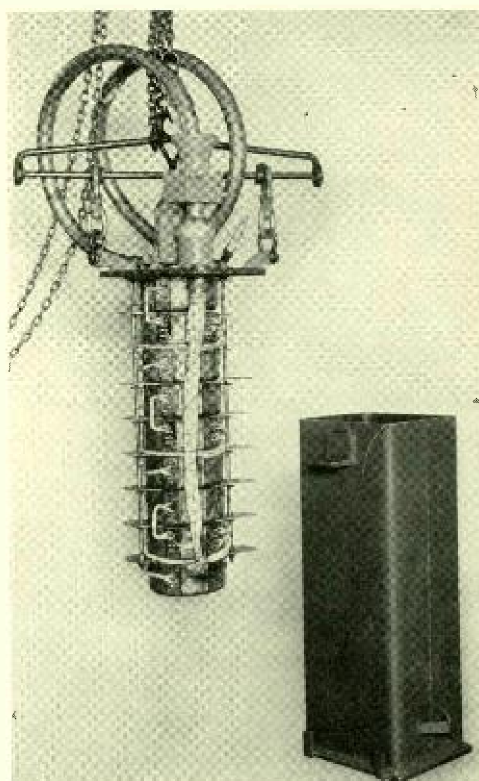


Fig. 1—Assembly of three phantom loading units for carrier circuits

are never used for carrier-telephone operation. Consequently, certain of the carrier loading coils at the present time are designed primarily for use on non-quadded pairs in entrance cables, while other types are used on side circuits of quads. Associated with the latter types are coils for loading the voice-frequency phantom circuits. The spacing required for carrier loading coils is considerably closer than that for voice-frequency loading coils. For quadded entrance cable, therefore, the loading will consist of side-circuit coils spaced at comparatively short intervals, and voice-frequency phantom coils at less frequent intervals.

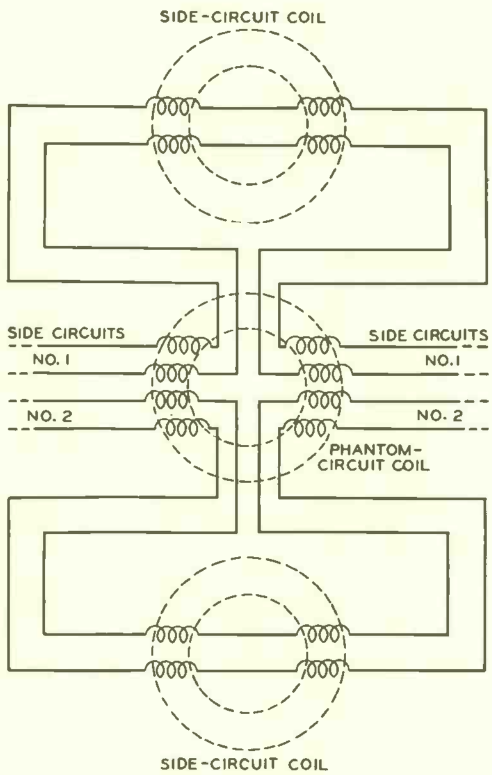


Fig. 2—Two unshielded air-core side-circuit coils and one unshielded iron-dust core phantom coil comprised the phantom group in former practice

At periodic intervals the side-circuit and phantom-circuit loading points are made to coincide, where the loading apparatus will consist of phantom-group loading units.

The major part of carrier loading thus consists of coils for loading non-phantomed circuits or the side circuits of phantom groups. In the original design, a group of such coils was potted in a common cast-iron case, and coil-to-coil or inter-system cross-talk was held to moderate values by spacing adjacent coils mounted on the same spindle to distances comparable to the thickness of the coils. Under the new requirements for overall cross-talk, the coil-to-coil cross-talk permitted in these original assemblies was not considered satisfactory. Accordingly, in the new design which is now available, the individual coils are completely shielded from one another to minimize inter-system cross-talk.

At the relatively small number of phantom loading points, the older types of phantom loading units in use comprised three loading coils for each phantom circuit: two for loading the side circuits and one for the phantom. The arrangement is shown in Figure 2. A group of these units was potted in a manner similar to the side-circuit coils. Shielding of the individual coils in a three-coil phantom unit of this type would still leave unbalanced coupling between the two pairs of line windings of the four-winding phantom loading coil, which are connected in the two side circuits, and this unbalanced coupling was the most prolific source of inter-system cross-talk in the loading apparatus. A study of methods of reducing this cross-talk indicated that the use of two-coil phantom loading (one coil in each side-circuit) was preferable to shielding the two pairs of windings from each other in a single phantom coil. As a result, a four-coil phantom loading-unit was developed, with each coil individually shielded. Its arrangement is indicated in Figure 3. To complete the shielding of the side-circuits from one another, the wiring between coils in the unit and in the cable stub pairs in the loading-coil cases was also shielded. This design of loading apparatus, employing four-coil phantom loading units and shielding of the individual coils, resulted in reducing the inter-system cross-talk to about two cross-talk units up to the highest operating frequencies.

With this design, each of the side-circuit coils is mounted in a separate cylindrical copper shield, and, in one of the common arrangements, the two phantom coils are mounted in a common container but separated by a transverse shield as shown in Figure 4. Groups of such units, mounted one on top of another, are assembled for mounting in the loading coil case which is shown in the photograph given in figure 1. Similar shielding arrangements are also provided in the new designs of terminal loading units except that in these designs, impedance-modifying networks, employed to improve the match between the impedance of the open-wire and cable circuits, are potted with their associated side-circuit coils in the same copper container.

As a result of the large cross-talk improvement mentioned above, the inter-system cross-talk due to the entrance-cable loading coils is held to a very low value when, as usually is the case, like-frequency currents in the mutually exposed systems are operated at approximately the same level. At any given loading point in the typical entrance-cable situation, there will be relatively large differences in level between the amplified outgoing transmission and the attenuated incoming transmission. In the typical situation, however, these differences in level are not important factors of inter-system cross-talk because the oppositely directed channels between which they apply operate at different frequencies.

It occasionally happens, however, that channels transmitting in the opposite directions have large differences in level, and use similar frequencies. Such

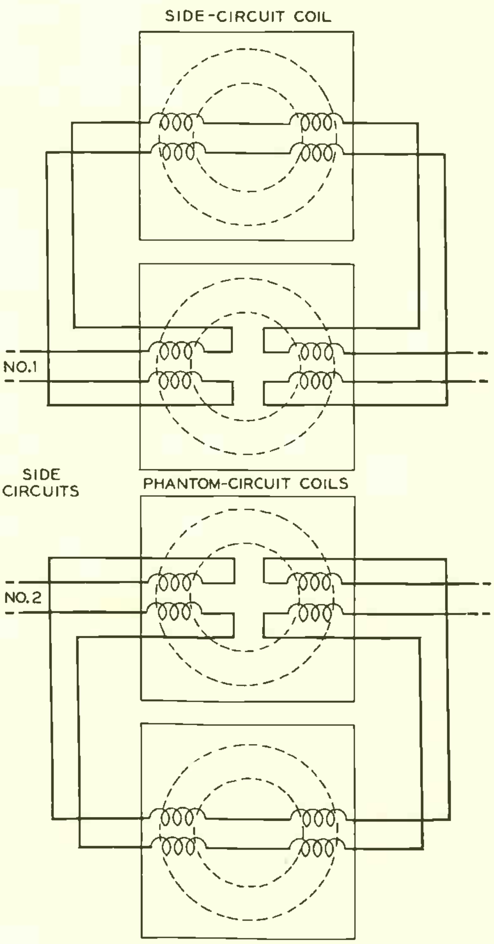


Fig. 3—With the new design, two phantom coils (with permalloy-dust cores) are provided, thus permitting complete shielding between the side-circuits

a condition may exist, for example, at an intermediate repeater station using high gain repeaters, where the circuits go into and out of the repeater station through the same entrance cable. In such situations, particularly when long loaded entrance cables are involved, even a very small amount of cross-talk between the coils in the like-frequency "IN" and "OUT" circuits could become intolerable after amplification by the high-gain repeaters. The probability of this result occurring has been greatly reduced by dividing the loading coils used at a particular load point into two groups, which are separated from each other within their common case as far as practicable. The shielded pairs in the stub cable connecting to these groups are also separated into two groups, and also are shielded from each other. These segregated groups of coils and their associated cabling are connected respectively to the "IN" and "OUT" circuits within the same entrance cable sheath, and in consequence the inter-system cross-talk due to this coil-to-coil cross-talk has been reduced to very low values. This group segregation feature of the new potting assemblies has occasionally made it possible to avoid the use of separate cases for the "IN" and "OUT" circuit coils which—without it—would have been necessary, and thus has achieved economies in potting and installation costs.

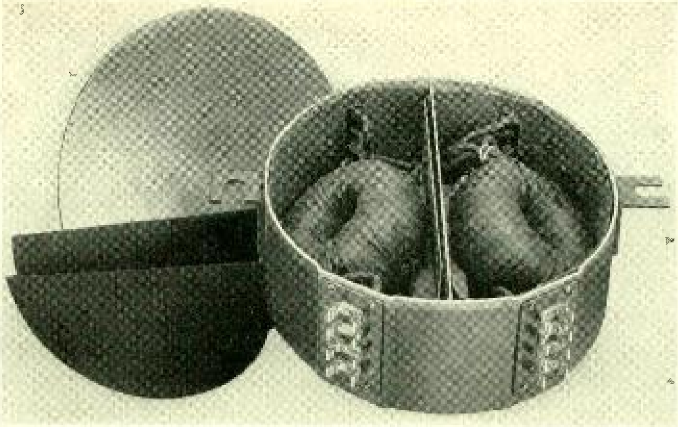


Fig. 4—In a typical assembly, the two coils loading the phantom circuit are mounted in the same container but separated by shielding

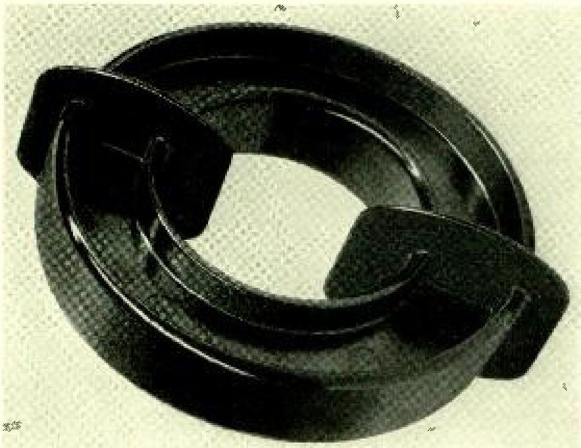


Fig. 5—Phenol-plastic core for side-circuit loading coils

In addition to the substantial improvements in inter-system cross-talk described above, the new apparatus designs also provide large reductions in inter-channel cross-talk. This type of cross-talk in the old standard designs was due to stray fields of the air-core carrier loading coils linking with the cast-iron cases in which the multi-coil assemblies of apparatus were potted. Although these leakage fields were very small because of the use of toroidal cores, they were large enough to cause appreciable inter-channel modulation. This modulation cross-talk was quite objectionable when a large number of coils were used in one of the longer lines. The practically complete shielding of the coils in the new designs reduced the magnetic linkage with the loading coil cases to negligible values. As a result the cross-talk due to modulation products was reduced from 40 to about 0.07 cross-talk units (from 90 to 143 db).

Besides the large reduction in different types of carrier-frequency cross-talk, other valuable improvements were also made in the new carrier loading apparatus. Greater symmetry of the windings of the air-core coils was secured by using molded cores with equally spaced integral winding separators, as shown in Figure 5, instead of wooden cores with fibre separators as used in the old designs. As a result of this improved symmetry, together with the imposition of more severe requirements on the inductance and resistance balance of the windings, phantom-to-side cross-talk and longitudinal unbalance were considerably reduced. Potting of the coils in individual containers resulted in a substantial improvement in insulation resistance. Such sealing also permitted the coils to be made up in advance of orders and to be stored for considerable periods without danger of deterioration. Shielding of the coils also permitted the design of more compact loading-coil case assemblies. As an example, in the new design, the maximum complement of sixteen side-circuit coils is potted in a single-spindle steel case having about the same overall dimensions as that used in potting ten coils in the original design. This improved carrier apparatus has contributed largely to the present high-grade standards of performance which are characteristic of open-wire carrier telephone systems.

Lower Rates for Long Distance Calls

For the sixth time in the past ten years a reduction in the cost to subscribers of long distance calls has been announced by the Bell Telephone System.

The new rates are effective on night (7 *p.m. to* 4:30 *a.m.*) *calls, person-to-person, for which the present rate is more than fifty cents; and the reductions range from about nine per cent to more than thirty per cent.*

A further saving to telephone users is the extension of night rates throughout Sunday. The lower rates effective for night calls, both station-to-station and person-to-person, are effective from 7 p.m. Saturday until 4:30 *a.m. of the following Monday.*

Secretarial Service

By H. M. HAGLAND
Equipment Development

NOT everyone can afford a private secretary to answer his telephone calls when he is out, but equipment has recently been made available by the Laboratories by means of which such service can be provided for a group of subscribers. With the new standard arrangement service is obtained by use of a small switchboard, located perhaps in the lobby of an apartment or other convenient place, where private calls can be answered and messages taken. This type of service is not limited to telephone users located in the same building. Even with the telephones in different buildings, as might happen with a group of physicians who desired to have their telephones answered in their absence, such secretarial service can be rendered from a single switchboard located where most convenient for the group.

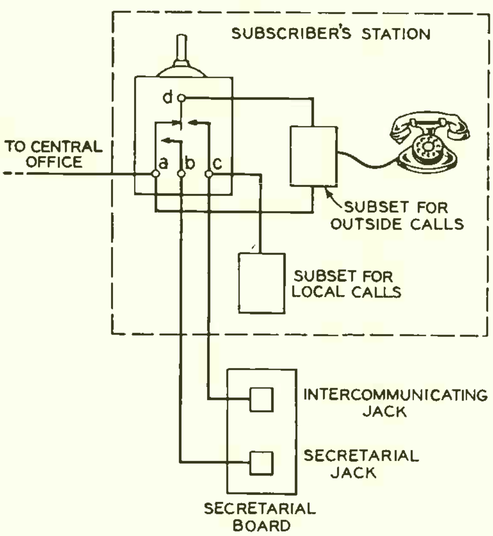


Fig. 1—One arrangement of the secretarial service provides a key at the subscriber's station, which is used to extend his central office line to the secretarial board over a secretarial line

Secretarial service differs from PBX service in that outgoing calls do not pass through the attendant, and incoming calls are answered there only when the subscriber wishes it. The switchboard furnished for this secretarial service is arranged, however, to give regular PBX service to a number of extensions such as might be used by the building superintendent, building garage, laundry, house valet, etc. It also provides communication between these service points and subscribers to the secretarial service. This intercommunication is not carried on over the regular telephone lines but over supplementary lines provided for this purpose.

The general objective of the design is to give the subscriber central-office service in the normal manner, and to bring in the secretarial function only at the will of the subscriber. Two ways of securing this have been made available in the new system. In one, the subscriber's outside line is run directly to his station, and a key at that point is arranged to switch the line to the secretarial board over the secretarial line when he desires to have the attendant answer his calls. A simplified schematic indicating the circuit arrangement for this method is given in Figure 1. With the key in the position indicated, the outside line is connected directly, and only, to the subscriber's telephone set, by way of terminals *a* and *d* in the key. When the subscriber wants his telephone answered by the attendant, or when he wants to talk to the attendant or other local stations, he throws his key to the secretarial position. In this position of the key, the central office line runs directly to the secretarial board by way of terminals *a* and *b*, while the subscriber's telephone is connected to the secretarial board by way of terminals *d* and *c* and the supplementary line. With the key in either position, however, the subscriber's bell will ring on all incoming calls through terminal *a*. The subscriber's bell for local calls is always connected to the secretarial board over terminal *c* and the supplementary line.

The other method of operation obtains essentially the same result but puts the operation of the "switch over" from one type of service to the other under the control of the secretarial attendant. The advantage of this arrangement is that the subscriber can call in from outside and ask the attendant to take over the answering of his calls should he have failed to make such an arrangement before leaving. With the arrangement shown in Figure 1, if the subscriber should forget to throw his key on leaving, there would be no way of having his telephone answered except by returning to his apartment. The circuit arrangement for this second type of service is shown in Figure 2. With this as with the other arrangement, one of the subscriber's bells is always connected to his outside line and one to his local line, but his talking connection is switched by the key.

The chief difference in the circuit for this alternative arrangement is that a direct connection from the subscriber's outside line runs to the secretarial board. Dummy plugs are provided at the board, and when one of them is inserted in the jack corresponding to any line, the lamp of that

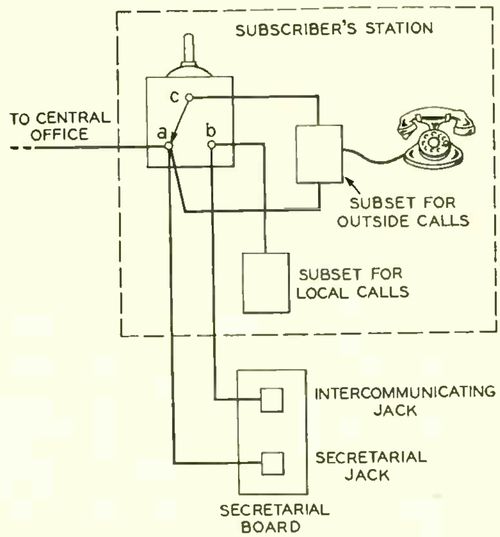


Fig. 2—Another arrangement of the secretarial service allows the attendant to change from direct answering to secretarial answering by inserting or removing a dummy plug from the jack of the secretarial line

line does not light when calls come in. When this plug is removed, however, the lamp lights on all incoming calls and the attendant answers them. These plugs are removed or inserted only at the request of the subscriber. As an alternative arrangement with this type of service, relays can be installed which automatically open the connection to the secretarial board when the subscriber is talking on the line. These relays act even though the secretarial attendant should answer the line first. In all cases the circuits are arranged so that the attendant cannot place calls over the sub-

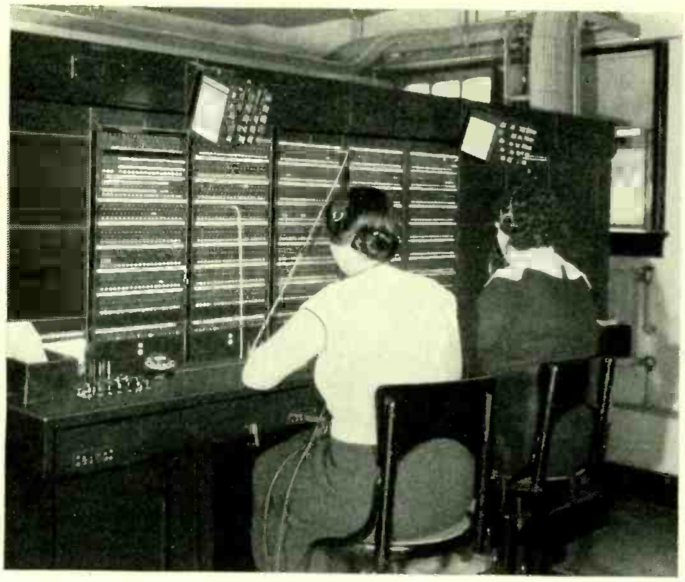


Fig. 3—The 554B is a multiple secretarial board of a capacity of 480 lines per position

plementary line to the same subscriber. Trunks to the central office and regular PBX station lines appear in the lowest row of jacks.

The attendant is provided with two types of cord circuits —one single-ended and the other double-ended. The single-ended cords are used only for answering calls on the secretarial lines, while the double-ended cords are used for completing calls between subscribers and service points, between two service points, or between a service point and the central office. The number of each type of cord circuit varies somewhat with the type and size of board.

scriber's telephone line. When the subscribers are in different buildings this latter type of service is always employed, usually without the automatic cut-off or the supplementary line for intercommunication service.

Two sizes of switchboards are available for this service: one with 220 and the other with 480 lines per position. The former is a non-multiple board, known as the 554C, and employs the framework of the 551B PBX.* The larger, known as the 554B, is a multiple board employing the framework of the 605A PBX.† The appearance of the 554B board is shown in the accompanying illustration. Each has two panels of jacks above the keyshelf, and each jack has a line lamp associated with it that lights on an incoming call. These jacks are grouped in rows according to the type of line, and the secretarial line to a subscriber is always immediately above the sup-

Secretarial service as provided by these new boards has many applications other than in apartment buildings. It is expected to find wide use as a centralized physicians' bureau. For this service each physician will have his own telephone, but secretarial lines will run to the bureau where all calls may be answered in the physicians' absence. These lines are connected to the subscribers' at the central office distributing frame, and the location of the bureau is immaterial.

Many apartment houses accommodate transient tenants, who rent an apartment for but a few weeks or a month. In such instances these secretarial boards may be employed to provide central office service. The tenant is given a regular station line, and his incoming and outgoing calls are handled as at any PBX.

*Record, *July*, 1928, *p.* 363.

†Record, *November*, 1929, *p.* 105.

I

Experimental pole line at the Chester field laboratory.

II

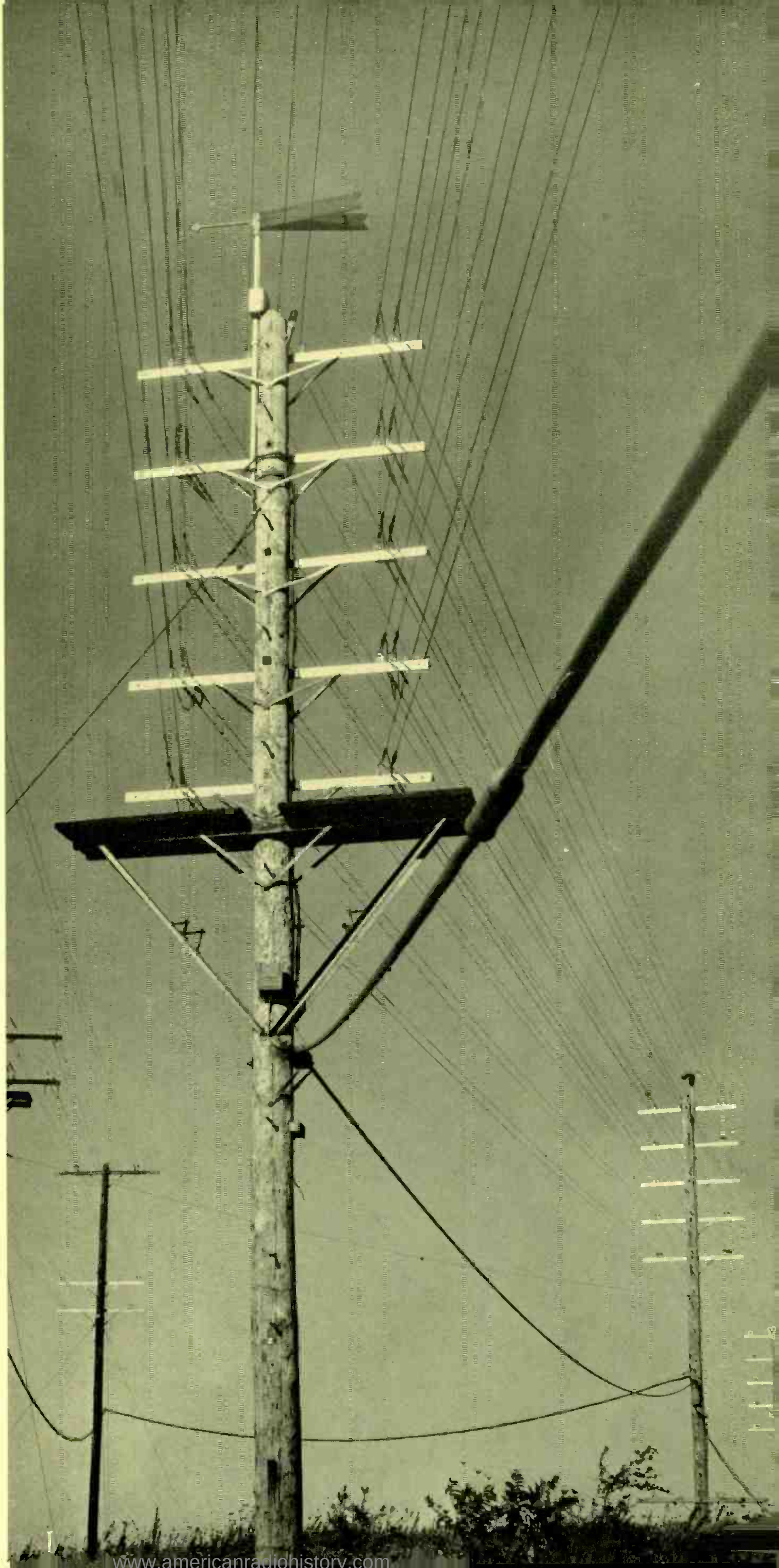
Cold-room test of step-by-step dial equipment for unattended offices.

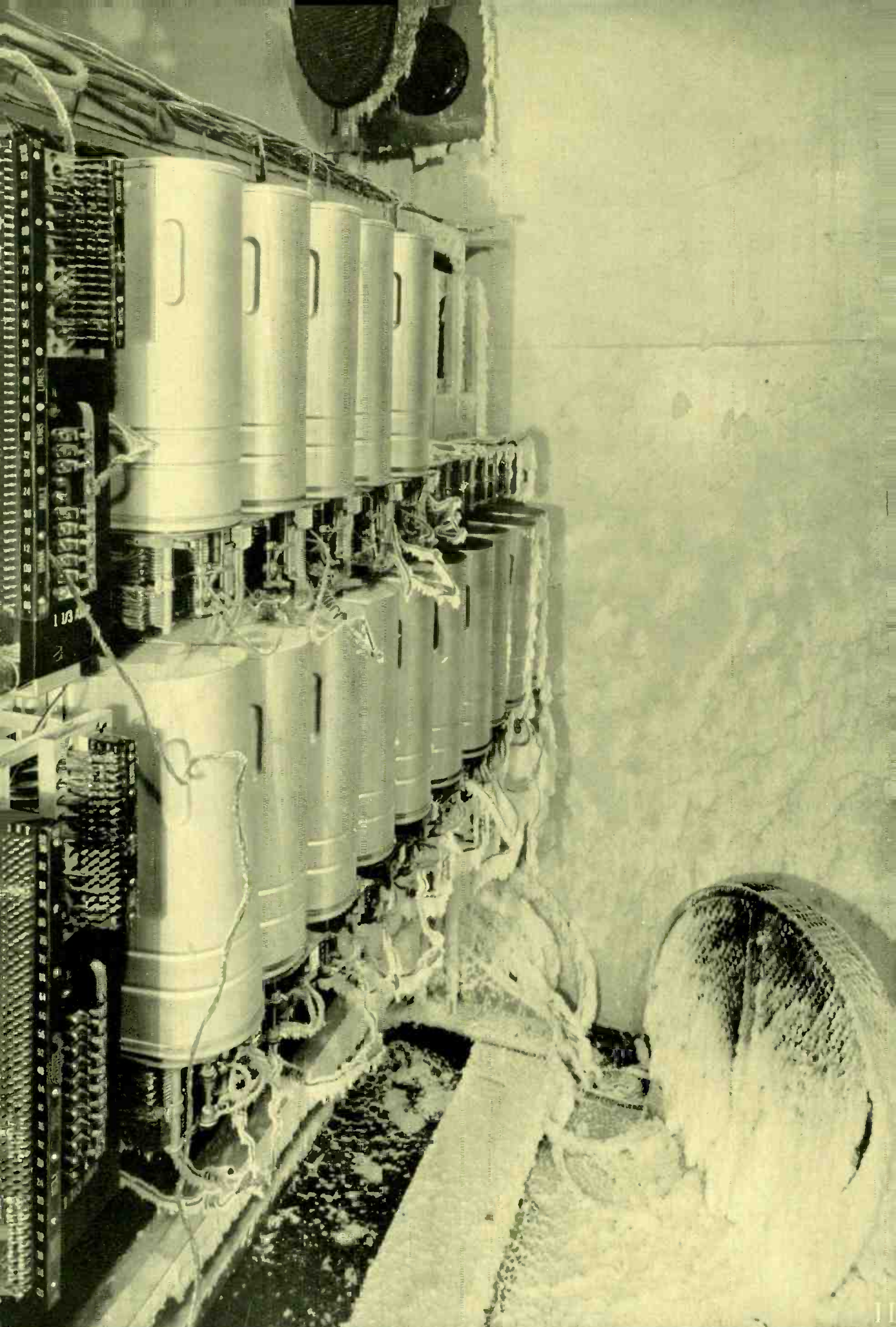
III

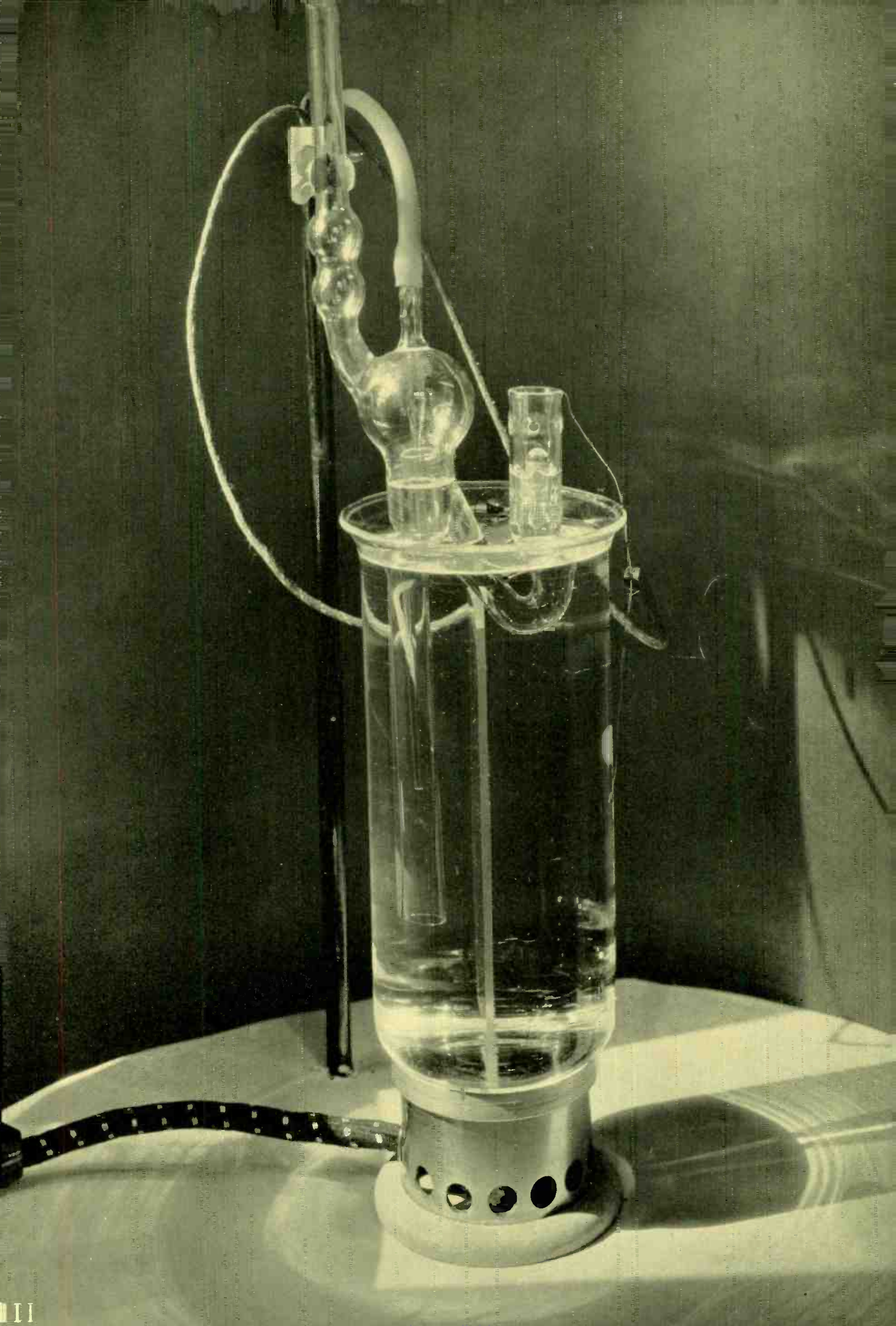
With this micro-electrolytic cell, traces of heavy metals as minute as one part in 100,000,000 have been detected.

IV

An uncut quartz crystal and photomicrographs of surfaces cut at different orientations.







Delay Equalizers for Telephotograph Transmission

By F. A. HINSHAW
Telephone Apparatus Development

CIRCUITS employed to transmit signals of the new telephotograph system must in certain respects meet more stringent transmission requirements than must those used for speech or music, because the eye is more critical to certain types of distortion than is the ear. Since the telephoto frequency band, 1200-2600 cycles, is within the telephone band, however, many of the requirements can be met by adjustment of existing circuit elements, but this is not true of the requirement that the delay, or time of transmission, of all frequencies within the band be the same. These various requirements are discussed in another article on page 178 of this issue of the RECORD.

The difference in delay at various frequencies, commonly termed delay distortion, is in general equalized by delaying those frequencies which arrive first until the slower ones have a chance to catch up. An equalized circuit will therefore have a greater total delay than an unequalized circuit. After studies of the effects of delay distortion on received pictures, it was decided that deviation of ±0.0003 second from the mean envelope delay over the frequency band required for the picture transmission was about all that should be allowed.

The first of the new telephoto systems to be installed extends throughout the United States. It connects Miami, Washington, New York, Boston, Chicago, Kansas City, San Francisco, Los Angeles, and many intermediate points, and involves some 7,400 miles of main circuit. Part of this system is open-wire and part cable, and in a single connection between sender and receiver there may be as much as 3,500 miles of cable and 2,500 miles of open wire. Since the envelope delay of such a circuit varies from about 0.195 second at 1200 cycles to about 0.208 second at 2600 cycles, the requirement set up for the new system that the envelope delay of the various frequencies be the same to within 0.0006 second means reducing the delay distortion from

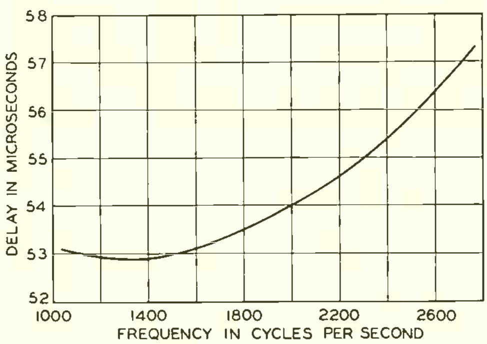


Fig. 1—Envelope delay characteristic per mile of 19 gauge H-44-S cable

something like 6.5 per cent of the total delay to about 0.30 per cent.

Before requirements for individual equalizers could be set up it was necessary to determine the delay-frequency characteristics of the circuits to be used. For this purpose two cable-circuit loops of the type to be used for telephoto service were set up between New York and Dallas via Chicago, St. Louis, and Kansas City, and a series of measurements was made to determine their delay characteristics. The measuring apparatus employed is shown in the photograph at the head of this article. It was felt that the delay measurements obtained on these circuits would fairly represent all cable circuits of similar type because of the length and geographical extent of the loops and the possibility of obtaining, in addition, tests on a number of loops made up of shorter sections of the same circuit such as New York to Cleveland, and New York to Chicago.

Measurements were also made on open-wire circuits between St. Louis and Yuma, via Dallas. The measurements were made from New York over the cable circuit to St. Louis. A switch at St. Louis made it possible to measure the delay of the cable to St. Louis plus the open wire to Yuma, or of the cable to St. Louis alone. This switch was operated from New York by means of a tone over the second cable loop. By subtracting one from the other, the delay of the open-wire line alone was obtained.

These cable and open-wire tests were supplemented by Laboratory measurements on component parts of circuits such as repeaters, composite sets, repeating coils, and filters. From the results of these two sets of measurements the representative delay per mile of the cable circuit including repeaters and composite sets, shown in Figure 1, and the representative delay of an open-wire repeater and associated apparatus, shown in

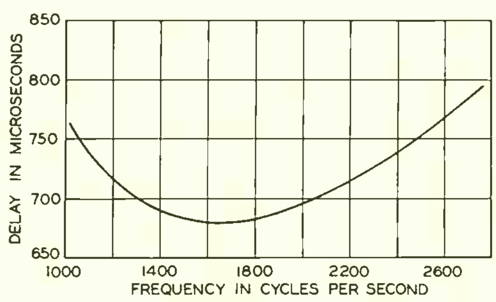


Fig. 2—Envelope delay characteristic of a complete open-wire repeater station

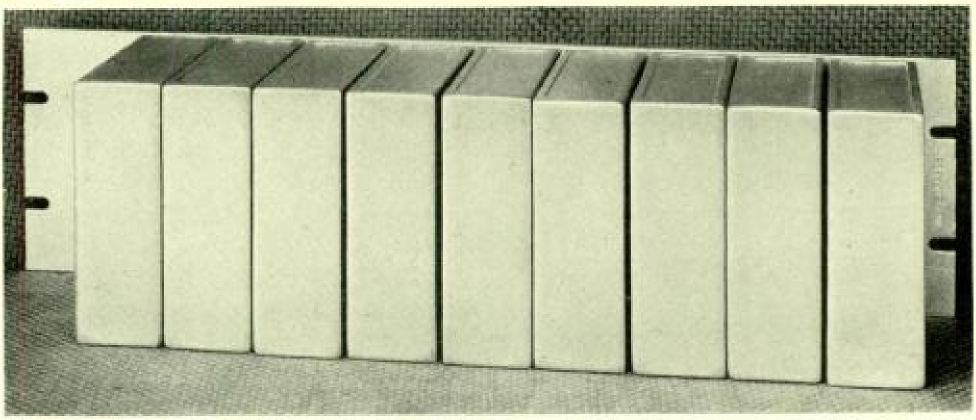


Fig. 3—The 1102A equalizer for cable circuits is composed of 26A, B, and C units

Figure 2, were worked out. By far the largest part of the delay distortion of the cable circuits is due to the loaded cable pairs themselves. In open-wire circuits on the other hand practically all the delay distortion is due to the repeaters and associated apparatus. Total delay distortion for any cable circuit will vary in proportion to its

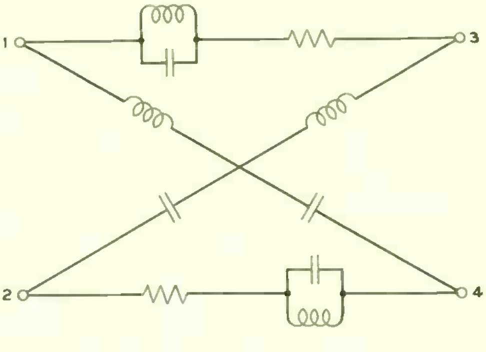


Fig. 4—Schematic diagram of delay correcting network for cable circuits

length, and the delay distortion of any open-wire circuit will vary with the number of repeaters.

The delay equalizing networks provided have been designed with this difference in view. For cables, equalization is provided which is adjustable in ten-mile steps. This is accomplished by using a single section known as the 26A equalizer to equalize ten miles of cable circuit, and two other sections, the 26B and 26C, which together equalize the delay in forty miles of circuit. Each of these single-section units is an all-pass lattice type network as shown in Figure 4. It is potted in a metal case approximately 5¼ by 4⅜ by 1¾ inches. Figure 3 shows an assembly comprising three each of the 26 type equalizers mounted on a 5¼ by 19-inch panel and designated the 1102A equalizer. This provides a convenient arrangement for the equalizers which must be located at the control points of the various circuit units to facilitate maintenance. In toll cable the telephotograph circuit units may range between thirty and 150 miles in length and contain from one to three repeaters. The 1102A equalizer is fitted to its particular circuit unit by connecting into the circuit the number of ten-mile or forty-mile equalizers corresponding to the total length of the circuit unit to the nearest multiple of ten miles.

The delay characteristics of individual circuits differ somewhat and so the correction provided by the 1102A equalizer may not level the delay

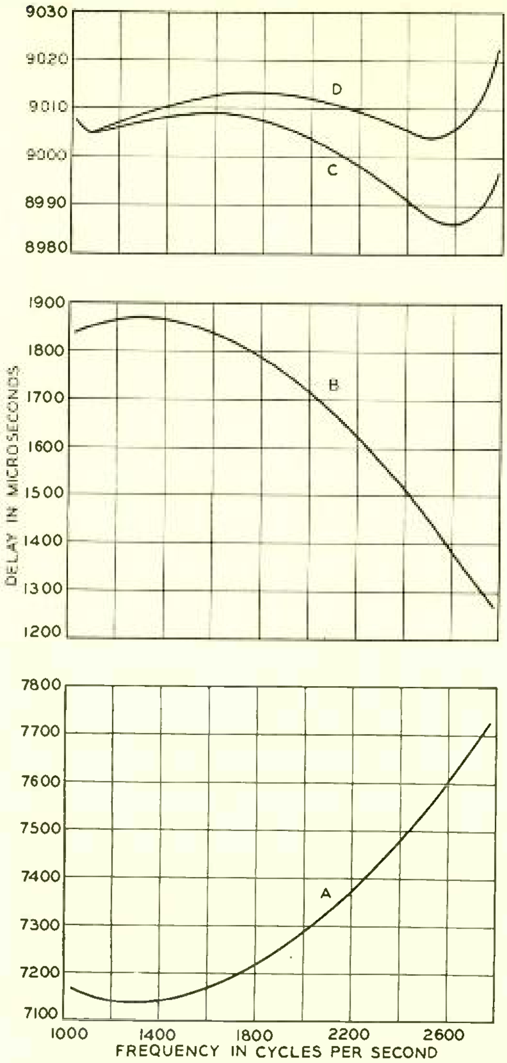


Fig. 5—The envelope delay of 135 *miles of cable is shown by curve A; of an* 1102*A equalizer by B; the resulting delay of the combination by C; and the final delay obtained by adding an* 1102*B equalizer by D*

characteristic to the required flatness. Measurements of the delay on the circuit in question indicate whether or not the equalization can be improved by departing from the normal adjustment of the 1102A equalizer, and also determine the proper adjustment of a supplementary delay equalizer known as the 1102B equalizer which is employed to correct the residual delay deviations. Like the 1102A equalizer, it is an assembly of smaller units of the same size as the 26A equalizer. It provides separate adjustment for the high and low frequencies. An example of the use of the above equalizers is indicated by the curves of Figure 5. Curve A gives the delay of a typical circuit 135 miles long. Curve B gives the characteristic of the 1102A equalizer employed, and curve C the sum of these two characteristics. This is still not quite good enough, and so an 1102B equalizer is added and adjusted to bring the characteristic up to curve D, which makes the envelope delay constant to within 5 millionths of a second.

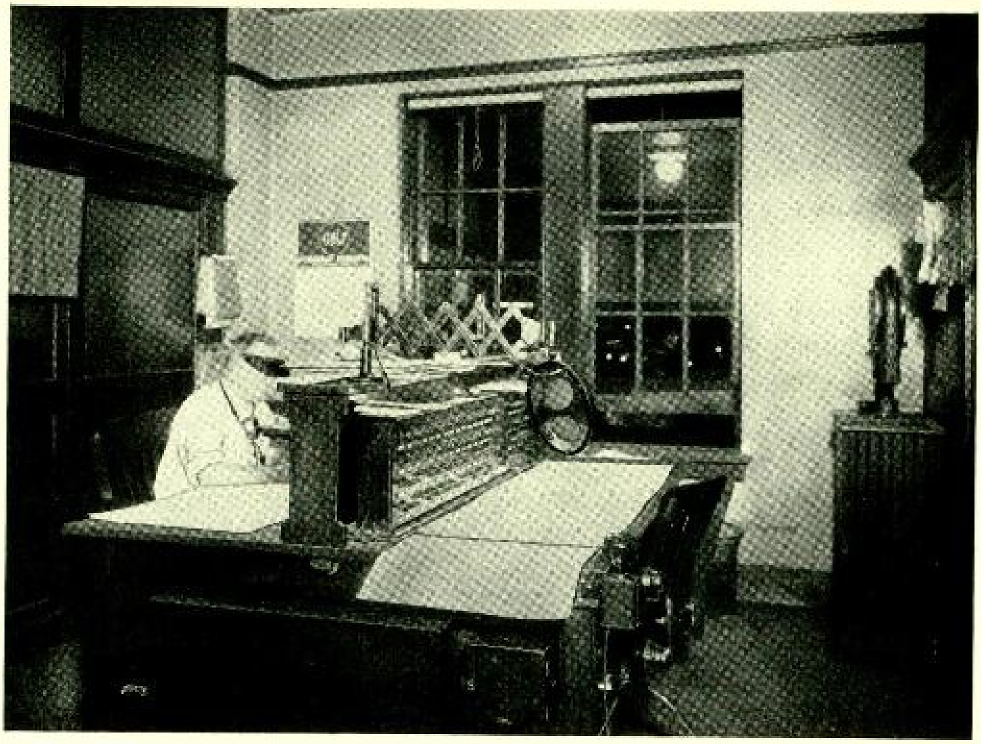
Since the delay distortion of an open-wire circuit is due mainly to the repeaters and associated apparatus, its equalization must be treated on a different basis. The number of repeaters rather than the length of circuit becomes the independent variable. The necessary range of adjustment has been provided by ten single-section equalizer units, the 26J to 26U, inclusive, which—taken in proper pairs—will compensate for 2, 1, ½, ¼, and ⅛ of the average delay distortion of one open-wire repeater and associated apparatus. Correction for fractions of repeaters is necessary because of the variation of individual repeaters from the average characteristic. A line of six repeaters for example would, in all probability, not give a delay distortion equivalent to that of six average repeaters. It would be something more or less than this, and the smaller equalizers permit the necessary correction to be made with little difficulty.

These 26 type equalizer units are mounted in groups and given separate designations, the first three of the equalizer pairs being known as the 1102C equalizer, and the last two, the 1102D equalizer. These two equalizers are capable of equalizing a circuit unit containing up to three repeater sections. The circuit units on the open-wire circuits consist of those portions of the circuit between two adjacent branching points and usually contain one to three repeaters.

Analytical summations of equalizer and circuit characteristics for the various circuits to be installed indicated that equalization to about ±50 millionths of a second could theoretically be attained even for the longest circuits encountered. The equalizers provided were adjustable, and although their initial adjustment could be predetermined, their final adjustment had to be made from delay measurements in the field on the equalized circuits. Because of seasonal temperature variations it may be necessary to readjust the equalizers from time to time. The testing apparatus employed in determining the delay frequency characteristics of the circuits prior to designing the equalizers, although suitable electrically for these field measurements, was not sufficiently portable. The testing apparatus* which employs the same measuring principle as the laboratory set-up but is sufficiently portable to be readily moved from place to place was used to determine the final adjustment of these equalizers. Measurements with this apparatus from Kansas City and with a test set employing a different measuring principle at New York, indicated that the delay distortion of the system was within acceptable limits.

*RECORD, *January*, 1936, *p.* 154.

The Hughes Medal of the Royal Society, London, England, awarded to Dr. C. J. Davisson on December 7, 1935, for research resulting in the discovery of the physical existence of electron waves through long-continued investigations on the reflections of electrons from the crystal planes of nickel and other metals



"Balance" in Railroad Dispatching Circuits

By L. C. ROBERTS
Toll Transmission Development

FOR many years railroad dispatching was all done by telegraph; the simplicity and reliability of the circuits required for this type of communication made them highly satisfactory for railroad use. The greater speed of communication by voice, however, has resulted in the widespread use of the telephone for dispatching in recent years. With this change the railroads very naturally looked to the Bell System for help in solving some of the problems that arose, and suitable apparatus has been made available to them. Although the problems encountered in the design of dispatching circuits are unlike those of ordinary telephone circuits, they are solvable by the same fundamental principles and techniques. Where amplification is required for the longer circuits, vacuum tubes are pressed into service as in telephone repeaters.

A vacuum tube amplifier, however, is a one-way device, so that when the currents of a telephone conversation are to be amplified, it is necessary either to use a four-wire circuit, where one pair of wires carries the speech currents flowing in one direction and the other pair, the currents flowing in the other direction, or to use some special circuit arrangement at the repeater station to permit a one-way device to amplify speech currents in either direction. In the latter case the most commonly employed method involves the operation at the repeater station of a short length of four-wire circuit with properly directed amplifying elements. These elements connect the two telephone wires through hybrid coils as shown in Figure 1, a schematic of a two-way, two-element telephone repeater.

The hybrid coil is the group of transformers and coils at each side of the illustration. When the networks—or more fully, balancing networks—have an impedance exactly simulating that of the line connected to the opposite terminals of the same set of coils, the combination is similar in action to a Wheatstone bridge. Voice energy coming from the east cannot pass through the upper amplifier, but readily passes through the lower one. From there it enters the "West" hybrid coil, where the amplified energy is divided in two—half going into the west network, where it is dissipated in heat, and half going out on the line west. Consequently, none of this energy is transmitted through the west hybrid coil into the upper amplifier.

This is the action when there is a perfect balance between the line and network. If, on the other hand, the network does not exactly balance the line, some of the energy will be transmitted through the west hybrid coil to the upper amplifier. Here it will be amplified and passed back over the line east by way of the east hybrid coil to interfere with direct transmission. If the balance between the east network and line is also not perfect, some of the energy will be transmitted across this hybrid coil and into the lower amplifier—thus reinforcing the energy originally supplied to it. If the loss of energy in passing across the hybrid coil in this manner is not greater than the amplification provided by the amplifier, the system thus becomes unstable—producing a "singing" condition that makes the entire circuit inoperative. The amount of amplification permissible at a repeater thus depends on the degree of balance between network and line. With perfect balance there could theoretically be unlimited amplification. With imperfect balance, however, the amplification cannot be greater than the loss suffered by the energy in passing across the hybrid coil to the other amplifier.

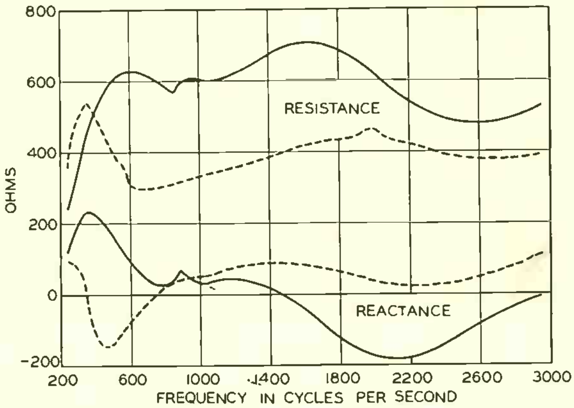


Fig. 2—Resistance and reactance of a dispatching line. The solid line represents measurements with all sets monitoring and the dotted line with one set talking

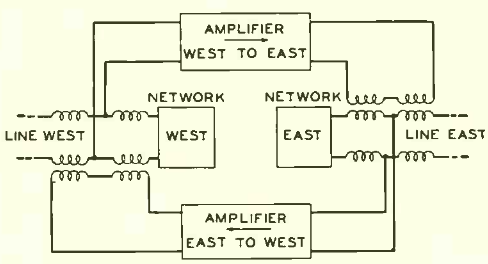


Fig. 1—Schematic of two-way, two-element telephone repeater

In the Bell System, ordinary repeatered circuits run between two points only, such as two repeater stations, and are of uniform impedance. It is comparatively simple therefore to design balancing networks that simulate them very closely, so that very satisfactory gains may be used in the repeaters. On railroad dispatching circuits, however, the situation is radically different. Since these dispatching circuits follow the railroad tracks, they branch wherever the railroad does, resulting in an impedance irregularity at each branch point. In addition, the line may be of different construction in different places. It is open wire for the most part, but there is generally a section of twisted pair at each station, causing a discontinuity at the point of junction.

A more serious obstacle to procuring a satisfactory balance between network and line is the telephone set at each station. Under the control of the station operator these may either be disconnected from the line, connected to it for listening only, or connected for both listening and talking, and the resulting impedance is different in each case. Some stations leave their sets in a listening position all the time, which is desirable from the dispatching standpoint since it allows the operator to hear what passes over the circuit all the time, and thus keeps him informed of train movements. In busy stations, however, where several wires must be answered, the telephone set may be connected to the dispatching circuit only for short intervals. To connect the set for talking, the operator depresses a switch with his foot, and when this is done the impedance bridged across the line may drop from several thousand ohms to about five hundred. Thus, on these dispatching circuits there are not only impedance irregularities, which make balancing difficult, but the impedance may be changed from time to time by considerable amounts.

In the design of the new repeater for railroad dispatching circuits, already described in the Record (May, 1934), this variation in line impedance was recognized, and as a result the balancing networks were made adjustable. This provision makes it possible to secure enough gain in the repeaters to make them suitable for dispatching lines of ordinary length. Where very long circuits are involved, however, something further must be done to improve the balance, and impedance correctors have recently been provided which allow a considerable increase in the length of line over which satisfactory transmission is obtained.

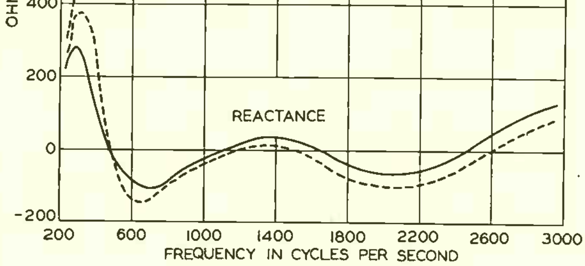


Fig. 3—Resistance and reactance of the same line under the same conditions as are represented in Figure 2, except that correctors have been added

These impedance correctors may take any of several forms depending upon the type of correction they have to make and the point in the circuit at which they will be placed. To reduce the variations in impedance of the telephone sets, they may be series resistances or transformers of one form or another; for branch circuits, only transformers are used. The correctors introduce some additional loss into the circuit, of course, but this is of no disadvantage on the far side of a repeater, since it can be more than made up by the repeater gain. The additional loss cannot be made up, however, when the impedance correctors are on the near side of the repeaters, and for this reason the repeaters may be located somewhat nearer the dispatcher's end of the circuit.

In connection with the development of the dispatching repeater, tests were made—through the courtesy of the New York, New Haven and Hartford Railroad—on a circuit extending between Pittsfield and New Haven. The dispatcher's desk at New Haven, from which this circuit is controlled, is shown at the head of this article. Measurements of the resistance and reactance of the circuit without impedance correctors is shown in Figure 2, where the solid curves are for all sets monitoring, and the dotted curves for a nearby set in the talking condition. The wide difference between the talking and monitoring condition is plainly evident. Similar measurements after impedance correctors had been inserted are shown in Figure 3. It will be noticed that the difference between talking and monitoring conditions is much less when impedance correctors are employed.

The wavy appearance of these resistance and reactance curves, particularly noticeable in Figure 3, is caused by reflection from a point of impedance irregularity. At such an irregularity, part of the current is reflected, and travels back over the line to the point of measurement. Since time is required for this back and forth transmission, the reflected cur-

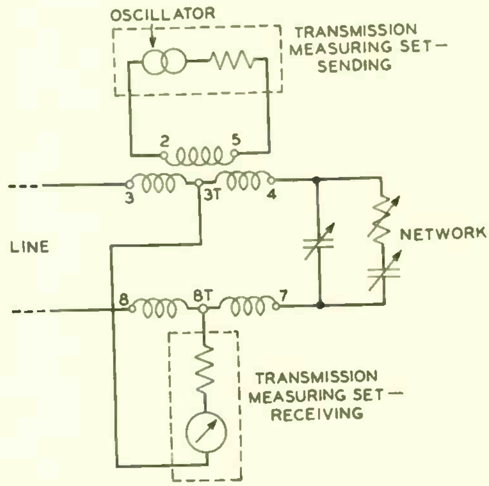


Fig. 4—Simplified schematic of circuit employed for measuring return loss

rent will, in general, be out of phase with outgoing current, and will add to or subtract from it depending on the frequency and the distance to the point of reflection. This makes it possible, if the speed of transmission is known, to compute the distance to the point of irregularity by counting the number of cycles between adjacent peaks or hollows.

The gain that may be used at the repeater, however, depends not on the impedance shown by these curves, but upon how closely the balancing networks can be made to simulate it. As has already been noted the limiting factor is the amount of energy transmitted across the hybrid coil and returned to the point of origin. Referring again to Figure 1, energy from the west-to-east repeater will, if the network exactly balances the line, divide equally between the network and line and none will be transmitted across the hybrid coil into the east-to-west repeater. The loss, in other words, is infinite for current crossing the hybrid coil. With an imperfect balance, this loss across the hybrid coil becomes less than infinity, and if it becomes as small as the gain in the amplifier, the circuit will "sing" and become inoperative. This loss is known as "return loss" and it is the value of return loss that determines the possible gain of the repeater. In no case can the amplifier gain be more than half the sum of the return loss of the two sides of the circuit. To allow a margin for variations it is usually made at least 5 db less than half the sum for telephone circuits; for dispatching circuits 3 db less was felt to be sufficient.

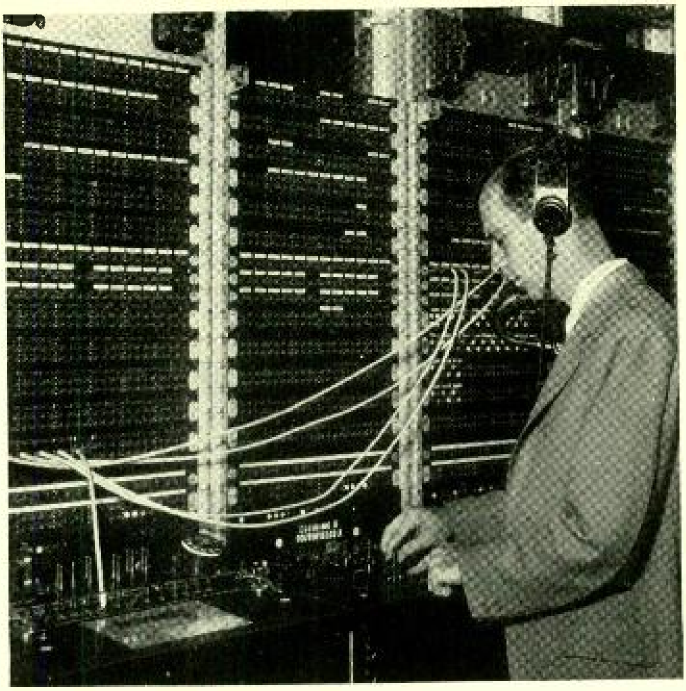
Table 1—Results of return loss measurements made at Canaan, Conn., on dispatching circuit between Pittsfield and New Haven

Circuit Condition	*Minimum Return Loss*
No correctors—All sets monitoring	15.5 db
No correctors—One set talking at Canaan	8.2 db
With correctors—All sets monitoring	16.7 db
With correctors—One set talking at Canaan	15.7 db

To measure return loss on the New Haven circuit, an arrangement similar to that shown schematically in Figure 4 was employed. An oscillator circuit replaces the west-to-east amplifier of Figure 1, and a transmission measuring set, the east-to-west amplifier. Some of the measurements made are shown in Table 1. The measured return losses at different frequencies are weighted according to the gain-frequency characteristics of the repeater, and the smallest weighted loss at any frequency serves as a criterion for the allowable gain of the repeater; these losses are shown in Table 1.

Considering first the circuit without impedance correctors, and assuming only one set talking, the permissible gain of the repeater would be 3 db less than half (15.5 + 8.2), or about 9 db. Since the loss on such a line is about 1 db for 15 miles, the use of repeaters alone, without correctors, would permit the line to be increased about 135 miles in length. Under the same conditions but with impedance correctors, the gain could be 3 db less than half of (16.7 + 15.7), or about 13 db, which is 4 db more than without correctors. By use of impedance correctors with the repeaters, therefore, the line could be extended by nearly 200 miles.

The advantages of using repeaters and impedance correctors on dispatching circuits is thus obvious. Even where a great length of line is not required, they would still prove economical by permitting smaller conductors to be used and a less expensive line installed without any sacrifice in transmission characteristics.



Locating Toll-Cable Faults

By C. E. CLUTTS
Transmission Development

At first glance the task of locating within a few feet a small and perhaps invisible fault in a section of toll cable several hundred thousand feet long would seem extremely difficult, especially if one appreciates the variety of conditions encountered which might lead to errors. However, with the testing equipment and correction methods and the highly trained personnel now available, insulation troubles and open conductors can be located in most cases within plus or minus one hundred feet. Thus cablemen, when directed to a certain calculated location, will have only a short section of cable to inspect.

The responsibility for locating these faults accurately usually rests with the attendant at the primary toll test board. This board was described in the December, 1928, issue of the Record. On receiving notification that a particular circuit is in trouble he determines the nature of the fault by means of a voltmeter; after that he proceeds to locate the position of the fault by making Wheatstone bridge measurements and introducing the values obtained into the proper formulas. A cableman is then dispatched to the point of trouble as quickly as possible to make repairs, to keep the trouble from spreading to other pairs and to reduce lost circuit time to a minimum.

Before toll cables came into extensive use the outside toll telephone plant consisted largely of open-wire lines which for the most part were located along highways, and the need for highly accurate fault locating measurements was not great since wire troubles were in general readily visible. In addition the wires were easily accessible and check tests could be made when necessary. As the telephone and telegraph facilities demanded from a given open-wire plant increased, however, it became important to reduce the time necessary to locate and clear cases of trouble.

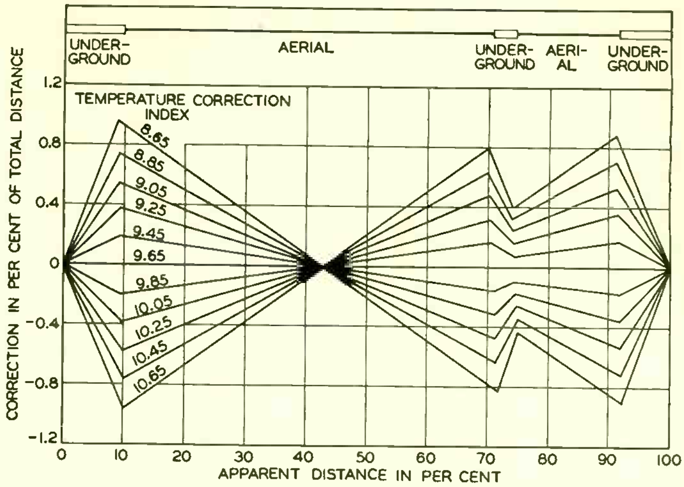


Fig. 2—Insulation faults are located by making resistance measurements on the cable. The apparent location has to be corrected by an amount which depends on the relative temperatures of the aerial and underground sections

With further growth, long toll cables containing large numbers of circuits have in many sections supplanted open-wire lines. In such cables all joints are permanently sealed so that in general there are no places outside the telephone offices where metallic contact can be made with the wires without opening the cable sheath. Moreover, every cable sheath opening adds considerably to the cost of trouble clearing. The introduction of toll cables has also involved the use of a much larger percentage of private right-of-way to which access may be difficult, and it is accordingly important to direct cablemen making repairs to the location of the trouble as accurately as possible.

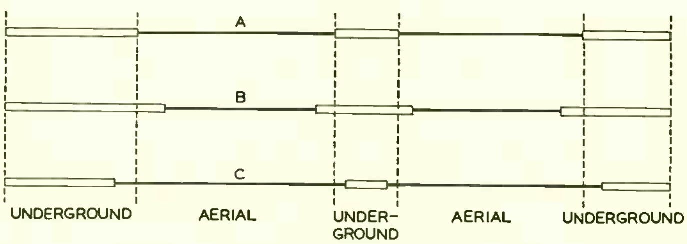


Fig. 1—The apparent lengths of the aerial and underground sections of a cable, as determined by resistance measurements, varies with the temperature of the different sections. If A represents the actual lengths, B and C show apparent lengths when the underground sections are at higher or lower temperatures respectively than the aerial sections

Thus, with the introduction of toll cable it became necessary to locate faults within a hundred feet instead of a mile or two—an increase in accuracy in the order of one hundred to one. To achieve this refinement, improvements have been made in two directions. The development of more accurate and sensitive Wheatstone bridges has resulted in improvements in the accuracy of fault locating measurements. In addition a further gain has been realized by analyzing fault locating methods and formulas and providing correction methods for calculations which may be in error because of irregularities in the cable conductors.

Formulas used in the location of faults by means of electrical measurements are based on the physical fact that certain electrical characteristics of a conductor are proportional to its length, but conditions which satisfy this relation are seldom realized in practice. In addition to such irregularities as those caused by loading coils, lumped capacitance, etc., the wires in the outer layers of a cable are longer than those near the center because the layers of wire are spiralled. In non-transposed cables this irregularity is balanced out by the large number of random splices in a fifty-mile cable section, but correction must be made in the case of transposed cable in which a single splice near the center of a cable serves to connect the wires in the outer layers on one side of the splice to wires in the inner layers on the other side. This is because the apparent distance along the cable sheath to a fault will vary, considerably, depending on whether the fault is located in an inner or outer group of conductors.

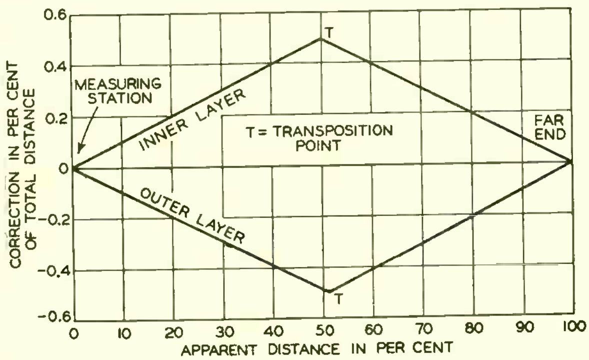


Fig. 3—The inner and outer layers of a transposed cable are interchanged at only one point which is located near the middle of the section. The correction for the apparent distance to a fault then becomes a maximum at the transposition point

Temperature variations have a marked influence on the resistance of wire and cause changes not only from season to season but from hour to hour. Thus, when sunshine is followed by a sudden downpour of rain a material change in conductor resistance may take place within a few minutes. This condition becomes complicated where some of the sections of a cable are aerial and some underground, because the aerial sections are subject to rapid temperature changes whereas the underground portions change relatively slowly. Under these circumstances what is known as an underground temperature correction is required. To determine this correction it is not necessary to know the true temperatures of either the aerial or underground sections or the actual difference between them, but merely the ratio of resistance of an underground section to the resistance of the entire cable pair containing the underground section. This ratio, or temperature correction index as it is called, is determined for each fault at the time that the regular loop and Varley measurements* are made. Taking the general case of a cable with one intermediate and two terminal underground sections the actual lengths of the aerial and underground sections may be as shown in Figure 1A. If, when making Wheatstone bridge measurements the underground sections are at higher or lower temperatures than the aerial sections, the several parts of the cable will appear to have lengths as shown in Figures 1B and 1C respectively. This

*The Varley measurement gives the resistance of a cable pair between the fault and the distant end of the cable section.

difference between actual and apparent lengths will cause an error in the location of a fault. The error will always be the same for a given temperature difference between the aerial and underground sections, however, and consequently corrections can be calculated for the temperature variations which are normally encountered. Such calculations are usually made at the time the cable is installed and become part of the permanent cable records. The corrections are recorded as a family of curves, like that shown in Figure 2, but with finer graduations. The values in per cent of total cable length are given for different temperature conditions in terms of the temperature correction factor which is expressed in per cent of the resistance of an underground section to the total resistance of the cable pair. For example, if the apparent distance of the fault is 20.00 per cent of the total cable length and the temperature correction factor is 10.25 per cent, the correction to be applied to the apparent distance is −0.40 and the corrected distance is 20.00 − 0.40 = 19.60 per cent of the total cable length.

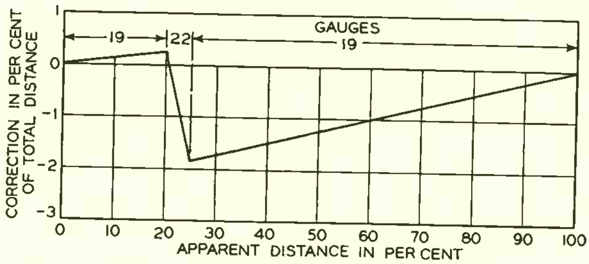


Fig. 4—Where sections of the cable are of different gauge, or if sections of different capacitance are used special correction curves are prepared

Figure 3 shows a correction curve which can be used for transposed cable, in which case the inner and outer layer pairs are spliced together near the middle of the cable section. In an average section of fifty miles this splice would be about twenty-five miles from the cable terminals. Measurements of average inner and outer layer pairs show a normal difference of about one ohm per mile. The error caused by such a difference is a maximum at the transposition splice and decreases to zero at both ends of the line. Corrections can be made either by calculation or from a curve which forms part of the cable records.

Lump capacitance such as that due to condensers or building-out cables can best be treated by simply subtracting these constants from the fault locating measurements as necessary, depending on the apparent location of the fault with respect to the added capacitance. Where sections of different gauge, or of different capacitance are involved correction can be made more easily by the use of correction curves of the type shown on Figure 4. These curves are constructed for particular sections of line and form part of the permanent records of the testing section.

Work sheets as well as correction curves are provided with the object of securing the greatest possible speed in the location of faults consistent with accuracy. A standardized form is thus attained and the tester is thereby relieved of the need to consider the order of procedure.

The use of the above correction methods has resulted in a substantial decrease in the average fault locating error which is now about one hundred feet in the toll cable plant. This has reduced the time required to locate faults with consequent gain in efficiency of operation and decrease in maintenance costs.

Contributors to This Issue

L. C. Roberts received the A.B. degree from Harvard in 1916, and immediately following spent a year and two summers at M.I.T., receiving the B.S. degree in Electrical Engineering in 1917. He then joined the Department of Development and Research of the American Telephone and Telegraph Company, remaining with them until that department was transferred to the Laboratories in 1934. His work has all been with the Toll Transmission Department—chiefly on telephone and telegraph repeaters. He spent some time, however, on development work concerned with wire connections to radio, and in 1931 spent three months in Honolulu in connection with the radio link with the United States.

After graduating from the U. S. Naval Academy and completing two years' sea duty in the Navy, C. E. Clutts joined the headquarters staff of the American Telephone and Telegraph Company in 1929. There he engaged in the study of toll circuit maintenance problems with particular reference to the development of toll test boards and methods for locating faults in the outside plant. He has continued this work since 1934 as a member of the Systems Development Department of the Laboratories and more recently as a member of the Transmission Development Department.

On receiving the degree of B.S. in E.E. in 1916 from Bucknell University, E. C. Hagemann joined the Crocker-Wheeler Company at Ampere, N. J., where he was engaged in advertising and sales engineering work. In November, 1917, he joined the A. T. and T. Company, where he engaged in transmission testing in the toll cable plant, working at various repeater stations between New Haven and Washington, D. C. The following year, he enlisted in the U. S. Naval Reserve, taking a course in the Navy steam engineering school which led to his commission as Ensign after a preliminary training on New York harbor craft and on a transport ship. In 1919, he joined the Physical Laboratories of the Western Electric Company, now Bell Telephone Laboratories. His first duties were concerned with testing and development of condensers, capacitance standards, and bridges, and with studies of

L. C. Roberts

C. E. Clutts

E. C. Hagemann

H. M. Hagland

Pierre Mertz

F. A. Hinshaw

materials and apparatus for use at radio frequencies. During the past ten years, he has been chiefly engaged in loading coil and retardation coil development work.

H. M. HAGLAND entered the employ of the Western Electric Company in the old Clinton Street, Chicago, factory and worked for a year on the inspection of subscribers' sets. He then went with the Chicago Telephone Company where he obtained a wide experience in telephone work. Until coming with the Western Electric engineering department in 1919 he worked on telephone installing, central office maintenance, local test work and switchboard repair. As a member of the Equipment Development group of the Western Electric Company and Laboratories he has been engaged on the engineering of toll equipment, local operating desks, local test desks and general standard practices. He has been doing equipment engineering of private branch exchanges since 1928.

PIERRE MERTZ received the A.B. degree from Cornell University in 1918. A year later he joined the Department of Development and Research, where he engaged in transmission studies. In 1923 he left to continue his studies, and after receiving the degree of Doctor of Philosophy, also from Cornell University, he returned to the Bell System. With the consolidation of the Department of Development and Research and the Laboratories, Dr. Mertz came to West Street where he has been engaged in the solution of transmission problems relating to telephotography and television.

F. A. HINSHAW received the B.S. degree in Electrical Engineering from Kansas State College in 1926 and immediately joined the Technical Staff of the Laboratories. Here he associated with the transmission networks group of the Apparatus Development Department, and since then has been engaged in the design of filters, equalizers and regulators. His first work was in connection with delay equalization for the original picture transmission system. Following this he designed equalizers and regulators for long toll circuits, such as high-grade program circuits, and more recently worked on the development of equalizers for the new nationwide telephotograph system.