BELL LABORATORIES RECORD

National defense and the Bell System: the Southwestern Bell Telephone Company lays buried cable at Fort Leonard Wood, near Rolla, Missouri

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Remote Control for Reversible Program Circuits

By A. E. BACHELET
Toll Switching Development

WIRE networks over which radio programs are transmitted form extensive systems, with broadcast stations or studios in most of the larger cities interconnected by high-quality circuits employing amplifiers. The transmission over these circuits differs from ordinary telephone transmission in that it is unidirectional and one-way amplifiers are employed. Because a studio may either transmit or receive programs, however, it is necessary to provide means for changing the direction of transmission over the network. This has been done in the past either by using separate facilities which transmit in opposite directions, or by interchanging the input and the output of the amplifiers by the use of patch cords or by switches* which are manually operated.

To provide quicker reversals, a remotely controlled reversing circuit has been developed which permits the reversing of the circuits to be controlled from the studio originating the program. Reversals are effected by relays controlled by direct current transmitted over the two conductors of the program circuit and returned through ground. Any studio may assume control and set up the network so as to transmit the program from it to the other points on the network. As long as this studio retains control, no other studio can alter the conditions; but upon release of control by one, any other studio may assume control, reversing such parts of the network as are necessary to permit transmitting the program to the rest of the network.

The reversing equipment is required at every amplifier point, which may be a simple amplifier station along the line, or a main junction or terminal connecting to a broadcast studio. The basic equipment, which is that required at a cable amplifier station, is shown in Figure 1. It consists of two relays L and M, which

*Record, *Feb.*, 1934, *p.* 162.

receive the control current from the line, and operate relays A and B that change the connections of the amplifiers and other equipment such as equalizers to conform to the desired direction of transmission. A green lamp and a white lamp are also provided to indicate the direction of transmission. With the relays in the positions shown in the diagram, transmission is from east to west, and the white directional light is lighted to indicate this fact. This condition had been brought about by connecting battery to the mid-point of a high resistance bridged across the line at some control point to the east of the amplifier station shown. The direct current resulting was taken from the line at the mid-point of the high-resistance bridge, and operated relay M through a back contact of L. The operation of M opened the circuit of the B relay and allowed A to operate through back contacts of L and B. The operation of A following the release of B closed a contact that changed the connections of the equipment for an east-to-west condition, and lighted the white light.

The battery connection at the control station should be maintained until a change of direction is desired. The control may be released some time before the change is made, if desired. This allows relay M to release, but relay A will remain operated, and thus the circuit will remain in the east-to-west condition. Relays L and M, now being released, are ready to receive operating current from either direction. If some station to the west of the amplifier station is to take control and transmit, for example, a similar direct current will be sent over the line from the west control point, and this current will operate L. When L operates, the holding circuit of A is opened and the B relay is operated through back contacts of M and A. This extinguishes the white lamp, changes the equipment connections for west-to-east transmission and simultaneously lights the green lamp.

These four relays, or equivalent ones, perform the reversing function at all amplifier points, but certain additional relays and keys are added to accomplish a number of other purposes. The A and B relays actually control the reversing changes and light the directional lamps to indicate which direction is in use. Each of these relays is interlocked through a back contact of the other so that only one is operated at a time. The L and M relays—also interlocked through a back contact on the other—receive the

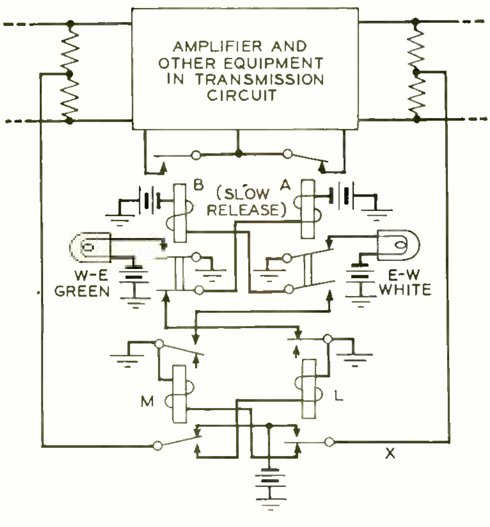


Fig. 1—Schematic of reversing circuit used at amplifier points between two cable sections

control current, and in turn operate the A or B relay. Whichever directional relay, A or B, is operated will remain operated when both L and M are released. This enables a station to relinquish control a few minutes in advance of the next reversal. Both A and B are given slow-release characteristics so that momentary disturbances on the line will not cause false operation.

Besides controlling its own directional relays, the L and M relays also send a control current over the next section of line. When a control pulse comes in from the east, for example, and operates M of Figure 1, battery will be connected through a front contact of M to the bridging resistance across the west-bound cable, so as to

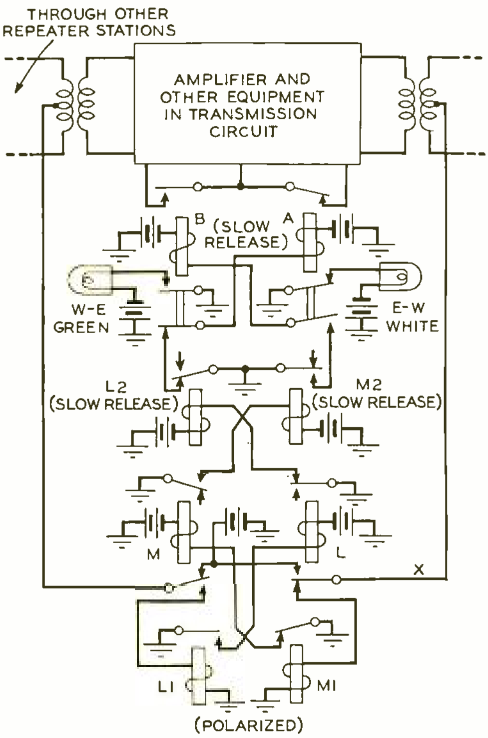


Fig. 2—Transmission-reversing circuit for use between open-wire lines

operate the M relay at the amplifier station next to the west. In a similar manner, this station will repeat to the next, so that control current sent from New York, for example, will reverse all the amplifiers along the line to the distant terminal. As is evident from the diagram, this repeating action works for both directions of transmission. A control current coming from the west will operate L of Figure 1, which will repeat it over the

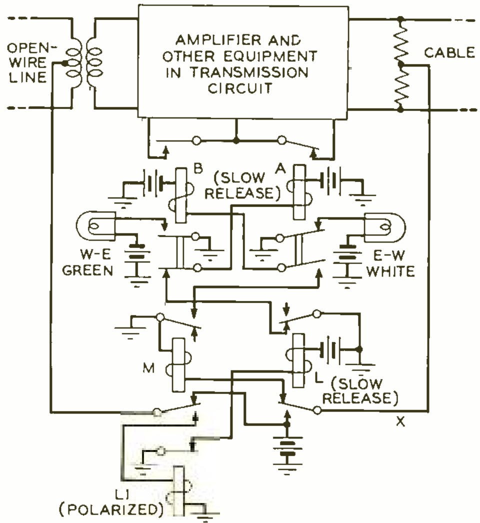


Fig. 3—Transmission-reversing circuit for use at junction of cable and open-wire line

next section of cable to the east, and so on. This repeating of the control current to the next section is not affected by the slow-release characteristics of the A and B relays, and thus the control current is transmitted rapidly over the entire circuit. One thousand miles of cable circuit, with amplifiers located at approximately fifty-mile intervals, may be reversed in a few seconds.

When the amplifier station is between two open-wire sections instead of between two cable sections, additional relays are required to insure satisfactory operation. These are needed because open-wire lines are not only much more subject to outside disturbances than are cables, but have much higher leakage to ground. The circuit arrangement for an amplifier station between two open-wire sections is shown in Figure 2. It will be noticed that the d-c control path is connected to the line at the mid-point of a repeating coil rather than of a high-resistance bridge. Because of the high leakage of the open-wire lines, much more current must be put on the line to insure that a sufficient amount reaches the distant station to operate the relays, so that the high-resistance feed is not satisfactory.

The current actually reaching the distant end varies widely not only because of varying leakage but because of variations in the ground potential. To make sure the relays do not operate falsely, their minimum operating current must be held to close limits, and for this reason polarized relays are used ahead of the regular L and M relays. These relays are marked L1 and M1—L1 operating L, and M1 operating M. Because of the greater likelihood of disturbances, it is necessary also to provide a greater time delay between the action of L and M and of A and B. This is provided by two slow-release relays, L2 and M2, between L and M and A and B. These enable A and B to "hold in" over longer surges of current than the slow-release of A and B alone would permit.

For amplifier stations between an open-wire line section and a cable section, these additional precautions need be taken only on the side toward the open-wire line. Only one polarized relay is employed therefore, as shown in Figure 3, and the additional delay between the L and M and the A and B relays is obtained by giving either the L or M relay slow-release characteristics. This puts a delay in the d-c transmission path, while the arrangement of Figure 2 does not. It is not satisfactory, therefore, for general use, but since the junctions of open wire and cable are of comparatively rare occurrence, it is permissible to take advantage of the simpler circuit that this arrangement permits.

Where the open-wire section is particularly subject to very wide variations in leakage and ground potential, a "metallic" path over the line is provided for the control current as shown

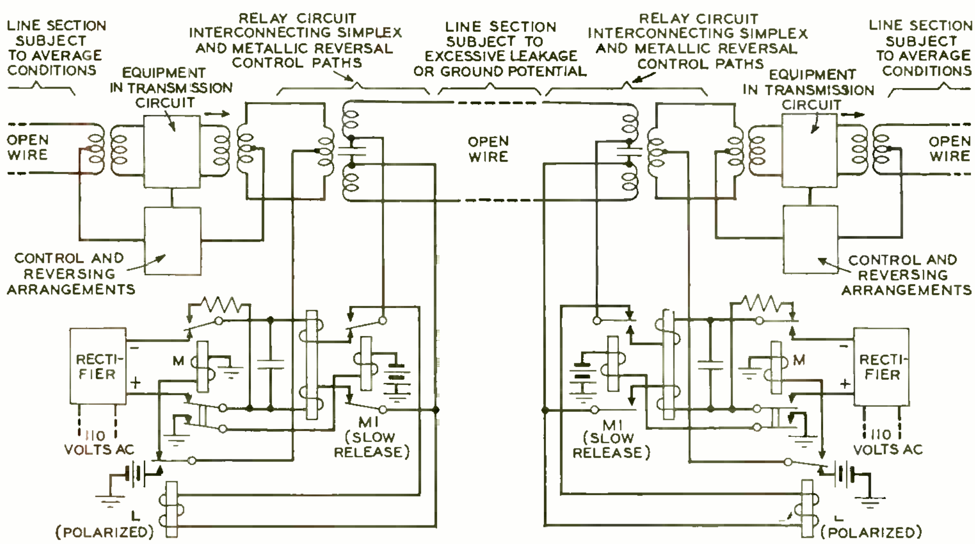


Fig. 4—Metallic control circuit used with open-wire lines subject to excessive leakage or ground potential difference

in Figure 4. The transmission-reversing circuit is the same as Figure 2, but between it and the open-wire line is another repeating coil with a large-capacitance condenser inserted in the line side of the coil. This provides the two feed points for a metallic control circuit, which is arranged in a similar manner at the other end. This circuit also uses a polarized relay, L, for receiving control current from the open-wire line, and an M relay to receive the grounded control current from the local amplifier station. With all relays released, grounded control current from the amplifier station operates M through a back contact of L. M operates M1, and connects d-c from a rectifier to the metallic line circuit. At the other end, this current operates L, which sends a grounded current to the amplifier station. A filter consisting of a retard coil and a condenser is connected between the rectifier and the line. When M releases, a resistance is connected across the line to discharge both the filter condenser and the condenser in the repeat coil to avoid false pulses or clicks in the program circuit due to the discharge current. The slow-release characteristic of M1 maintains the connection to the repeating-coil condenser for a long enough time to discharge it.

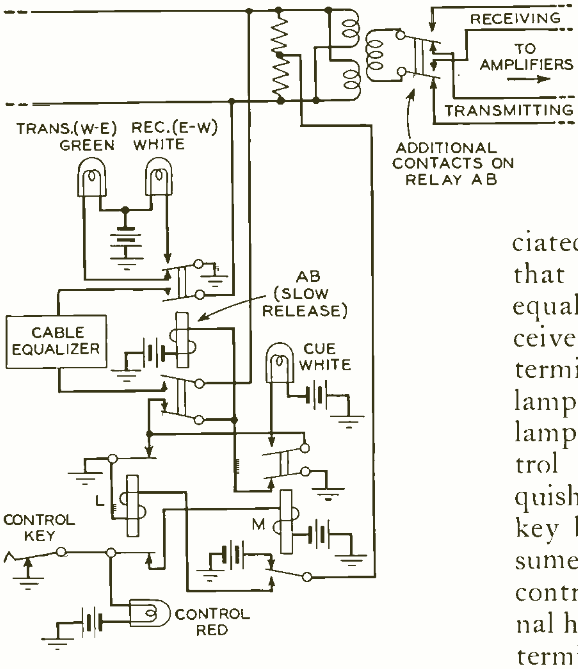


Fig. 5—Schematic diagram of typical control circuit for a terminal

At a terminal the amplifiers are under control of the broadcasting company, and the only switching of equipment associated with the line required at that point is the insertion of an equalizer when that terminal is to receive, and its disconnection when that terminal is to transmit. Directional lamps are also provided, and a "cue" lamp is added to indicate when control of the circuit has been relinquished. In addition there is a control key by which that terminal may assume control of the circuit. A red control lamp lights when that terminal has control. A schematic of such a terminal circuit is shown in Figure 5. The cue lamp is lighted only when no station has control of the circuit, since it is extinguished by the operation of M, or by the operation of L, if M is released. A single relay, AB, takes the place of the A and B relays at amplifier points, and operates on outgoing control current, and releases on incoming. Its only function is to light the directional lamps, and to insert an equalizer across the line when the direction of transmission is inward, and to remove it when the direction of transmission is outward.

Certain amplifier points act as junctions for a number of lines, and the direction of transmission might be from any one of them to all the others

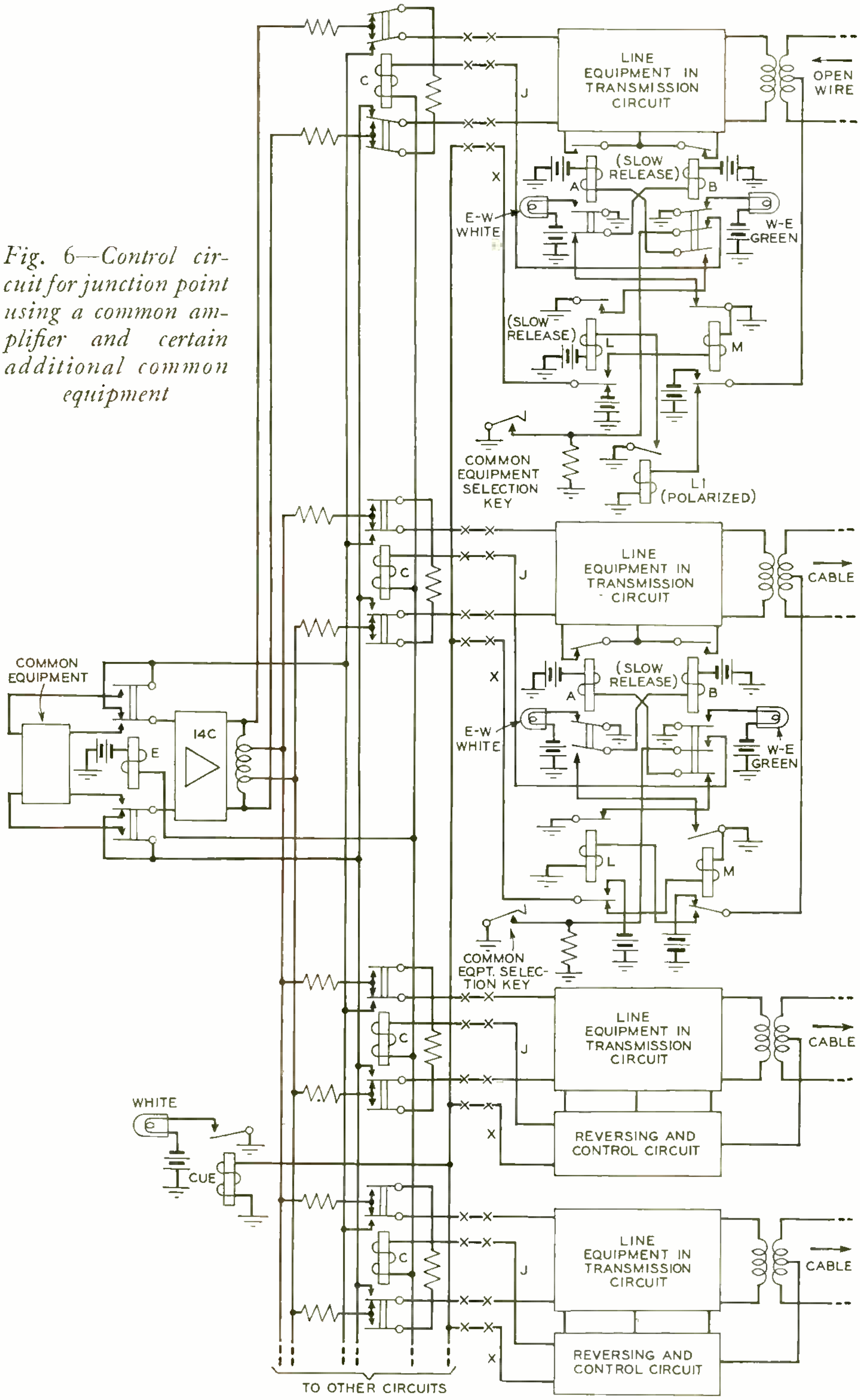


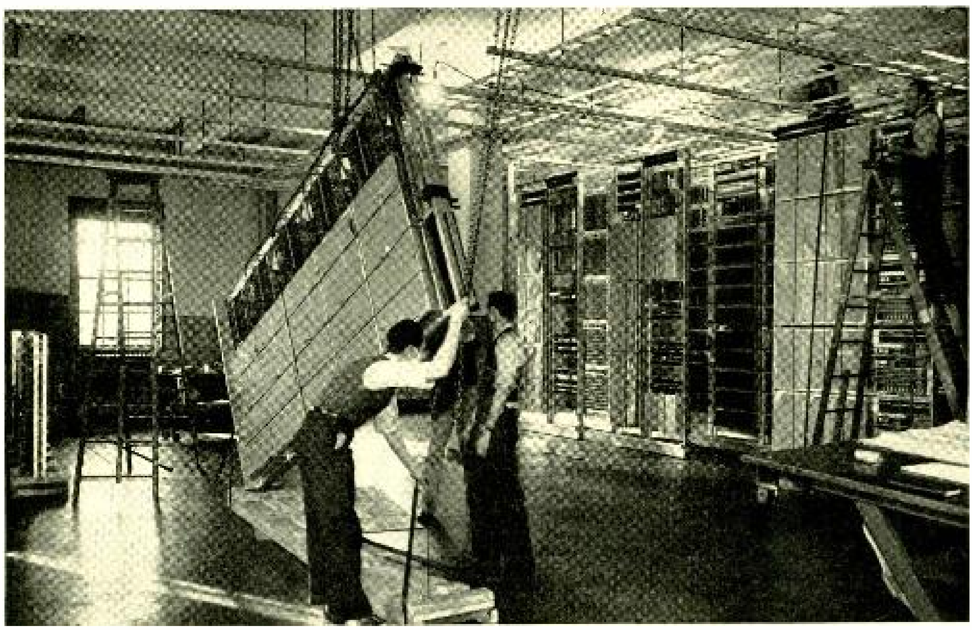
Fig. 6—Control circuit for junction point using a common amplifier and certain additional common equipment

through a bridging multiple.* Under these conditions there would be a reversing control circuit like one of those illustrated above for all the lines. Then by connecting all the leads "x" from the L relays together, the proper reversals will take place as the various lines assume control.

Under these conditions, however, it is frequently more economical to use only a single amplifier to supply all the outgoing circuits, rather than one for each circuit, and possibly a certain amount of other common equipment as well. This is made possible by adding one relay, C, for each line and one common relay, E, as shown in Figure 6. Here, it will be noticed, the X leads are all tied together as already mentioned. In addition another contact has been added to the B relays and the lead from it, J, runs to the added relay C whose winding is in series with that of the common relay E. This latter is a marginal relay, and requires more current to operate than do the C relays. It operates, therefore, only when a "common equipment selection key" is operated for one of the lines. When E is not operated, only the amplifier is used in common, but when one of the "common equipment" keys is operated, E also operates and inserts the additional common equipment.

Throughout the development of this reversing system, stress has been laid upon simplicity of operation and on dependability of service. The remote control feature constitutes an important improvement in nation-wide program-network operation.

*Record, *Aug.*, 1940, *p.* 362.



Swinging a unit of crossbar switching equipment into place in a Washington, D. C., central office, as part of a program to increase telephone facilities required by defense activities in the nation's capital. Normal installation periods are being shortened by as much as fifty per cent and it is expected that 22,500 *additional telephone lines will be in service by the end of* 1941

Detecting Faults While Laying Buried Telephone Wire

By J. B. HAYS
Cable Apparatus Development

INSULATED wires* buried directly in the ground are being used to serve rural subscribers as an alternative in some localities to the familiar one or two-pair open-wire telephone lines. Each pair of such wires has a rubber covering to insulate it from ground, and it is installed about eighteen inches below the surface with a special plow drawn by a truck or tractor. With one present type of plow, three pairs can be installed simultaneously, although the economic advantage of buried wire generally limits long installations to two pairs. The manner of installation is illustrated by the photograph above.

Troubles on an open-wire line, such as broken conductors or insulators, can usually be located without difficulty by an electrical measurement or a visual inspection. With buried wire, however, electrical methods of locating troubles often require considerable time and expense because of the difficulty in accurately locating the high-resistance faults caused by small injuries to the insulation. Visual inspection is obviously out of the question except where the damage is evidenced by a disturbance of the soil.

*RECORD, *Nov.*, 1936, *p.* 66.

On the other hand, the buried wire is not so subject to disrupting influences as is the open-wire line. Once in place there is little likelihood of its being damaged, but faults may occur while the wire is being buried. To detect them at once, the D-157237 test set has been designed. It is arranged for mounting on the wire-laying plow, and is connected to the conductors of the wire being installed to provide a continuous test of the wire for broken conductors or damaged insulation. It sounds an alarm at the occurrence of such trouble so that the plowing can be stopped immediately. By manipulation of the keys on the set, the type of damage which caused the alarm may be determined. The wire may then be readily removed from the ground for a short distance behind the plow and inspected for trouble.

Fig. 1—The D-157237 test set

This test set is shown in Figure 1. After it has been mounted on the plow together with the reels of wire, the inside end of the wire on the reels is connected to the line terminals of the set, and a ground connection is made to the frame of the plow. At the further end of the pair, the conductors are short-circuited and insulated from ground. When several pairs are being installed simultaneously, the inside ends are connected in series between the line terminals.

The circuit of the test set and its connection to the buried wire is shown schematically in Figure 2. The tube is a cold-cathode gas-filled device with two conducting paths: a main gap and a control gap, as indicated on the drawing. The main gap, which is in series with a 135-volt battery and the winding of a relay, remains non-conducting as long as the voltage across the control gap is less than 72 volts. When the potential across the control gap exceeds 72 volts, current flows in it, and the main gap becomes conducting, permitting battery current to flow through the relay.

Connected in series across the battery are the resistor R1, the conductors of the buried wire, and resistor R2. These form a voltage divider across part of which the control gap is connected. With no fault on the buried wire, the potential across the control gap is that across R2. This potential is set at about 67 volts by adjusting the variable resistor R1. This voltage is not sufficient to cause the main gap to become conducting, but if a break were to occur in the wire being installed, the voltage divider circuit would be opened, and the full 135 volts from the battery would be applied across the control gap in series with R1. This would cause the main gap to conduct current, and the relay and alarm system to operate. The charging of condenser C at the moment of breakdown gives a small additional current across the control gap to insure sufficient ionization to break down the main gap.

The insulation resistance of the wire appears in parallel with the resistor R1. A decrease in insulation resistance due, for instance, to physical damage to the wire as it is being installed, increases the current through the R2 resistor, and thus raises the voltage across it. If this increase is sufficient to bring the potential to 72 volts, the main gap will become conducting and the relay and alarm circuit will operate. An alarm is thus given both when a conductor breaks and when it becomes grounded.

After the main gap becomes conducting, it remains so even though the potential across the control gap subsequently falls below 72 volts. This enables the test set to give a permanent alarm on troubles which give only a momentary indication, such as a conductor break in which the conductors are immediately pulled back into contact by the tension of the rubber insulation. The set must be restored to normal by temporarily opening the battery circuit.

The action of the test set in detecting low insulation resistance is modified by the capacitance of the buried wire to ground. When a high-resistance ground occurs, the charge on the wire flows through the ground and tends to maintain nearly normal voltage across R1 during the discharge period. As a result, there will be a delay between the occurrence of a damage to the insulation and the operation of the set. The set is so designed that the delay does not exceed 0.5 second when detecting a 20-megohm fault. To prevent a change in sensitivity with different battery voltages and tube characteristics, the set is calibrated from time to time by adjusting the voltage divider circuit when the calibrating resistance RC is connected in place of the insulation resistance of the wire. This adjustment is made by throwing the three-position key to CAL and decreasing the adjustable resistance in the voltage

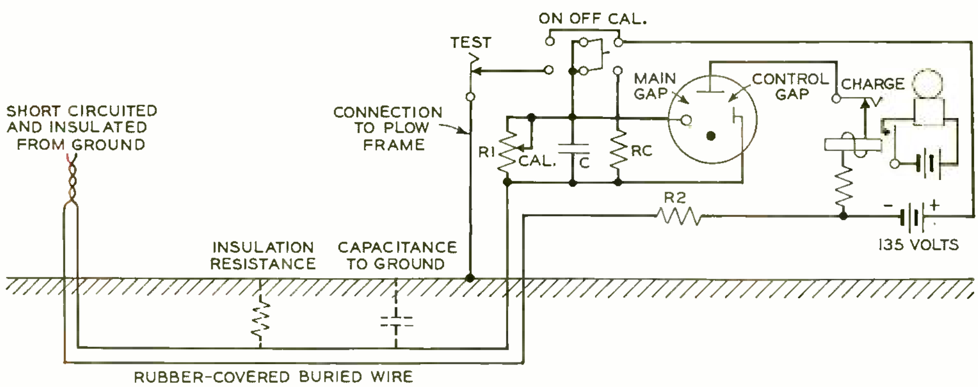


Fig. 2—Circuit of the test set and its connection to the buried wire

divider from maximum until the point is reached where the set operates.

To prevent the set from operating each time it is turned on because of the initial charging current through the buried wire and the condenser C, the battery voltage is removed from the gas-filled tube by holding the CHARGE button depressed for several seconds. This button is also used to restore the set to normal after the alarm has sounded. The TEST button opens the ground connection, and is used to determine whether the sounding of the alarm is a result of a broken conductor or damaged insulation. In this operation the CHARGE and TEST buttons are depressed simultaneously and the CHARGE button released after several seconds. If the bell rings when the CHARGE button is released, the fault is a broken conductor; if the bell does not ring, the fault has been caused by damage to the insulation.

The Pursuit of Curiosity

Curiosity is as good an explanation of the Edison Medal award as I could find. . . .

In the Bell System I have found the greatest opportunity for the pursuit of curiosity. It was a fascinating field 40 *years ago, and during that interval its expansion has been phenomenal, both quantitatively and qualitatively. What was even more important in my own case was that I became a part of a research and development organization with clear-cut goals, high standards of performance, recognition of the importance of the division of labor, and the advantage of teamwork.*

In the Bell Organization, I was assigned assistants who could do many things with greater dispatch and efficiency and perfection than I could. To some of these assistants I later reported myself, and others have carried on the work into difficulties which I myself could never have surmounted.

You will see that it is perfectly natural that I am an admirer of that kind of teamwork which represents a division of labor in the intellectual field. At one and the same time it gives a greater opportunity to those whose talents lie within rather narrow fields, and it results in an integrated product greater than the sum of the individual efforts. For reasons I have just explained, I feel that I am a beneficiary of the group method of attacking scientific problems. Without the collaboration of innumerable associates in the Bell System, the contributions you have designated to be mine I probably should not have succeeded in making. It is a distinct pleasure to me to recall these many associations and to testify that those who have been my colleagues over the years are in large part responsible for the honor of receiving the 1940 *Edison Medal.*

—George A. Campbell,
in his acceptance of the Edison Medal of 1940.

Locating Hits on Telegraph Circuits

By T. A. MARSHALL
Telegraph Development

THE fidelity required in the transmission of telegraph messages makes the detection and localization of a faulty element in a circuit of utmost importance. An interruption of only a few thousandths of a second may cause the misspelling of an important word by a teletypewriter. These short-time interruptions are known as "hits." When they appear, they may be recurrent, and it is essential to locate their source quickly. A single extensive telegraph network* may connect a large number of cities, and hits occurring on any one of the many line sections or associated repeaters may affect the messages at many receiving stations.

Such telegraph networks are usually operated on a half-duplex basis; transmission can proceed in either direction over the line, but when a subscriber who is receiving wishes to send, he must "break" into the circuit by sending a "space" signal of about two seconds' duration. An interruption of this length renders the transmitting equipment at the sending station inoperative, and thus serves as an indication that some other subscriber wishes to send. The short interruption of a hit, however, generally has no effect on the transmitting equipment, and thus the sender is ignorant of its occurrence, but it may cause an error in all the receivers on the circuit. A typical circuit is indicated in Figure 1. Here the subscriber on loop 1 out of office A is represented as sending to all the other stations, and the direction of transmission is indicated by the solid arrows. Should a hit of sufficient duration occur at office X, its effect would be transmitted to all the other offices as indi-

*RECORD, *Jan.*, 1934, *p.* 154.

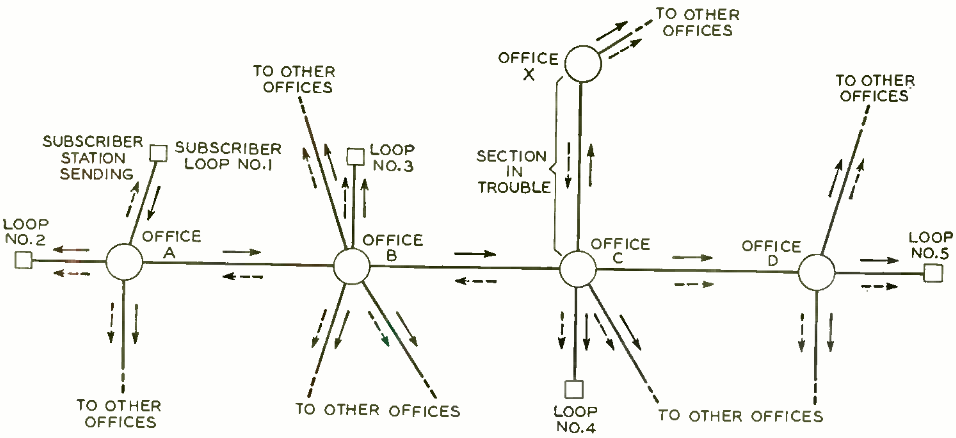


Fig. 1—Typical telegraph circuits. Solid arrows indicate direction of transmission and dotted arrows, the direction of transmission of a hit occurring on the line to office X

cated by the dotted arrows, Figure 1.

Recurring hits are, of course, of infrequent occurrence. On these large networks, however, there is always the possibility of a condition arising

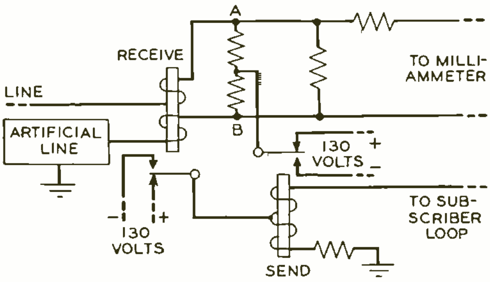


Fig. 2—Simplified schematic of a half-duplex telegraph repeater circuit

at some point that will cause them. Because of the harmful effect of such hits on reception, it is important that their source be promptly located so that a spare circuit or equipment may be put in place of the defective one while the source of the trouble is being more definitely located and removed. The defective messages received indicate when hits are occurring, and the nature of the half-duplex circuit makes possible a rather simple method of determining their location.

A simplified schematic of a half-duplex repeater circuit is indicated in Figure 2. Signals coming in over the line from the left operate the receiving relay, and the armature of this relay—following the telegraph pulses—sends similar pulses out on the loop to the right through the windings of the relay that is sending. The sending relay does not operate because the two windings oppose each other when battery is applied to their mid-point. Signals coming from the right, on the other hand, operate the sending relay and thus connect battery, in accordance with the telegraph pulses, to the two windings of the receiving relay. This relay does not operate under these conditions, but the signals are sent over the line to the left. When signals are being transmitted from left to right, the potential across the points A and B follows the telegraph pulses, but when the signals are being transmitted from right to left, the sending battery establishes no potential across A and B because of the balanced circuit. If a milliammeter were connected across A and B, therefore, it would give a steady reading when transmission was from right to left. Should a hit occur in the line or equip-

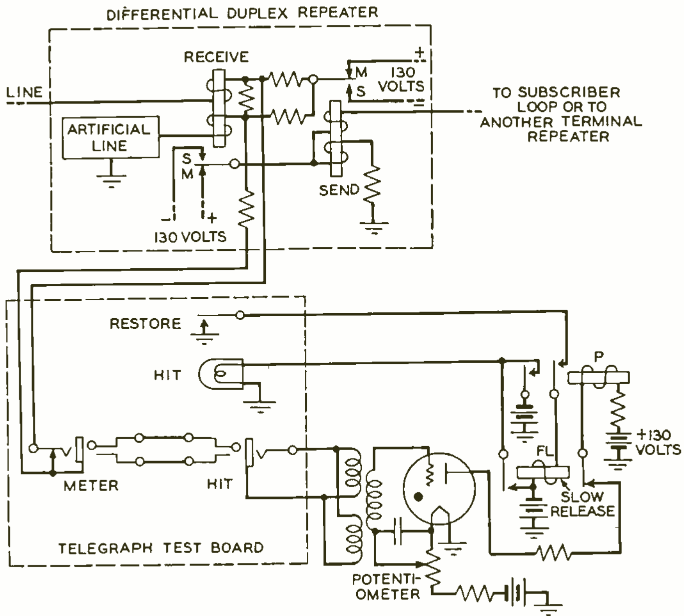


Fig. 3—The 162B1 *hit-indicator circuit, shown in simplified form at the right, is "patched" to a telegraph circuit as desired*

ment to the left, however, it would cause a momentary deflection of the meter for each hit. In certain instances, especially where the line section to the left consists of separate send and receive paths, as in four-wire metallic circuits, hits may occur on the sending side of the circuit. In this event the meter does not indicate, and the method here described does not lead to a definite location of the trouble.

In the more usual case, a section and its terminal equipment in which hits are occurring may be located by the observation of meters connected at the various offices on the circuit. At each office where the effect of the hit is traveling in a direction opposite to the direction of the telegraph transmission, there will be a deflection of the meter for each hit. Where the hit is traveling in the same direction as the telegraph transmission, however, no deflection will appear. Thus for the transmission conditions indicated in Figure 1, the meters at offices A, B, and C would show deflections, while that at D would not. This would determine that the hit was in some line leaving office C, and with meters on all the circuits leaving this office, the faulty section could readily be located. This method has been used in the past but it requires close attention on the part of the maintenance force. Not only are the meter deflections very rapid, but at many offices there will be a number of them, one for each branch, and they must all be watched simultaneously to see which ones do and which do not deflect.

To simplify this location of hits, the 162-type hit indicator has been developed. It is connected to the circuit in the same manner as the milliammeters, but it includes a gas-filled tube and lights a lamp as a permanent signal each time a hit occurs. This lamp will remain lighted until the circuit is reset, and thus the strain of watching for a number of simultaneous indications is avoided. The new circuit is arranged in two forms, known as the 162A1 and the 162B1. The latter is a low-impedance circuit and connects to the repeater over two wires. Some repeaters, however, are arranged for connecting the meter to the armature of the receiving relay over a single conductor, and the 162A1 is a high-impedance device which is used for this type of connection.

The arrangement of the 162B1 and

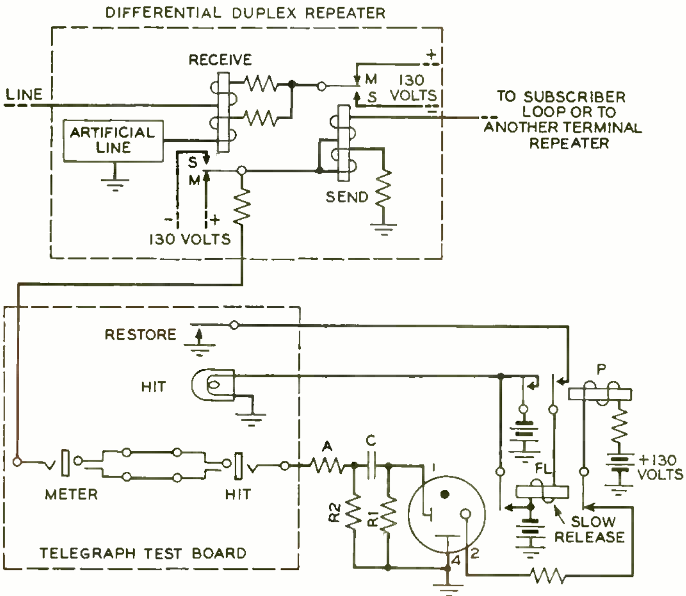


Fig. 4—The 162A1 hit indicator employs a cold-cathode gas-filled tube with a high-impedance input circuit

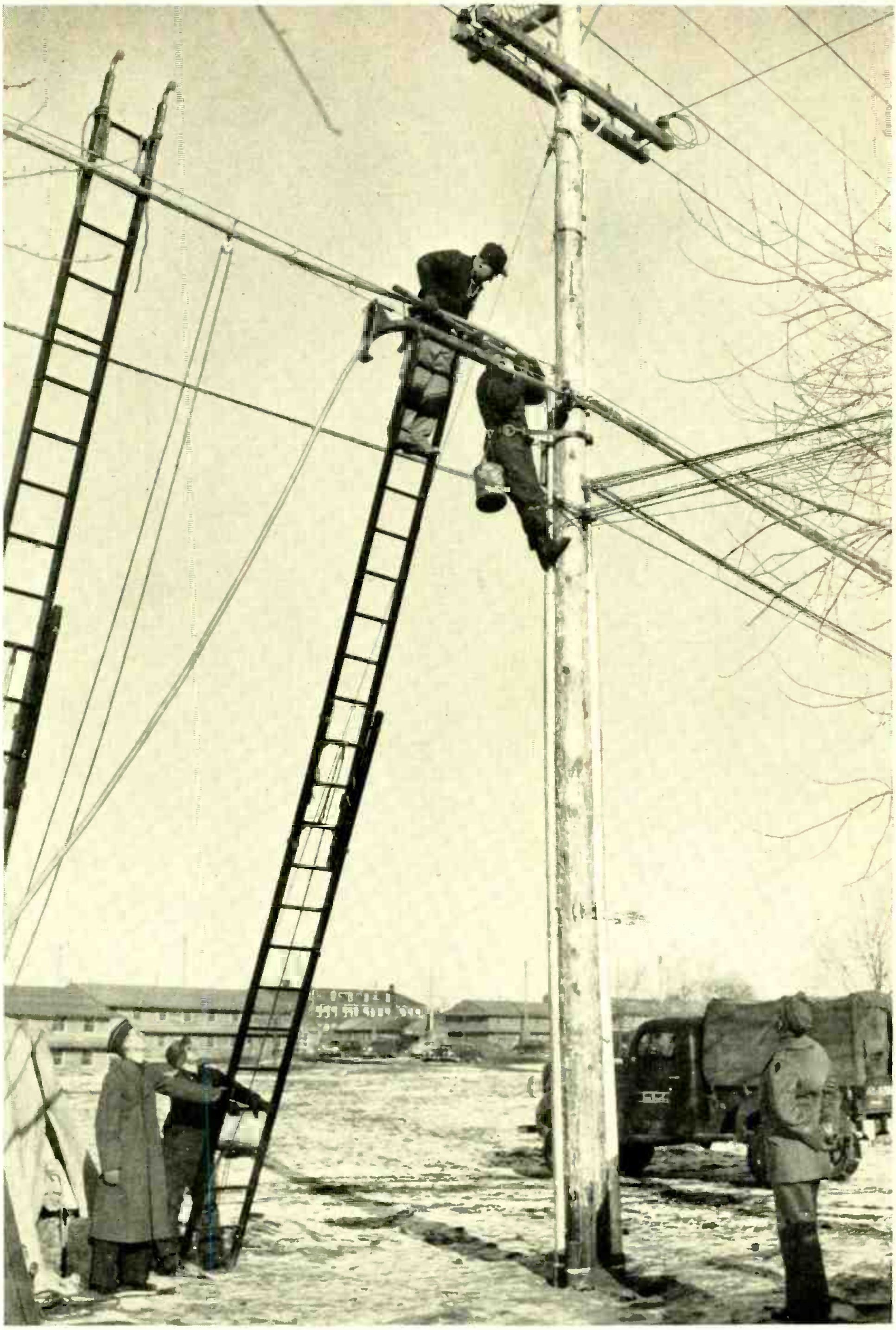
its connections to the telegraph repeater are shown in Figure 3. Connections from the circuit of the receiving relay carried to jacks in the telegraph board are already available for use with the milliammeters of previous practice. The hit-indicating circuit is also connected to a jack in the test board, and may thus be "patched" to any telegraph circuit as desired. When a hit occurs, relay P is operated, and lights a lamp as an indication. This lamp remains lighted until the restoring key is operated. This key operates relay FL, which opens the circuit to relay P.

A high-ratio transformer serves as the input to the hit indicator, and its secondary winding is connected across the grid of the hot-cathode gas-filled tube and a potentiometer in the filament circuit. No current will pass through the tube when the grid voltage is more than about eight volts negative, and the potentiometer is set to make the grid about eleven volts negative with no input to the transformer. A hit that will give more than three volts on the secondary of the transformer will cause the tube to conduct, and once the tube becomes conducting, it will remain so until the current through it is interrupted. In this way, a hit lasting only a few thousandths of a second will cause a lamp to light and remain lighted until released. This enables a single attendant to watch a number of circuits simultaneously without the strain of watching for momentary deflections on a number of meters.

For the 162A1 indicator, a very similar circuit is employed except that a cold-cathode gas-filled tube with a high-impedance input circuit is employed. A simplified schematic is shown in Figure 4. The input is connected to the armature of the receiving relay, which—when transmission is proceeding from right to left—remains on its back contact so that the condenser C is charged to 130 volts. Under these conditions, there is no voltage across the control gap, terminals 1 and 4, of the tube, and no current flows through the main gap. When a hit comes in from the left of sufficient value to move the armature of the receiving relay away from its back contact, the condenser discharges through resistances R1 and R2, and in doing so impresses sufficient voltage across the control gap of the tube to make the main gap conducting. From this point on the circuit acts as with the 162B1 indicator.

With either circuit, a change in the direction of transmission will cause the indicators to respond because the receiving relays will be operating intermittently. Whether a lighted lamp means a hit, or merely that the direction of transmission has been changed, is readily determined by holding the restoring key operated. If transmission is now in the opposite direction, the lamp will flash irregularly at a rate determined primarily by the release time of the FL relay.

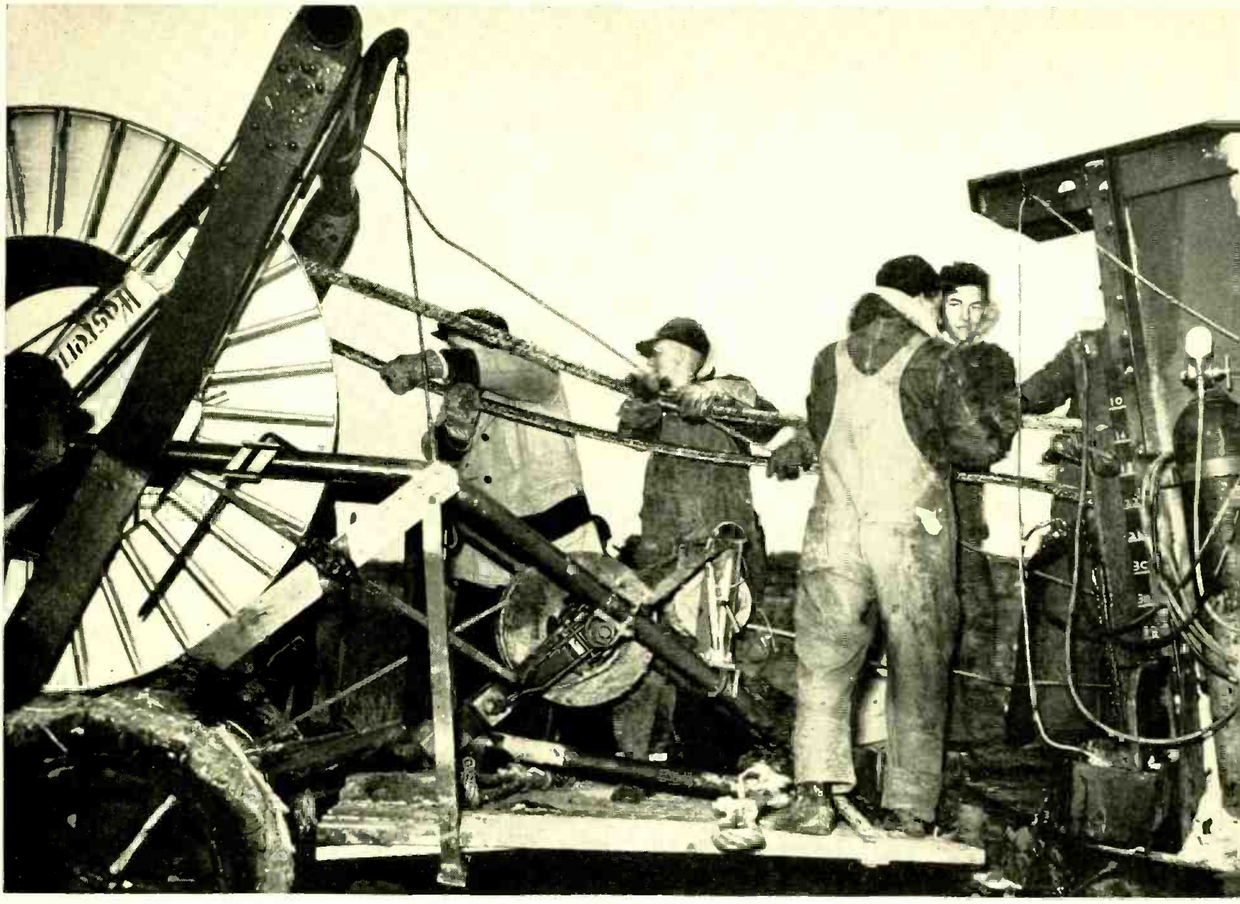
All the apparatus for these hit-indicating circuits is on a four-inch relay-rack panel that may be mounted in any convenient place in the office. They are provided in lots of four and are multipled so as to appear at several positions of the test board. Besides the apparatus shown, busy lamps and non-interfering circuits are incorporated to prevent the crossing up of telegraph circuits.



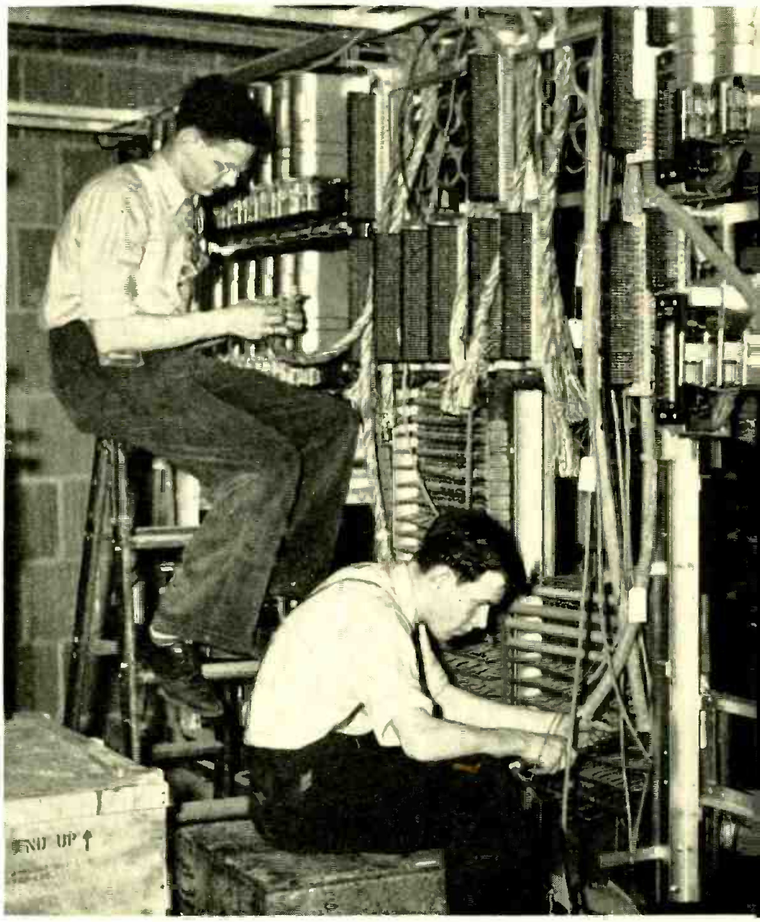
t Fort Custer, near attle Creek, a Michi-an Bell crew installs new 303-pair cable

NATIONAL DEFENSE *and the* BELL SYSTEM

Telephone companies are rapidly putting in new poles, cables, switchboards, to care for the many additional needs for service occasioned by the National Defense Program. Works and warehouses of Western Electric are meeting difficult schedules, in order that construction crews may receive a constant flow of materials. Throughout the United States the work goes forward as shown in these pictures from widely scattered places



On their way to Sacramento, this Long Lines crew plows in cable across Northwestern Bell territory to increase the security of transcontinental circuits

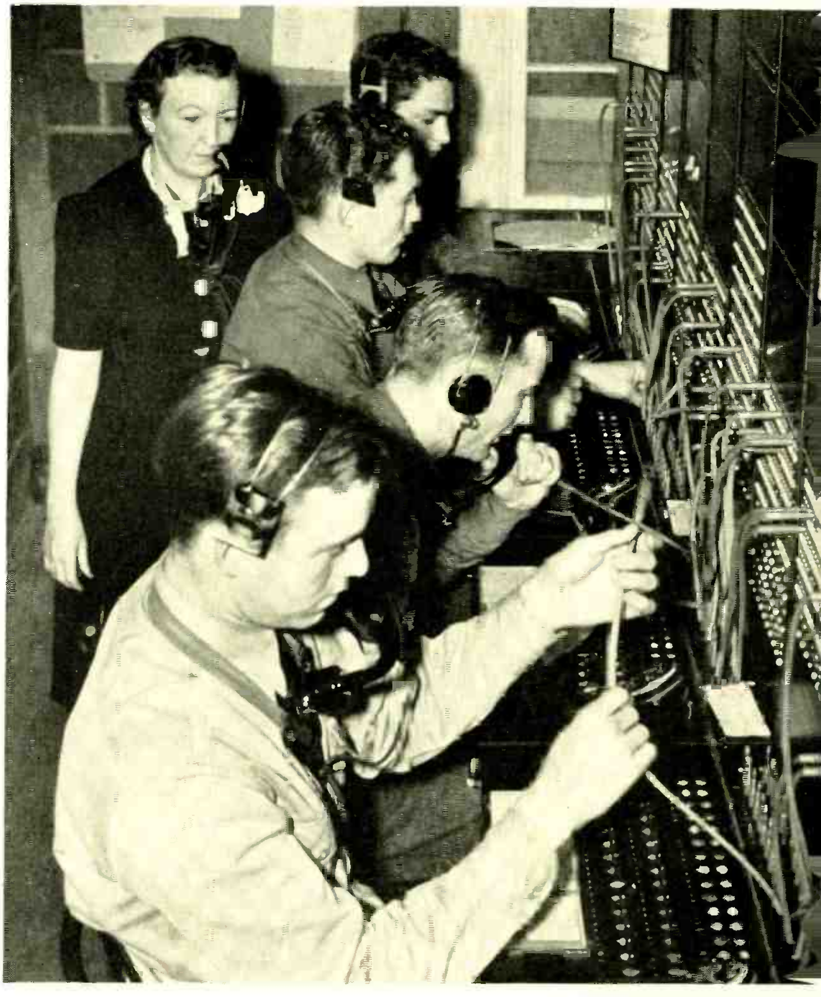


Greatly expanded activity at an arms factory in Connecticut required the installation of this new PBX by The Southern New England Telephone Company

As Illinois Bell men guard the cables, a metal building housing a dial PBX is lifted to a roof-top without interrupting service

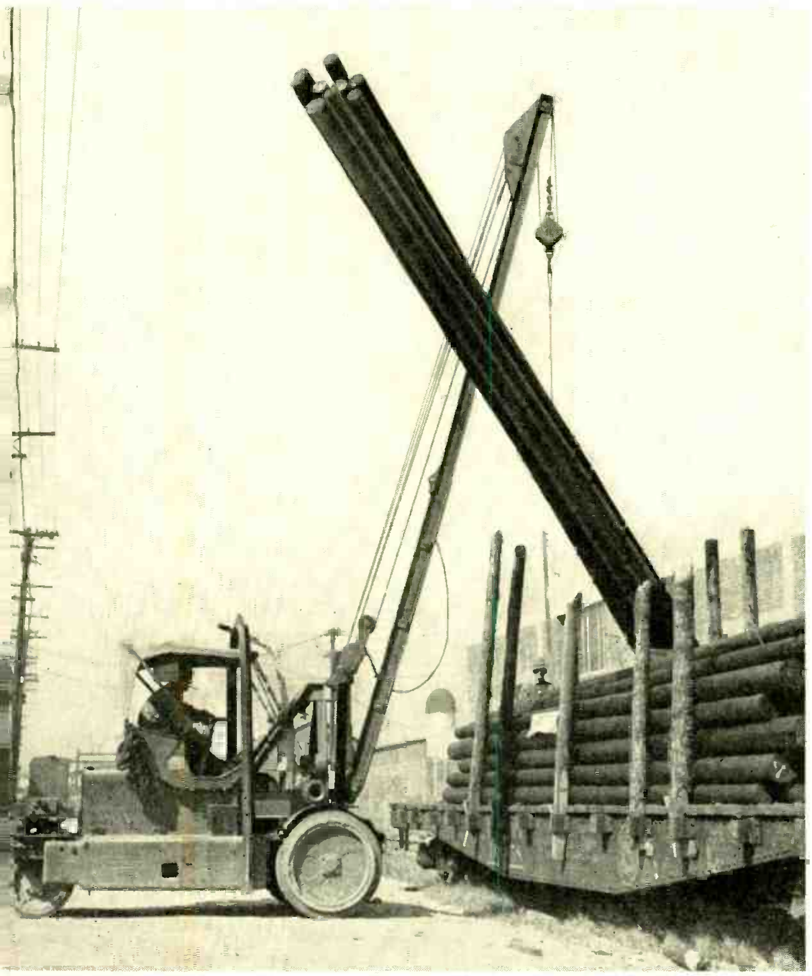
Construction of a new Army camp required that a telephone cable be moved to a new position. New England Bell splicers are here shown joining two sections of the cable in its new location along the Cape Cod Canal

After fire had destroyed the communication center at Norfolk Naval Base on the morning of January 26, 1941, a temporary switchboard was installed by The Chesapeake and Potomac Telephone Company. This photograph was taken three days after the fire



Army telephone men are being trained by a Southwestern Bell instructor to operate this four-position switchboard at Fort Sill

The expansion required for telephone service to an Army camp is well illustrated by the history of the Mt. Holly, New Jersey, Central Office. Twelve positions have been added to the original ten and twelve more will shortly be in service



Defense preparations have made it necessary for the Southern California Telephone Company to increase the supplies at its pole yard. Here a "handful" of poles is being unloaded from a flat car

"No-Such-Number" Tone for Dial Systems

By M. E. KROM
Switching Development

OCCASIONALLY a customer's error in dialing results in his reaching a group of numbers not assigned for service. In such cases a tone may be used to inform the customer of his error, and the "no-such-number" tone has been developed for this purpose. A distinctive tone was desired, which could be easily remembered and associated with the idea of disconnecting and then dialing the number again. Various combinations of existing tones were tried but none was distinctive enough to prevent confusion with those used to convey other information. An entirely new tone was developed which varies continuously in frequency, like that of a siren, alternately rising and falling at half-second intervals. Its sound is quite different from any other tone used in the Bell System.

A wave-form of the tone is shown in Figure 1; the fundamental frequency at the lowest pitch is 200 cycles per second, and at the highest pitch 400 cycles. Harmonics up to 6000 cycles are in both tones as shown in Figure 2; these give the tones a richness not found in single-frequency waves.

The circuit used to supply this tone is shown in Figure 3. A relaxation oscillator which consists of a vacuum tube T1, the condenser C1 and resistance R1 generates a tone whose frequency is a function of the potential on the grid of the tube. This grid potential is made to vary through a range of approximately one-half volt by the rate of charge and discharge of the condenser C2 through the resistance R4. With the relay INT alternately operated and released every half second the fundamental frequency varies between approximately 200 cycles and 400 cycles per second. Potentiometers P1 and P2 are maintained at one-half volt difference in potential by resistances R2 and R3 in the filament circuit. Since these two potentiometers are similar and have a shaft that is common to both, their rotor terminals always differ in potential by one-half volt.

Potentiometers, rather than fixed potentials, are employed to permit compensation for variations in the vacuum tube characteristics. The tone circuit operates from the 48-volt central-office battery and variations in voltage are compensated by a bal-

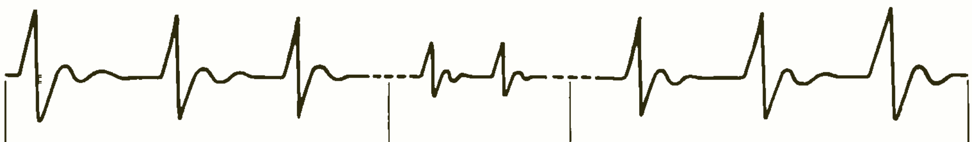


Fig. 1—The "no-such-number" tone is a train of oscillations whose fundamental frequency varies between 200 and 400 vibrations per second

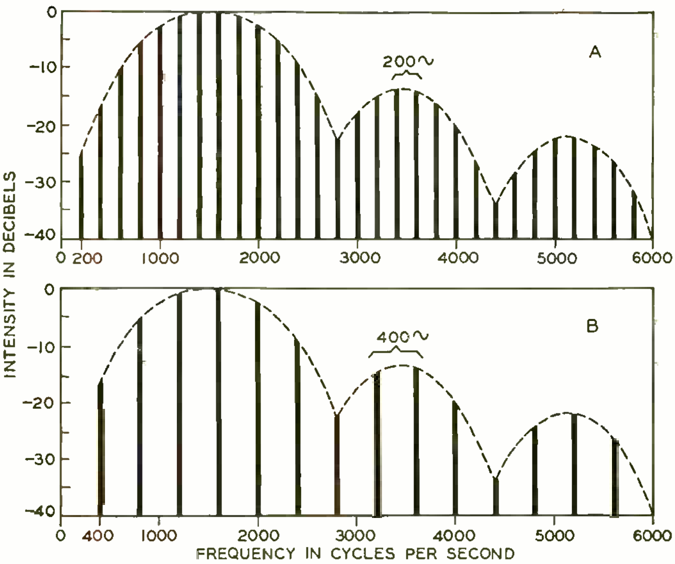


Fig. 2—Each oscillation of the tone consists of a fundamental and many harmonics. The envelope of the intensities of the harmonics is substantially the same for any fundamental frequency between 200 *and* 400 *vibrations per second*

above that of the dial and busy tones. Relay TO functions as the output transformer. Its output winding has a low internal impedance to allow for large fluctuations in load without appreciably affecting the output level. The potentiometer P3 permits adjusting the output to a satisfactory level. There is a difference of only 7 db between the no-load and the full-load conditions. The amplifier stage also serves to isolate the load circuit from the generating circuit, thereby preventing

last lamp. In practice the tone is connected to vacant code trunks in the panel and crossbar systems and to vacant local selector levels in the step-by-step system.

The tone is amplified by the vacuum tube T2. This raises the level variations in load impedance from affecting the character of the tone.

To lengthen the life of the vacuum tubes, the plate circuits are closed only when the tone is required. The filaments are continuously heated, however, to maintain the circuit in

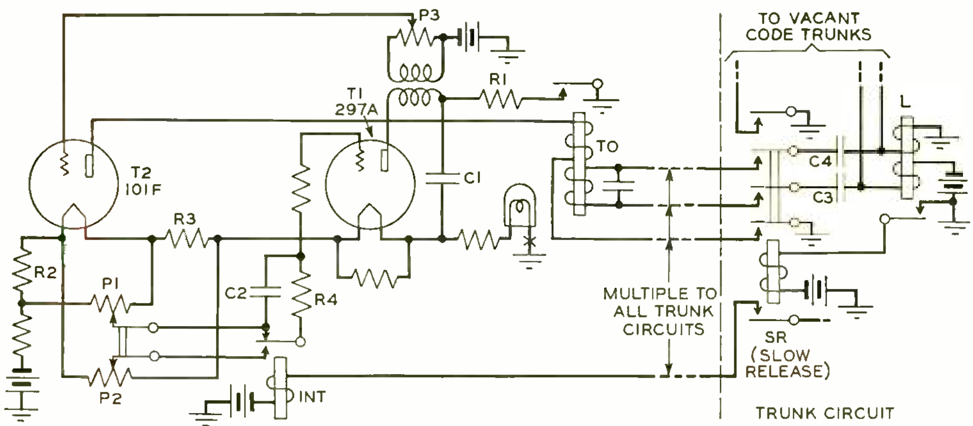


Fig. 3—The tone is generated by a relaxation oscillator which consists of vacuum tube T1, *condenser* C1, *and resistance* R1. *The frequency of the tone is controlled by the rate of charge and discharge of condenser* C2

readiness for instant service. This demand is indicated by the operation of relay SR through the associated relay L. One L relay is connected directly to each vacant code trunk and operates as soon as the trunk is seized. The relay SR releases slowly to hold during dial pulses, if the subscriber continues to dial after the trunk is seized. Operation of the relay SR starts the tone circuit immediately by connecting the plate battery to the vacuum tubes. It also applies the ground pulses to operate the relay INT and cuts the tone through to the associated trunk. The tone is applied to the trunk through condensers C3 and C4 to provide a high tone level and to minimize noise coupling with other circuits. The circuit can supply tone for twenty trunks simultaneously, which is more than will be required for any one central-office unit. Ordinarily one regular and one reserve tone-generating circuit will be provided so that transfer from one to the other can be made in case of failure in either circuit.

"No-such-number" tone is pleasing, yet distinctive and arresting enough to receive immediate attention from the subscriber. During field trials it has reduced circuit holding time on numbers wrongly dialed and resulted in a higher percentage of correct numbers on the second dialing.

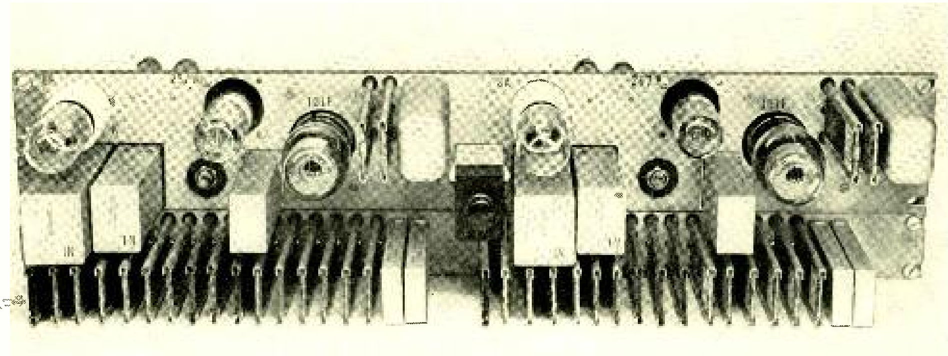
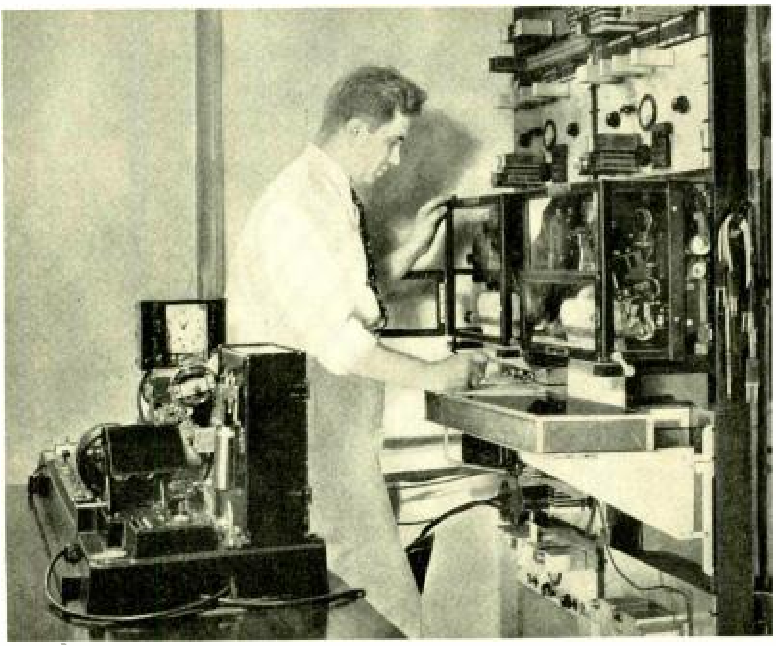


Fig. 4—"No-such-number" equipment warns the subscriber of his error by sounding a distinctive tone. One regular and one reserve generator are provided with a key for transferring from one to the other in case of failure of either



Studying the Performance of Toll Circuits

By L. L. GLEZEN
Toll Transmission Engineering

A MODERN long-distance telephone line is a far-flung and complex structure. It is subjected to a wide variety of weather conditions such as sleet, wind, and lightning, and to radical changes in temperature. Telephone circuits associated with such a line include a great number of pieces of intricate electrical apparatus, which are necessary to preserve the original quality and volume of the transmitted signals. With a type-K carrier system, for example, there may be sixty repeaters in a thousand-mile circuit; sixty points, in other words, where the circuit passes through equipment such as equalizers and amplifiers, and where automatic adjustments are made to compensate for variations in loss. All the equipment is designed so that the net loss over each circuit will not vary by more than a small amount for all normal changes. Because of this complexity of equipment, it is particularly important in the field trial before commercial application to study the behavior of the circuits under all sorts of conditions, to perfect adjustments, and to weed out unsatisfactory elements. This work has been greatly aided in recent years by the use of a group of special recording equipment.

Some of the changes that occur in transmission over a toll line, such as those due to temperature variations, arise slowly, and may last for a considerable time; others, such as lightning disturbances, may endure only a few thousandths of a second. To secure a record of all kinds of changes, therefore, it has seemed best to employ two types of apparatus. One, used primarily to record the slower changes, is a graphic meter that runs continuously. The chart moves a little over an inch in an hour, and gives a 24-hour record in a space of about thirty inches. The other is a string oscillograph that is set in motion only when a sudden change in transmission of appreciable magnitude occurs. It runs a predetermined but adjustable interval and is then automatically stopped, and restored to normal to be ready for the next sudden change.

When a circuit is to be studied, 1000-cycle testing power, at about the level used for normal transmission, is supplied to one end, and this recording equipment is connected at the other end. How long the test is continued will depend somewhat on conditions, but it is generally desirable to extend the test over a period of six or eight months so selected as to secure the extreme range of conditions. Under normal circumstances simultaneous records are made on at least two transmission paths to make sure the conditions recorded are representative.

The arrangement of the apparatus is shown in block schematic form in Figure 1. At the receiving end of the circuit under test, a terminating network is provided to match the impedances of the toll line and the recording apparatus, and to divide the circuit to be tested into three branches.

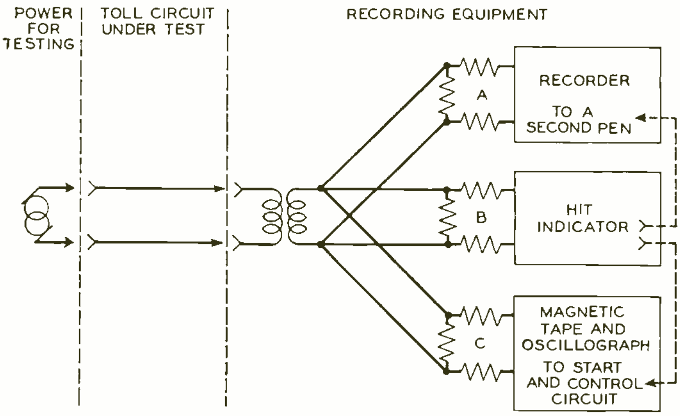


Fig. 1—Block schematic of recording equipment used for studying conditions on toll lines

The "A" branch is that to the continuous recorder, which may be any of several types. In general it does not record changes in transmission that last less than one second, nor does it record the true value of changes lasting less than five or six seconds, or even longer for changes of large magnitude. The calibrated range of the recorder may be changed as desired, but it is usually ±3 or ±6 db. With such scales a change of 0.1 db occupies 0.1 or 0.05 inch of space.

The "B" branch comprises a "hit" indicator. A "hit" may be defined as a momentary disturbance due to a sudden change in the net loss of the circuit or the addition of energy to the circuit from some external source. Operation of the hit indicator starts the oscillograph in branch "C." It also causes a small deflection of a second pen on the recorder in branch A to enable the oscillograph record to be correlated with events on the continuous chart. The hit indicator is usually calibrated to operate on changes greater than 3 db and lasting longer than about 3 milliseconds. For changes lasting less than 3 milliseconds, the circuit has an integrating characteristic; a 20-db hit lasting about one millisecond, for example, will operate it, as will a 10-db hit lasting two milliseconds. The hit indicator may be adjusted to operate on changes of other magnitudes as desired for special conditions.

The film of the oscillograph in branch C is normally at rest, and the lamp is operated at greatly reduced brilliancy. To bring the film up to speed and the lamp to full brilliancy requires an appreciable time—perhaps longer than the duration of the hit. To permit the hit to be fully and correctly recorded, it is necessary therefore to introduce some delay in the path between the line and the string of the oscillograph. The equipment used in branch C employs a magnetic tape recorder* for this purpose. A simplified schematic of the arrangement is shown in Figure 2. Other methods of accomplishing this with equipment used for somewhat similar purposes have already been described in the RECORD.†

The tape machine includes a recording unit, a reproducing unit, and a polarizing unit. The recording unit makes a continuous record on the tape of the energy on the line. After a short delay, depending on the adjustable distance between the recording and reproducing units, this record is picked up by the reproducing unit and operates the string of the oscillograph. Normally, however, no record is made on the film because the lamp is at reduced brilliancy and the film is stationary. After passing the reproducing unit, the tape passes around the driving pulley, makes a number of turns around the storage pulley, and then passes through the polarizing unit, which erases the record so that the tape will be in proper condition for again passing through the recording unit. This tape machine operates continuously in this manner whether hits are present or not.

When a hit of sufficient magnitude occurs, the hit indicator operates and actuates relays to start the film in the oscillograph and to bring the lamp to full brilliancy. By the time the part of the tape carrying the hit reaches

*RECORD, *Sept.*, 1937, *p.* 2.
†RECORD, *Jan.*, 1940, *pp.* 140 *and* 145.

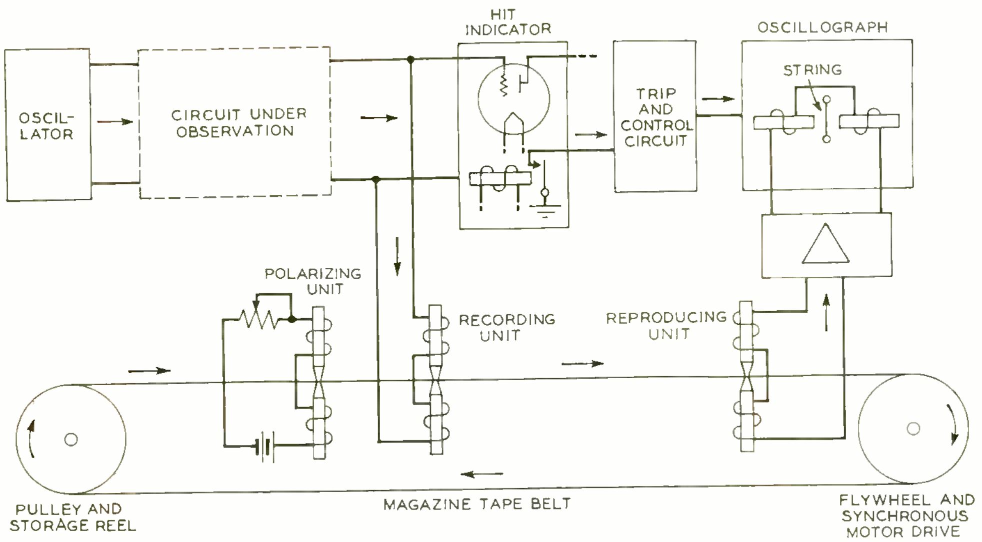


Fig. 2—Schematic of delay features of oscillographic record

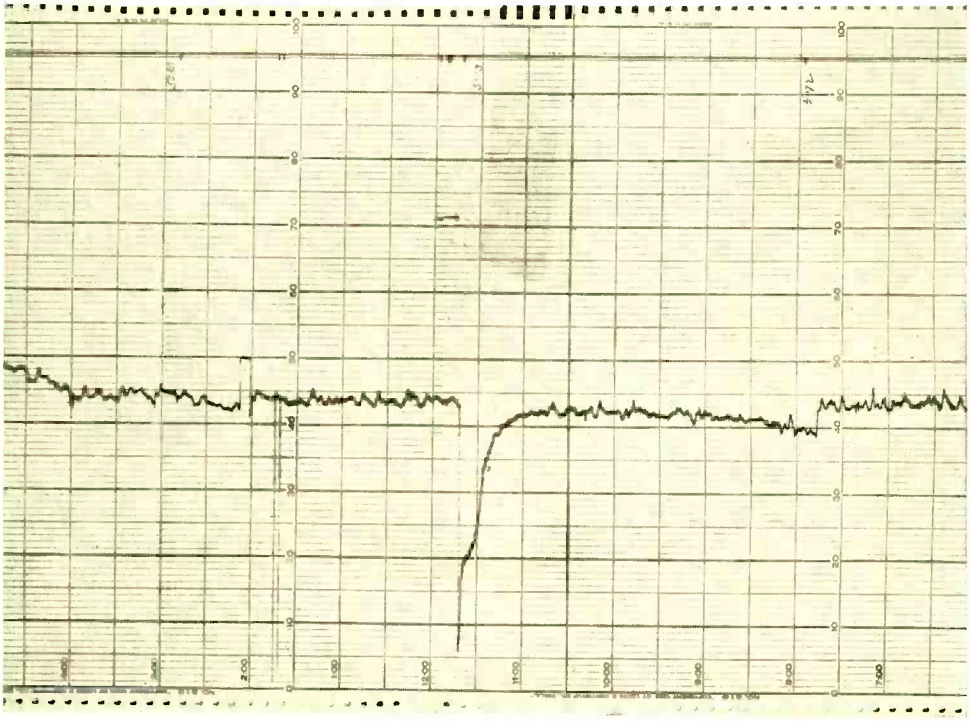


Fig. 3—Section of chart for an 11-hour period. Ordinate scale divided by 10 is in dbs

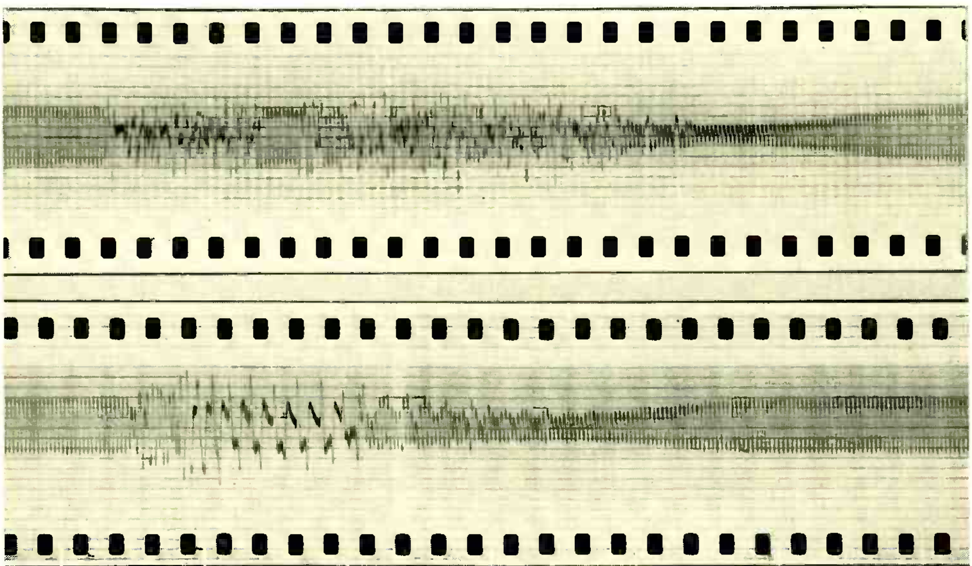


Fig. 4—Two oscillographic records showing typical effects of lightning disturbances

the reproducing unit the oscillograph is operating and a correct record of the hit disturbance can be made. As a matter of fact, the reproducing unit is spaced for sufficient delay to permit a small interval of normal transmission to be recorded before the hit occurs. After the record has been made, a sequence switch that controls the sequence of operations after the hit indicator has operated causes the date, location, and time of day to be photographed on the film immediately following its record of the transient disturbance. With this information available, the records of hits on the oscillograph film may be correlated with the data on the slow-speed chart and with other information.

A section of a chart covering an 11-hour period is shown in Figure 3. The heavy horizontal lines are 1 db apart, and the fine horizontal lines, 0.1 db. The first major change in level begins at about 11 A.M., and shows the effect of a gradually developing contact resistance. At about 11:40, probably some vibration or perhaps a sudden increase in the energy caused the contact to become good, and the testing energy suddenly returns to its normal level. Later, a little before and a little after 2 P.M., two sudden changes occur. The two before 2 P.M. were large enough to operate the hit indicator, as indicated by the deflections of the pen riding along the upper edge of the chart. The sudden changes immediately after two o'clock were not large enough to operate the hit indicator, since they were only about .75 db. A glance at the upper, or hit, curve shows that hits occurred just before 8 A.M. and just before noon that were too rapid to show on the slow-speed chart. These would appear on the oscillographic record for these times.

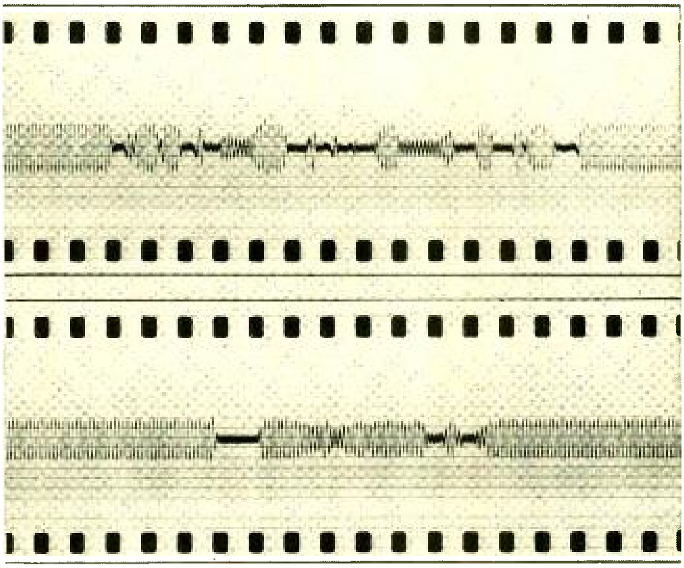


Fig. 5—Oscillographic record of contact trouble, below, and line swings, above

Typical oscillographic records are shown in Figures 4 and 5. Time flows from left to right, and the trace at uniform height at the right and left of each oscillogram is the normal 1,000-cycle testing wave. Figure 4 shows two effects of lightning. The lower of these oscillograms shows an unusual resonance effect near the central portion of the disturbance. The lower oscillogram of Figure 5 shows a form of contact trouble, while the upper one shows the effect of the conductors of an open-wire line swinging together, which sometimes occurs during a windstorm.

The charts and oscillograms are removed periodically for study. The causes of certain of the disturbances may be fairly obvious, and steps may be taken to correct the conditions that are causing them. Other disturbances may be very difficult to identify, and special apparatus may be installed to measure them and determine their source. Nothing can be done, of course, about the occurrence of lightning, but often steps can be taken to minimize its effects on the circuit when these are known. Certain of the hits may indicate incorrect behavior of some elements of the circuit, behavior that could not be foreseen when the equipment was being designed. While new systems are being subjected to field trial, a determination of their performance through studies of this kind aids in disclosing difficulties that may be corrected or features that may be improved before large-scale commercial application of any system is made.

A typical installation of this apparatus is shown in the photograph at the head of this article. Here two of the slow-speed chart recorders are shown mounted on relay racks with their associated equipment. The oscillographic recorder is on the table at the left. The tape delay machine is in the flat horizontal cabinet projecting from the rack below the recorders.

To clear the open-wire telephone lines from a large area where a munitions works is to be erected, the Illinois Bell Telephone Company has transferred a number of its important circuits to a cable shown here in the process of being laid by a buried-cable train

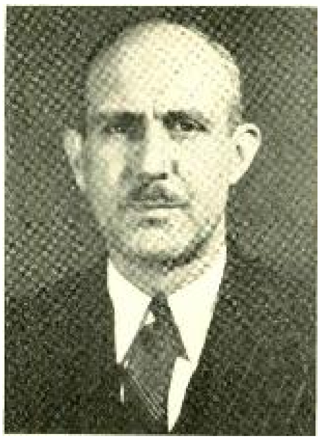
Contributors to this Issue

T. A. MARSHALL received a B.S. degree in Electrical Engineering from the University of Kansas in 1922, and immediately joined the Technical Staff of the Laboratories. After a year spent in the preparation of specifications in the Apparatus Development Department, he transferred to the toll development group. Here he was engaged in the design of test-board and switchboard circuits. More recently he has been occupied with the development of telegraph test-board facilities for the maintenance of telegraph and teletypewriter service.

L. L. GLEZEN entered the Long Lines Department of the A. T. & T. at Denver, Colorado, in 1917, after four years in the Electrical Engineering School of Colorado College. In 1918 he attended the Signal Officers Training School and received his commission as Second Lieutenant in the Signal Corps Reserve. In 1919 he attended the First Transmission School given by the A. T. & T. in New York and then returned to Denver as District Engineer, serving as such until 1922 when he was transferred to the Department of Development and Research. Here his work concerned the design of telephone repeaters, signaling equipment, public address systems, toll test boards and the development aspects of toll equipment maintenance. He transferred to the Systems Development Department of the Laboratories in 1934 with the consolidation of these departments and since 1935 has been in the Transmission Engineering Department where his work has concerned studies of the overall transmission performance of toll systems and toll transmission maintenance.

A. E. BACHELET joined the Toll System Department of the Laboratories in 1923. With the toll switching group he early engaged in studies and development work for improving toll lines for use of the rapidly growing broadcast industry. As these systems expanded, switching circuits had to be developed, and they have been steadily improved. He also carried on an extended fundamental study of the characteristics of gas-filled tubes—at the same time carrying on his program switching and transmission work.

T. A. Marshall



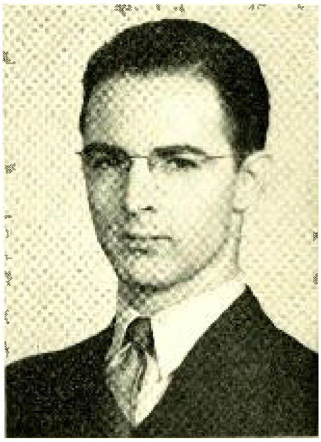
L. L. Glezen

A. E. Bachelet

M. E. Krom was graduated from Purdue University with the degree of B.S. in E.E. in 1923. He joined the Laboratories immediately after graduation and spent the first two years in the panel-dial laboratory. Then followed six months of relay design after which he was transferred to a laboratory group which handled ringing and tone studies. Nearly four years were spent in this work. Then he transferred to a group concerned with means of measuring and suppressing radio interference. In 1932 this work became a function of the ringing and tone studies group. Mr. Krom was transferred at the same time and has since been responsible for all radio interference tests and the development and application of radio filters to telephone equipment. Since this work no longer requires full time his efforts are now partly devoted to ringing and tone studies.

J. B. Hays received a B.S. degree in Electrical Engineering from the University of Colorado in 1936. After spending a year with the Southern California Edison Company he entered the Outside Plant Development Department of the Laboratories. During 1940 he was with the New England Telephone and Telegraph Company studying outside plant problems. He has now resumed his work in the electrical testing group of the Outside Plant Development Department.

M. E. Krom



J. B. Hays