Am. Tel. & Tel. Co.
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Appendix #1
September 8, 1919


# TEST AND MORSE BOARDS

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Page #1

# TEST AND MORSE BOARDS

## Description and Operation of #4 Test Boards

DIVISION PLANT SUPERINTENDENTS:
DISTRICT PLANT SUPERINTENDENTS:

These instructions describe the equipment and circuits of the #4 test-board and the tests which may be made with the testing equipment.

### 1. GENERAL

This bulletin is issued for the information of those who will operate the standard #4 testboard. Theory sketches are included in the text to aid in the explanation of the circuits. If specific information regarding details of the testboard assembly or circuits is desired, the drawings under which the installation was made should be referred to.

Only the latest standard arrangement of equipment and circuits are described herein. The explanations and descriptions, however, may be applied with a few modifications to #4 testboard equipments, which have been installed with circuits which differ in detail from the latest standards.

### 2. ASSEMBLY OF EQUIPMENT

No. 4 testboard provides facilities for terminating and testing toll line circuits, phantom sets, composite sets and simplex sets. It is also used for terminating and testing duplex telegraph sets, telegraph repeater sets, Morse subscribers' loops, telephone loops and Morse battery taps in offices where the amount of telephone equipment is not sufficient to require a separate board.

#### a. Sections

No. 4 testboard is made up in one-position and two-position sections. The sections are so designed that they will line up with each other end to end or with standard #4 Morseboard sections. The sections are arranged so that they may be equipped either as testboards or as combined test and Morse boards. Where complete sections are equipped as separate Morse boards, the general arrangement of the equipment will be somewhat different from the testboard. This is described in a separate bulletin.

#### b. Face Equipment

The jacks for the toll lines, trunks, phantom sets, composite sets, simplex sets, polar duplex circuits and miscellaneous circuits are mounted in strips of 10 or 20 in horizontal rows. These unit strips of jacks are arranged at the testboard, in such a manner that the associated jacks of each circuit form a vertical line.

c. <u>Keyshelf Equipment</u>

A keyshelf is provided for 1 and 2 position testboard sections on which are located cords and plugs, keys, testing instruments and Morse testing sets.

Figure 1 shows the arrangement of apparatus on the keyshelf of a 1-position section of testboard.

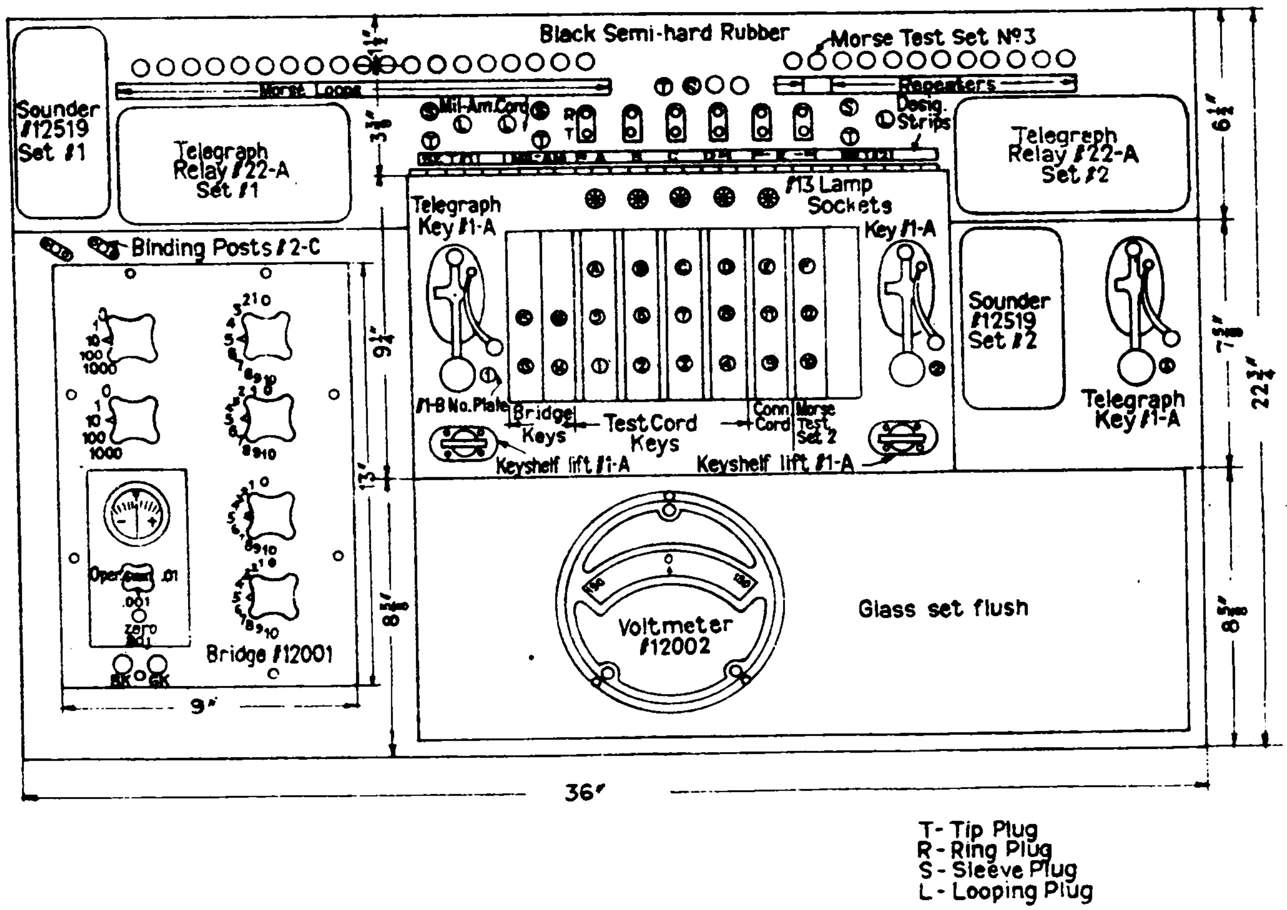



**FIGURE 1**

Keyshelf equipment. Position section #4. Testboard.

The keyshelf equipment of a 2-position section is made up of 2-groups of equipment similar to the 1-position section except that only one Wheatstone Bridge is provided for the two keyshelves. The bridge is located in the right hand keyshelf, and accordingly Figure 1 may be considered to represent also the right hand keyshelf of a 2-position section. The location of the bridge as shown makes it convenient of access from both positions.

## 3. DESCRIPTION OF CIRCUITS AND APPARATUS

### a. Testing Equipment

The testing equipment associated with 1-position testboard consists of

1 Testing circuit made up of test cords, keys, voltmeter, Wheatstone Bridge, telephone set and Morse set #1.
1 Connecting cord circuit
1 Morse set #2
1 Morse set #3

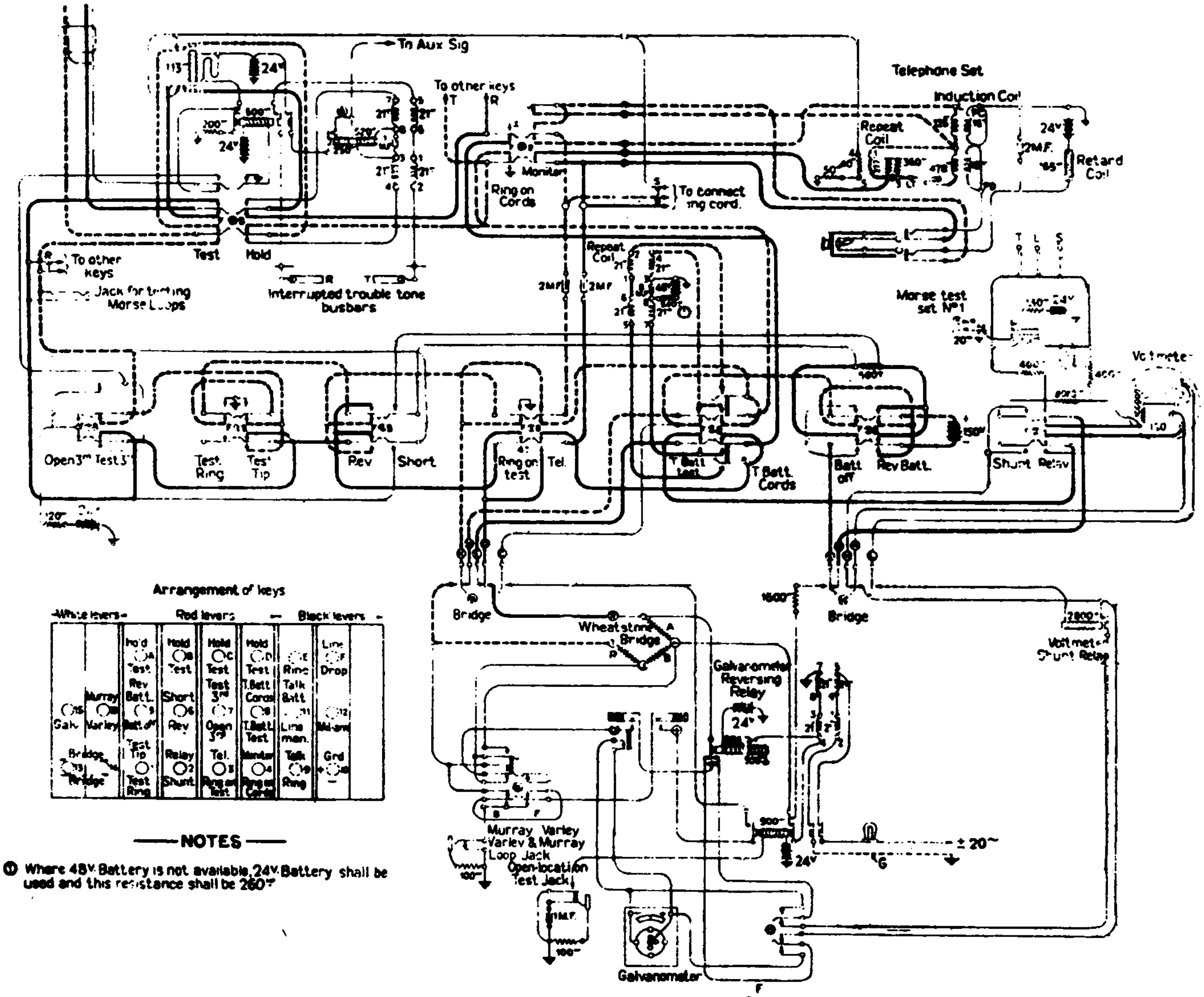
The operation of each of these circuits is described in the same order as listed above.

#### (1) Testing Circuit

Figure #2 shows a schematic of the testing circuit, with cords, keys, telephone sets, Wheatstone bridge, and Morse set #1. The letters F and B on this figure adjacent to the keys refer to the position of the key with reference to the testboard operator. "F" means the key is thrown toward the operator and "B" means the key is thrown away from the operator. The words "forward" and "back" are used in the following explanation corresponding respectively to the "F" and "B" positions of the keys.

##### (a) Test cords

Four test cords with twin plugs and four single test cords are provided in connection with the testing circuit shown on Figure #2. The shells of the twin plugs have the tip side knurled and the ring side plain to enable the testboard operator to distinguish readily between the tip and ring side of the circuit. When inserted horizontally the knurled edge is turned to the left and when inserted vertically the knurled edge is turned toward the top. Each of the four sets of cords is provided with a test cord key so wired that when the keys are normal the tip and ring terminals of the plug are connected to the busy test winding of the telephone set, as shown in Figs. 3 and 4.




## NOTES

① Where 48V. Battery is not available, 24V. Battery shall be used and this resistance shall be 260Ω.

**FIGURE 2** Diagram of Testing Circuit.

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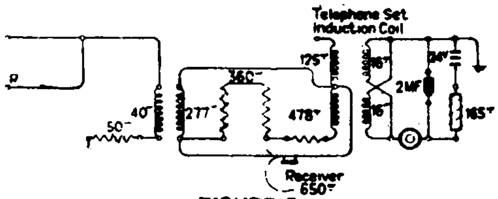



FIGURE 3
Busy test All keys normal. Plug not inserted in jacks

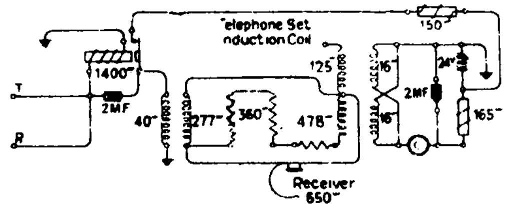



FIGURE 4
Busy test with busy test relay. All keys normal Plug not inserted in jacks

This permits the operator to obtain a busy test in the usual manner on either line, drop, or listening jacks without operating any keys. If a test cord key is operated the busy test will not be obtained on the associated cord, but the busy test on the other cords will not be affected. Single plugs are provided in connection with test cords "C" and "D" to facilitate testing for crosses and to enable the test board operator to test on split pairs when desired. The single test cords are also used in making open-location tests described later.

The test cords are arranged so that they may be used independently of each other, that is, cord "A" may be used for testing the line while cord "B" is being used for talking and cords "C" and "D" for holding. When more than one test cord is in use care should be taken to see that each key is in the proper position to prevent connecting the different cords together. When the test board operator is testing on cord "A" and talking on cord "B" the operation of the telephone key No. 3 disconnects the telephone set from cord "B" and connects it to cord "A" as shown in Fig. 5, thus making it unnecessary to change cords or operate additional keys.

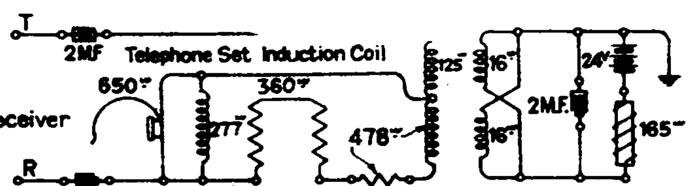



FIGURE 5
Talking. All keys normal. Plug inserted in jacks. (Or key A,B,C or D thrown forward or key 3 thrown back.)

In taking up a line for test, one of the regular test cords should be used, the busy test being made before inserting the test plug. The test plug should first be inserted in the line jacks in order that tests may be made to determine the nature of the trouble on the line and whether the trouble exists outside or inside the office. The battery on the sleeve of the test cord then operates a relay in the toll circuit which disconnects the line relay and operates the busy signals at the toll switchboard.

The insertion of the test plug in the line jacks operates a relay in the sleeve of the test cord which connects the telephone sets across the line, as shown in Fig. 5 so that the usual talking, ringing or listening tests may be made. When the key associated with the test cord is thrown, the telephone set is disconnected from that particular cord but the connection to the other cord is not affected. When a test cord key is thrown the telephone set may be disconnected from the other test cords and connected to the associated cord by throwing key No. 3 of the testing circuit forward as described above. Condensers are connected between the telephone set and the testing circuit so that the telephone set may be bridged across the line without interfering with the testing circuit, except when an open-location test or a capacity test with the voltmeter is being made. This enables the test board operator to listen and test on a line at the same time if he desires.

If in addition to inserting a test plug in the jacks of the line circuit, key No. 8 is thrown back, talking battery may be supplied to any of the test cords which are up, as shown in Fig. 6. This is intended for supplying talking battery to linemen equipped with common battery hand sets or telephone loops equipped with common battery subscribers' sets, but is not intended for supplying talking battery to common battery subscribers' lines.

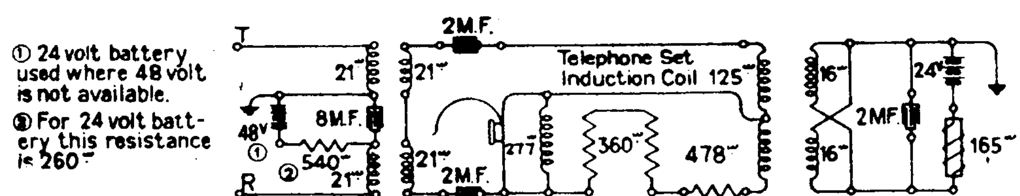



FIGURE 6

Talking battery common to all cords. Test cord keys normal. Key 8 thrown back

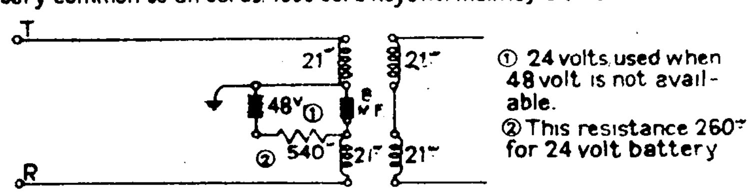



FIGURE 7

Talking battery on test cords. Test cord key A,B,C or D thrown forward. Key 8 thrown forward.

When a test cord key is thrown forward talking battery may be supplied to the associated cord by throwing key No. 8 forward the circuit arrangement being as shown on figure 7.

Ringing current may be connected simultaneously to all of the test cords which are up, provided the test cord keys are normal, by throwing key No. 4 forward. When a test cord key is thrown forward, ringing current may be connected to the associated cord by throwing key No. 3 forward, the circuit arrangement being as shown in Fig. 8.

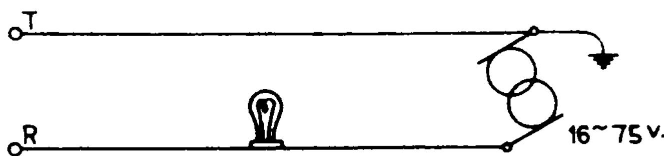



FIGURE 8
Ringing. Key 4 thrown forward (or test cord key A, B, C or D thrown forward and key 3 thrown forward.)

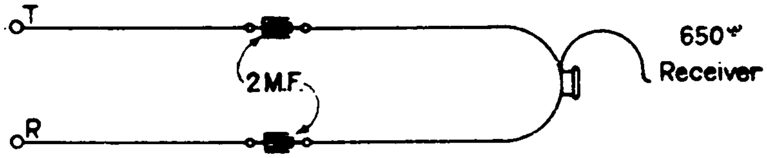



FIGURE 9
Monitoring Key 4 thrown back. Plug inserted in jacks

When key No. 4 of the testing circuit is thrown back the induction coil of the telephone set is disconnected from the circuit and the high impedance receiver in series with condensers, is bridged across the circuit, as shown in Fig. 9. This gives a maximum receiving efficiency and eliminates such noise as may reach the circuit through the operator's transmitter. It is intended to be used when the operator desires to monitor on a line, or when it is desired to eliminate the side tone in the operator's set when listening on a line for noises, etc. It is not desirable to provide a battery cutout key at the testboard for opening the transmitter circuit to eliminate the side tone when making these listening tests.

It should be noted in regard to the use of the telephone set, that while the circuit arrangement shown on Fig. 9 causes considerably less transmission loss than the arrangement shown on Fig. 5, this loss is appreciable particularly on loaded circuits amounting to as much as 3 miles of standard cable on such circuits. On non-loaded circuits the loss is about one mile of standard cable. This fact should be carefully noted in order that connections will not be monitored under the impression that no appreciable transmission loss occurs.

It is also important to note that telephone repeatered lines cannot be monitored at the line jacks in the testboard when the telephone set would be bridged on one side of the telephone repeater. Telephone repeater monitoring jacks are provided where necessary for monitoring on repeatered circuits.

When one of the test cord keys is thrown back its associated cord is disconnected from the other test cords and the tip and ring of the plug are connected to a repeating coil, across the middle of which a ring-up relay is connected, as shown in Fig.10. The other winding of the coil is connected to the interrupted trouble-tone circuit so that this tone may be sent out on the line by inserting the test plug in the line or listening jacks. The cord may then be used as a holding cord for the lineman to call in on, the tone serving to indentify the circuit and the ring-up relay providing a ringdown signal. When the test cord key is thrown back the sleeve circuit is opened so that the busy signals at the toll switchboard will not be operated.

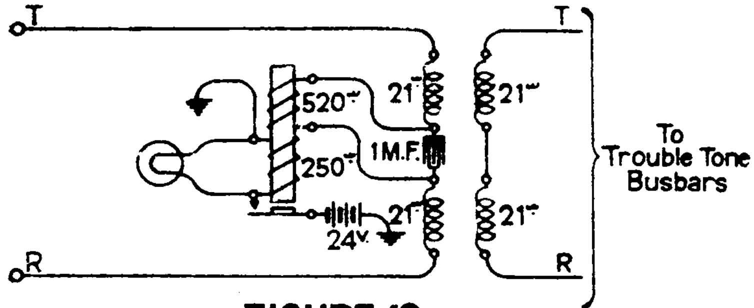



**FIGURE 10**
Holding. Test cord key A,B,C or D thrown back.

(b) Telephone Sets

The telephone set associated with the testing circuit is wired as shown in schematic on Figs. 2 and 3 or Fig. 4. The telephone set in Figs. 2 and 3 and Fig. 4 differ in the method of wiring the busy test feature. In Figs. 2 and 3 the tip and ring of the testing plug is normally connected to ground through a repeating coil and resistance in series. The combined resistance of the repeating coil and the resistance is 90 ohms. The secondary winding of the repeating coil is connected across the terminals of the receiver. Thus, if the tip and ring of the plug is connected to a potential above ground, a current will flow from the tip or ring to ground through the repeating coil and resistance. This current will cause a noise or "busy click" in the telephone receiver.

The busy test feature of the arrangement shown on Fig. 4, is obtained by connecting the tip and ring of plug to ground through a 1400 ohm relay. The operation of this relay when the tip or ring is connected to a potential above ground, closes a circuit through the repeating coil associated with the receiver. The closing of this circuit gives the "busy click" in the receiver.

The arrangement shown in Fig. 4 is used on testboard positions where outgoing call wire toll lines, or outgoing switching trunks appear which may be connected to cord circuits having a marginal relay in the sleeve circuit. The low resistance of the path from the tip and to ground on Fig. 3 may cause the false operation of this relay. This false operation is avoided by the use of the high resistance relay in Fig. 4.

The telephone set is not provided with any direct current holding deature, condensers being wired between both the testing circuit and connecting cord circuit and the telephone set. When a direct current holding feature is required, a trunk of the type which provide this feature is employed.

(c) Voltmeter

The voltmeter used in the testing circuit is a No.12002 voltmeter similar to the Weston portable voltmeter and has a central zero scale with a full scale reading of 150 volts in each direction from the zero point. It has a resistance of 100,000 ohms and is provided with a shunt coil which when bridged across the instrument reduces its resistance to 1,000 ohms and converts it to a milammeter. When the shunt key is thrown, the scale reading in volts is equivalent to the current flowing in the circuit in milliamperes.

As it is desired to use the voltmeter in all preliminary tests, it is wired in the circuit so that it is used in place of the galvanometer in making Wheatstone bridge tests when obtaining a preliminary balance. When used in this manner, the 100,000 ohm winding is cut out of the circuit and the moving coil connected directly across the bridge. The galvanometer is substituted for the voltmeter for making the final adjustments by throwing key No. 15 forward.

The use of the voltmeter and the operation of keys in the testing circuit for making various tests is described under the heading "METHOD OF LINE TESTING".

(d) Wheatstone bridge

Wheatstone bridge No.12001 which is used in the testing circuit is an inverted dial type bridge with sliding contacts having two ratio arms and four groups of adjustable resistance in the rheostat arm. The wiring of the bridge is shown on Fig. 11.

The bridge is made up of three adjustable resistances designated "A", "B" and "R". The resistances "A" and "B" are known as the ratio arms and have four coils each, the resistances of these coils being 1, 10,100 and 1,000 ohms respectively. The resistance of the coils in the ratio arms is accurate to within 1/20 of 1 per cent. arm "A" being measured from terminal posts (R) and (-) and arm "B" being measured between the terminal posts (-) and (J). The resistance "R" represents the rheostat arm and is made up of four adjustable resistances of 10 steps each which are designated as units, tens, hundreds and thousands. The resistances of these coils are accurate to within 1/10 of 1 per cent. when measured from the terminal posts (J) and (T). These resistances may be adjusted to give a total resistance in series of from 1 to 11,110 ohms.

The maximum allowable power consumption in any arm of the bridge is 1 watt.

The galvanometer is mounted in the bridge and provided with a shunt key for reducing the magnitude of the deflection and to protect the galvanometer against injury from excessive currents. In making the preliminary balance the shunt should first be set at .001 and changed when a balance is obtained at this position to .01, then .1 finally to "open". If the needle fluctuates the galvanometer should be shunted sufficiently to keep the needle within a range of two positions from the zero point.

The use of the Wheatstone bridge is described under "METHOD OF LINE TESTING".

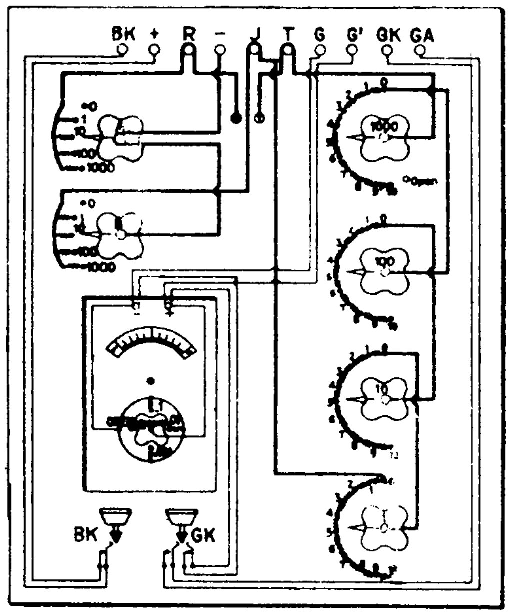



FIGURE 11
Wheatstone Bridge Nº 12001. Wiring and arrangement of terminals.

(e) Morse test Set No.1

Morse test set No. 1 is arranged so that it can be used in place of the voltmeter as shown in Fig. 12, in making continuity tests. To substitute Morse test set No.1 for the voltmeter, key No.2 is thrown back, which disconnects the voltmeter and bridges Morse test set No. 1 across the circuit in series with two 400-ohm resistances. Morse test set No. 1 is also arranged so that it can be used for continuity tests without employing the test cords or testing battery, by using the cords associated with the test set and connecting battery or ground to the test set or circuit under test, as shown in Fig. 13, Drawing No. 137-A-56. In tests of this kind the battery taps used should always be special testing taps.

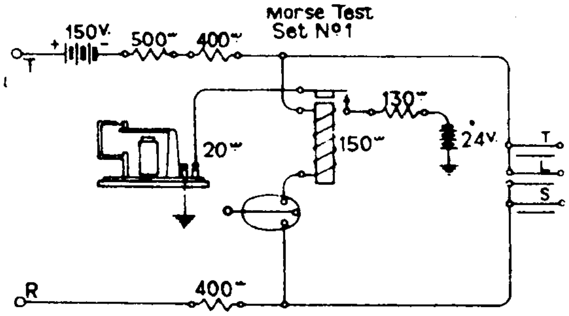



FIGURE 12
Morse test set Nº1 on test cord. Test cord Key A.B.C or D thrown forward. Kev 2 thrown back.

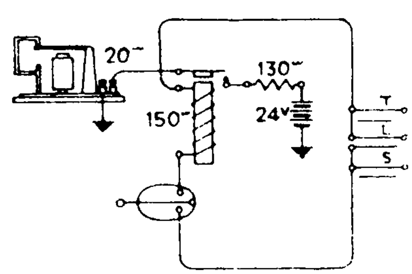



FIGURE 13
Morse test set Nº1 on Morse cords All keys normal

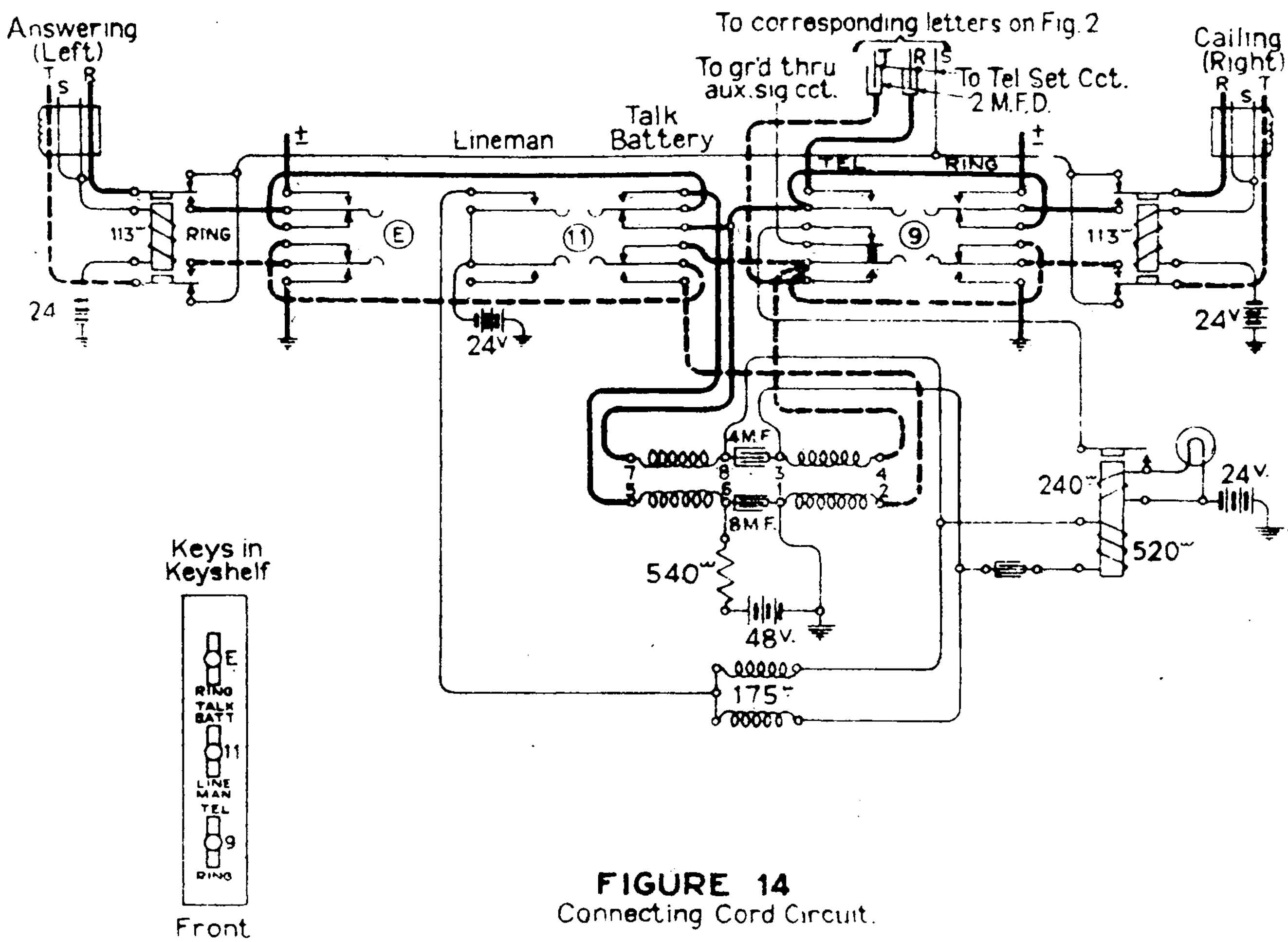



**FIGURE 14**
Connecting Cord Circuit.

(2) Connecting cord circuit

One connecting cord circuit wired as shown on Fig.14 is provided in each test board position for the purpose of connecting toll lines together or with the various desk telephones or other terminal sets in the toll office, and like the testing circuit is arranged to supply talking battery when required. The connecting cord may also be used as a secondary cord for handling incoming and outgoing calls and is designed to be used in conjunction with the lineman's signaling circuit shown on Figure 15, for signaling a lineman's station.

The signaling circuit at the lineman's station, as shown on Figure 15, is wired to a toll line which is not equipped with composite, simplex or phantom apparatus. To call the lineman's station, the test board operator first makes the usual busy test on the toll line to which the lineman's signaling circuit is connected. If the toll line is not busy, the test board operator inserts the calling plug of the connecting cord into the listening jacks and rings the lineman's station in the usual manner by throwing key No.9 forward. If the toll line is busy, the calling plug is inserted in the listening jacks but the ringing key is not operated. The test board operator then takes up one of the test cords, selects an idle line which appears at the lineman's station, and inserts the test plug to hold it; the proper code signal is then sent over the lineman's circuit by throwing key No. 11, of the connecting code circuit, forward. Code signals thus sent over the circuit indicate to the lineman the number of the idle toll line upon which the test board operator is waiting to talk to him.

When key No. 9 is thrown back, the telephone set of the testing circuit is bridged across the connecting cord. If in addition key No. 11 is thrown back, talking battery may be supplied, the circuit arrangement being similar to that shown in Fig. 10. This is intended for supplying battery to linemen equipped with common battery sets but is not intended for supplying talking battery to common battery subscribers' lines.

Ringing current may be connected to either cord of the connecting cord circuit by throwing key "E" forward, for the left or answering cord, and key No. 9 forward for the right or calling cord.

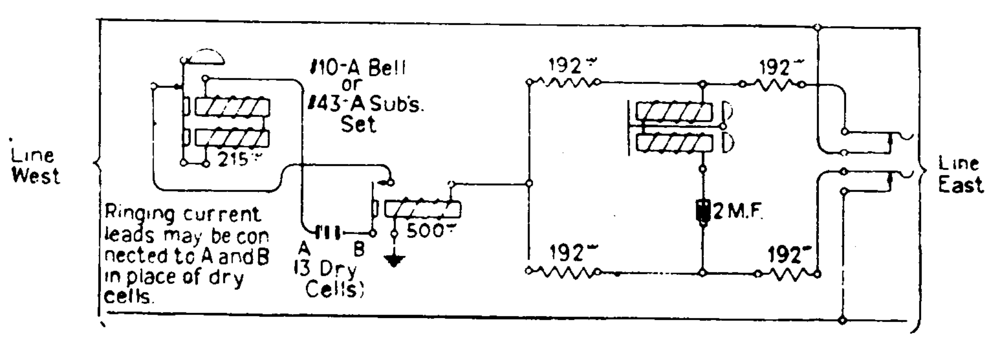



FIGURE 15
Signaling circuit at Linemans station

(3) Morse Test Set #2.

Morse test set No. 2 is provided for testing Morse lines and Morse subscribers' loops. When telegraph circuits are terminated at the toll test board, a mil-ammeter is provided as shown on Figure 17. Separate looping and single cords are provided in series with the mil-ammeter in addition to the Morse test set cords and are arranged so that when the looping plug is inserted in the looping jack of a Morse line terminal, the mil-ammeter is connected in series with the circuit. The mil-ammeter used for this purpose is the No. 111076, and is similar to the Weston round pattern, Model 24, having a central zero scale with a full scale reading of 150 milliamperes in each direction from the zero point. The principal feature of the Morse set #2 when a mil-ammeter is provided are similar to those on the testing circuit of the Morse board which is described in the bulletin on the #4 Morseboard.

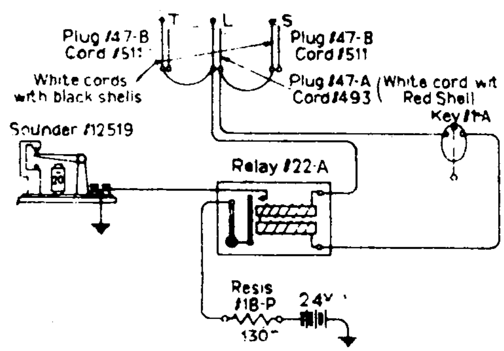



FIGURE 16
Morse test set No.2 For use at position where mil-ammeter is not required

Where a separate Morse board is provided for terminating telegraph circuits, no mil-ammeter is provided at the test board, and Morse test set No. 2 is wired in accordance with Figure 16.

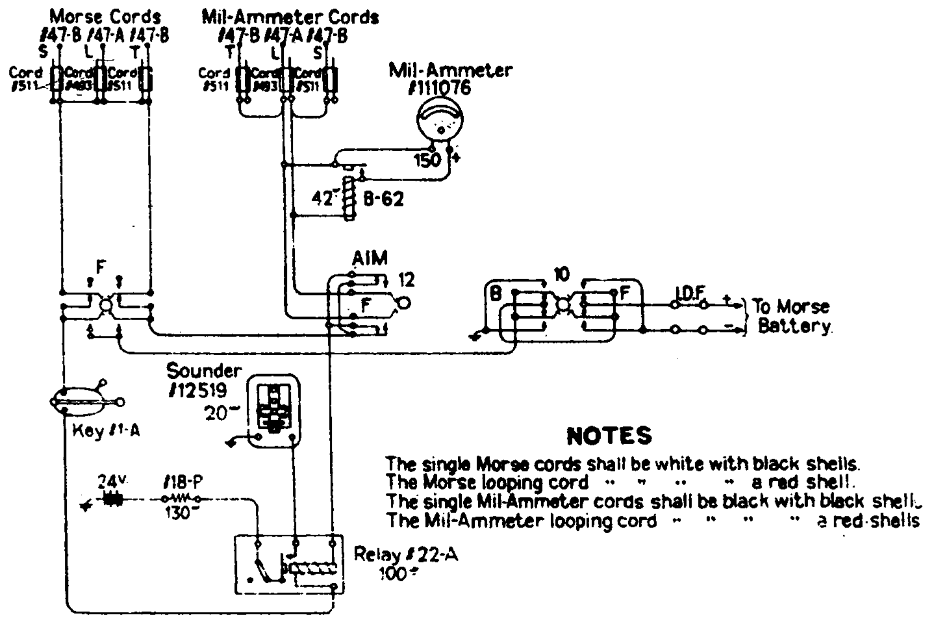



**FIGURE 17**

Morse Test Set #2. For use at positions where Mil-Ammeter is required.

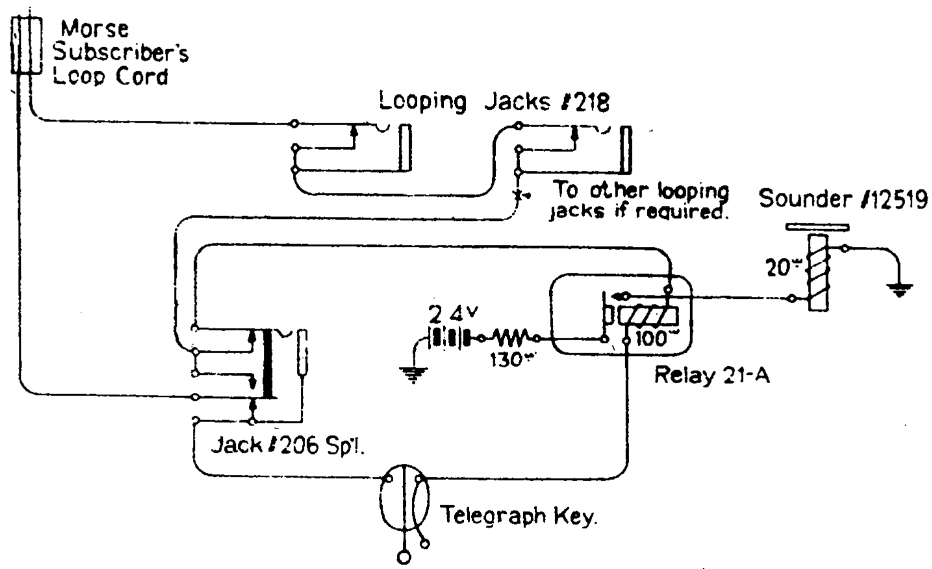


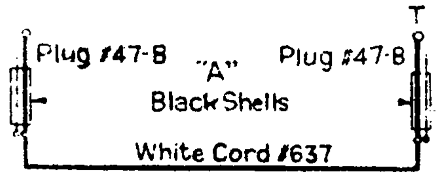

**FIGURE 18**

Morse Test Set #3 For use with test wire.

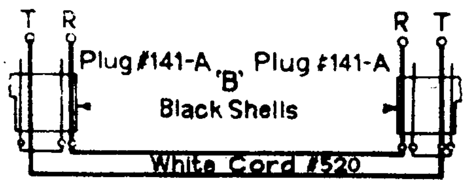
(4) <u>Morse Test Set #3</u>.

Morse test set No. 3 is provided for use with the test wire circuit and is arranged as shown on Figure 18.

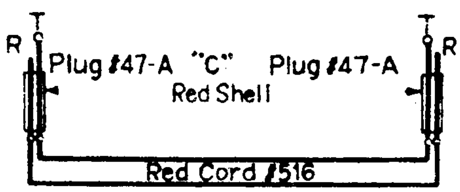
This page supersedes Page 14 dated September 19, 1919.



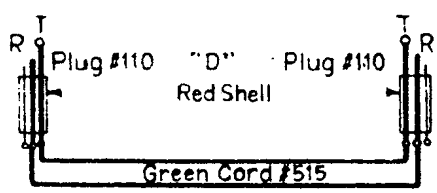

Used for crossing, grounding and patching single wires.



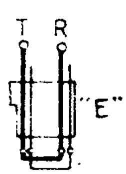

Used for making patches between lines, drops, composites, simplexes, and phantom sets. Two 'A' cords may be used instead of one 'B' cord.




Used for patching Morse loops only.

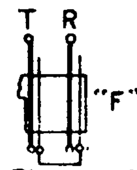



Used only at Composite Ringer Jack Box for patching.




Plug #141-C
Black Shell

Used for plugging out composite, simplex or phantom sets and for short-circuiting lines, drops, etc.

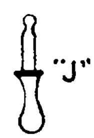



Plug #141-B
Red Shell

Used for opening both sides of a circuit, or plugging out composite, simplex or phantom sets.

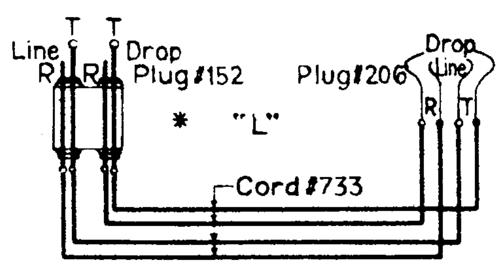

Plug #116-B
Black Shell

Used for connecting the trouble tone across the tip and ring wires of circuits.

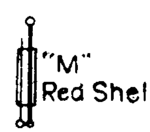



Wooden Plug #165 (formerly #94340)

Used for opening single wires, battery taps, etc.




Used for patching from main frame to main frame box only.




Plug #110

Used for short-circuiting composite ringers in Composite Ringer Jack Box.

Supersedes page 15, dated Sept. 19, 1919
*Indicates Revision.

## FIGURE 19

Toll Test Board No 4. Patching Cords and Plugs.

This circuit is wired to a Morse subscriber's loop plug at the test or Morse board which is plugged into a loop jack of a Morse line terminal for connection to a test wire.

b. Lines and Associated Equipment

(1) Line circuits

The jacks of line circuits at the testboard correspond in order of arrangement to the normal pin positions of the wires on the last line crossarm before entering the office. The normal pin positions are understood to be the pin positions of the wires as they would appear if no changes in pin positions occurred on account of the existing transposition scheme. Phantom simplex and composite sets normally associated with a line circuit are wired to jacks which, together with the line jacks form a group known as a "line circuit".

This arrangement avoids the use of patching cords under normal conditions.

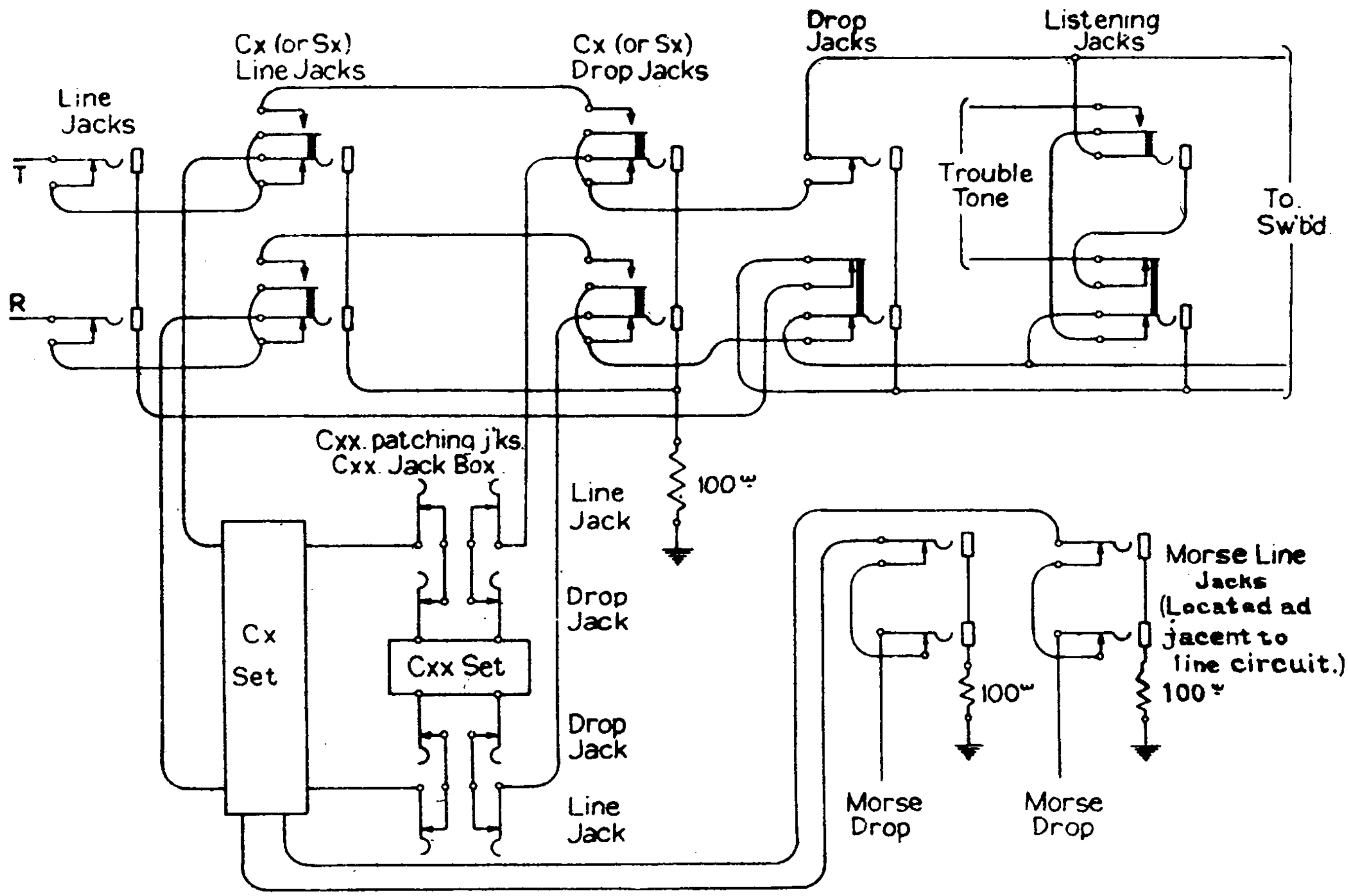
Typical line circuits are shown on Figures 20 and 21.

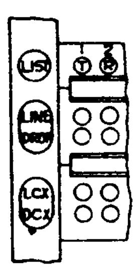
(a) Busy Test

The sleeves of the line, drop, and listening jacks are wired to the sleeves of the corresponding jacks at the toll switchboard to enable the test board operator to obtain a busy test when the circuit is in use at the toll switchboard and to operate the busy signals at the toll switchboard when a plug is inserted in the jacks at the toll board. The sleeves of phantom, simplex and composite jacks are not wired to the corresponding line jacks and a busy test, therefore, cannot be obtained on these jacks.

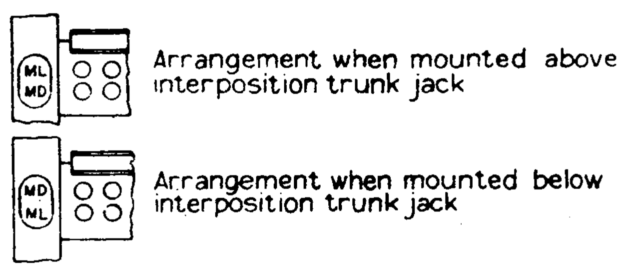
The sleeves of the line jacks are wired through the contacts of a jack on the drop side, so that when the drop is patched to another line circuit the wire connecting the line and drop sleeves is open. This feature enables the testboard operator to make the usual tests from the line jacks, if the corresponding drop jacks have been patched to a good circuit, without making the patched circuit busy. When a drop is patched to another line, the key associated with the test cord must be thrown forward, when the test plug is inserted in the corresponding line jacks, otherwise the telephone circuit is open because there is no ground to operate the busy test relay.

When toll line circuits are connected through an office to another toll line the busy test features will not be used. In this case the sleeve circuit will be connected through a 100 ohm resistance to ground so as to operate the sleeve relays of the testing and connecting cord circuit.




Arrangement of jacks in line panel.

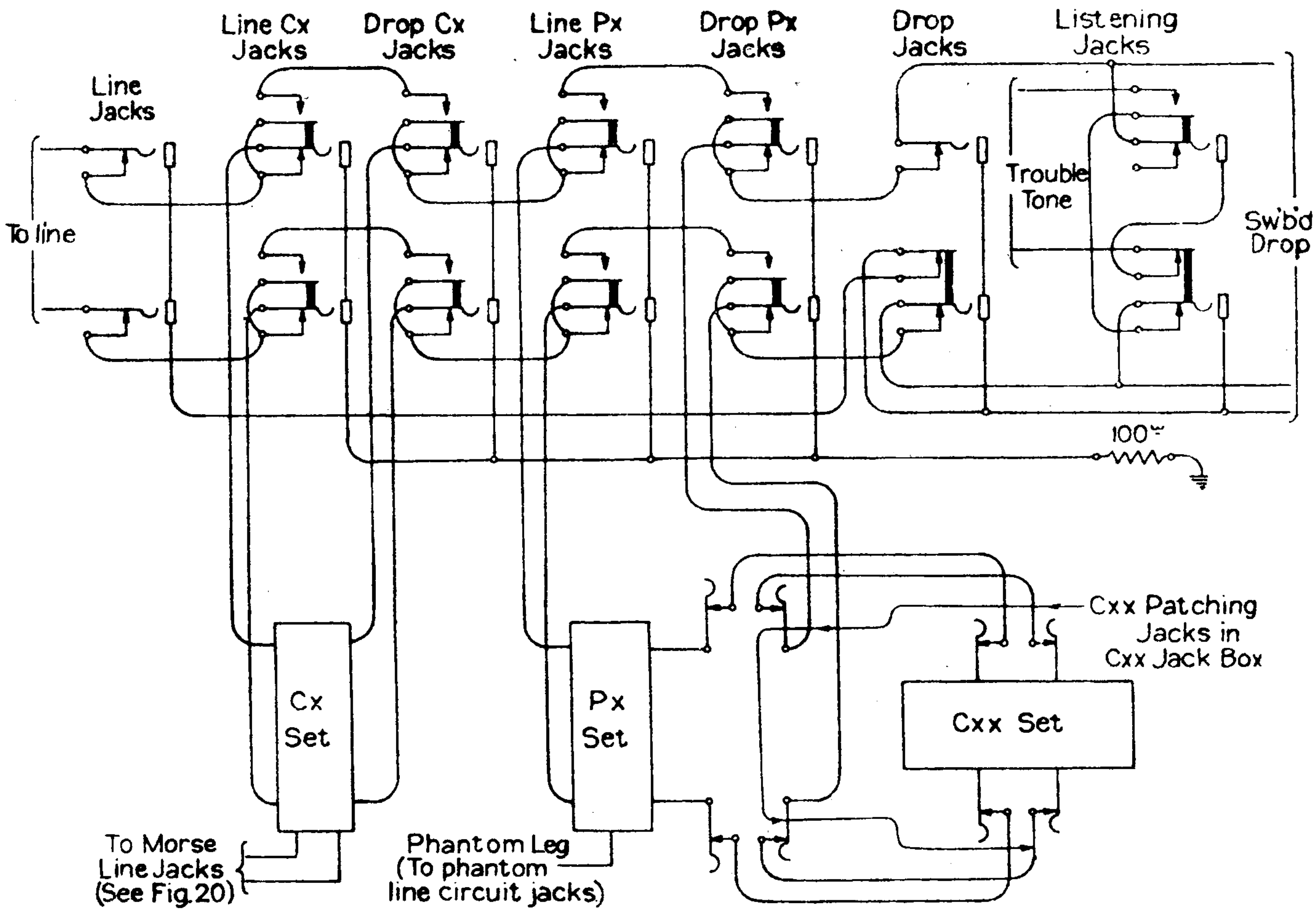


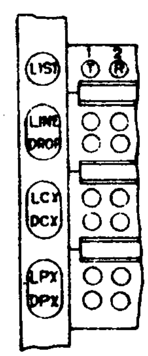

Arrangement of Morse line jacks.

**FIGURE 20**

Typical toll line circuit in testboard. 10 Jack composite circuit. (showing Cx and Cxx patching jacks and Morse line jacks.)

This page supersedes page 17 dated September 19, 1919.




Arrangement of jacks in line panel

**FIGURE 21**
Typical toll line circuit in Testboard 14 Jack composite and phantom circuit.

This page supersedes page 18 dated September 19, 1919.

(b) Trouble Tone

The toll lines are wired so that a metallic interrupted trouble tone may be connected to the tip and ring wires of the toll line by inserting a short-circuiting plug in the tip listening jack, in order that the toll operator may know when the line is out of order. The trouble tone may also be connected to the tip and ring wires by means of the test cords, provided the key associated with the test cord is thrown back. The tone may be connected to either the line or drop jacks separately by means of the test cords or it may be connected to the entire circuit by inserting the plug in the listening jacks.

In order to prevent the toll operator from reporting as busy a line which is out of order, the circuits are arranged so that the busy signals will not be operated when a trouble tone is connected to the line, either by the insertion of a short circuiting plug in the tip listening jack, or by means of the test cords. The operators at each end of the line will be able to hear the trouble tone if the nature of the trouble does not interfere with its transmission. Where a line is short-circuited near the testing station, it will be necessary to open the line side of the circuit in order to obtain a satisfactory tone at the toll switchboard.

(c) Patching Lines and Associated Apparatus

To remove a composite, simplex, or phantom set from a line and cut the line through to the switchboard insert the cordless plugs "F" shown on Figure 19 in the line and drop jacks of the set to be removed. The local contacts on the jacks are so wired that the line will be cut through with the set removed.

To transfer a phantomed, simplexed, or composited line from one drop terminal to another, insert horizontally with the knurled edge to the left one plug of the cord "B", Figure 19, in the drop jacks of the phantom, simplex or composite set and the other plug in the drop jacks of the new drop terminal.

To substitute a new line for one normally phantomed, simplexed or composited, insert horizontally with the knurled edge to the left one of the cords "B",Figure 19, in the line jacks of the phantom, simplex, or composite set, and the other plug in the line jacks of the new line.

To composite a line normally composited or to substitute another composite set for one normally composited or to substitute another composite set for one normally connected to a line, insert horizontally with the knurled edge to the left one of the cords "B", Figure 19, in the line jacks of the spare composite set, and one plug of another similar cord into the drop jacks of the spare set; then connect in a similar manner the other plug of the cord connected to the line jacks of the composite set to the line jacks of the line circuit and the other plug of the cord connected to the drop jacks of the composite set to the drop jacks of the line circuit. Both ends of the line should be changed simultaneously. In substituting a composite set for the one regularly used, the Morse legs of the spare set should be patched to the Morse line terminal normally wired to the set to be removed, using the single patching cords "A", Figure 19. Phantom sets and simplex sets may be patched in the same way as composite sets.

(d) Patching Composite Ringers

In order to provide means so that all composite ringers in an office may be easily interchangeable between the various circuits to which they are regularly connected, each set is wired through four jacks in the composite ringer jack box, as shown on Figures 20 and 21, and patching cords and plugs "D" and "M", Figure 19 are provided.

If one of the patching cords "D", Figure 19 is inserted in each of the composite ringer drop jacks of any set, that set may be connected directly to any line by plugging the other ends of these cords into the composite ringer line jacks of that line.

If it is desired to remove a composite ringer from a line it is only necessary to insert one of the short-circuiting plugs "M" into each of the line jacks of the composite ringer set.

When the side circuits of a phantom are composited, the composite ringer sets normally associated with the composite sets must be shifted to the drop side of the phantom repeating coil, otherwise the phantom line will be opened when either of the composite ringers is operated. This arrangement may be effected at the frame if the assignment is permanent. This is the case shown on Figure 21. If the assignment is temporary, the composite ringer will be associated with the composite set shown on Figure 20 which it is desired to patch to the phantom side, and the change may be made by inserting short circuiting plug M, Fig. 19 in the line jacks of the composite ringer sets and then connecting the composite ringer drop jacks be means of patching cord D, Fig. 19 to looping jacks on the side of the phantom set. These jacks are located in the composite ringer jack box and are part of the equipment of phantomed lines which are not regularly composited but which may be composited for temporary changes in layout.

(2) Interposition Trunks

Interposition trunks are provided for patching purposes between test board positions and between test board and Morse board positions so that circuits terminating in one position may be patched to circuits terminating in another position. They are arranged to provide a busy test through the operator's telephone set.

Interposition trunks are used between (a) test board positions for patching Morse lines, telephones, composite sets, etc (b) test board and Morse board positions for patching Morse lines (c) test board positions for patching Morse subscriber's loops when a separate Morse board position is not provided (d) test board positions and cable test board positions for patching line circuits, etc.

(3) Talking Trunks

Direct talking trunks between the test board and points to which frequent communication from the test board is required, are provided. Several different arrangements may be specified such as one-way or two-way trunks and automatic or ringdown signalling. The trunk terminates in the test board in jacks and lamps in mountings located beneath the other jack panel units. These jacks may be multipled to other positions if desired.

Trunks outgoing from the test board are generally arranged for ringdown signalling.

(4) Testing Trunks to Distributing Frame

This circuit is used where all of the circuits entering the office are not looped through the test board and it is desired to gain access of these circuits at the distributing frame. Figure 22 shows the wiring of the circuit. The connection between the jacks at the distributing frame and the toll line is made by means of cord and plug L, Figure 19. The jacks at the distributing frame are mounted in a jack box.

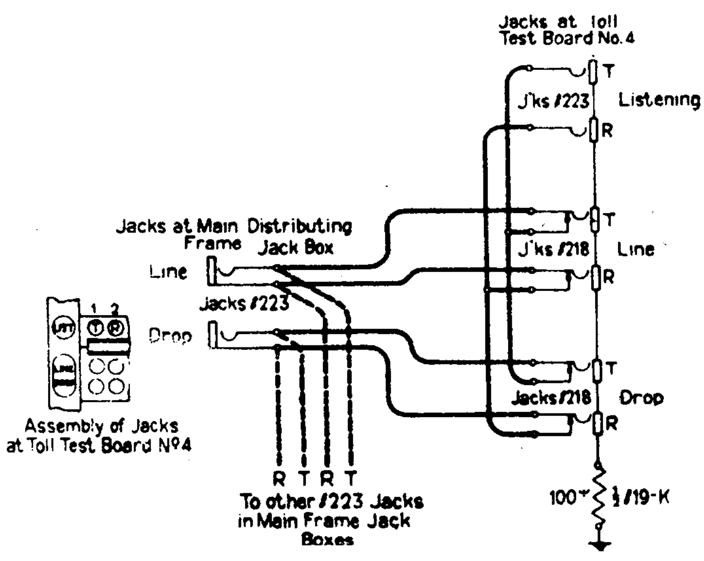



FIGURE 22
Testing Circuit to Distributing Frame.

(5) Morse Line Circuit

The Morse legs of composite and simplex sets are wired to Morse line jacks at the test board. These jacks are shown on Figure 20. This arrangement permits patching between the Morse lines and the various circuits at the test board or Morse board.

(6) Morse Circuits

When a separate Morse board position is not provided, Morse circuits if required are installed in the test board. These consist of

Polar duplex jack circuits
Morse line terminal circuits
Single line repeater loop cords
Miscellaneous Morse circuits

The operation of these circuits when installed in the test board will be the same as when installed in a Morse board and will be described in a bulletin on Description and Operation of the #4 Morse board.

c. Miscellaneous Circuits

(1) Auxiliary Signal and Buzzer Circuits

An auxiliary signal and buzzer circuit is provided. This circuit consists of a lamp and key associated with the trunk and cord lamp signals. The lamp is located in the piling rail below one of the jack panels and lights when any trunk or cord signal lamp is lighted. The lamp is extinguished at the same time as the trunk or cord lamp.

* The key is located by the side of the lamp. The operation of the key connects a buzzer in the circuit which operates whenever the auxiliary lamp is lighted. This key may be strapped in the operated position in offices where it is desired to have an audible alarm at all hours.

(2) Monitoring Circuit

Telephone repeater monitoring jacks are provided to enable the test board man to listen on circuits equipped with through line telephone repeaters without unbalancing the circuit. Figure 23 shows the wiring of the telephone repeater monitoring circuit.

A repeater cut-out feature is provided with the jacks of the circuit. The repeater may be cut out by inserting a dummy plug in the ring jack of the monitoring circuit. This cuts the circuit through without the repeaters and indicates by a lamp and an audible signal at the repeater rack, the particular repeater set that has been cut out.

* Indicates revision
This Page supersedes Page 22

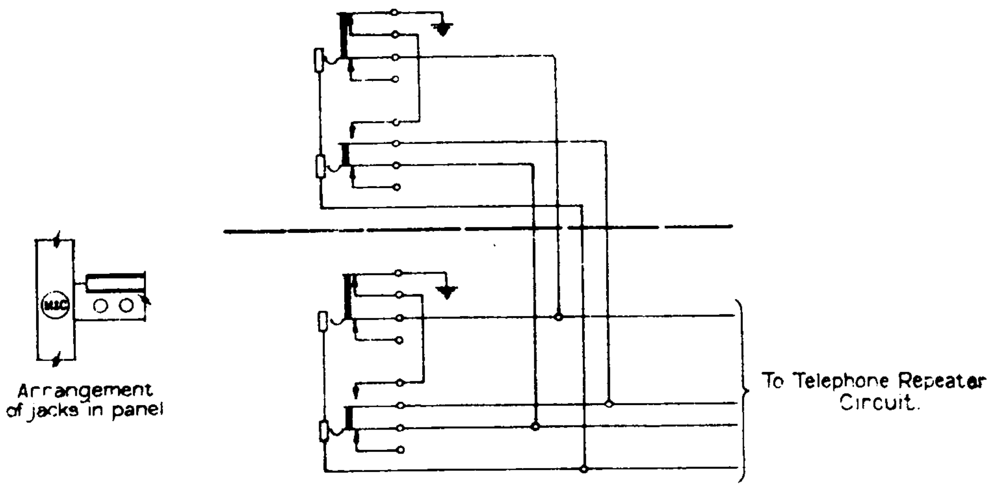



**FIGURE 23**
Through line telephone repeater monitoring jacks.

One group of jacks is provided at each position where the telephone repeatered lines terminate. The circuit is so arranged that when the repeater attendant is monitoring at the repeater rack a tone will be connected to the monitoring jacks at the test board, should the test board operator attempt to monitor. This tone is also connected to the monitoring jacks at the test board when the repeater has been cut out of service by the repeater attendant thus indicating to the test board operator that the repeater operation is being supervised by the repeater attendant and that it will not be necessary for him to take any further action with respect to it. This circuit is intended for use when the repeaters are located some distance from the test board and their operation is not supervised by the test board operator.

(3) Network Circuits.

Lines equipped with telephone repeaters require balancing equipment on the network side of the repeaters. Balancing equipment is terminated on jacks in order that any changes made in the line equipment may be compensated for by similar changes in the balancing equipment. Spare line circuits are used for network circuits when the network jacks are located at the test board.

(4) Battery Tap Jacks.

Battery tap jacks terminating Morse battery taps are provided for testing and the use of Morse circuits.

(5) Ground Jacks.

Grounded jacks are provided for testing and other miscellaneous purposes.

This page supersedes page 23 dated September 19, 1919.

(6) Spare Test Wire.

Spare test wires are provided for looping test wires through a position which are normally connected to Morse sets at other positions.

(7) Combination Composite Leg Jacks.

Jacks are provided for changing combination composite sets from sets normally terminal to intermediate or vice versa. Figures 24 and 25 show both arrangements.

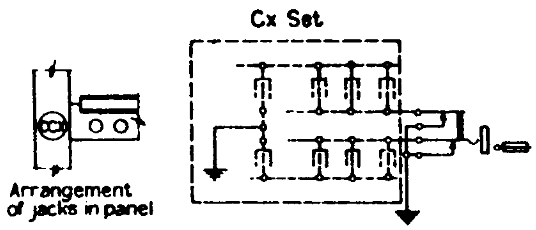



FIGURE 24
Combination composite set jack
Normally terminal.

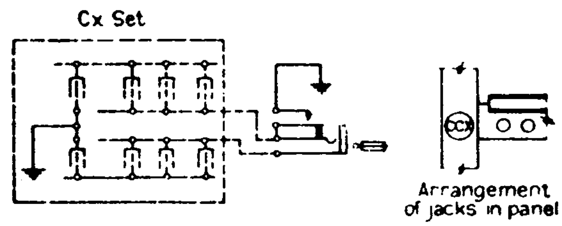



FIGURE 25
Combination composite set jack
Normally intermediate.

The change from terminal type set to intermediate type set is made by inserting a plug "I" Fig. 19 in the jack associated with the set it is desired to change.

d. Power Equipment

(1) General

Standard central office storage battery having a normal potential of 24 volts is used for operating test board circuits unless otherwise specified. 48-volt battery is used for supplying talking battery to the testing circuit and connecting cord whenever available. Ringing and Tone Test Leads are obtained from standard ringing machines.

(2) Testing Battery

The testing battery consists of dry cells, connected in series to give a working potential of 150 volts. The dry cells are mounted outside the section and should be arranged in such a way that additional cells may be added to keep the potential normally at 150 volts. One testing battery which is used for both voltmeter and Wheatstone bridge tests, is furnished for each test board position.

4. METHODS OF LINE TESTING.

a. Precautions in the Use of Testing Equipment.

In order to prevent giving shocks to linemen or cablemen care should be taken not to connect testing battery or ringing current to the line before notifying them. When inserting the test plugs all keys should be normal and the test cord key should not be thrown before notifying the lineman if he is on the line. Shunt key No. 2 should be operated only long enough to make the necessary tests and should never be left in an operated position.

Provision must be made to keep the line current below 100 milliamperes when the line accidentally becomes grounded or short-circuited near the office where the battery is located. For this reason each battery or generator tap wired to the test board for use as a testing tap or spare tap must have a resistance of at least 10 ohms per volt inserted in the lead.

b. <u>Classes of Line Tests</u>

The testing circuit is provided at the #4 testboard for the purpose of determining the nature and location of troubles occurring on toll lines outside the office and in the apparatus associated with them inside the office. The testing circuit is provided with a voltmeter and Wheatstone bridge as shown on Figure 2. The voltmeter is used in preliminary tests for determining the nature of the trouble on the circuit and the Wheatstone bridge is used in locating faults after the nature of the fault has been determined by means of the voltmeter. For convenience, therefore, the tests described below are divided into two general classes:

Voltmeter tests, or tests for determining the nature of a fault.

Wheatstone bridge tests, or tests for determining the location of the fault on the line.

For reference purposes the formulas used in the voltmeter and Wheatstone bridge tests are numbered consecutively.

c. <u>Voltmeter Tests</u>

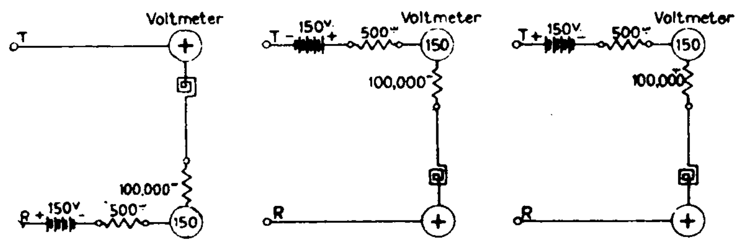
As mentioned above, the voltmeter is used to determine the nature of the trouble existing on the line, that is, whether the line is open, grounded, short-circuited, or crossed with another line or with a source of foreign or earth potential. The different tests which may be made with a voltmeter are further classified as follows:

Continuity tests
Bridged apparatus tests
Tests for grounds
Rough resistance measurements
Tests for insulation resistance and leakage

Tests for crosses
Tests for foreign or earth potentials
Morse subscribers

(1) <u>Continuity Tests</u>

The operator in taking up the line for test first makes the usual busy test using one of the regular test cords, and if the line is not busy inserts the plug in the line jacks in order that preliminary tests may be made to determine the nature of the trouble on the line and whether the trouble is outside or inside the office. If there is no one on the line the test cord key associated with the test cord used is thrown forward which connects 150-volt metallic battery to the tip and ring wires of the circuit in series with the voltmeter, as shown in Fgiure 26. In testing a toll line the circuit will normally be closed at the distant end if the line is O.K., and a deflection will be obtained on the voltmeter indicating that the line is continuous, the magnitude of the deflection being a measure of the resistance of the line and the apparatus at the distant end. If the circuit is open, a momentary throw of the voltmeter pointer will sometimes be obtained, expecially if the line is long and its insulation resistance high. In making continuity tests, non-grounded battery is used and therefore, other tests with a grounded battery may be required.




Test circuit reversed. Test cord key A.B.C or D thrown forward Key 6 thrown forward.

Battery reversed. Test cord key A.B.C or D thrown forward. Key 5 thrown back

Voltmeter test. Test cord key A.B.C or D thrown forward.

**FIGURE 26**
Voltmeter Connections

(2) <u>Bridged Apparatus</u>

In testing toll lines which have drops connected to them at the distant end, the presence of this apparatus will be indicated by a steady deflection of the voltmeter as soon as the test cord key is thrown if the line is continuous. However, if the apparatus at the distant end should include a series condenser, the voltmeter needle will be deflected only temporarily. The presence of a bridge of this type can always be determined by operating reversing key No. 6 which will cause the voltmeter to be deflected by the discharge of the condenser at the distant end, the magnitude of the deflection being a rough measure of the capacity bridged across the line. On lines having more than one bridge of this type or on long cable circuits, the deflection may be too large to be read accurately on the voltmeter. In such cases shunt key No. 2 is thrown forward to reduce the deflection. The telephone key must not be thrown while making these tests since the bridge condensers in the telephone set will cause a momentary throw of the voltmeter needle similar to the bridged apparatus at the distant end.

(3) Tests for Grounds

To test for grounds Key No. 1 is first thrown forward which opens the tip side of the circuit and connects the voltmeter to the ring side in series with the testing battery, as shown in Fig. 27. The voltmeter deflection will then be an approximate indication of the resistance between the ring side of the circuit and the ground.

If the bridged apparatus at the distant end includes a series condenser, the above test would not indicate a ground existing on the tip side of this circuit. Therefore, Key No. 1 should be thrown back to test the tip side of the circuit, the arrangement being as shown in Fig. 28. If the voltmeter reading is in excess of the one previously obtained, it would indicate that a ground or leak existed on the tip side of the line.

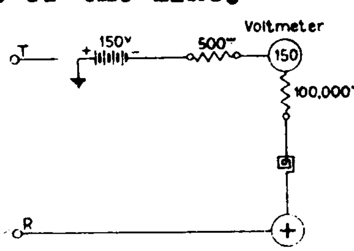



FIGURE 27
Test ring Test cord key A,B,C or D thrown forward and key 1 thrown forward

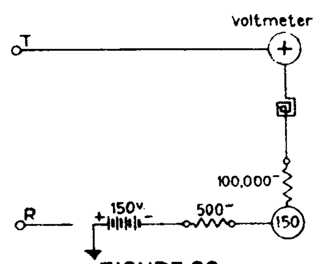



FIGURE 28
Test tip Test cord key A,B,C or D thrown forward. Key 1 thrown back

If the bridged apparatus or repeating coil at the distant end does not include any series condensers, the reading obtained when Key No. 1 is thrown forward will be approximately equal to the reading obtained when key No. 1 is thrown back. However, if the line is long and the resistance of the fault is low, the reading will generally be larger in the former case than in the latter if the ring side is grounded near the testing station, and smaller if the tip side is grounded near the testing station. If the two readings are approximately equal and large enough to indicate that a ground exists, the fault is presumably near the distant station.

(4) Resistance Measurements with Voltmeter

The voltmeter may be used to make rough resistance measurements. An approximate figure for the resistance may be obtained quickly by remembering that the scale divisions from the zero point to the needle represent the resistance of the voltmeter and that the scale divisions from the needle to the battery voltage (150 volts) represents the resistance under test. This may be expressed by the following formula:

$$X = \frac{r\,E}{D} - r - r' \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where: X = the resistance under test
r = the voltmeter resistance
E = the test battery voltage
D = the voltmeter reading when in series with resistance X and the testing battery
r'= The resistance in series with the testing battery.

The 500-ohm resistance r' is in series with the testing battery and must, therefore, be subtracted as indicated in the above formula when accurate results are desired.

Since the resistance of the voltmeter will be either 1,000 or 100,000 ohms the value of X usually may be determined mentally. For example, if when the circuit is closed and the shunt key No. 2 is thrown forward making the voltmeter resistance 1,000 ohms as shown on Figure 29, the deflection is 75 volts and when Key No. 6 is thrown forward the deflection is 150 volts, from formula (1)

$$X = 1{,}000 \times \frac{150}{75} - 1{,}000 - 500 \quad \text{Or}$$

X = 500 ohms which is the resistance of the circuit under test. The same method and formula apply when the voltmeter is used without the shunt except that the voltmeter resistance r is 100,000 ohms instead of 1,000 ohms and the 500 ohm resistance r' may be neglected as described later.

When making resistance measurements with the voltmeter the battery voltage should be noted carefully at the time of making the test. If the shunt key is used in making a resistance measurement, the battery voltage should be read while the shunt key No. 6 is thrownback which connects the tip and ring wires together and has the effect of connecting the voltmeter directly across the testing battery, as shown in Fig. 30. The voltmeter reading then indicates the potential of the testing battery.

In measuring resistances with the voltmeter the results are more accurate when the resistance of the voltmeter is nearly equal to the resistance being measured. For this reason shunt Key No. 2 should be

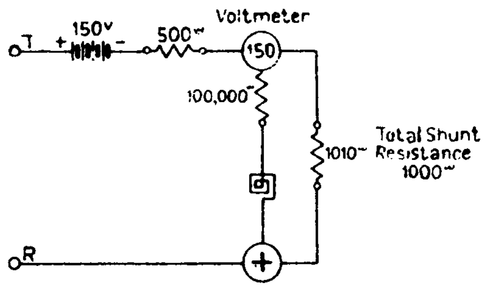



**FIGURE 29**
Voltmeter shunt. Test cord key A, B,C or D thrown forward. Key 2 thrown forward.

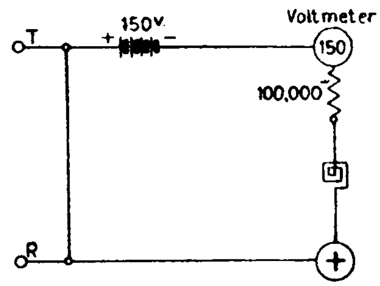



**FIGURE 30**
Measuring battery voltage Test cord key A,B,C or D thrown forward. Key 6 thrown back

operated when measuring resistance up to 10,000 ohms. For resistances higher than this value the shunt key should not be used. In making resistance measurements upon grounded circuits, care should be taken to determine whether any foreign or earth potentials are present, since resistance measurements, as a general rule, are not very accurate when foreign or earth potentials exist.

(5) Insulation Resistance and Leakage

The voltmeter is used for approximate resistance measurements only, the Wheatstone bridge being used when accurate results are desired. Since insulation resistances are generally in excess of 10,000 ohms shunt key No. 2 should not be used in making these measurements. The voltmeter resistance is then 100,000 ohms and assuming that the resistance being measured is above 10,000 ohms, the 500 ohm resistance r' may be neglected with small error so that formula (1) may be simplified as follows:

$$X = \left(\frac{E}{D} - 1\right) \times 100,000 \quad \ldots \ldots \quad (2)$$

Where X = the resistance being measured
E = the testing battery voltage
D = the voltmeter reading when in series with resistance X and the testing battery

100,000 = the resistance of the voltmeter in ohms.

For example, if in measuring the insulation resistance of a line a deflection of 5 scale divisions representing 10 volts is obtained and when key No. 6 is thrown back the reading is 150 volts, substituting these values in formula (2) gives

$$X = \left(\frac{150}{10} - 1\right) \times 100,000 \text{ or}$$

$X = (15 - 1) \times 100,000 = 1,400,000$ ohms, which is the insulation resistance of the entire line.

This page supersedes page 29 dated September 19, 1919.

Generally when line insulation resistance measurements are made the interpretation of results requires that the insulation resistance be expressed in megohms per mile. This may be done by multiplying the resistance obtained by (2) into the length of line expressed in miles.

A more convenient method is to use a formula similar to (2) which gives the resistance in megohms per mile directly as follows:

$$X = \left(\frac{E}{e} - 1\right) RL \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where

X = Insulation resistance in megohms per mile
E = Battery voltage
e = Deflection in volts
R = Voltmeter resistance in megohms
L = Length of Wire in miles.

To measure the insulation resistance between the wires of a pair the circuit should be opened at the distant end and the test cord key thrown forward to give the circuit arrangements shown in Fig. 26. The voltmeter reading will then indicate the insulation resistance between the two wires and its approximate value in megohms may be determined if desired by substituting the values in formula (3). The insulation resistance between each wire of the pair and ground may be determined by throwing key No. 1 forward to test the tip side and back to test the ring side as described above in making tests for grounds.

In making measurements of insulation resistance shunt key No. 2 should be used unless the voltmeter reading is in excess of 135 volts with the shunt key normal and a test battery voltage near normal. However, if the reading is in excess of this value it will indicate that the insulation resistance is about 10,000 ohms or less and better results may be obtained by operating the shunt key and substituting in formula (1) when determining the resistance.

(6) Tests for Crosses.

Crosses may be divided into two classes, (1) crosses between the wires of a pair, commonly known as "short circuits", and (2) crosses between either wire of a pair and another circuit. The other circuit may or may not have battery or ground connected to it. Crosses between the wires of a pair, or "short circuits", will always be determined by the low resistance obtained when measuring the insulation between the wires as described above.

When it is not known what wire the circuit under test is crossed with, the line should be opened at the distant end and tests made to determine, either by listening on each wire or by the kick of the voltmeter needle on testing each wire to ground, which wire of the pair is crossed with another line. The presence of the cross is usually indicated by a greater volume of noise when the test-board operator listens on the wire that is crossed. This may be done by throwing key No. 1 either forward or back depending on which wire of the circuit is crossed and throwing telephone key No. 3 back. This combination grounds one side of the telephone set and connects the other side to the line. The cross may also be determined by the voltmeter as follows: Key No. 1 is thrown in the proper direction to connect the wire under test to the voltmeter. Battery reversing key No. 5 is then operated to reverse the direction of current through the voltmeter. Each time the battery reversing key is operated a momentary deflection of the voltmeter will be obtained. On comparing the deflection obtained on the wire under test and the deflection obtained on the good wire of the circuit it will be found that the deflection in the former case is considerably larger than the latter. In making this test telephone key No. 3 should be normal. If it is not possible to determine conclusively which wire of the pair is crossed either by the voltmeter or by listening tests, the capacity of each wire to ground may be measured by means of the open-location test feature as described later. The capacity of the faulty wire to ground will generally be considerably larger than the capacity of the good wire to ground.

After determining which wire of the pair is crossed the test plug should be removed from the circuit and one of the single plugs inserted in the line jack of the faulty wire. The other single plug should then be inserted momentarily in such circuits as may be suspected of being crossed with the defective wire. As soon as the test plug is inserted in the wire which is crossed with the wire under test, the voltmeter needle will be deflected. By throwing key No. 2 back the Morse relay may be used in place of the voltmeter or the Morse relay may be used independently of the testing set. When it is not possible to determine which wire of the pair is crossed with another circuit these tests should be made with the pair short-circuited at the distant end.

If the wires of the pair are not crossed with each other, either one may be crossed with some other circuit which is not grounded and does not appear at the office where the test is being made. Frequently, crosses of this kind can be determined by ringing on the defective circuit, sufficient of the ringing current passing through the cross to operate the relay connected with the drop on the outside circuits. The answering operator on the outside circuit will be able to define the circuit. Crosses of this kind can

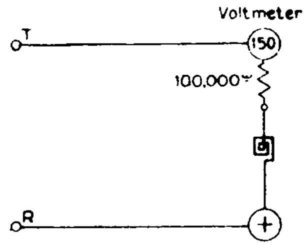



FIGURE 31
Battery off Test cord key A.B. C or D thrown forward. Key 5 thrown forward

usually be located between two test stations and the line records should show the location of circuits with which crosses might occur. If possible, these tests should be repeated with grounded battery and the circuits with which a cross is suspected grounded momentarily at the test station. A deflection of the voltmeter needle will be obtained when the wire with which the circuit under test is crossed is grounded at the test station.

(7) Tests for Foreign or Earth Potentials

This test is made in a manner similar to that employed in the test for leakage or insulation resistance to ground with the exception that key No. 5 is thrown forward to disconnect the testing battery from the circuit. With key No. 1 in its normal position the operation of key No. 5 connects the voltmeter directly across the circuit as shown in Fig. 31, so that any deflection would indicate the presence of a foreign potential on the circuit. When key No. 1 is operated the negative side of the voltmeter is connected to ground and the positive side is connected to either the tip or ring wires of the test plug, (to the tip wire when the key is thrown back and to the ring wire when the key is thrown forward) so that any ground potential on either of these wires would be indicated by a deflection of the voltmeter needles. This test is particularly useful on toll lines that are likely to become crossed with common battery subscriber's lines, since the potential of the common battery subscriber's lines is always known. If the testboard operator in testing for foreign potentials finds that the toll line is crossed with a circuit having a potential of 24 volts, an attempt should be made to identify the subscriber's line. This may be done by throwing shunt key No. 2 forward, reducing the voltmeter resistance to 1,000 ohms and operating the line relay in the usbscriber's line circuit. Key No. 3 should be thrown back so that the testboard operator may identify the line when the subscriber's operator answer the line signal.

(8) Testing Morse Subscribers' Loops

Where Morse subscriber's loops are terminated at the testboard, a special jack is provided at the test board for testing the loops as shown on Fig. 2, the tip spring of the jack being connected directly to the tip side of the testing circuit and sleeve of the jack connected to the ring side of the testing circuit. To test a Morse subscriber's loop, it is plugged into this special jack, and the usual voltmeter and Wheatstone bridge tests may then be made on the loop. In using this jack care should be taken to see that the test cords "A", "B", "C" and "D" are in their normal position, otherwise the test will not be made accurately.

d. Location of Faults

In making measurements for the purpose of locating crosses, grounds or other troubles, it is essential to know whether the circuit contains conductors of different gauges and how many feet or miles of the various conductors are in the circuit. It is also desirable to know the resistances of the various sections of dissimilar conductors. For these reasons it is necessary that records be kept showing the length, gauge and kind of conductors in each circuit, together with their resistance under different atmospheric conditions, and also the location of test poles, cable boxes, test stations and junction points or any other irregularities in construction which may aid in locating the fault. It is particularly important that all the connections involved in the circuit be perfect, otherwise the locations will be inaccurate. Linemen and testboard operators should be impressed with the importance of making reliable connections.

(1) Effect of Temperature

In making locations on open wire lines, it should be remembered that the resistance will vary considerably with the temperature. In bright, sunshiny weather the wires are several degrees warmer than the air, sometimes as much as 30 degrees. During cloudy weather or at night, the temperature of the line wires will be the same as the surrounding air. It has been found that the resistance of No. 12 copper wire may vary from 8.2 ohms per mile loop at 30 degrees below zero, to 11.3 ohms at 100 degrees above zero. At 52 degrees Fahrenheit, the resistance of No. 12 N. B. S. gauge copper wire is about 10 ohms per mile loop.

(2) Correction for Temperature

On account of the change in resistance, due to variation in atmospheric conditions, it is important that at the time it is desired to make a Varley or Murray loop test a resistance measurement be made on the line in trouble. This resistance, divided by the distance between the testing station and the distant station, will give the average loop resistance per mile of the line under test under the atmospheric conditions existing at the time the fault is to be located. This value of the average loop resistance per mile should always be used, when obtainable, in the calculations involved in Murray and Varley loop tests. For example, on a cold day the loop resistance of a line 100 miles long may be 900 ohms making 9 ohms the proper average resistance per loop mile to be used in calculating the distance to a fault on that line under the existing weather conditions. On a hot day, the resistance of the same line may be 1200 ohms, thus making 12 ohms the proper average resistance per mile loop to be used in calculating the distance to a fault then existing.

(3) Preliminary Location

In making tests for locating trouble, it is first necessary to determine between what two test stations the fault exists. If the preliminary voltmeter tests indicate that the line is in trouble, the line should first be opened or short-circuited at the first test station to determine whether or not the trouble exists in that portion of the circuit between the test board and the first test station. This should be repeated at consecutive stations until the fault is located between the two stations. Generally the test-board operator nearest the fault should then proceed with the accurate location of the trouble.

e. Wheatstone Bridge Tests

After the nature of the fault and its approximate location on the line have been determined by the voltmeter tests described above, the fault may be located accurately by the Wheatstone bridge. The Wheatstone bridge tests which may be employed are classified as follows:

Loop resistance measurements
Single wire resistance measurements
Insulation resistance measurements
Varley loop tests
Murray loop tests
Open-location tests.

One Wheatstone bridge is provided for each two positions, and keys No. 13 and No. 14 are provided so that the bridge may be connected to the test cords in either position. When these keys are thrown forward the bridge is connected to the test cords in the right-hand position and when thrown back the bridge is connected to the test cords in the left-hand position. When key No. 13 only is thrown, the ratio arms "A" and "B" and the rheostat arm "R" are connected in series to the test cords, as shown in Fig. 32, so that they may be used as a variable resistance in adjusting relays, etc.

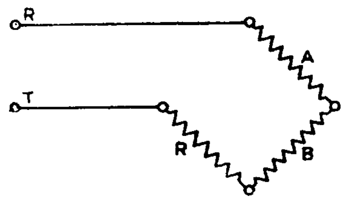



FIGURE 32
Wheatstone Bridge used as adjustable resistance. Test cord key A.B.C or D thrown forward. Key 13 thrown forward or back.

(1) Loop Resistance

Assuming that the nature of the trouble has been determined, and it has been found between what two test stations the trouble exists, a loop resistance measurement should then be made, in order to determine the loop resistance per mile to use in calculating the distance to the fault. To do this the wires should be "short-circuited" at the first test station beyond the fault. As soon as the voltmeter reading indicates that the "short-circuit has been connected, keys Nos. 13 and 14 should be thrown forward or back, leaving all other keys normal. These keys throw the bridge to the left position if thrown back and to the right position if thrown forward.

The circuit arrangements are then as shown in Fig. 33.

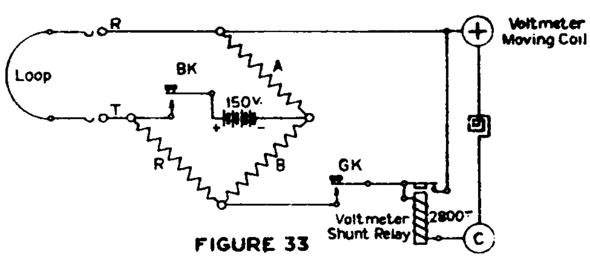



FIGURE 33
Loop resistance measurement Test cord key A.B.C or D thrown forward. Keys 13 and 14 thrown forward or back Key 15 normal using voltmeter moving coil and shunt relay in place of Galvanometer.

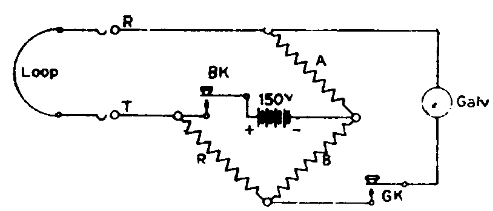



FIGURE 34
Loop resistance measurement. Test cord key A.B.C or D thrown forward. Keys 13 and 14 thrown forward or back Key 15 thrown forward to substitute for voltmeter.

It is always desirable, in obtaining the preliminary balance, to have the ratio arms equal. Loop resistances are usually made with ratio arms "A" and "B" set at 1,000 ohms. The resistance measurements will then be correct to within 1 ohm. If a balance cannot be obtained with equal ratio arms or if a very accurate measurement is desired, unequal values should be used with the ratio arms as indicated in the table below:

| If resistance measured is | A | B | Resistance R should be: |
|---|---|---|---|
| Less than 10 ohms | 1 | 1,000 | Divided by 1,000 |
| 10 to 100 ohms | 10 | 1,000 | " " 100 |
| 100 to 1,000 ohms | 100 | 1,000 | " " 10 |
| 1,000 to 10,000 ohms | 1000 | 1,000 | Equal to Line Resistance |
| 10,000 to 100,000 ohms | 1,000 | 100 | Multipled by 10 |
| 100,000 to 1,000,000 ohms | 1,000 | 10 | " " 100 |
| Over 1,000,000 ohms | 1,000 | 1 | " " 1,000 |

Resistance measurements of cable circuits are usually made with unequal ratio arms, as a greater accuracy may be obtained in this way when measuring resistance less than 1,000 ohms. When equal ratio arms are used, the resistance in "A" and "B" should be as near in value as possible to the resistance being measured.

After the bridge has been adjusted the battery key is locked down. The galvanometer key on the bridge is then closed long enough to determine the direction and magnitude of the deflection of the voltmeter needle. The resistance in the rheostat arm "R" is then adjusted until there is no movement of the voltmeter needle when the galvanometer key is opened and closed. The galvanometer shunt is then set at .001 and key No. 15 is then thrown forward, which disconnects the voltmeter and connects the galvanometer in its place as shown on Fig. 34. The resistance in "R" is then adjusted until there is no movement of the galvanometer needle when the galvanometer key is open and closed. This adjustment is then repeated with the galvanometer shunt set consecutively at positions .01, .1 and finally "open". The value of the resistance in "L" may then be determined by the formula-

$$L = \frac{AR}{B} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

Where L = the loop resistance of the circuit under test
A = the value of resistance in arm "A"
B = " " " " " " "B"
R = " " " " " " Rheostat arm

If the ratio arms are equal the resistance in "L" will then be equal to the resistance in the rheostat arm. If the ratio arms are not equal the value of resistance in "L" will be the sum indicated on the dials in the rheostat arm, multipled or divided by the figures, indicated in the above table.

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(2) Single Wire Resistance Measurements

If three single wires are available between two testing stations, the resistance of any one of them may be determined as follows: Let the three wires be represented by a, b, and c. Wires a and b are strapped at the distant end and their loop resistance measured. In a similar way measure the loop resistance of wires a and c, and b and c. As each of the wires has now been measured twice, evidently one-half the sum of the three loop resistances equals the sum of the resistances of the three wires and the resistance of any one wire is the difference between its resistance and the loop resistance of the other two. This may be expressed in a formula as follows:

$$A = \frac{(a + b) + (a + c) + (b + c)}{2} - (b+c) \quad \ldots\ldots\ldots (5)$$

where, a, b, and c represent the resistances of the respective wires. The resistances of the other two wires may then be readily determined from the relation

$$b = (a + b) - a$$
$$c = (a + c) - a$$

For example, suppose the loop resistance of wires a+b = 210 ohms, a+c = 240 ohms and b+c = 250 ohms. The sum of these resistances equals 700 ohms, which divided by 2 to obtain one-half the loop resistances, equals 350 ohms. Then

$$a = 350 - 250 = 100 \text{ ohms}$$
$$b = 210 - 100 = 110 \text{ ohms}$$
$$c = 240 - 100 = 140 \text{ ohms}$$

When two wires are available between two test stations, the resistance of either of them may be determined by measuring their loop resistance and then making a Varley or Murray loop test as described later with the two wires grounded at the distant station.

It is possible under favorable conditions to measure the resistance of a single wire to ground by means of the bridge. However, the results obtainable by this method are not sufficiently reliable to warrant their use when more than one wire is available between the test stations. This test is made in the same way as loop resistance measurements, except that the single wire is connected to the tip side of the bridge and the ring side of the bridge connected to ground by throwing key No. 1 forward or back to test the tip or ring side, as shown in Figs. 35 and 36. Before attempting to measure the resistance, the rheostat arm "R" should be set at approximately the resistance previously determined by the voltmeter tests. If a foreign or earth potential is present, it will cause the galvanometer needle to be deflected when the galvanometer key is closed and the battery key open. If this reading is larger than the full scale reading when the galvanometer shunt is open and the resistance in the rheostat arm is approximately equal to the line resistance, the voltmeter should be used in the bridge in place of the galvanometer. In balancing the bridge when a foreign or earth potential is present, the rheostat should be adjusted until opening and closing the battery key with the galvanometer key closed does not change the deflection of the needle. When a resistance is measured in this way, it includes the resistance in the ground and ground connections at each end of the line.

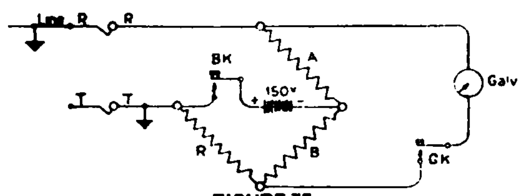


FIGURE 35
Single grounded wire resistance measurement. Test cord key A, B, C or D thrown forward. Key 13 and 14 thrown forward or back. Key 1 thrown forward to test ring side. Key 15 thrown forward to connect Galvanometer in place of voltmeter

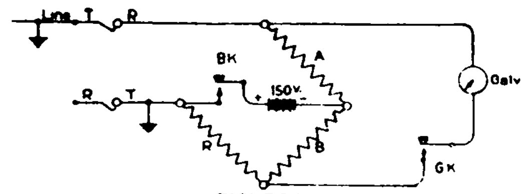


FIGURE 36
Single grounded wire resistance measurement. Test cord key A, B, C or D thrown forward. Key 13 and 14 thrown forward or back. Key 1 thrown back to test tip side. Key 15 thrown forward to connect Galvanometer in place of voltmeter

### (3) Varley Loop Test

The Varley test is particularly desirable in locating trouble as it is independent of the resistance of the fault. In making a Varley test a good wire is necessary and preferably this should be the mate of the bad wire. If, however, the two wires of a pair are crossed or grounded, it is necessary to select a good wire from some other circuit on the line. On open wire lines this should be, where practicable, a non-loaded #12 gauge circuit in order not to interrupt service on a high grade circuit. In making locations in cable where the mate of the bad wire is in trouble, a good wire of the same grade and loading as the bad wire should be taken from the same layer of conductors, since in other wires some inaccuracy would be likely to rsult on account of the difference in length due to the twist in the layup of the cable and since in the cable on account of the large circuit groups the use of a high grade conductor for trouble locations is not so objectionable as in the case of open wire lines. The circuit arrangements for making Varley loop tests are shown in figures 37, 38 and 39.

#### (a) Method #1

After the loop resistance has been determined as described above, key #16 is thrown forward to give the Varley loop connection. The ratio arms should be equal and set at 100 or 1000 ohms, preferable the latter. If the trouble is on the ring side or even numbered wire of the pair, a balance cannot be obtained until revers-

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ing key #6 is thrown forward. This connects the bad wire to the tip side of the bridge. If the trouble is on the tip side or odd numbered wire of the pair, it will not be necessary to operate key #6 to obtain a balance. After the proper connections have been made, the battery key is then locked down and the rheostat adjusted until no deflection of the galvonometer needle is obtained under the most sensitive conditions, i.e., with the galvonometer shunt open. The distance from the testing station to the fault can then be obtained by the formula

$$d = \frac{L-R}{M} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (6)$$

where

$d$ = the distance in miles from the testing station to the fault

$R$ = Varley reading, i.e., the resistance in the rheostat arm when a balance is obtained on a Varley test.

$L$ = The loop resistance of the line under test

$M$ = the loop resistance per mile of the line under test.

This formula applies only when the good and bad wires are of the same gauge and grade, i.e., having the same resistance between the testing point and the distant station. The L and R (loop and Varley) readings should be corrected to give the actual line wire resistance, i.e., by subtracting the resistance of the office wiring, arresters and cabling between the test board line jacks and the line wires proper at both the testing point and the distant station. These resistances will generally be known and recorded at all offices so as to be immediately available when making trouble locations. When so corrected, the values L and R represent the loop and Varley reading, respectively, of the line wires only, either cable or open wire, as the case may be. For example, under the conditions above noted where the good and bad wires are of the same grade of loading, if the corrected loop resistance L of a line 50 miles long is 550 ohms at the time the test is made, the loop resistance per mile at that time for the line under test will be 11 ohms. Then if the corrected Varley reading is 330 ohms and the ratio arms are equal, we have by Formula (6)

$$d = \frac{550-330}{11} = 20 \text{ miles, distance from the}$$

testing station to the fault.

Similarly, the resistance between the fault and the distant station may be obtained by the formula

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$$d_1 = \frac{R}{M} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (7)$$

Where $d_1$ is the distance in miles from the fault to the distant station. Where R is the corrected Varley reading and M the loop resistance per mile of the line wires under test.

Thus in the example given above:

$d_1 = \frac{330}{11} = 30$ miles, i.e., the distance from the fault to the distant station.

It is usually better to use Formula (7) when working to a lineman's cross beyond the fault or when testing to a distant station if the fault is near that station. In any case, if time is available it is usually well to make the location by both formulas using one as a check against the other.

(b) Method #2

Method #2 described below is a simpler and more reliable method since it is independent of temperature and is not affected by the use of a good wire of different gauge and loading than the bad wire. In this method the loop resistance of the good and bad wire should be determined regardless of inequalities in gauge and loading. The Varley measurement should then be taken as above described in the usual way, and both readings corrected for office cabling, arresters, etc. at both ends of the wires under test. Formula which then applies is:

$$X = \frac{L - R}{2} \quad \ldots\ldots\ldots\ldots\ldots \quad (8)$$

and

$$d = \frac{XK}{Y} \quad \ldots\ldots\ldots\ldots\ldots \quad (9)$$

where

X = resistance of bad wire from testing point to the fault.
Y = resistance of bad wire from testing point to distant station.
K = the distance in miles from the testing station to the distant station.
d, L and R as defined above.

In the case of open wire lines, if the good and bad wires are of the same gauge and loading Y is equal to 1/2 the corrected loop reading. Where the bad wire is not of the same gauge and loading as the good wire a second loop reading should be taken between the good wire and its mate. Correct this reading for office cabling, etc., at both ends and subtract 1/2 of the result from the corrected loop, reading L. The remainder will be Y.

The resistance Y of the bad wire between the testing station and the distant station may be divided by the number of poles between the testing point and the distant station, the result being the number ohms per pole or per span which may be divided into X to find the number of poles between the testing point and the fault. Then by knowing the pole number at the testing point the pole number at the fault may be readily computed. A more accurate location may be obtained by computing d in accordance with formula (9) and referring to the line record book which should show exact line measurements from the testing station to various

This Page supersedes Page 40-A.

poles located a few miles apart. From this record the pole number whose recorded distanceis nearest to d is selected. The difference between the recorded distance and d should then be divided by the average pole spacing of the region of line in which the trouble is located, the result being the number of poles distant the trouble is from the selected location.

In the case of aerial cable the same procedure should be followed, but in the case of underground cable it is better to change the resistance X to miles by dividing X by the number of ohms per mile for the wire under test. Where necessary this can be corrected for temperature, but normally underground cables do not change their resistance greatly with reasonable changes in temperature. After determining the distance in miles from the testing point to the fault, the nearest manhole can be found by reference to underground cable records.

The following example is given showing the use of this method as applied to trouble on open wire lines:

Suppose a loaded #8 gauge pair (wires 7 and 8) is crossed and wire #8 is chosen as the bad wire; the mate (7) is of course not available as a good wire and it is undesirable to take a second loaded #8 gauge circuit out of service to make the test. Assume that there is on the line a non-loaded #12 gauge circuit, wires 13 and 14, and that #14 be chosen as the good wire. Have wires #8 and #14 crossed at the distant station, make a loop and Varley measurement on these wires as above outlined, correcting both readings for office cabling, etc. at both ends. Assume that the corrected reading L is 550 ohms and the corrected reading R 330 ohms, the calculation would then be

$$X = \frac{550-330}{2} = 110$$

Make a loop reading on wires 13 and 14 and assume that after subtracting the resistance of the office cabling, etc. at both ends the result is 735 ohms. One-half of this or 367 should then be subtracted from the corrected loop reading L giving

550-367=183 ohms the resistance of the bad wire from the testing point to the distant station.

Assume that the office pole at the testing point is 142 and the office pole at the distant station 2554. There is then

2554-142=2412 poles between the stations.

This divided into 183 ohms gives

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$$\frac{183}{2412} = .0759 \text{ ohms per pole}$$

The actual result is .07587, but .0759 is sufficiently accurate for the purpose. This result divided into 330

$$\frac{330}{.0759} = 435$$

The actual result is 434.0, but 435 is sufficiently accurate for the purpose.

The touble is 435 poles from the testing point and the pole number at the test location is

$$142+435=577$$

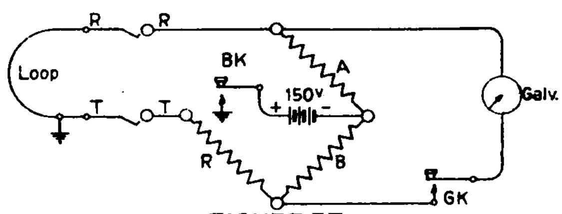


FIGURE 37
Varley loop test. Test cord key A,B,C or D thrown forward. Keys 13 and 14 thrown forward or back. Key 16 thrown forward. Key 15 thrown forward to connect Galv. in place of voltmeter. (For voltmeter used as Galv. with key 15 normal see Fig 32)

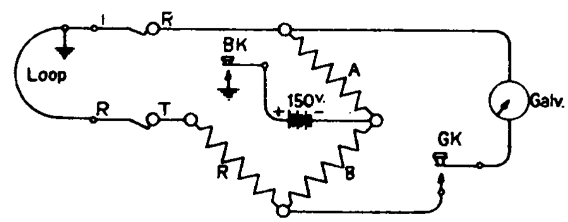


FIGURE 38
Reversed Varley loop test. Test cord key A,B,C or D thrown forward. Key 13 and 14 thrown forward or back. Key 16 thrown forward. Reversing key 6 thrown forward. Key 15 thrown forward to connect Galv. in place of voltmeter. (For voltmeter used as Galv. and key 15 normal see Fig.32)

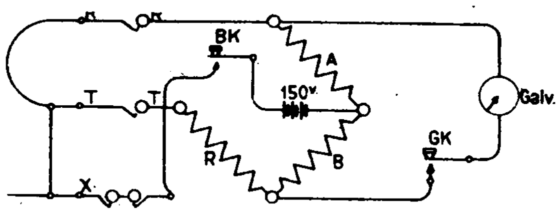


FIGURE 39
Metallic Varley test. Test cord key A,B,C or D thrown forward. Keys 13 or 14 thrown forward or back. Key 16 thrown forward. Varley and Murray loop jack patched to line X. Key 15 thrown forward to connect Galv. in place of voltmeter. (For voltmeter used Galv. with key 15 normal see Fig.32.)

(4) <u>Murray Loop Test</u>

When it is desired to locate a fault on a line in which both conductors are of the same gauge and conductivity throughout their length the Murray loop test may be used to advantage in determining the distance between the testing station and the fault, as a location can be made in this case without a knowledge of the loop resistance of the pair under test. If it is desired to determine the distance from the fault to the distant station, the Murray loop test is not so convenient as the Varley test. The circuit arrangements when making Murray loop tests are shown in

Figs. 40, 41 and 42. The position of the keys for this test is the same as when making Varley loop tests, except that key No. 16 if thrown back to give the Murray connection to the bridge.

(a) Method

To make a Murray loop test key No. 16 is thrown back which short-circuits the ratio arm B and substitutes the rheostat arm R in its place. Arm A is usually set at 1,000 ohms and the bridge adjusted in the usual way. If a more accurate result is desired arm "A" should then be adjusted as nearly as possible to a value equal to one-half the loop resistance and another balance obtained. When a balance is obtained the location of the fault may be determined by means of the formula -

$$d = \frac{D' R}{A + R} \quad \ldots\ldots\ldots\ldots \quad (10)$$

Where: d = distance from testing station to the fault
D'= Twice the distance between the testing stations
R = resistance in the rheostat arm what a balance is obtained.
A = the resistance of arm A.

Thus if the distance between testing stations is 40 miles and if a balance is obtained in making the Murray loop test when A = 1,000 ohms and R = 600 ohms,

$$d = \frac{40 \times 2 \times 600}{1,000 + 600}$$ = 30 miles, the distance from the testing station to the fault.

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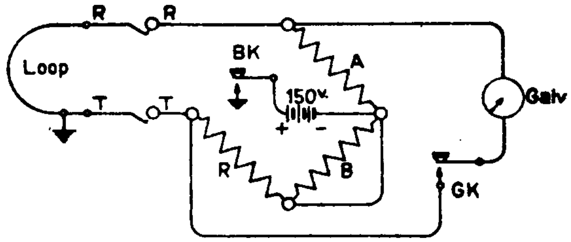


**FIGURE 40**
Murry loop test. Test cord key A,B,C,or D thrown forward. Keys 13 and 14 thrown forward or back. Key 16 thrown back. Key 15 thrown forward to connect galvanometer in place of volt-meter.

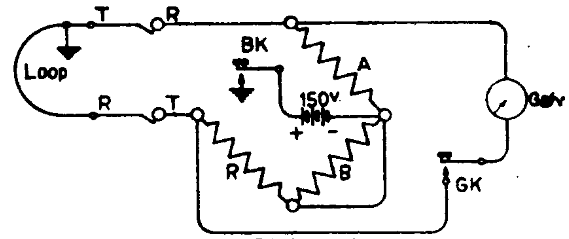


**FIGURE 41**
Reversed murray loop test. Test cord key A,B,C or D thrown forward. Keys 13 and 14 thrown forward or back. Key 16 thrown back. Reversing key 6 thrown forward Key 15 thrown forward to connect galvanometer in place of voltmeter.

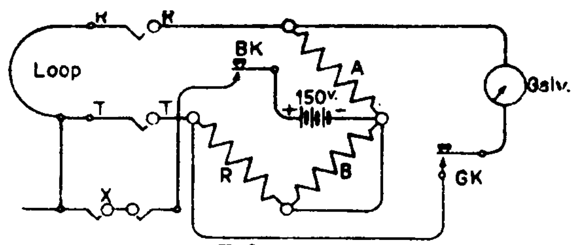


**FIGURE 42**
Metallic murray loop test. Test cord key A,B,C or D thrown forward. Keys 13 and 14 thrown forward or back. Key 16 thrown back. Varley and murray loop jack patched to line X. Key 15 thrown forward to connect galvanometer in place of voltmeter.

This result may be checked by throwing reversing key No. 6 forward. The value of d determined by formula (10) is then the distance from the testing station to the distant station and back to the fault. Thus in the above case if the reversing key is operated and a balance is obtained when R = 1,667 ohms according to formula (10).

$$d = \frac{40 \times 2 \times 1667}{1,000 + 1667} = 50 \text{ miles, the distance from the testing}$$

station to the distant station and back to the fault. Adding these two values of d, 50 + 30 = 80 miles, which is twice the distance between testing stations.

Formula (10) applies when the two wires under test are of the same gauge and conductivity throughout their length. In such cases this formula is more convenient than formula (6) when the lineman is working from the testing station toward the fault since it is not necessary to know the loop resistance to locate the fault.

(b) <u>Single-Wire Resistance with Murray Loop</u>

When two wires are available between testing stations

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the resistance of either of them may be determined by measuring their loop resistance and then making a Murray loop test with both wires grounded at the distant station similar to the method described above for Varley loop tests. When a balance is obtained with key No. 16 thrown back and key No. 6 normal the resistance in the tip side of the line or the odd numbered wire of the pair will be given by the formula,

$$Y = \frac{R\,L}{A + R} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (11)$$

Where: Y = the resistance of wire in the tip side of the line from the testing station to the distant station.
L = loop resistance of the two wires
R = resistance in the rheostat arm when a balance is obtained
A = the resistance in ratio arm A

For example, suppose the loop resistance of the two wires is 240 ohms and when making the Murray loop test with key No. 6 normal and both wires grounded at the distant station a balance is obtained when A = 1,000 ohms and R = 714 ohms. Then substituting in formula (11) -

$$Y = \frac{714 \times 240}{1000 + 714} = 100$$ ohms, the resistance of the wire in the tip side of the line.

This value may be checked by throwing key No. 6 forward and again obtaining a balance. The value of Y obtained from formula (11) will then be the resistance in the ring side of the line and this value added to the value obtained for the resistance in the tip side should be equal to the loop resistance of the line under test. Thus in the example given above if a balance is obtained with key No. 6 thrown forward when A = 1,000 ohms and R = 1,400 ohms,

$$Y = \frac{1400 \times 240}{1000 + 1400} = 140$$ ohms, the resistance in the ring side of the line.

This value added to the value previously obtained for the tip side gives 240 ohms, the loop resistance of the line under test.

(5) Tests with Either Varley or Murray Loop

(a) Varley and Murray Tests when a Good Wire of the Same Gauge as the Bad Wire is not Available.

When a good wire of the same gauge as the bad wire is not available it is necessary to know the resistance of the bad wire from the testing station to the distant station before an accurate location can be made. If the bad wire is grounded the single wire resistance measurements described above cannot be employed for

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determining the resistance of the single wire. In such cases, the bad wire and good wire should be strapped at the distant end and their loop resistances measured. If a third wire of any gauge or conductivity which is free from crosses or grounds is available, the three wires should be strapped at the distant station and the line jack of the third wire at the testing station patched to the Varley loop jack of the testing circuit. A Varley or Murray loop test may then be made in exactly the same way as described above for measuring single-wire resistances and the same formulas apply in calculating the resistance of the bad wire. If a third wire which is free from crosses or grounds is not available, the good wire should be grounded at the distant station and its resistance to ground measured as previously described under "Single Wire Resistance Measurements". This resistance subtracted from the loop resistance of the good and bad wires will then be equal to the resistance of the bad wire between two testing stations.

Having determined the resistance of the bad wire between the two testing stations, the Varley and Murray loop tests should then be made for locating the fault. It will sometimes be found when the good wire is of a smaller gauge than the bad wire that a balance cannot be obtained when the bad wire is connected to the tip side of the bridge. In such cases reversing key No. 6 should be thrown forward which reverses the connections of the tip and ring wires at the bridge.

In making the Varley loop test with key No. 6 normal and the ratio arms A and E equal the resistance in the bad wire between the testing station and the fault is given by the formula.

$$X = \frac{L - R}{2} \quad \ldots\ldots\ldots\ldots \quad (12)$$

When key No. 6 is thrown forward the resistance to the fault is expressed by the formula.

$$X = \frac{L + R}{2} \quad \ldots\ldots\ldots\ldots \quad (13)$$

Where: X = the resistance of the bad wire from the testing station to the fault.
L = loop resistance of the pair consisting of the good and bad wire of different gauges.
R = the resistance in the rheostat arm R when a balance is obtained.

Having determined the resistance to the fault and the resistance of the bad wire between the two testing stations, the distance to the fault can be calculated by means of the formula -

$$d = \frac{X D}{r} \quad \ldots\ldots\ldots\ldots \quad (14)$$

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Where: d = distance from the testing station to the fault.
X = resistance of the bad wire from the testing station to the fault.
r = the resistance of the bad wire from the testing station to the distant station.
D = distance between the two testing stations.

If the Murray loop test is used in making the location test and a balance is obtained with key No. 6 normal the resistance to the fault is given by the formula -

$$X = \frac{R\,L}{A + R} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (15)$$

Where: X = resistance of the bad wire from the testing station to the fault,
L = loop resistance of the pair consisting of the good and bad wires of different gauges.
R = the resistance in rheostat arm R when a balance is obtained.
A = resistance in ratio arm A.

If it is necessary to throw key No. 6 forward to obtain a balance the resistance to the fault is obtained by the formula -

$$X = \frac{A\,L}{A + R} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (16)$$

Where: A, L and R have the same values as above,

When the resistance from the testing station to the fault has been determined the distance to the fault may be determined by means of formula (13) which applies to both Varley and Murray loop tests.

(b) Swinging Faults

In making Varley or Murray loop tests on a line where the ground or cross is intermittent it is always desirable to insert a Morse relay in the grounded side of the testing battery. This may be done by inserting the looping plug of Morse test set No. 1 in the Varley loop jack. This arrangement causes the Morse relay to operate each time the battery key on the bridge is closed if the circuit is grounded or crossed, thereby indicating to the test board operator that the trouble is present and that he may proceed to balance the bridge.

(c) Location of Crosses

As there is usually an appreciable resistance in the cross itself which may vary in amount during the test due to corrosion of the wires or poor contact between them, the measurement of the loop

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resistance through the cross itself does not afford a reliable means for locating the fault. For this reason a Varley or Murray loop test should always be used when attempting to locate a cross. Unless there is a considerable leakage in the line, the accuracy of the Varley or Murray loop tests will not be affected by the resistance in the cross itself.

In locating a cross by either the Varley or Murray loop tests one of the faulty wires should be strapped at the distant station to a good wire, preferably its mate and the loop resistance of the two measured The other faulty wire which is crossed with the faulty wire of the loop being measured is then connected to ground at the testing station. If, for example, wires 2 and 3 are crossed and wire 1 is free from faults and the same gauge as wire 2, wires 1 and 2 should be strapped at the distant station and wire 3 connected to ground at the testing station. The Varley and Murray loop tests may then be made in the usual way and the distance to the fault calculated by means of formula (6) or (10).

If the crossed wires are of the same gauge and conductivity a check test may be made by opening both wires at the distant station and measuring the loop resistance through the cross and then making Varley loop tests with one of the wires grounded at the distant end. The resistance determined by the Varley measurement will then be the resistance of the cross itself and this resistance subtracted from the loop resistance through the cross will be the loop resistance of the two wires to the fault.

(d) Location of Crosses with Metallic Battery

During bad weather the accuracy of the Varley or Murray loop tests made with grounded battery will be affected by the line leakage to ground. A more accurate location of a cross may be made under these conditions by employing metallic instead of grounded battery. This may be accomplished by employing the method described above except that wire 3 should be patched to the Varley loop jack as shown in Figs. 39 and 42 instead of being connected to ground. The insertion of a patching cord in the Varley loop jack and the line jack of wire 3 will disconnect the positive side of the battery from ground and connect it to wire 3. The Varley or Murray loop tests may be then made in the usual way.

(6) Open-Location Test

This test is essentially a capacity measurement, the Wheat stone bridge being used with low frequency alternating current as a means for comparing the capacity of the open wire to ground with that of an accurate 1-mocrofarad condenser at the test board. In making open-location tests the Murray loop connection is employed, the ratio arm A and the rheostat arm R forming two arms of the bridge and the open wire and the grounded condenser forming the other two arms. When the rheostat arm R is adjusted until no current flows through the galvanometer, the resistances in the armsA and R are inversely proportional to the capacities of the line and condenser or

$$\frac{A}{R} = \frac{C1}{C2} \quad \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \quad (17)$$

where $C_1$ equals the capacity of the grounded condenser in the testing circuit, $C_2$ is the distributed capacity between the open wire and ground and A and R the resistances in the bridge arms A and R.

In making open-location tests arm A should always be set at 1,000 ohms, then since $C_1$ is 1 microfarad, formula (16) may be simplified to the form.

$$C_2 = \frac{R}{1000} \quad \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \quad (18)$$

which is the distributed capacity between the open wire and ground when a balance is obtained.

Since the distributed capacity of a line to ground for a short line is nearly proportional to its length, this measurement affords a simple means for determining the distance to the point where the line is open. This relation holds sufficiently well for all practical purposes in locating opens in loaded or non-loaded open wire lines up to 200 miles in length or on loaded or non-loaded underground cable up to 40 miles in length. The measurements are less useful when the open is further away from the testing station since the resistance and inductance in the line cause the relation between the capacity and length to vary.

The open-location test also affords a convenient means for measureing the capacity of the condensers in circuits other than line circuits, the testing circuit being connected to the circuit or apparatus to be measured in the same way as to an open wire. When a balance is obtained formula (18) may be used for calculating capacity. This method may be employed in measuring capacity up to 11.1 microfarads.

The open-location test may also be used to advantage to determine which wire of a pair is crossed with another circuit when this fact cannot be determined conclusively by voltmeter or listening tests, since the capacity of the wire which is crossed will generally be considerably larger than the capacity of the good wire.

(a) Method of Making Measurements

After determining which wire of the pair is open, the single test plug connected to the (R) terminal of the bridge is plugged into the line jack of the open wire and the single plug connected to the (T) terminal of the bridge is plugged into the open-location test jack shown on Fig. 2. Plugging into the open-location test jack operates a relay in the Wheatstone bridge circuit which connects alternating current through the repeating coil to the junction of the bridge arms and starts the operation of the galvanometer-reversing relay. By making and breaking only once per cycle the galvanometer-reversing relay serves to reverse the connection to the voltmeter or galvanometer in such a way that the current will pass through it in one direction only. Ratio arm A should then be set at 1,000 ohms and keys Nos. 13 and 14 thrown forward or back to connect the bridge to the desired position and key No. 16 thrown back to give the Murray connection of the bridge. The circuit arrangements are then as shown in Fig. 43. The rheostat arm R is then adjusted until no deflection of the voltmeter is obtained when the galvanometer key is closed. The galvanometer shunt should then be placed at .1 and key No. 15 thrown forward to connect the galvanometer in place of the voltmeter for making the final balance. It is important that the galvanometer be used in place of the voltmeter in making the final adjustment since the results obtained with the galvanometer are somewhat different from those obtained with the voltmeter. When a balance is obtained with the shunt at .1 a more accurate balance may sometimes be obtained on short lines with the shunt open. The capacity of the open wire to ground may then be obtained from formula (17) and from this value the distance to the open can be determined.

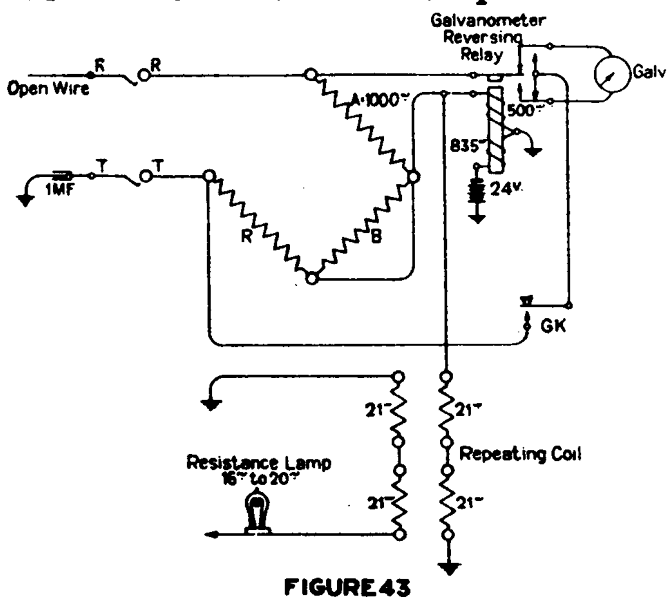


FIGURE 43
Open location test. Test cord key A,B,C or D thrown forward. Key 13 or 14 thrown forward or back. Tip test cord inserted in open location test jack. Key 16 thrown back Key 15 thrown forward to connect Galvanometer in place of Voltmeter. (For Voltmeter used as Galvanometer and key 15 normal see Fig. 22.)

(b) <u>Location of Opens</u>

In locating an open the best results can be obtained when open-location measurements have been made previously on the line in question to points on both sides of the fault. This can be accomplished by making and recording such measurements on all lines entering the office at times when no trouble exists. The measurements on each line should include all points where appreciable electrical irregularity occurs due to any cause, such as a change in gauge or the character of the line or the occurrence of intermediate apparatus and should extend throughout the limits of the testing station concerned. The number of ohms per mile to use in the open-location test can then be determined for the various sections of all lines entering the office and the distance between the fault and the points nearest it where previous readings have been obtained may be readily calculated. At the time when the open occurs a measurement should be made on the other wire of the pair, if not in trouble, or on some other wire of the same gauge and character and in the same lead, in orderto determine the number of ohms per mile to use in calculating the distance to the fault. For example, suppose no previous data available but the mate of the open wire is free from crosses or grounds and that the distance to the distant station is 40 miles, and in making an open-location test on the good wire with the pair open at the distant station a balance is obtained when R = 600 ohms. This value divided by 40 equals 15 ohms, the proper value in ohms per mile to use in calculating the distance to the fault, assuming that the wire is in the same gauge and character throughout its length. Then, if on making an open-location test on the bad wire a balance is obtained when R = 345 ohms, $\frac{345}{15} = 23$ miles, the distance between the testing station and the fault.

Where a line is made up of sections of different character, such as open wire and underground cable previous data permit accurate locations to be made, and also to increase the length of uniform line over which accurate locations can be made. For example, a line 55 miles long consists of 5 miles of underground cable and a previous reading of 450 ohms has been obtained to the end of the cable and a total reading of 1,200 ohms to the end of the line. The ohms per mile of the cable is then $\frac{450}{5}$ or 90 ohms and $\frac{1,200 - 450}{50}$ ohms per mile for the open wire. If when making an open-location test on this line a balance is obtained when R = 600 ohms, the fault is 600 - 450 or 150 ohms from the end of the cable. Since the previous reading has given 15 ohms per mile for the open wire, the distance from the end of the cable to the open is $\frac{150}{15}$ or 10 miles, so that the fault is located 15 miles from the testing station.

When neither previous data nor a good wire are available for comparison, an approximate location of the fault can be obtained by assuming a value in the open-location test of 15 ohms per mile for open-wire lines and 90 ohms per mile for underground cable.

(c) Conditions Affecting Accuracy of Results

It is desirable for the satisfactory operation of the open-location test that the specified electrical and mechanical adjustments of the galvanometer-reversing relay be maintained as nearly as practicable, since these adjustments affect the results obtained more than any other factor in the testing circuit. The voltage of the battery used to polarize the galvanometer-reversing relay, the speed and voltage of the generator and the load on the generator also affect the results but the combined effect of these factors will not ordinarily amount to more than 1 per cent. when the standard adjustment of the galvanometer-reversing relay is maintained. The repeating coil which supplies alternating current to the relay and the resistance lamps in the ringing leads are important factors in the accuracy of the operation and should be maintained at all times as indicated on the drawings. The accuracy of the condenser is of considerable importance since its capacity directly affects the results to the same extent as the bridge arm. The condenser being parallel with the galvanometer-reversing relay also affects its operation, and, for these reasons, it is desirable to use only the condenser specified.

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APPROVED:

A. W. DRAKE

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Enclosure:
Appendix #1