# TRUNK TESTING



## 1. INTRODUCTION.

1.1 The subject of trunk testing can be divided into two main categories. The first category is the testing of physical trunk lines and the second the testing of derived trunk circuits such as carrier telephone circuits.

The tests performed on a faulty physical trunk line should determine the nature of the fault and its precise physical location.

The tests performed on a faulty derived trunk circuit should determine the nature of the fault and give an indication of faulty equipment or bearer.

1.2 Trunk testing facilities have undergone many changes in recent years, particularly in the field of physical locations. Pulse echo type testing equipment, which is described in the paper "Pulse Echo Testing", is now often used in preference to bridge type location equipment. However the principles of bridge type locations are still important and are described in this paper.

1.3 Until recently all trunk circuits had an appearance on jack circuits on one or more Trunk Test Boards in the Line Transmission Equipment station. With the introduction of ARM exchanges it is possible that only physical trunk lines will have jack appearances on the trunk test boards and test access facilities for all speech circuits will appear in the ARM exchange.

Another function of trunk test boards is the rearranging of trunk lines and station equipment so that circuits are made available to take the place of those temporarily out of service whilst faulty. In addition, special rearrangement of circuits can be readily taken care of at this point.

Three types of trunk test board are in common use; they are Composite (Combined), Primary and Secondary. The Composite T.T.B. caters for testing and patching on both physical and derived circuits. Originallly all T.T.Bs. were of the composite type and these boards are in use at many older installations and are also installed at small modern installations.

Primary and Secondary T.T.Bs. are used in conjunction with each other. The Primary T.T.B. caters for physical trunk lines and the Secondary T.T.B. caters for derived trunk circuits.

Details of the test access facilities provided by Composite, Primary and Secondary T.T.Bs. are given in the paper "Layout, Cabling and Test Access for Line Transmission Equipment".

## 2. GENERAL PRINCIPLES.

2.1 Fault Reporting. At the time of writing, the fault reporting and recording procedure for Country Exchanges is being revised but a number of general principles can be stated.

A fault docket (EM5) is to be used to record the relevant information for trouble reports and detected faults for all communication services. When suitably tabulated and filed, these dockets will provide the Supervising Technician with a visual indication of the fault incidence of the trunk and junction circuits under his control. They will also be used to provide input data for computer analysis systems. In order to effectively satisfy these requirements it is essential that each fault docket is accurately completed.

The object of this proposed system is to ensure a high grade of service to the subscribers, by carefully analysing the trunk and junction fault incidence and concentrating the work force to upgrade any apparent weakness. The relevant E.Is. on the subject should be studied in conjunction with this paper.

2.2 Procedure. Each fault docket is attached to the appropriate trunk line master card which gives details of intra-office cabling and equipment and also the necessary information regarding the bearer. An examination of the trouble reports and detected faults in hand at any time can often give an indication of the location of a fault. The testing officer should analyse these reports in an effort to establish any common factors that could hasten the location of the faults and the restoration of service. The following two examples show the principle.

Example 1. If the trouble reports show that all channels of a carrier system are faulty, then a common equipment or bearer fault is indicated. Simple tests can quickly determine whether the fault is in the equipment or the bearer, and the necessary action can be taken to restore service.

Example 2. If a group of circuits, for example, those using channels 1, 4, 7 and 10 of a twelve channel system with a modulation plan assembling four sub-groups each of three channels, are reported faulty, then a fault in the sub-group equipment is indicated. Initial tests should be made to confirm this suspicion and to determine the station at which the fault exists.

Having analysed the trouble reports in hand and formed initial conclusions concerning the faults, the testing officer makes any preliminary patching arrangements which may be required because of the priority of the circuits affected. Details of patching procedure are given in the E.I. LONG LINE EQUIPMENT General P 0010. The succeeding tests should determine whether the fault is in the equipment at the local station, in equipment at some other station, or in the bearer. Details of the procedure adopted for equipment faults are not given in this paper.

2.3 Physical Trunk Line Faults. When testing physical trunk lines it is important to ensure that the fault is proved out of the local station. Physical trunk lines faults can be classified broadly as follows:-

:: Contact between the two wires of a pair - usually termed a "short circuit".

:: Contact between a wire or wires of one pair and another circuit - usually termed a "cross".

:: Contact between one wire of a pair and an earthed circuit or object - usually termed an "earth".

:: A high resistance contact or leakage to another conductor or earth - termed L.I.R. (Low insulation resistance) between the pair, to another circuit or earth as the case may be.

:: An open circuit of one or both wires of a pair without contact with other pairs or earth - termed an "open circuit".

:: Noisy circuit - due usually to one or more of the previous faults.

Before an attempt is made to determine the location of a fault, reference is made to the trunk line master card, on which is recorded the equipment in circuit, the gauge and type of wire, particulars of entrance and intermediate cables and other details relevant to the testing of the circuit.

If shunt or series equipment exists on the line, such as in intermediate offices, it is first necessary to clear the line by either opening off or patching out the unwanted equipment.

With regard to the line, it is generally sufficient to know the approximate resistance of the various sections, as the actual resistance values vary throughout the year due to temperature changes. For practical purposes, the following values for loop mile resistance of the various gauges for wire are generally used:-

| | | | |
|---|---|---|---|
| 600 lb. Copper | ... | ... | 3 ohms per loop mile. |
| 300 lb. Copper | ... | ... | 6 ohms per loop mile. |
| 200 lb. Copper | ... | ... | 9 ohms per loop mile. |
| 100 lb. Copper | ... | ... | 18 ohms per loop mile. |
| 100 lb. Bronze | ... | ... | 40 ohms per loop mile. |
| 70 lb. Bronze | ... | ... | 58 ohms per loop mile. |
| 70 lb. Cadmium Copper | | ... | 30 ohms per loop mile. |
| 400 lb. Galvanised Iron | | ... | 27 ohms per loop mile. |
| 200 lb. Galvanised Iron | | ... | 54 ohms per loop mile. |
| 100 lb. Galvanised Iron | | ... | 108 ohms per loop mile. |
| 40 lb. Trunk Type Cable | | ... | 44 ohms per loop mile. |
| 20 lb. Trunk Type Cable | | ... | 88 ohms per loop mile. |

It will be appreciated that preliminary location tests will be an approximation, and that the longer the section of line tested the greater will be the error. When dealing with faults on long circuits, a check test is made in conjunction with the fault lineman in the vicinity of the advised location, and this enables the degree of error to be reduced and usually provides an accurate location.

2.4 Precautions. When carrying out tests on trunk circuits, the testing officer must ensure that other trunk circuits in operation are not interrupted. Preliminary listening or speaking tests on a physical line must be made from a test access point which does not cause the loss of circuits derived by a carrier system operating on that physical. Trunk circuits must first be monitored and only tested after the testing officer has ensured that they are not in use.

Test voltages of 3V, 45V and 135V are provided in the Test Cord circuits of composite and primary T.T.Bs. These voltages can be applied to the voltmeter or bridge circuits by the operation of the appropriate battery keys. Because of the possibility of damage to physical circuits, or the possibility of "sealing up" a fault, a low testing voltage (3V) should be used for preliminary testing and in some cases should be used for the duration of the test. Common examples of the continued use of the 3V battery are as follows:-

:: When testing a noisy line where the noise is suspected to be due to a dry joint. Application of the 135V potential may seal up the dry joint making a location test impossible.

:: When making a loop resistance or a location test on a line with faulty insulation. The 135V potential may cause further damage to the insulation and produce varying test results.

:: When measuring an unknown resistance, such as a relay coil or transformer winding, where the resistance may be very low in value. In this case, excessive current from the 135V battery could damage the item under test.

When the possibility of high voltages sealing up a fault exists, steps should also be taken to ensure that ringing current is not applied to the line. The fault lineman should be instructed to call in on another circuit or, if this is not possible, the line can be monitored with the monitoring amplifier and speaker and contact can be made with the lineman using this method. The switchboard equipment is "opened off" to prevent ringing current being applied from the switchboard.

3. COMPOSITE TRUNK TEST BOARD.

3.1 General. The standard composite T.T.B. is made as a single position unit on a rack 9' or 10'6" high by 1'8¾" wide by 2'1" deep. A number of racks can be installed side by side to complete the T.T.B. suite. Fig. 1 shows the face layout of a typical composite T.T.B.

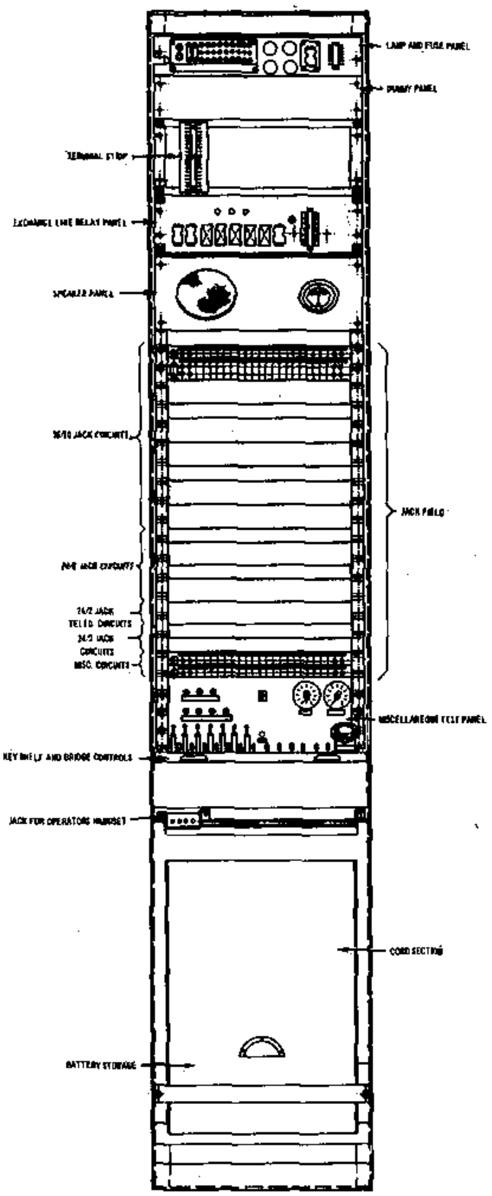



FIG. 1. FACE LAYOUT OF TYPICAL COMPOSITE T.T.B.

The horizontal desk section incorporates the Voltmeter, Wheatstone Bridge and keyshelf. The unit is hinged and may be raised to provide access to the wiring, the plug shelf and dial. A directory shelf and the operator's telephone jacks are mounted underneath the desk section.

The vertical section on the front of the T.T.B. comprises the following equipment, commencing at the top; the Lamp and Fuse Panel, the Terminal Strips, the Exchange Line Relay Panel the Speaker Panel, the Jack field, and the Miscellaneous Test Panel which is mounted immediately above the desk section.

The jack fields of earlier composite T.T.Bs. are wired to terminal strips at the top of the rack, but the jack fields of later boards are wired direct to the I.D.F. A morse sounder and key are provided on earlier composite T.T.Bs.

The vertical section of the board below the desk houses the cords and the dry batteries used to provide the testing voltages.

The equipment mounted on the rear of the board comprises the Monitoring Amplifier Panel, which is mounted directly behind the Speaker Panel, the Cord Rail, the Four-Wire Monitoring Panel, the Wheatstone Bridge Panel, and the Telephone, Dialling, Lineman Call and Connecting Cord Circuit Panels, all of which are located in the lower section at the rear of the board.

3.2 Facilities. The facilities provided by the T.T.B. are:-

:: Patching trunk circuits.

:: D.C. line testing.

:: Speaking and monitoring on the trunk circuits.

:: Ringing and dialling on the trunk circuits.

:: Connecting a trunk circuit to a local manual or automatic line.

3.3 Testing. The testing facilities provide for speaking and signalling tests on trunk telephone circuits, and D.C. voltmeter and bridge tests on physical lines. Testing can be performed on the following types of circuits:-

:: Physical lines.

:: Phantom and earthed phantom (cailho) circuits.

:: Circuits derived from carrier systems.

3.4 Cord Circuits. A schematic of the testing, speaking and signalling circuit of a typical composite trunk test board is shown in Fig. 15. The cord circuits and their associated keys can be classified into three types:-

:: Connecting Cord Circuit. Twin plugs designated "Trunk" and "Exchange" are connected to this cord circuit and may be used for connecting a trunk line circuit to a local manual or automatic line. Dialling and ringing facilities are provided on both the Trunk and Exchange plugs for the various types of circuits likely to be encountered.

:: Test Cord Circuit. The Test Cord Circuit is fitted with a twin plug for normal testing and two single plugs which are used for testing single wire lines and for certain bridge tests. The test facilities provided on this circuit are stated in the paragraphs describing voltmeter and bridge testing.

:: Four-Wire Monitoring Cord Circuit. Two twin plugs designated "Trans" and "Rec" are connected to the Four-Wire Monitoring and Talking Cord Circuit. Facilities are provided on this cord circuit for monitoring four-wire connected circuits singly in each direction, or in both directions simultaneously, and for speaking at suitable level points on a circuit in the direction not being monitored. Ringing facilities are available individually on each cord.

A Telegraph Test Cord Circuit is provided on earlier T.T.Bs. Two single plugs designated "Telegraph Test" are connected to the Telegraph Test Cord Circuit. The Telegraph Test Cord Circuit comprises a Morse Key, a Morse Relay and a Milliameter connected in series between the two single Test Cord Plugs. A Morse Sounder is wired to the contacts of the Morse Relay. The facilities of monitoring on telegraph circuits and measuring telegraph current values are provided by this circuit.

3.5 Functions of Keys in Testing Circuits. The functions of the keys associated with the various testing and speaking circuits are summarised in Tables 1-4. The keys are sub-divided into those associated with the connecting cord circuits, the two-wire and monitoring circuits (associated with the test cord circuit), the test cord circuit and the four-wire monitoring cord circuit.

CONNECTING CORD CIRCUIT

| KEY | FUNCTION |
|---|---|
| Speak | Allows the operator to speak on the connecting cord circuit. |
| Dial Exch. | Completes a loop dialling circuit to the exchange plug. |
| V.F. Tone Clear | Applies a 600c/s tone to the trunk plug. |
| V.F. Tone Call | Applies a 750c/s tone to the trunk plug. |
| Batt. Feed | Connects a transmission bridge to the trunk line plug for the lineman's transmitter. |
| Dial V.F. | Allows the operator to transmit a dial train of VF impulses to the trunk line plug. |
| Ring Exch.<br>Ring Trunk | Applies ringing tone via the master ringing key to the exchange and trunk plugs |

TABLE 1. KEY FUNCTIONS FOR CONNECTING CORD CIRCUIT.

2-WIRE AND MONITORING CIRCUITS

| KEY | FUNCTION |
|---|---|
| Disc. Sleeve | Disconnects sleeve circuit of test plug. |
| Cailho Dial | Used in conjunction with "Dial on Test" key establishes suitable connections for Cailho Dialling on the test plug, either from earth or battery in the test board. |
| Mon. on Test | Used for monitoring on a two wire circuit in conjunction with the test plug. |
| Dial on Test | Completes a loop dialling circuit to the test plug. |
| Speak on Test | Allows the operator to speak on the test plug without breaking down a test in progress. Also, if the transmitter switch is not pressed, the operator may listen for foreign noises while the line is being tested. |
| Ring on Test | Applies ringing in conjunction with the master key to the test plug. |
| Ring 1000c/s | Master ring key. Applies 1000c/s to the individual ringing keys. |
| 16c/s | Master ring key. Applies 17c/s to the individual ringing keys. |
| Ring 4 Wire | Used in conjunction with "Talk Chan." and "Mon. Trans". or "Mon. Rec.", to apply 1000c/s ringing to either of the four-wire monitoring cords. |

TABLE 2. KEY FUNCTIONS FOR 2 WIRE AND MONITORING CIRCUITS.

TEST CORD CIRCUIT

| KEY | FUNCTION |
|---|---|
| B.C.O. | Cuts off internal testing battery supply. |
| 3V | Applies 3V Battery for Bridge and Voltmeter Tests. |
| 150V | Applies 45V Battery for Voltmeter and 135V for Bridge Tests. |
| Earth | Applies an earth to the A wire of test cord. |
| V.M. Shunt | Connects a shunt across the Voltmeter, reducing the combined resistance to 1000 ohms and giving the meter an effective scale of 150-0-150 mA. |
| Line Reverse | Reverses the A and B wires of the test plug with respect to the testing circuit. |
| Short | Short circuits the A and B wires of the test plug and the test battery guard resistances, and is used in conjunction with the Voltmeter key for checking the test battery voltage. |
| Test A | Disconnects B wire and applies an earth to the testing circuit. |
| Test B | Disconnects A wire and applies an earth to the testing circuit. |
| Voltmeter | Applies the voltmeter with 150-0-150V range to the test plug. |
| Bridge | Applies the Wheatstone Bridge across the test plug. Requires 3V or 150V key to be operated to provide testing voltage. |
| Murray | Used in conjunction with the Bridge key establishes suitable connections for carrying out the Murray Loop test. |
| Varley | Used in conjunction with the Bridge key establishes suitable connections for carrying out the Varley loop test. |

TABLE 3. KEY FUNCTIONS FOR TEST CORD CIRCUIT.

4-WIRE MONITORING CORD CIRCUIT.

| KEY | FUNCTION |
|---|---|
| Talk Chan. | Used in conjunction with "Mon.Rec." and "Mon. Trans." to permit the operator to talk in either direction on a four-wire circuit. |
| Mon. 4-Wire | Allows the operator to monitor both channels simultaneously on a four-wire circuit. |
| Mon. Rec. | Allows the operator to monitor on the receive channel of a four-wire circuit. |
| Mon. Trans. | Allows the operator to monitor on the transmitting channel of a four-wire circuit. |

TABLE 4. KEY FUNCTIONS FOR 4 WIRE MONITORING CORD CIRCUIT.

3.6 Disconnection of Sleeve. Insertion of the Trunk Plug of the Connecting Cord circuit, or the Test Plug of the Test Cord circuit, into a trunk line jack will cause either battery or earth potential to be applied to the sleeve circuit or third wire of the trunk line circuit according to the busying conditions required at the particular installation. The "Disc. Sleeve" key, when operated, removes this potential, enabling the operator to ring or dial into the drop equipment from the T.T.B.

3.7 Lineman Call Feature. When a fault location test has been made on a line and the lineman has been notified, the faulty line may be patched to the Lineman Call (Ring) or Lineman Call (Batt) jacks which are located on the Miscellaneous Jack strip. The choice of jack depends on whether the lineman has a ringing generator or not. Tone is fed out to the faulty line to assist the lineman in identification. When the lineman rings on, or loops the line, he causes a lamp to light on the T.T.B., attracting the attention of the operator. As stated in para. 2.4, the lineman should be instructed not to ring on certain faulty lines.

It should be noted that certain conditions, for example, a loop fault or a line normally looped by a transformer, preclude the use of the Lineman Call feature.

3.8 Monitoring Amplifier. The Monitoring Amplifier can be associated with the loudspeaker or the operator's telephone receiver. The amplifier is designed to introduce a bridging loss of less than 0.5dB to any circuit across which it is connected and has an output impedance of 600 ohms to match the loudspeaker impedance and to suit connection to the operator's telephone receiver. The amplifier has a gain of about 37dB controlled by a potentiometer on the face of the T.T.B.

3.9 Patching. Patching of trunk line circuits connected to the board is carried out with loose patching cords. These cords are generally two conductor cords fitted with twin plugs, but three conductor cords are required if it is necessary to patch any sleeve connections associated with the circuits.

3.10 Battery, Ring and Tone Supply. Dry batteries, 3V and 135V (the 135V battery is tapped to obtain 45V), are used to derive the testing voltages for the Voltmeter and Wheatstone Bridge testing circuits.

A 17c/s supply is provided for ringing purposes and for use with the open location test using the Wheatstone Bridge.

Facilities are provided for the connection of 600c/s, 750c/s and 1000/17c/s tones to permit normal supervisory and signalling facilities over physical and carrier derived circuits employing voice frequency signalling.

3.11 Jack Field. Details of the jack field of a typical composite T.T.B. are given in the miscellaneous note, MLR 034. The jack field provides the following main circuits:-

:: 36-10 jack circuits.

:: 24-6 jack circuits.

:: 24-2 jack telegraph circuits.

:: 24-2 jack miscellaneous circuits.

A jack field with this capacity is generally only suitable for small installations, although composite T.T.Bs. are in use at some older large installations.

## 4. PRIMARY TRUNK TEST BOARD.

4.1 General. The standard primary T.T.B. is made as a single unit position on a rack 9' or 10'6" high by 1'8¾" wide by 2'1" deep. A number of racks can be installed side by side, together with secondary T.T.Bs., to make up a suite. The face layout of the primary T.T.B. is similar to that of the Composite T.T.B. The main features are shown in Fig. 2.

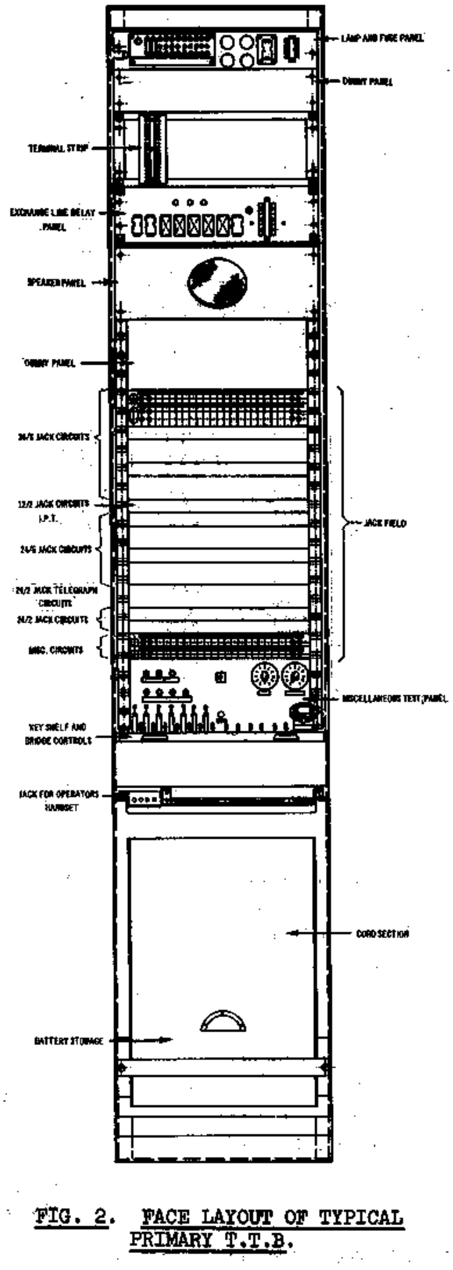



FIG. 2. FACE LAYOUT OF TYPICAL PRIMARY T.T.B.

4.2 Facilities. The facilities provided by the primary T.T.B. are:-

:: Patching trunk lines.

:: D.C. line testing.

:: Speaking and monitoring on the trunks.

4.3 Testing. The D.C. voltmeter and bridge testing facilities provided by this board are identical to those provided by the Composite T.T.B. and are described in Section 5.

Testing can be performed on the following types of circuits:-

:: Physical lines.

:: Earthed phantom (cailho) lines.

4.4 Cord Circuits and Miscellaneous Features. In general the cord circuit functions provided by a typical primary T.T.B. are identical to those described for the composite T.T.B. and are summarised in para. 3.4. Similar miscellaneous features to those of the Composite T.T.B. are provided and these are described in paras. 3.5 to 3.9.

The primary T.T.B. is designed primarily for physical trunk line and telegraph testing and, although signalling and speaking facilities are provided, it is not normal to make speaking and signalling tests from this board. These tests are made from the secondary T.T.Bs. which are installed in conjunction with the primary T.T.Bs.

## 5. VOLTMETER AND BRIDGE TESTING.

5.1 Voltmeter Testing. The voltmeter mounted in the desk section is a dual range, centre zero, horizontal mounting type with scales 150V - 0 - 150V and 3V - 0 - 3V. The movement is of the moving-coil type with a resistance of 1000 ohms per volt.

When associated with the Voltmeter circuit, by the operation of the Voltmeter Key and other keys as required, the Test Cord circuit provides the facilities to carry out the following tests:-

:: Tests for short circuit.

:: Measurement of conductor resistance.

:: Measurement of insulation resistance.

:: Tests for earth.

:: Tests for foreign potential.

:: Tests for open circuit.

:: Comparative capacity measurement.

The main elements of the voltmeter test circuit are shown in Fig. 3. The testing voltages available are 3 volts and 45 volts and are applied by operation of the 3V and 150V keys respectively. For both conditions the 3V terminals of the meter are used. The 150V terminals of the meter is used to test for foreign potential.

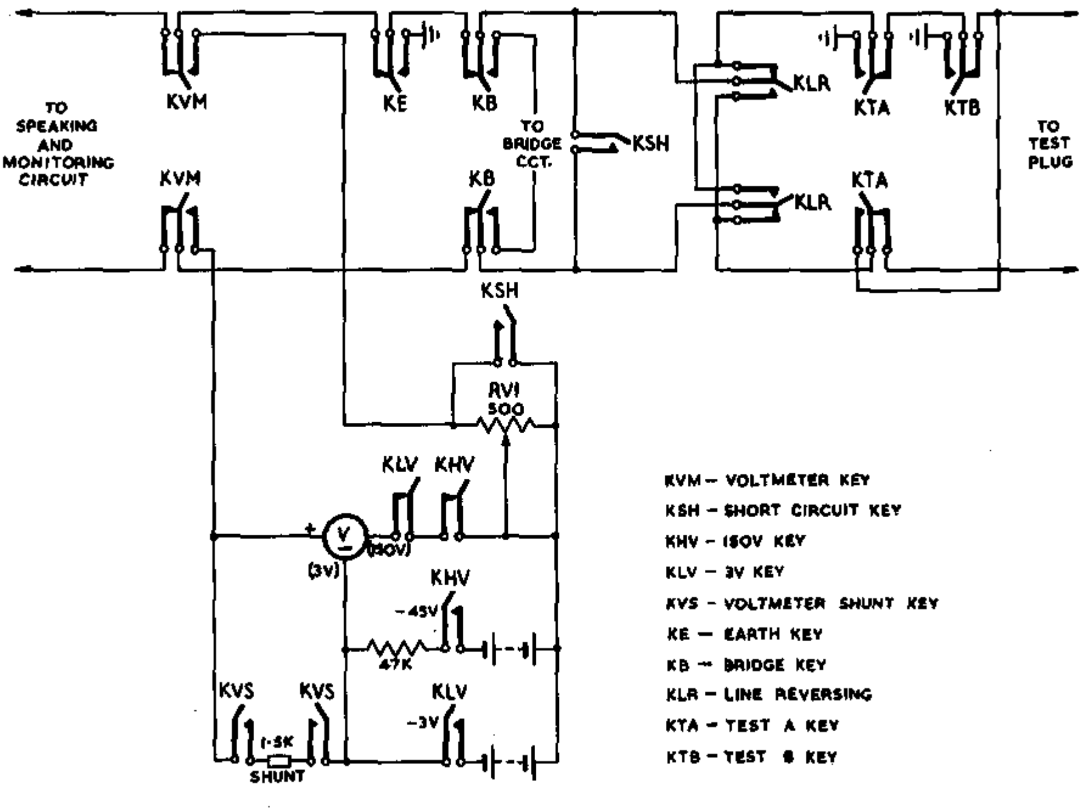
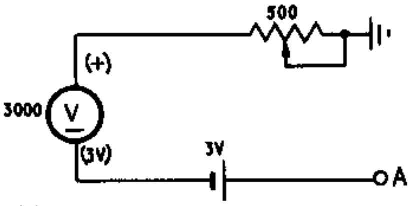
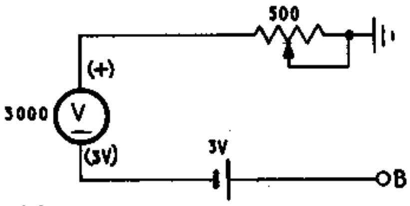



FIG. 3. MAIN ELEMENTS OF VOLTMETER TEST CIRCUIT.

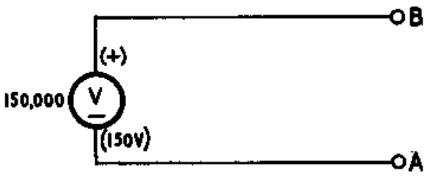
Simplified circuits of various voltmeter testing conditions are shown in Fig. 4. The keys operated to give the conditions have been included and reference should be made to Fig. 3 for circuit details.



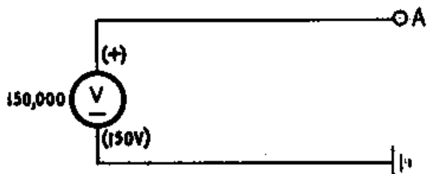

TEST 'A' KEY, VOLTMETER KEY AND 3V KEY OPERATED.
TESTS FOR EARTH ON 'A' LINE.



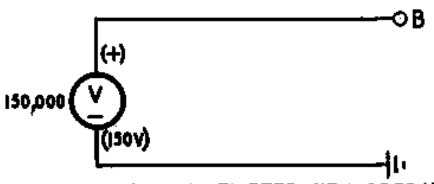

TEST 'B' KEY, VOLTMETER KEY AND 3V KEY OPERATED.
TESTS FOR EARTH ON 'B' LINE.



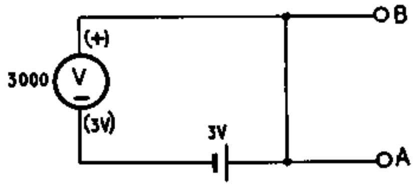

VOLTMETER KEY OPERATED.
TESTS FOR FOREIGN POTENTIAL.



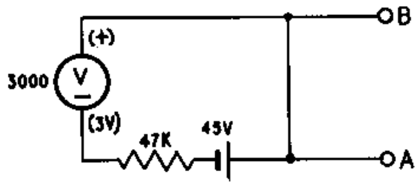

TEST 'A' KEY AND VOLTMETER KEY OPERATED.
TESTS FOR FOREIGN POTENTIAL ON 'A' LINE



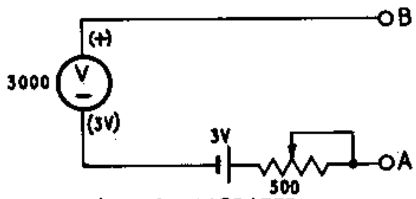

TEST B KEY AND VOLTMETER KEY OPERATED.
TESTS FOR FOREIGN POTENTIAL ON 'B' LINE.



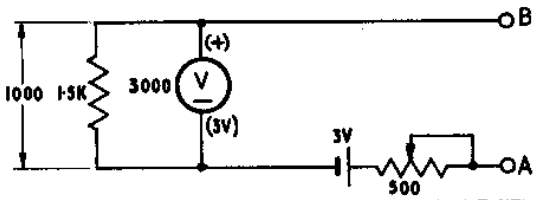

VOLTMETER KEY, SHORT KEY AND 3V KEY OPERATED.
CHECKS 3V BATTERY POTENTIAL.



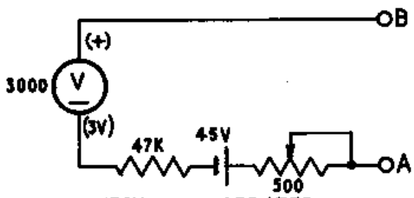

VOLTMETER KEY, SHORT KEY AND 150V KEY OPERATED.
CHECKS 45V BATTERY POTENTIAL.




VOLTMETER KEY AND 3V KEY OPERATED.
MEASURES CONDUCTOR RESISTANCE.




VOLTMETER KEY, 3V KEY AND VOLTMETER SHUNT KEY OPERATED.
MEASURES CONDUCTOR RESISTANCE.




VOLTMETER KEY AND 150V KEY OPERATED
MEASURES CONDUCTOR RESISTANCE.

FIG. 4. MAIN ELEMENTS OF VOLTMETER TEST CIRCUIT.

5.2 Use of Voltmeter to Measure Resistance. The bridge circuit is normally used for accurate conductor resistance measurement, but the voltmeter circuit can also be used and greatest accuracy is obtained when the Voltmeter resistance approximates the resistances to be measured. The Voltmeter resistance is 1,000 ohms per volt, but the operation of the Voltmeter Shunt Key places a shunt across the Voltmeter.

With the Voltmeter key operated, the following voltmeter resistances are obtained:-

:: 3000 ohms with 3 Volt key operated (i.e. 3 volt battery, in series with the 3 volt section of the meter, is applied to the test cord).

:: 1000 ohms with 3 volt key and V.M. shunt key operated.

:: 50,000 ohms with 150 volt key operated (i.e. 45 volt section of the battery, in series with 47,000 ohms and the 3V section of the meter, is applied to the test cord).

Values of resistance may be determined using the following formula:-

$$Rx = Rm \left(\frac{D}{D1} - 1\right) - RV1$$

where Rx = resistance under test.

Rm = Voltmeter circuit resistance.

D = Deflection with short circuit key operated. (RV1 is normally adjusted to give f ll scale deflection).

D1 = Deflection with short circuit key normal; that is with the unknown resistance Rx and potentiometer resistance RV1 in circuit.

RV1 = Voltmeter guard resistance; that is the portion of the 500 ohm potentiometer in circuit.

For small values of Rx it is necessary to estimate this value but for large values of Rx it becomes negligible.

5.3 Measurement of Test Voltages. The voltages of the 3V and 45V testing batteries are measured by operating the Voltmeter, Short and 3 Volt or 150 Volt keys, and should be checked periodically to ensure accuracy in evaluating resistance measurements.

5.4 Measurement of Comparative Capacity. The comparative capacity measurement test can be used to determine the approximate location of a break in one wire of a pair. The Voltmeter Key, 150V or 3V Key, and Test "A" key should be operated and then the Line Reverse Key. This latter key will cause the "A" line capacity to earth to discharge, and then, with the voltage reversed, recharge through the voltmeter causing a certain deflection. The same test should now be applied, substituting the Test "B" key for the Test "A" key. The difference in the amount of capacity between each wire and ground is indicated by the difference in the maximum voltmeter deflection observed with the key operated to the Test A and Test B position in turn. If the length of the sound wire is known, the position of the break may be calculated by comparison. This test may also be applied using the single test plugs on a sound wire and a broken wire not necessarily of the same pair.

5.5 Wheatstone Bridge Testing. Before describing Wheatstone and Varley bridge testing methods the wheatstone bridge principle should be revised. Referring to Fig. 5, if $\frac{R1}{R2} = \frac{X}{RV1}$ there will be no potential difference between points P and Q and so no deflection of the meter.

R1 and R2 are called the ratio arms of the Bridge and if R1 = R2 (unity ratio arms) then X = RV. For unequal ratio arms, $X = \frac{R1RV}{R2}$.

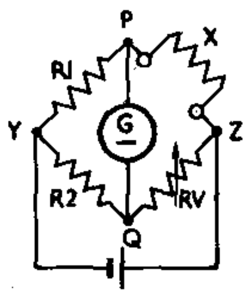



FIG. 5. WHEATSTONE BRIDGE.

Main Features of the Bridge Circuit. The Wheatstone Bridge, mounted horizontally in the desk section, is a direct current instrument, and is connected to the Test Cord circuit by operation of the appropriate switching keys to make the following measurements:-

:: Loop resistance.
:: Single wire resistance.
:: Insulation resistance.
:: Varley Loop
:: Murray Loop.
:: Open Location.

The main features of a typical bridge circuit are shown in Fig. 6. Details of the Open Location relay contacts (OL) and the Murray key contacts are not shown. The bridge consists of two ratio dials R1 and R2, to each of which are connected resistance spools of 10,100,1000 and 10,000 ohms values; a four-dial variable resistance RV which covers the range 0-9999 ohms in steps of 1 ohm; and a galvanometer. The unknown resistance to be measured forms the fourth arm of the bridge. By adjustment of R1, R2 and RV until no deflection is obtained on the galvanometer, an unknown resistance may be calculated by multiplying the value of RV by the ratio $\frac{R1}{R2}$.

Four shunt keys, designated 1, 0.1, 0.01 and 0.001, are provided on the bridge panel to reduce the sensitivity of the galvanometer. These keys complete the battery and galvanometer circuits in the bridge, at the same time introducing a shunt across the galvanometer to safeguard the movement winding. The sensitivity is lowest when the 0.001 key is depressed and is increased as successive keys to the right are operated in turn. When the key designated 1 is depressed the shunt across the galvanometer is at its maximum value and the galvanometer is giving its most sensitive reading. The galvanometer is an integral part of the bridge and is a moving coil reflecting type. The scale is marked "Bridge High" and "Bridge Low" to assist the operator in obtaining a balance in the bridge circuit.

Two terminals, A1 and B1, are provided on the bridge panel for testing circuits and items of equipment which cannot be conveniently connected to the Test Cord.

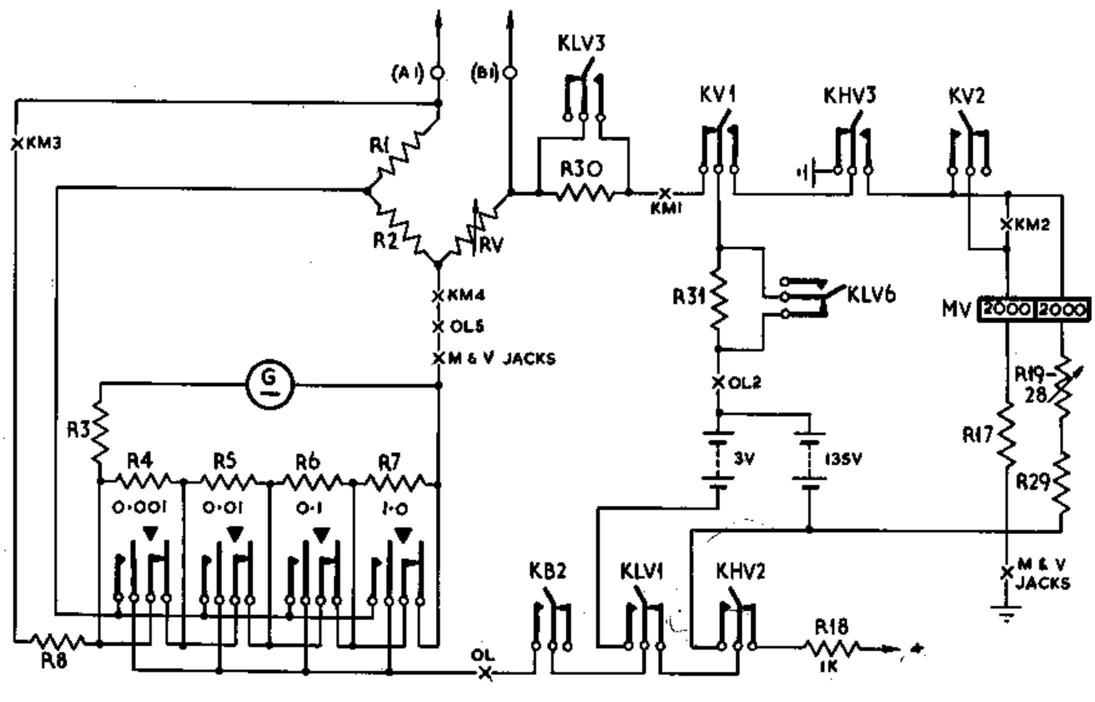



FIG. 6. TYPICAL BRIDGE CIRCUIT.

5.7 Murray and Varley Feature. The Murray and Varley testing circuits incorporate a double wound relay (MV). One coil of this relay is in series with the test current to line, whilst the other coil is used in conjunction with the MV Ins. Res. Bias Potentiometer (R19 - R28), to provide an electrical bias on the relay under certain test conditions. This relay is only in circuit when 135 volts is applied to the bridge. The functions of the MV Relay are:-

:: On operation, to cause the MV Test Lamp to light thereby providing a visual indication that the line under test is earthed.

:: When distributed leakage to earth is present on the line under test, the bias winding current is varied within limits to counter the effect of the leakage current to line so that the relay operates only on the actual earth fault current The bias current is adjustable to counter leakage currents for lines having an insulation resistance to earth of approximately 10,000 ohms or greater.

:: When earth at the MV jack springs is replaced by an earth patched to the M and V jack, the Galvanometer is disconnected from the Bridge circuit until the MV Relay operates. Testing for the location of an intermittent earth fault often causes severe "jolts" to the Galvanometer, due to high unbalanced currents in the Bridge circuit when the earth fault lifts. Lifting of the earth fault in this case however causes the MV relay to release, opening the circuit to the Galvanometer. A visual indication is also given by the extinguishing of the MV Test Lamp.

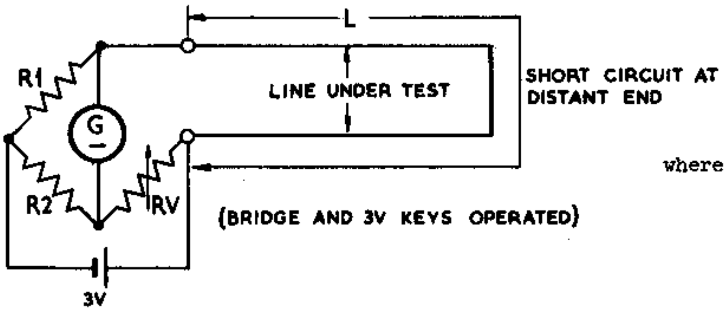
5.8 Loop Resistance. In order to make loop resistance measurements of a line, the pair of wires to be tested is looped at the distant end. The Bridge is then connected to the line via the twin test plug and the operation of the Bridge and the 3 Volt Keys. A simplified circuit is shown in Fig. 7. If the approximate resistance is unknown, a balance is first obtained with the ratio arms R1 and R2 equal.

The shunt key designated 0.001 is depressed and the resistance arm RV adjusted until a balance is obtained. The other shunt keys 0.01, 0.1 and 1, are then depressed in turn and the balance adjusted if necessary.

When the approximate resistance is known, a more accurate measurement can be obtained by varying the ratio arms. To obtain the most accurate results, the following settings should be used:-

| | Settings of | |
|---|---|---|
| Resistance under test. | R1 | R2 |
| 99,999 - 999,999 ohms | 1000 | 10 |
| 9,999 - 99,999 ohms | 1000 | 100 |
| 999 - 9,999 ohms | 1000 | 1000 |
| 99 - 999 ohms | 100 | 1000 |
| 0 - 99 ohms | 10 | 1000 |

When the final balance has been obtained, the resistance of the loop can be calculate from the formula:-




$$L = RV \times \frac{R1}{R2}$$

where L = unknown loop resistance.
RV = resistance in rheostat arm
R1 = ratio dial setting.
R2 = ratio dial setting.

FIG. 7. MEASUREMENT OF LOOP RESISTANCE.

5.9 Singe-Wire Resistance. A single wire resistance measurement can be made in a similar manner. In this case, the distant end of the line is earthed, and the single test plugs are used - "Test A" plug being inserted in the Earth jack on the Miscellaneous Jack strip. The formula $X = RV \times \frac{R1}{R2}$ is applied.

This measured result may not be accurate because it will include the resistances of the earth connections at the distant end and at the Wheatstone Bridge testing circuit.

Three Wire Method. An alternative method of determining single wire resistance, which does not involve consideration of the earth connection resistance, is the three wire method. Three wires are required and one of the three wires is the wire to be measured. The test arrangement for this method is shown in Fig. 8.

Assume these wires are called a, b and c. First wires a and b are looped at the far end and a loop resistance measurement taken. Wires b and c, and then a and c are similarly measured.

$$\text{The sum of the three readings} = (a + b) + (a + c) + (b + c) = 2a + 2b + 2c.$$

As each wire has been measured twice, half the sum of the three readings will be equal to the sum of the resistances of the three wires.

Then if X is this known quantity, $X = a + b + c$

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

$b = X - (a + c)$

$c = X - (a + b)$

So the resistance of any of the wires can be found by subtracting the combined resistance of the other two wires from half the sum of the three readings.

Example. $a + b = 500\Omega$ $b + c = 700\Omega$ $a + c = 600\Omega$

Then $a = \frac{1800}{2} - 700 = 200\Omega$

$b = \frac{1800}{2} - 600 = 300\Omega$

$c = \frac{1800}{2} - 500 = 400\Omega$

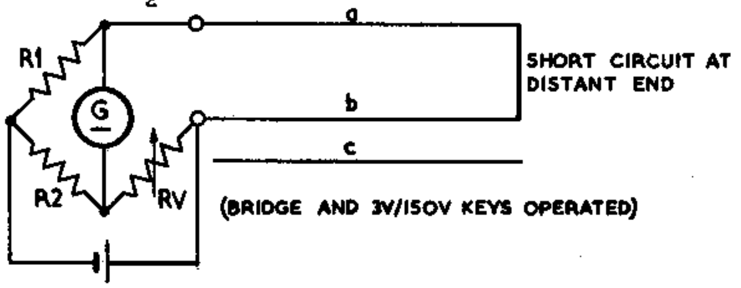



FIG. 8. MEASUREMENT OF SINGLE WIRE RESISTANCE.

5.10 Insulation Resistance. The Wheatstone Bridge may be used for measuring insulation resistance up to five megohms, but beyond this value the error is likely to be quite large due to leakages in the Bridge, the Trunk Test Board and office wiring. The 3 Volt testing battery should be used for the reason stated earlier.

Measurement of insulation resistance of a pair of wires is carried out similarly to the measurement of loop resistance, with the exception that the distant end is open circuited and not looped as before.

5.11 Varley Loop Tests. (Location of Earth Conditions). In order to determine the location of an earth condition by the Varley Loop method, the loop resistance of the pair under test must be ascertained, as set out in para. 5.8, using the 3V testing battery.

Two alternative conditions are now possible:-

:: Steady Earth Condition. When a steady earth condition exists on a line and the insulation resistance is high, the Battery key is operated to the 150V position and the Murray Varley key is operated to the Varley position. These operations disconnect the positive pole of the battery from the Bridge and connect it to earth at the M and V Jack via one winding of the MV relay and the resistance R17 in series. The battery and relay circuit can now be completed only to the earth on the line. The MV relay will operate and its contacts will complete the circuit to the M and V Test Lamp on the Miscellaneous Panel. This lamp will light confirming the presence of the earth condition on the line to which a location test can be made. Circuit details are shown in Fig. 2.

:: Intermittent Earth Condition. If the earth condition is intermittent in nature, damage may result to the galvanometer due to heavy out of balance currents which flow in the bridge circuit if the earth condition disappears when the bridge is nearly balanced and is being operated in its most sensitive condition.

To minimize this effect, the MV relay is patched by a single patch cord from the M and V jack to an Earth jack. The contacts of the M and V jack now being operated, the galvanometer circuit can only be completed through contacts of the MV relay which will operate intermittently to the intermittent earth condition on the line.

If the line under test has low insulation resistance, the leakage current flowing through the MV relay after the disappearance of the earth condition may cause the relay to hold up or be slow to release. As quick release of the relay is required to safeguard the galvanometer from damage, the MV relay Bias Potentiometer is provided to counteract the effect of this leakage current. This potentiometer is in series with the second winding of the MV relay and the testing battery and can be adjusted to provide a bias current through this winding sufficient to balance out leakage currents on lines having an insulation resistance of over 10,000 ohms. It is important to note that this adjustment must be made when the earth condition is not present, and that the bias current should be increased until the MV relay releases quickly after the disappearance of the earth condition.

When the earth condition appears on the line, the MV relay operates due to the increased current in the line winding and closes the circuit to the galvanometer and the M and V Test Lamp. This lamp lights indicating the presence of the earth condition, to which a location test can be made.

5.12 Varley Bridge Conditions. Fig. 9 shows the main elements of the varley bridge arrangement. The line is connected as shown with the faulty side wired to the RV arm of the bridge. With the "Bridge" key operated the bridge is prepared for wheatstone testing and with the "Bridge" and "Varley" keys operated the bridge is prepared for Varley testing.

When the bridge is balanced for wheatstone conditions the resistance of the variable arm (RV) is equal to the loop resistance if the resistance of the ratio arms is equal. When unequal ratio arms are used, the formula $RV \times \frac{R1}{R2}$ is applied to calculate the loop resistance.

When the loop resistance L is determined, the key is operated to the Varley position and RV varied until a new balance is obtained.

The condition then is $R2 (L - X) = R1(RV + X)$

Where X is the single wire resistance to the fault.

But the ratio arms R1 and R2 are equal so $L - X = RV + X$

$$\text{and } X = \frac{L - RV}{2}$$

The resistance of the fault forms part of the battery circuit and therefore does not affect the location test provided that the resistance is low compared with the normal I.R. of the line.

Having obtained the resistance of the faulty wire from the testing office to the fault, the distance to the fault can be calculated from the line data recorded on the trunk line master card.

The formula $X = \frac{L - RV}{2}$ is the basic Varley formula for equal ratio arms, and can be applied to a circuit even though the two wires of a pair are of unequal resistance

In order to obtain the distance to the fault it is necessary to divide the single wire resistance to the fault by the single wire resistance per mile of the wire gauge concerned.

Where it can be safely assumed that the two wires of a pair are of equal resistance, it is possible to simplify the formula to:-

$$2X = L - RV \quad \text{(When } 2X = \text{ loop resistance to the fault)}$$

In order to obtain the distance to the fault in this case, it is necessary to divide the loop resistance to the fault by the loop resistance per mile of the wire gauge concerned.

Distance of Fault from Far End. It is often desirable to determine the distance of a fault from the far end of a looped line, particularly when the fault is nearer that end. If, as is usually the case, both wires of the pair under test are of similar gauge, it is possible to determine this distance from the results of the Varley Loop test already made:-

$$\text{as } 2X = L - RV$$
$$\therefore RV = L - 2X$$

Referring to Fig. 9, it will be seen that, if 2X is deducted from the loop resistance L, then RV equals the resistance of all the wire remaining in circuit between the fault and the far end. In other words, 2X represents the loop resistance of the faulty pair between the testing station and the fault, and RV equals the loop resistance between the fault and the far end.

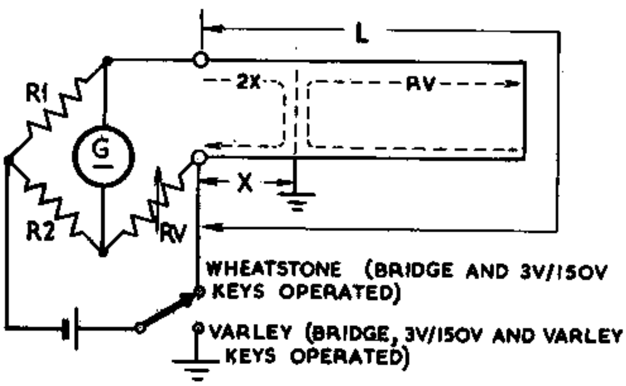



FIG. 9. VARLEY TESTS FOR EARTH FAULTS.

5.13 Location of a Short Circuit or Loop Condition. If the two wires of a pair are looped due to a fault, any loop resistance measurement taken will include the resistance of the fault.

To obtain the true loop resistance of the pair to the fault the pair is open circuited at the distant end and one wire is connected to earth as shown in Fig. 10. This applies an earth to the short circuit fault and a Varley loop test is then carried out. With equal ratio arms in the bridge, the RV will be equal to the resistance of the loop fault and the corrected loop resistance to the fault can be found by subtraction. If the fault is a short circuit then the varley reading will equal 0 ohms.

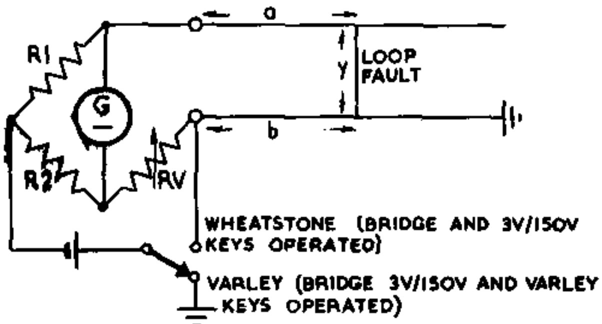



FIG. 10. LOCATION OF LOOP FAULT.

With the varley bridge balanced the following conditions exist:-

R1 (RV + b) = R2 (a + y)
As R1 = R2 and a = b
Then RV = y
where R1 = Ratio dial setting
R2 = Ratio dial setting
RV = Variable bridge arm
a = Single wire resistance to the fault.
b = Single wire resistance to the fault.
y = Fault loop resistance.

5.14 Check Testing with Linemen. Assuming that a line has been examined in the vicinity of a fault without locating the fault, the testing officer can request a loop (short circuit) from the lineman and if the lineman is on the testing side of the fault a varley reading of 0 ohms will result. If the lineman is beyond the fault then the varley reading will represent the loop resistance from the linemans short circuit to the fault.

5.15 Murray Loop Tests (Location of Earth Condition). The Murray Loop test can be used to determine the location of an earth condition on a line of relatively low resistance and is particularly suitable for location on short cable sections. Fig. 11 shows the main elements of the Murray Bridge circuit.

The Murray Varley key is operated to the Murray position, transferring the galvanometer from its normal position to a bridging position across the line and short circuiting the second ratio arm R2. Ratio arm R1 is set to the highest reading possible consistent with a balance being obtained on the Bridge. The faulty wire is connected to the B terminal, and RV adjusted until a balance is obtained then RVX = R1 (L - X) or RVX + R1X = R1L, therefore $X = \frac{R1L}{RV + R1}$. The value of X is in the single wire resistance of the faulty wire from the testing station to the fault.

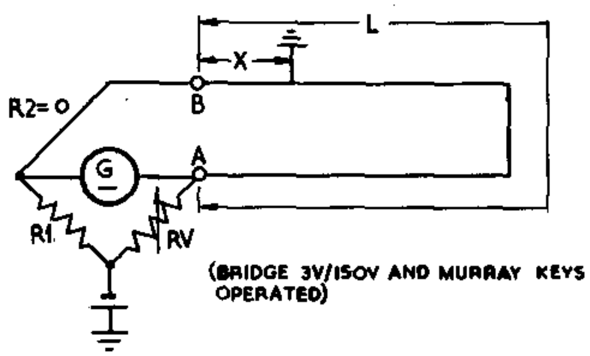



FIG. 11. MURRAY TEST, LOCATING AN EARTH FAULT.

5.16 Location of "Crosses" by Varley or Murray Loop Tests. To locate a "cross" fault it is first necessary to determine the lines in contact. One pair should then be looped at a station beyond the fault, and the faulty wire of the other pair earthed either at the distant station or at the testing station as shown in Fig. 12. The conditions are then equivalent to an earth fault and the same tests can be made to determine the distance to the fault.

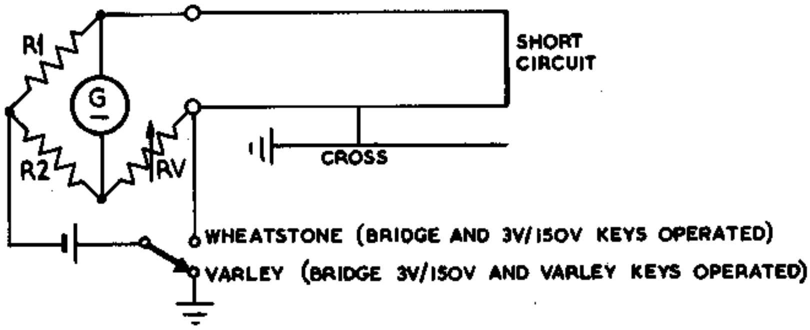



FIG. 12. LOCATION OF A "CROSS" - VARLEY BRIDGE.

5.17 Open Location Tests. The open location test feature of a T.T.B. is rarely used but a brief outline of the circuit is included. A capacity balance method is used and Fig. 13 shows the main circuit features. The single test plugs are used, Test A plug being inserted in the line under test and the Test B plug in the "Open Location" jack. The "Bridge" key only is operated.

The insertion of the test plug in the Open Location jack connects the "B" side of the Test Circuit through a 1µF capacitor to earth and also operates relay OL. Contacts of relay OL short circuit the ratio arm R2, replace the direct current supply to the bridge with a 17c/s supply, introduce a metal rectifier in series with the galvanometer and arrange the circuit as shown in Fig. 13.

The 1µF capacitor becomes one arm of the bridge and the capacity of the broken line to earth becomes the unknown arm of the bridge. A balance is obtained in the usual way and the following formula gives the capacity of the wire to ground:-

$$C = \frac{RV}{R1}$$

where C = capacity of wire in microfarads.

R1 = ratio arm setting.

RV = rheostat arm setting.

The approximate capacity of a sound conductor can be determined in a similar manner and assuming the line is of uniform construction the position of the break may be calculated from the ratio of the two results. On lines of composite construction it is necessary to record typical capacity to earth values at junction points in the line because direct ratios would give misleading results.

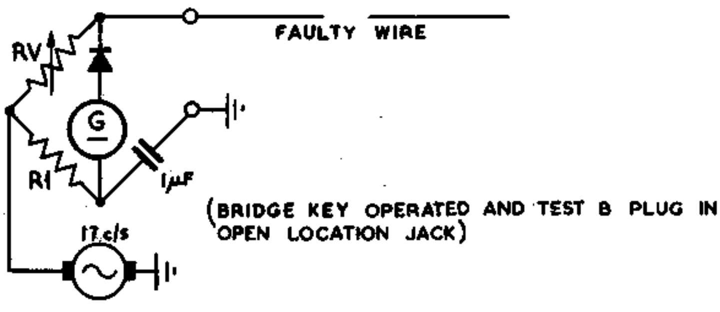


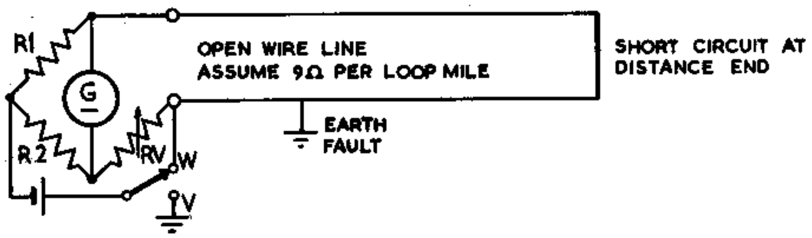

FIG. 13. PRINCIPLE OF OPEN CIRCUIT LOCATION.

5.16 Example Problems. A number of simple problems are included to give an indication of a suitable approach to bridge locations. In most problems composite cable and open wire lines are used and it is advisable to produce simple sketches showing the line conditions. When making practical locations from a T.T.B. reference should be made to Trunk line Master Cards and Trunk Line Maps to obtain the essential information concerning the line or lines involved in the tests.

Unless the loop or single wire resistance of the lines is specified, or can be calculated, the values shown in Para. 2.3 can be used.

Example 1. An earth occurs on one side of a 200 lb. copper open wire trunk line. A wheatstone reading of 153 ohms and a varley reading of 99 ohms are obtained. Calculate the distance from the testing station to the fault.

*Solution.*




:: *Calculate loop resistance from the testing station to the fault.*

$2X = L - RV$

$2X = 153 - 99 = 54$ *ohms.*

:: *Calculate the distance from the testing station to the fault.*

$$\textit{Distance in miles} = \frac{\textit{Loop resistance to fault (2X)}}{\textit{Resistance per loop mile of line}}$$

$$= \frac{54}{9} = 6 \textit{ miles.}$$

*Answer.* *Earth fault is 6 miles from the testing station.*

Example 2. A physical trunk line consists of:-

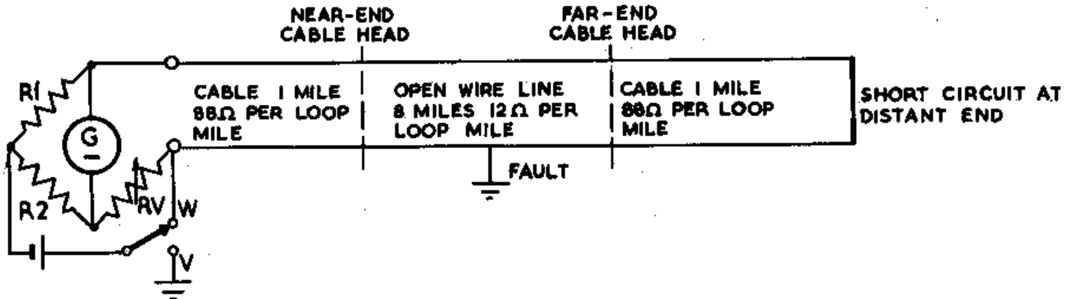
:: One mile of 20 lb. trunk entrance cable from the testing station to the near-end cable head.

:: Eight mile of 150 lb. copper open wire line (12 ohms per loop mile).

:: One mile of 20 lb. trunk entrance cable from the far-end cable head to the distant station.

When tested the line is found to be earthed on one side. A loop reading of 272 ohms and a varley reading of 148 ohms are obtained. Calculate the distance to the earth fault.

*Solution.*



:: *Calculate loop resistance from the testing station to the earth fault.*

*2X = L-RV*

*2X = 272 - 148 = 124 ohms.*

:: *Calculate loop resistance of open wire line to the earth fault. (Subtract loop resistance of the near-end trunk entrance cable from total loop resistance to the fault).*

*Loop resistance of open wire line to fault = 124 - 88 = 36 ohms.*

:: *Calculate the distance from the near-end cable head to the earth fault.*

$$\text{Distance} = \frac{\text{Loop resistance of open wire line}}{\text{Resistance per loop mile of open wire line}}$$

$$= \frac{36}{12} = 3 \text{ miles}$$

:: *Calculate total distance to the earth fault.*

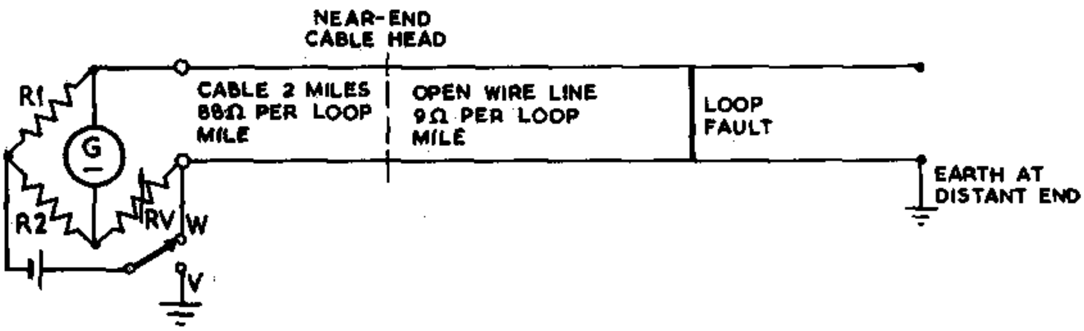
*Total distance = 3 miles of open wire line and 1 mile of trunk entrance cable.*

*= 4 miles.*

*Answer.* *Earth fault is 4 miles from the testing station.*

Example 3. A 200 lb. open wire line with two miles of 20 lb. trunk entrance cable at the near-end has become permanently looped. With an open circuit at the distant end a wheatstone reading of 356 ohms is obtained. A varley reading of 4.5 ohms is obtained with an earth on one side at the distant end.

*Solution.*




:: *Calculate the true loop resistance to the loop fault. Loop resistance to fault = Total loop resistance - resistance of fault.*

*= 356 - 4.5 = 351.5 ohms.*

:: *Calculate loop resistance of open wire line to the earth fault. (Subtract loop resistance of the near-end trunk entrance cable from the true loop resistance).*

*Loop R of open wire line to fault = 351.5 - 176 = 175.5 ohms.*

:: *Calculate the distance from the near-end cable head to the earth fault.*

$$\text{Distance} = \frac{\text{Loop Resistance of open wire line}}{\text{Resistance per loop mile of open wire}}$$

$$= \frac{175.5}{9} = 19.5 \text{ miles.}$$

:: *Calculate total distance to the fault.*

*Total distance = 19.5 miles of open wire and 2 miles of trunk entrance cable*

*= 21.5 miles*

*Answer.* *Loop fault is 21.5 miles from the testing station.*

## 6. SECONDARY TRUNK TEST BOARD.

6.1 General. The standard secondary T.T.B. is made up as a single position unit on a rack 9' or 10'6" high by 1'8¾" wide by 2'1" deep. A number of racks can be installed side by side, together with primary T.T.Bs. to make up a suite. The face layout of a typical secondary T.T.B. is shown in Fig. 14.

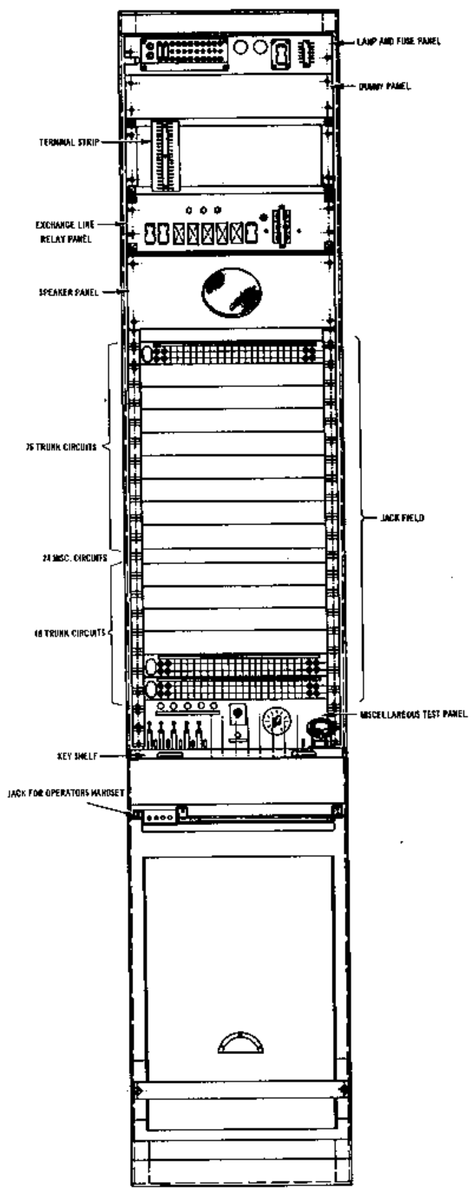



FIG. 14. FACE LAYOUT OF TYPICAL SECONDARY T.T.B.

The horizontal desk section incorporates the Milliameter and Key Shelf, and is hinged and may be raised to provide access to the wiring, the Plug Shelf and Dial. A directory shelf and the operator's telephone jacks are mounted underneath the desk section.

The vertical section on the front of the board comprises the following equipment, commencing at the top; the Lamp and Fuse Panel, the Exchange Line Relay Panel, the Speaker Panel, the Jack Field, and the Miscellaneous Panel, which is mounted immediately above the desk section.

The vertical section of the board below the desk houses the Test cords.

The equipment mounted on the rear of the board comprises the Monitoring Amplifier Panel, which is mounted directly behind the Speaker Panel, the Cord Rail, the Telephone, Dialling and Connecting Cord Circuit Panel, which are located in the lower section of the rear of the T.T.B.

Although battery storage facilities are provided, dry batteries are not required because D.C. voltmeter and bridge circuits are not included in the test circuits.

The secondary T.T.B. is designed specifically for testing voice circuits and must be considered in conjunction with the primary T.T.B. to understand the complete testing facilities provided.

6.2 Facilities. The facilities provided by the Secondary Trunk Test Board are as follows:

:: Patching 2-wire trunk line circuits.

:: Testing overall trunk circuit loss.

:: Speaking and monitoring on the trunk telephone circuits.

:: Ringing and/or dialling on trunk telephone circuits.

:: Connection of a trunk circuit to a local manual or automatic line.

6.3 Testing. The testing facilities provide for speaking and signalling tests on trunk telephone circuits and also loss measurement on trunk circuits.

Testing may be performed on the following types of circuits:-

:: Physical lines. (V.F. tests only).

:: Earthed Phantom (Cailho) circuits.

:: Phantom circuits.

:: Circuits derived from carrier systems.

:: Signalling leads associated with trunk circuits.

A schematic circuit of a secondary T.T.B. is shown in Fig. 16. The testing facilities are applied through the various cord circuits which can be divided into the following types:-

:: Connecting Cord Circuit. C.B. type plugs designated "Trunk" and "Exchange" are connected to this cord circuit which can be used for connecting a trunk line circuit to a local manual or automatic line. Dialling and ringing facilities are provided for the various types of circuits likely to be encountered on both the Trunk and Exchange plugs.

:: Test Cord Circuit. Two test cord circuits (1 and 2) are fitted with C.B. type plugs and used for testing and monitoring purposes. Each cord provides facilities for sending a standard test tone to line, measuring the level of received test tone, loop dialling, monitoring and speaking on through lines.

A twin test cord plug is inserted simultaneously in the line and drop jacks and with all keys normal a through circuit is provided. By operating the Test Line/Test Drop key to the Test Drop position, facilities are provided to test or talk on the drop side while the line side is terminated in 600 ohms. This action can be reversed by operating the split circuit key. The circuit side not under test is terminated to prevent circuit instability.

The T.M.S. Send-Rec. Key, in association with the Test Circuit key, enables both the transmission of a standard level to line and measurement of received level on an A.P.O., T.M.S.

:: Carrier Signalling Cord Circuit. A twin C.B. type plug designated "Carrier Sig." is connected to this cord circuit, which can be used for dialling over carrier systems employing E and M leading dialling facilities.

This cord circuit also allows the checking of signalling current in either the E or M lead, on a 100mA - 0 - 100mA meter.

A summary of the testing facilities, giving functions of keys is shown in Table 5.

| KEY | CIRCUIT FUNCTION |
|---|---|
| Speak Connect.<br>Dial Exch. | Allows the operator to speak on the connecting cord circuit.<br>Completes a loop dialling circuit to the exchange plug of the connecting cord circuit. |
| V.F. Tone Clear<br>V.F. Tone Call | Applies 600c/s tone to the connecting or test cords under the control of the "Speak on Test" key.<br>Applies a 750c/s tone to the connecting or test cords under the control of the "Speak on Test" key. |
| Dial Carrier Signal<br>Dial V.F. | Applies earth or battery to the carrier signal cord, via the dial contacts and the "Measure E and M Sig." key.<br>Allows the operator to transmit a dial train of V.F. impulses to the trunk connecting cord or the test cord under the control of the "Dial on Test" key. |
| Ring Exch.<br>Ring Trunk | Applies ringing tone via the master ringing key to the exchange and trunk plugs of the connecting cord circuit. |
| Disc. Sleeve. Circuit 1.<br>Battery | Disconnects sleeve circuits of circuit 1 cord.<br>Provides battery in place of earth on carrier and cailho dialling circuit. |
| Measure and Signal | Normal position of this key permits the current in the "M" signalling lead to be measured while dialling into the exchange equipment connected to the "E" lead. |
| Cailho Dial | Used in conjunction with "Dial on Test" establishes suitable connections for cailho dialling on the test plug, either from earth or battery in the test board. |
| Mon. on Test<br>Dial on Test | Used for monitoring on the two wire circuit.<br>Provides for dialling on the circuit under test. |
| Speak on Test<br>Ring on Test | Allows the operator to speak on the test circuit.<br>Applies ring in conjunction with the master key to the test circuit. |
| Ring 1000c/s<br>16c/s.<br>Disc. Sleeve Circuit 2. | Master ring key. Applies 1000/17c/s to the ringing commons.<br>Master ring key. Applies 17c/s to the ringing commons.<br>Disconnects sleeve circuits of circuit 2 cord. |
| Send<br>Receive | Applies test tone to Circuit 1 or Circuit 2 cords, under the control of Test key.<br>Connects receive T.M.S. across Circuit 1 or Circuit 2 cords, under the control of Test key. |
| Operate Circuit 2 (normal).<br>Operate Circuit 1. | Connects circuit 2 cord to test circuit.<br>Connects Circuit 1, in place of Circuit 2, to the test circuit. |

TABLE 5. FUNCTIONS OF KEYS IN TESTING CIRCUIT.

| KEY | CIRCUIT FUNCTION |
|---|---|
| Test 2<br>Test 1 | Enables send or receive testing on Circuit 2 cord.<br>Enables send or receive testing on Circuit 1 cord. |
| Test Line Circuit 1 (Normal) Test Drop Circuit 1 | Splits Circuit 1 enabling drop side to be checked and also terminates the line side in 600 ohms to guard against "spilling" within the carrier system. |
| Test line Circuit 2 (Normal) Test drop Circuit 2 | Splits Circuit 2 enabling drop side to be checked and also terminates the line side in 600 ohms to guard against "spilling" within the carrier system. |
| Split Circuit 1 | Reverses the action of the "Test Line - Test Drop" key (Circuit 1) permitting testing of the line side and terminating the drop side. |
| Split Circuit 2 | Reverses the action of the "Test Line - Test Drop" keys (Circuit 2) |

TABLE 5 (CONT). FUNCTIONS OF KEYS IN TESTING CIRCUITS.

6.4 Monitoring Amplifier. The Monitoring Amplifier is designed to amplify signals for monitoring with the associated loudspeaker or the operator's telephone receiver. The amplifier is designed to introduce a bridging loss of less than 0.5dB to any circuit across which it is connected and has an output impedance of 600 ohms to match the loudspeaker impedance and to suit connection to the operator's telephone receiver. The amplifier has a maximum gain of approximately 37dB which is controlled by a potentiometer located on the face of the T.T.B.

6.5 Patching. Patching of trunk line circuits connected to the board is carried out by means of patching cords provided in the cord shelf. Cords are three conductor type fitted with C.B. type plugs and each pair of cords is wired to twin jacks situated in the jack field. These jacks provide facilities for monitoring on the patched circuit, with the test cord circuit, without breaking the patched circuit.

6.6 Ring and Tone Supplies. Facilities are provided for the connection of tones of 600c/s, 750c/s and 1000/17c/s, and of 17c/s ringing supply to permit normal supervisory and signalling facilities over physical and derived circuits.

7. *TEST QUESTIONS.*

1. *A physical trunk line consists of the following construction:-*

    *2 miles of 40 lb. cable from the testing station T.T.B. to the cable head.*

    *75 miles of 200 lb. copper open wire line to the far cable head.*

    *7 miles of 40 lb. cable to the T.T.B. at the distant station.*

    *When tested the line is found grounded on one side and a varley reading of 533 ohm is obtained.*

    *Calculate the distance to the fault.*

    *Answer = 52 miles.*

2. *A fault is reported on a physical trunk circuit consisting mainly of open wire construction, but with short sections of entrance cable at each end of the circuit. Voltmeter tests show that the circuit is earthed on one side. Office records at the testing station show that the length of the aerial section is 52 miles, and that the loop resistances from the trunk test board to the normal test points are as follows:-*

    *To nearest cablehead - 62 ohms*
    *To distant cablehead - 520 ohms*
    *To distant trunk test board - 548 ohms.*

    *A varley reading of 266 ohms with unity ratio arms is obtained at the testing office. What is the distance to the fault from the cablehead near the testing station?*

    *Answer = 25 miles*

3. *A 200 lb. open wire pair has become permanently looped. With an open circuit at the distant end a loop resistance of 194 ohms is measured. With an earth on one side at the distant station, a varley reading of 27 ohms is obtained.*

    *Calculate the distance from the testing station to the fault.*

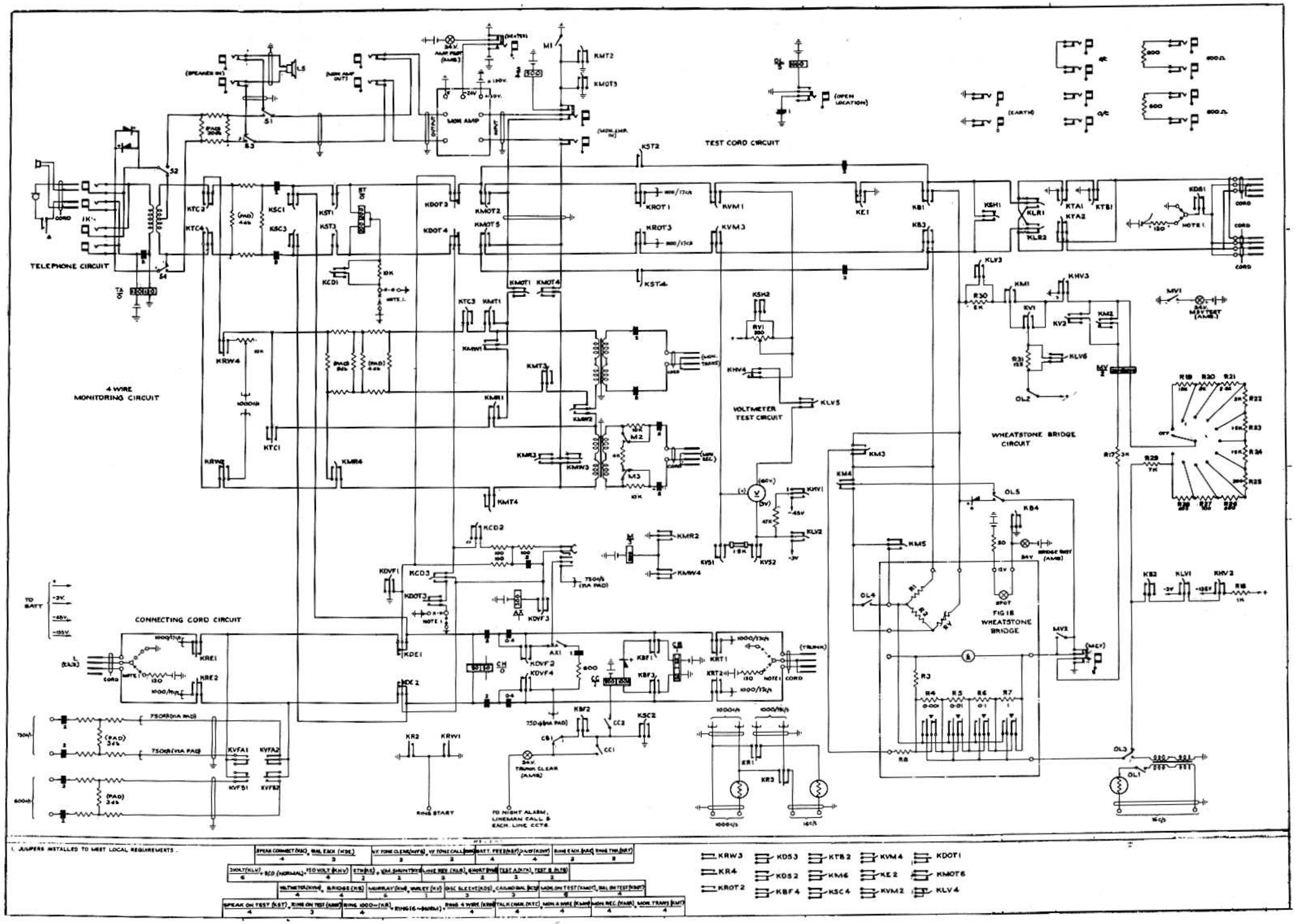
    *Answer = 16 miles.*

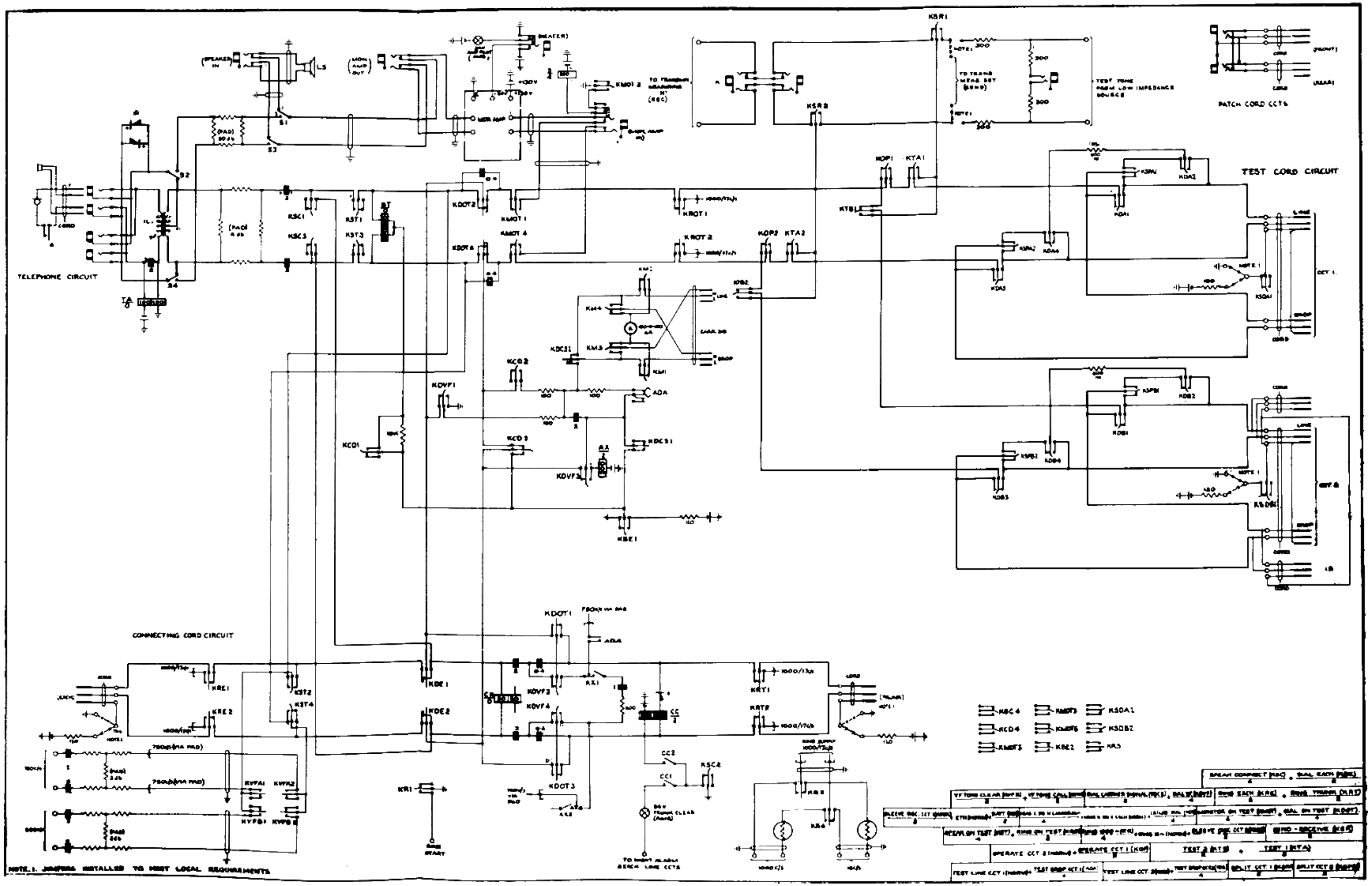
4. *On an open wire trunk route between two stations, two physical circuits are reported "crossed".*

    *(i) With the aid of explanatory sketches, show in correct sequence the tests which would be made from a standard trunk test board using the voltmeter circuit, to determine the nature of the fault as a preliminary to making an accurate location by means of the bridge.*

    *(ii) If it is found that one wire of one pair is broken and contacting a wire of the second pair, and a Varley reading of 220 ohms is obtained with unity ratio bridge arms when a loop is given at a point 50 miles distant, what is the distance to the fault from the testing station? All wires are of uniform construction and of resistance 8.8 ohms per single wire mile.*

    *Answer (ii) = 25 miles.*


TELEPHONE CIRCUIT
4 WIRE
MONITORING CIRCUIT
TEST CORD CIRCUIT
VOLTMETER
TEST CIRCUIT
WHEATSTONE BRIDGE
CIRCUIT
FIG 18
WHEATSTONE
BRIDGE
CONNECTING CORD CIRCUIT
TO
BATT
RING START
TO NIGHT ALARM,
LINEMAN CALL &
EACH LINE CCTS
1. JUMPERS INSTALLED TO MEET LOCAL REQUIREMENTS.


TELEPHONE CIRCUIT
TEST CORD CIRCUIT
PATCH CORD CCTS
CONNECTING CORD CIRCUIT