APPARATUS FOR MAINTENANCE TESTING AND FAULT LOCATING

Varley And Murray Tests For Earth Or Contact Faults, Using A Bridge Ohmmeter (Non-Electronic)

1 GENERAL A general description of Bridge Ohmmeters is given in F1052, and full details of Varley and Murray tests are given in F0031 and F0032 respectively. This instruction gives all necessary details for making Varley and Murray tests with "Ohmmeters Nos. 5, 6 and 7."

2 SELECTION AND IDENTIFICATION OF WIRES The first operation is the selection of 'good' and faulty wires and, to permit check tests, it is desirable to select more than one of each when possible. The wires should be selected by ohmmeter tests for insulation resistance. When the faulty cable does not contain 'good' wires, pairs in another cable should be used, if possible. When making a sub-location over a short distance a 'good' wire may be obtained by running out a length of twin or quad lead along the roadside. The opening of joints in an adjacent cable to obtain a 'good' wire should be avoided if possible.

3 The identification of individual wires at both ends of the cable section is a matter requiring careful attention. Difficulty in identifying faulty wires arises when the resistance of the fault is very low and when the section of cable includes a crossed joint. Generally, however, buzzer tests or battery-and-galvanometer tests with a loop to a 'good' wire will identify the faulty wire but, as a last resort, loop resistance of the 'good' wire looped to the possible faulty wires in turn might be measured, and the correct wire identified by its lower resistance.

4 EARTH-FAULT LOCATION, USING "OHMMETER NO. 5" Having selected one 'good' wire and one faulty wire, these should be looped together at the far end. The tests to be performed are

(a) loop resistance measurement

(b) Varley test

(c) where the 'good' and faulty wires are not identical in construction - a test for the single-wire resistance of the faulty wire.

5 TO MEASURE THE LOOP RESISTANCE

(a) Set the instrument on a firm, level base, and adjust the levelling screws as necessary.

(b) Turn the handle at full speed and turn the index adjuster until the pointer remains steady over the INFINITY mark.

(c) Set the change-over switch to BRIDGE and ratio switch to 1.

(d) Connect the resistance box to the two terminals marked R, and the cable loop to the two terminals marked X, as shown in Fig 1.

(e) Set all the resistance box dials to zero.

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(f) Turn the generator handle slowly clockwise; the needle will take up a position off the scale and above the line marked "G"; that is to say, on the side marked INCREASE R.

(g) While turning slowly with the right hand, raise the value of R step by step by turning the resistance switches, beginning with the thousands switch, and going on with the hundreds, tens, and units until the pointer reads accurately on the line G.

(h) Increase the speed until the clutch is felt to slip to secure the maximum sensitivity, and see that the final adjustment of the box is correct. Read off the result by the figures showing on the resistance box. This is the value of the loop resistance under test.

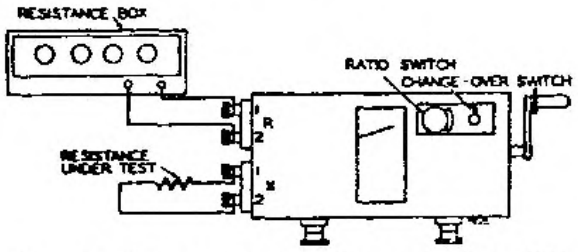

FIG. 1.—CONNEXIONS OF "OHMMETER No. 5" WHEN MEASURING LOOP RESISTANCE

6 Should the resistance be under 999 or 99 ohms, a more accurate result may be obtained by shifting the ratio switch to 10, or to 100. Put all the dials to zero and obtain a fresh balance. The value of the resistance under test is then equal to the box reading divided by 10, or by 100, as the case may be.

7 The electrical connexion set-up in making the above test, and shown in Fig 2, will be recognised as the Wheatstone bridge.

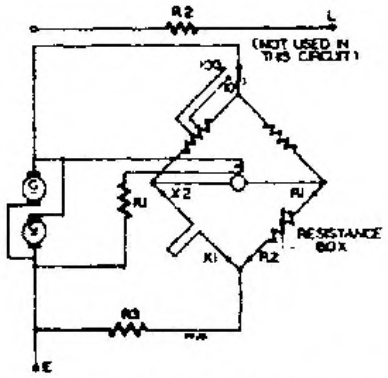

FIG. 2.—ELECTRICAL CIRCUIT OF "OHMMETER No. 5" WHEN MEASURING LOOP RESISTANCE

8 TO MAKE THE VARLEY TEST

(a) disconnect the resistance box and the loop, and reconnect them to the ohmmeter in the manner shown in Fig 3. This produces the simple Varley loop circuit as shown in Fig 4

(b) set the ratio switch to 1

(c) set all the resistance-box dials to zero

(d) turn the generator handle slowly clockwise, and increase the resistance step by step until the pointer floats above the INFINITY mark on the scale.

(e) increase the speed of turning until the clutch slips and make a final adjustment of the resistance.

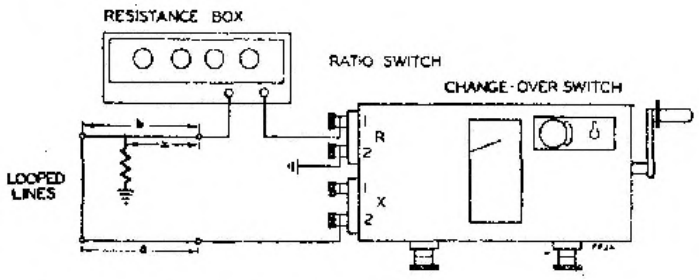

FIG. 3.—CONNEXIONS OF "OHMMETER NO. 5" WHEN MAKING A VARLEY LOOP TEST

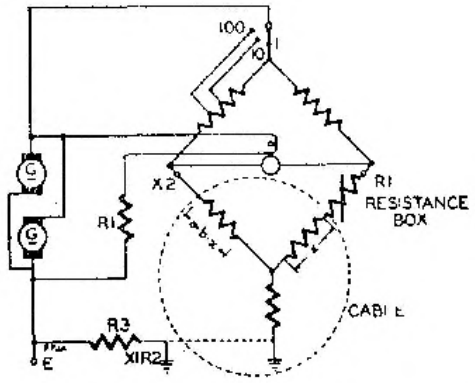

FIG. 4.—ELECTRICAL CIRCUIT OF "OHMMETER NO. 5" WHEN MAKING A VARLEY TEST

9 The resistance of the faulty wire from the testing end to the fault is then given by:-

$$\text{Resistance in ohms} = \frac{\text{Loop resistance} - \text{Varley reading}}{2} \text{ ohms}$$

If the 'good' wire and faulty wire are equal in length, equal and uniform in gauge and also unloaded, then:-

$$\text{Distance to fault (metres)} = \frac{\text{Loop resistance} - \text{Varley reading}}{\text{Loop resistance}} \times \text{length in metres}$$

NOTE: The "Varley" reading in this formula is the resistance box reading only when the ratio switch is in position 1 (see par 11).

10 USE OF RATIO SWITCH Measurement with the ratio switch at 1 will always give a useful guide to the position of the fault, but if the loop resistance is low or the fault is near the far end, greater accuracy may be obtained by using the ratio switch.

11 If the balance for either "loop" or "Varley" test leaves the thousands dial of the resistance box at 0, an extra digit may be obtained by turning the ratio

switch to 10 and repeating the measurement. If the balance in either case leaves both the thousands and hundreds dials at 0, one extra digit may be obtained by turning the ratio switch to 10, and two extra digits may be obtained by turning the ratio switch to 100. The loop resistance in this case will be:-

$$l = \frac{1}{10} \text{ or } \frac{1}{100} \times \text{Resistance-box reading}$$

It is important to remember, however, that the "Varley" reading is not $\frac{1}{10}$ or $\frac{1}{100}$ of the resistnace-box reading, but the resistance to the fault in ohms is given by the formulae in Table 1.

TABLE 1

RATIO SWITCH	RESISTANCE TO FAULT (OHMS)
1	$\frac{l - R}{2}$
÷ 10	$\frac{10l - R}{11}$
÷ 100	$\frac{100l - R}{101}$

where l = loop resistance (in ohms)
R = resistance-box reading in Varley test

12 It is generally desirable for the ratio switch to be in the same position for both the loop-resistance measurement and the Varley test; an impression of greater accuracy may be obtained by using different positions of the switch for the two tests, but there is not often any real gain in precision by doing so.

13 CONTACT-FAULT LOCATION, USING "OHMMETER NO. 5"

(a) Two faulty wires and a 'good' wire are needed for the test. The 'good' wire and one faulty wire are looped at the far end.

(b) Loop resistance is measured as described in par 5.

(c) The Varley test circuit is connected as shown in Fig 5. This uses the Wheatstone bridge network shown in Fig 6.

(d) The Varley test is made exactly as described in par 8, and the resistance to the fault is calculated as detailed in pars 9 to 12.

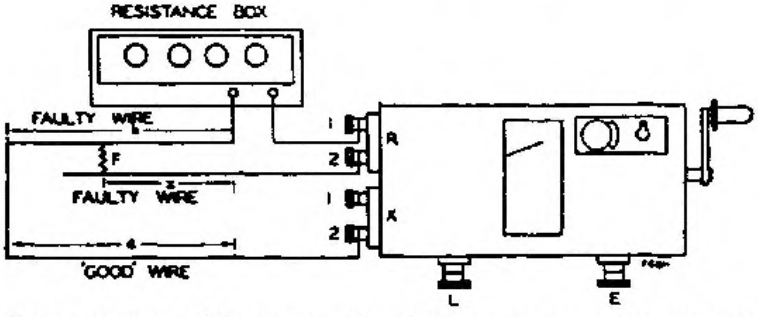

FIG. 5.—CONNEXIONS OF "OHMMETER NO. 5" WHEN LOCATING A CONTACT FAULT

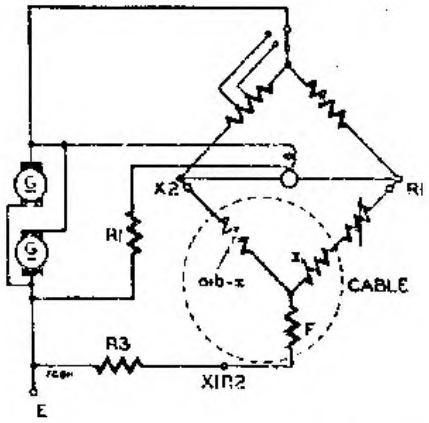

FIG. 6.—ELECTRICAL CIRCUIT OF "OHMMETER NO. 5" WHEN LOCATING A CONTACT FAULT BY VARLEY TEST

14 EXTERNAL ELECTRICAL DISTURBANCES Difficulty is sometimes experienced in making loop or Varley tests with an "Ohmmeter No. 5" due to extraneous voltages in the loop under test, which affect the movement of the instrument and make accurate balancing a matter requiring considerable experience. The effect of these disturbing voltages can be reduced by connecting an external shunt across temminals R1 and X2. A 40-ohm shunt has been found very useful, but a lower value should not be used since it would decrease the sensitivity of the instrument. This device can be applied to other types of ohmmeters but in these cases the shunt is connected across the LINE and GUARD terminals.

15 EARTH-FAULT LOCATION, USING "OHMMETER NO. 6 (OR NO. 7)" Testing with an "Ohmmeter No. 6" differs from testing with an "Ohmmeter No. 5" in some details but not in principle. The resistance box is built into the main instrument, and the external terminals differ from those of "Ohmmeter No. 5". Moreover, the switch has three positions, MEGGER, BRIDGE, and VARLEY. The switch is, of course, set at MEGGER for all preliminary insulation testing.

16 To measure loop resistance

(a) set the instrument on a firm, level base

(b) set the switch to MEGGER, turn the handle at full speed, and adjust the INFINITY adjuster until the pointer swings freely over the INFINITY mark

(c) turn the switch to BRIDGE and the ratio switch to 1, and all the resistance dials to zero

(d) connect the loop to the two terminals LINE and EARTH

(e) turn the generator handle at a slow, steady speed, and adjust the resistance dials until the pointer swings freely above the INFINITY mark

(f) turn the generator handle at increased speed, until the clutch is felt to slip and obtain further adjustment of the resistance dials

(g) If the loop resistance is low, use the ratios ÷ 10 or ÷ 100, as described for the "Ohmmeter No. 5".

17 The electrical circuit used in this loop measurement is a Wheatstone bridge as shown in Fig 7.

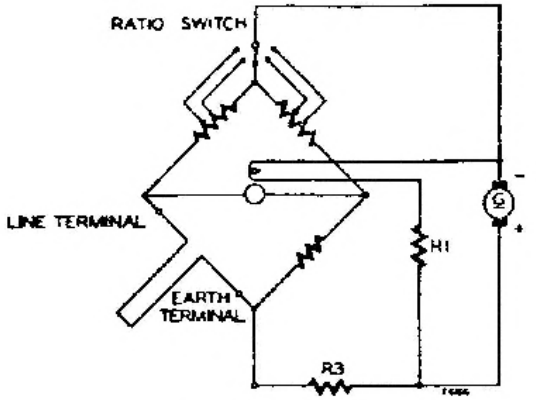

FIG. 7.—ELECTRICAL CIRCUIT OF "OHMMETER No. 6" WHEN MEASURING LOOP RESISTANCE

18 TO MAKE THE VARLEY TEST

(a) set the switch to Varley, the ratio switch to 1, and the resistance dials to zero

(b) connect the loop to the instrument as follows

(i) The 'good' wire to the LINE terminal

(ii) The faulty wire to the EARTH terminal

(c) connect the VARLEY EARTH terminal to earth, eg to a lead cable sheath if possible

(d) turn the generator handle at slow speed, and adjust the resistance dials for balance

(e) turn the generator handle at increased speed, until the clutch is felt to slip and adjust the resistance dials until the pointer is steady at the INFINITY mark

(f) If desired, the ratio switch may be turned to ÷ 10 or ÷ 100, to make use of all the dials in the resistance box

(g) The resistance in ohms to the fault is obtained by using the formulae given in Table 1.

19 The electrical circuit of the "Ohmmeter No. 6" for the Varley test is shown in Fig 8.

Fig 8 follows

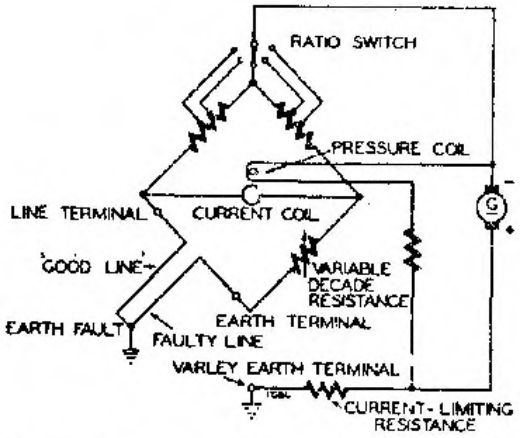

FIG. 8.—ELECTRICAL CIRCUIT OF "OHMMETER No. 6" WHEN MAKING A VARLEY TEST

20 VARLEY TESTS USING "OHMMETER NO. 6 (OR NO. 7)" IN CONJUNCTION WITH AN EXTERNAL GALVANOMETER The sensitivity of the "Ohmmeter No. 6" limits its use to low-insulation faults of something less than one megohm. Its usefulness for low-insulation faults may be extended by using it in conjunction with a more sensitive detector such as a "Galvanometer No. 41B".

21 To make the Varley test using an external galvanometer the procedure is as follows:-

(a) Connect the 'good' wire of the loop to the LINE terminal, the faulty wire to the EARTH terminal and the earth (cable sheath) to the VARLEY EARTH terminal.

(b) Connect the galvanometer with a universal shunt to the LINE and GUARD terminals of the ohmmeter.

(c) Set switch to VARLEY, the ratio switch to 1, and the resistance dials to zero positions.

(d) Turn the generator handle at slow speed and adjust the resistance dials for balance.

(e) Turn the generator handle at increased speed until the clutch is felt to slip, and adjust the resistance dials until there is no deflexion of the galvanometer indicator with the shunt in the XI position and the galvanometer on its most sensitive range. The ohmmeter should be firmly held while carrying out the test as an induced current due to movement of the current coil of the ohmmeter in its magnetic field will cause a deflexion of the galvanometer indicator.

(f) The ratio switch can, of course, be turned to ÷ 10 or ÷ 100 positions.

(g) The distance to the fault is calculated from the formulae given in Table 1.

22 Where the loop is subjected to inductive interference from adjacent circuits in the cable, a modified Simon test described in F0038 can be made using an ohmmeter as above in conjunction with a galvanometer having a differently wound coil, eg "Galvanometer No. 27A".

23 **CONTACT FAULT LOCATION USING "OHMMETER NO. 6"** The loop resistance test is made in exactly the same manner as already described, and the Varley test differs from that previously described in that the VARLEY EARTH terminal is connected to the second 'faulty' wire instead of to earth. The test and the calculation are then as already described.

24 **CALCULATION OF DISTANCE IN METRES** The tests described give the resistance of the faulty wire from the testing end to the fault and an approximate location can be obtained by dividing this resistance by the nominal ohm-km constant. It is, however, more accurate to use the loop resistance measurement and the length of the circuit between the testing end and the distant end. Where the 'good' and faulty wires are of the same gauge and length, the distance to the fault will be given by:-

$$\frac{\text{Resistance to fault}}{\text{Loop resistance}} \times 2 \times \text{length of circuit}$$

This method, being most accurate, should always be used where possible.

25 Where the 'good' and faulty wires are not equal in gauge and/or length, but the faulty wire is uniform throughout, the single-wire resistance of the faulty wire should be obtained. This may be obtained by using the tests described in F0010. Since the faulty wire is already earthed at one point, it will generally be preferable to use the three-wire test.

(a) Two 'good' wires 'a' and 'b' and one faulty wire 'f' are necessary.

(b) Loop resistances are measured for the two 'good' wires a + b, and for each 'good' wire in turn with the faulty wire, ie (a + f) and (b + f).

(c) The resistance of the faulty wire is given by

$$\frac{(a + f) + (b + f) - (a + b)}{2}$$

(d) The distance to the fault is then

$$\frac{\text{Resistance to the fault}}{\text{Resistance of faulty wire}} \times \text{Length of circuit}$$

26 When the faulty wire is made-up of sections of different gauges, it is necessary to use average resistance/km figures.

27 **EXAMPLE** An example will make the method clear. A cable with Cu conductors starts from the exchange for 500 metres as 0.5 mm cable, then for 800 metres as 0.63 mm cable and for 1500 metres as 0.9 mm cable. Tests from the exchange indicate a fault as 60 ohms away.

The resistances/km are

0.5 mm	84.1 ohms/km
0.63 mm	54.7 ohms/km
0.9 mm	27.3 ohms/km

The resistance of the 0.5 mm cable (500 metres) = $\frac{1}{2}$ x 84.1 = 42.05 ohms.

The resistance of the 0.63 mm cable (800 metres) = $\frac{4}{5}$ x 54.7 = 43.76 ohms.

The resistance of the 0.5 mm and 0.63 mm cable (1300 metres) = 85.81 ohms.

Hence the fault is in the 0.63 mm cable.

Resistance of the 0.63 mm wire up to the fault = 60 - 42.05 = 17.95 ohms.

Length of 0.63 mm wire up to the fault

$$= \frac{17.95}{54.7} = 0.328 \text{ km}$$

$\therefore$ distance to fault = 0.500 + 0.328
= 0.828 km

* Correction for different gauges can also be made using units of length. For example if a 200 metre length of 0.63 mm copper conductor exists in a cable where the remainder is 0.9 mm copper conductor, the overall length can be considered as increased by 200 metres, the resistance of 0.63 mm per unit length being approximately double that of 0.9 mm. Care must be exersised in determining the geographical position when using this method of correction.

28 **MURRAY TEST, USING "OHMMETER NO. 6 (OR NO. 7)"** It is possible, by using an extra resistance box and a galvanometer, to perform a Murray test with an "Ohmmeter No. 6 or No. 7". The best results are obtained from this method when the resistances of the 'good' line and the faulty line are fairly high, say of the order of 100 ohms each, but they need not be equal to one another. The connexions to be made to the ohmmeter are shown in Fig 9 and it will be seen that the LINE and GUARD terminals are short circuited, thus short circuiting the ratio arms and the current coil. The pointer of the ohmmeter is not used in this test. The ratio switch should be set to ÷ 100, for in this position the lowest resistance is in series with the generator lead, allowing a maximum testing current to flow from the generator. The ohmmeter supplies voltage to the Murray test circuit (see Fig 10) and balance on the external galvanometer can be obtained by adjusting the two resistances P and Q.

Then the resistance to the fault is given by

$$X = \frac{Q}{P + Q} \times \text{Loop resistance}$$

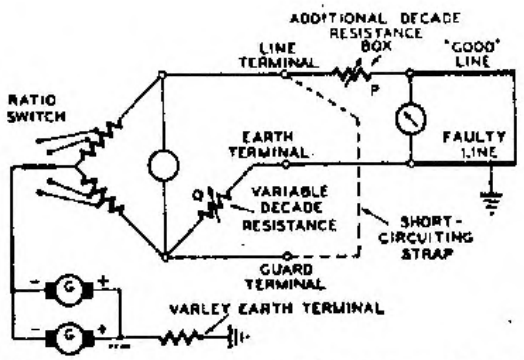

FIG. 9.—CONNEXIONS OF "OHMMETER No. 6" WHEN MAKING A MURRAY TEST

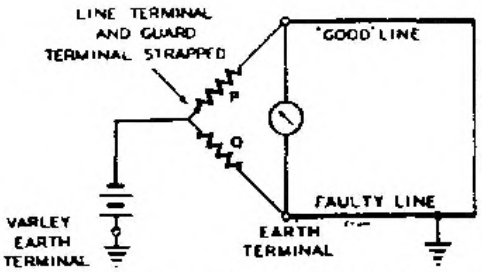

FIG. 10.—ELECTRICAL CIRCUIT OF "OHMMETER No. 6" WHEN MAKING A MURRAY TEST

29 THE MURRAY TEST, USING "OHMMETER NO. 6A" The "Ohmmeter No. 6A"; has an extra terminal fitted so that the Murray test can be made without the use of external apparatus. The sensitivity of this method is somewhat lower than that using external apparatus as described in par 27, but it has the advantage of only requiring a single item of apparatus. The connexions to be made to the "Ohmmeter No. 6A" when used for the Murray test are shown in Fig 11.

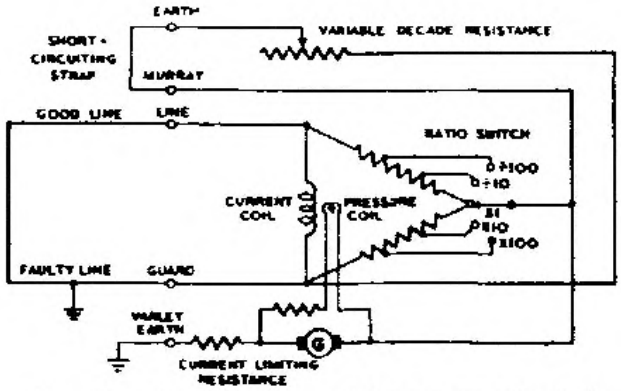

FIG. 11.—CONNEXIONS OF "OHMMETER No. 6A" WHEN MAKING A MURRAY TEST

30 To make the Murray test

(a) connect a short circuiting strap across the EARTH and MURRAY terminals

(b) connect the 'good' wire to the LINE terminal

(c) connect the faulty wire to GUARD terminal

(d) join together the remote ends of 'good' and faulty wires with thick wire

(e) connect the VARLEY EARTH terminal to earth

(f) set the change-over switch to VARLEY and ratio switch to XI position

(g) turn the generator handle at slow speed, and adjust the resistance dials for balance

(h) turn the generator handle at increased speed until the clutch is felt to slip, and adjust the resistance dials until the pointer is steady at the INFINITY mark

(j) the resistance in ohms to the fault is given in Table 2.

NOTE: As the variable resistance is in another arm of the bridge in this test it is necessary to increase R when the pointer moves towards the inscription Decrease R and similarly to decrease R when the pointer moves towards the inscription Increase R.

TABLE 2

RATIO SWITCH	RESISTANCE TO FAULT (OHMS)
x 100	$\left\{\frac{R}{101R + 2200}\right\}$ x Loop resistance
x 10	$\left\{\frac{R}{11R + 2020}\right\}$ x Loop resistance
x 1	$\left\{\frac{R}{2R + 1111}\right\}$ x Loop resistance
÷ 10	$\left\{\frac{R}{1.1R + 202}\right\}$ x Loop resistance
÷ 100	$\left\{\frac{R}{1.01R + 22}\right\}$ x Loop resistance

31 In the Murray test position the variable arm of the bridge consists of a fixed resistance connected in parallel with the variable decade resistance. The total value of the variable arm, therefore, does not vary uniformly with equal steps of the decade resistance and, furthermore, it cannot exceed the value of the fixed resistance. For this reason, depending upon the position of the fault, it may not always be possible to obtain a balance with the ratio switch in the XI position.

32 The XI ratio should be used if balance can be obtained with values of R up to about 2,000 ohms. Above this value it is usually advantageous to use the ÷ 10 position. With the latter ratio, the adjustment of the bridge is in coarser steps and intermediate values should be estimated from the pointer swing. With the ÷ 100 position the steps are too coarse, and x 10 and x 100 positions can be used for faults near the testing end.

33 If leads are used to connect the instrument to the 'good' and faulty wires their resistance should be kept as low as possible by using heavy gauge conductors. This is especially important when the loop resistance is small and it may be necessary in this case to take the resistance of the leads into account when calculating the resistance to the fault.

34 By using an external galvanometer connected to the LINE and GUARD terminals of the instrument similar to that described in par 20 for the Varley test, it is possible to carry out Murray tests with higher value faults.

(Sv5.1.2) E N D