CHAPTER 4

INSULATION RESISTANCE TESTERS

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INSULATION RESISTANCE TESTERS

Introduction

1. The safety and efficiency of electrical installations and apparatus demands a high standard of insulation and electrical continuity between joints. Tests of the standard of insulation should be made at the time of installation, and thereafter at regular intervals to prevent the development of faults or to locate such faults if and when they do develop. These tests are most conveniently carried out by testing the insulation resistance of the circuit or apparatus and a variation of the tests applied may be used to locate breaks in the cable, faulty insulation, loose connectors, moisture or similar conditions likely to cause deterioration and faults in the insulation.

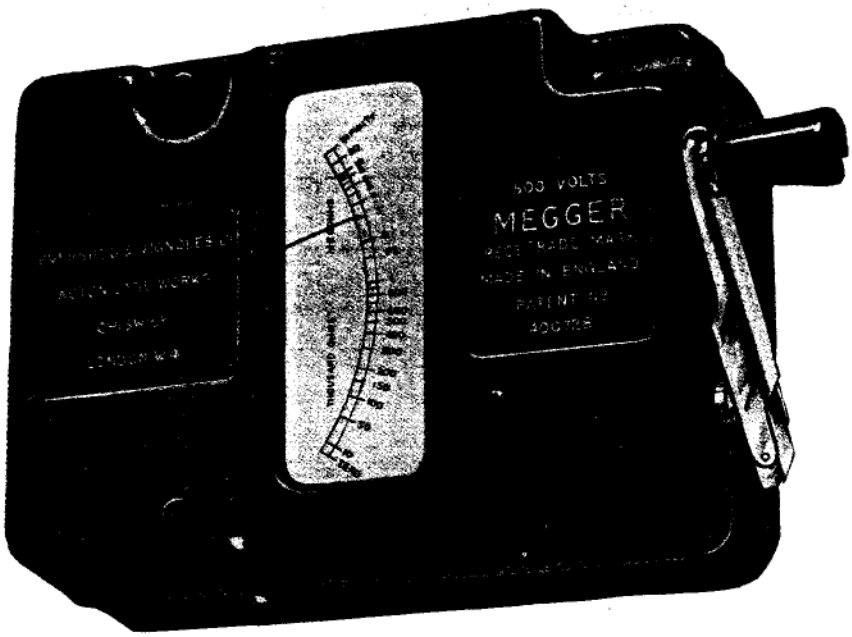


Fig. 1.—Insulation tester, type A

2. A convenient way of making the necessary tests to the installation *in situ* is by the use of an ohmmeter, or an insulation tester which combines an ohmmeter and a magneto-generator assembled as a single unit; the generator, which is hand-driven, developing a testing voltage of 30, 250, 500 or 1000 volts according to the type of tester.

3. The ohmmeters and insulation resistance testers here described are portable and self-contained. When the operator is familiar with the various possible adaptations to particular resistance measuring requirements, accurate resistance measurements may be made over a wide range. In addition to the general uses suggested above, tests can be made of high resistance for wireless aerial and earth installations, aerial transmission and communication lines, and of miscellaneous apparatus.

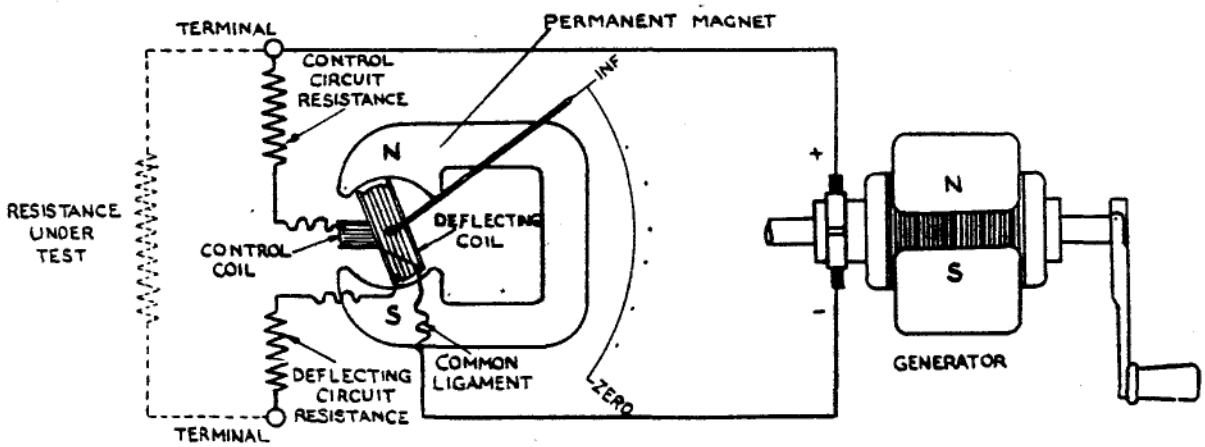


Fig. 2.—Diagram of circuit of insulation resistance tester, types A and B

4. The insulation resistance testers described in this chapter are of eight types.

		A.M. stores ref.		
Insulation resistance testers				
Type A.	Wee-Megger tester	5G/1621	developing	500 V variable pressure
B.	,,	5G/2275	,,	250 V ,, ,,
C.	,,	5G/152	,,	250 V limited pressure
D.	Record minor tester	5G/203	,,	500 V variable pressure
Combined insulation tester and Wheatstone bridge				
Type B.	Bridge-Megger tester incorporating resistance	5G/1708	developing	500 V limited pressure
C.	Bridge-Megger tester with attachable resistance	5G/2282	,,	1000 V variable pressure
Safety ohmmeter—current limited type				
Type B.		5G/2843 0–5 ohms 12·00 milliamperes		
C.		5G/2844 0–10,000 ohms 12·00 milliamperes		

DESCRIPTION

Insulation Resistance Testers

5. The testers are supplied in leather carrying cases. The handle of the combined generator-ohmmeter has a simple freewheel device which ensures that the armature is rotated in a clockwise direction only and prevents strain on the apparatus if the handle-turning suddenly stopped. The tester itself is so constructed that it will withstand a considerable amount of vibration and shock without injury; it is sealed against dust, sand, damp and other harmful substances and conditions and will stand up to a tropical climate.

Type A

6. This type of tester, shown in fig. 1, is better known as the Wee-Megger tester. The generator is of the two-pole permanent magnet type, driven by a handle which folds back into a recess in the casing when not in use. The armature, drive and all moving parts are mechanically balanced and run on roller bearings. The whole unit is enclosed in a case of mottled red insulating material, the indicator scale being covered by safety glass or transparent material; it weighs approximately 3 lb. and the overall dimensions are 5 × 4 × $2\frac{3}{8}$ in.

7. The type A tester has a variable-pressure generator, the voltage varying with the speed of handle-turning. It develops a pressure of 500 volts at a handle-speed not exceeding 160 r.p.m. The armature has one winding, connected to a simple split-ring commutator.

Fig. 3.—Test-and-carry case in use

8. A simplified diagram of the circuit is given in fig. 2. From this it will be seen that the ohmmeter is of the moving coils type, formed of two coils mounted at a fixed angle to one another and free to rotate in the field of a permanent magnet. Both coils are in parallel across the generator, the control coil being in series with the fixed control circuit resistance and the "deflecting" coil in series with another fixed resistance (to limit the current at zero) and the resistance under test. A pointer mounted on this moving coil system gives a direct indication on a dial scaled in megohms and ohms. It is freely pivoted on spring-mounted jewels and when no current is flowing will tend to rest at some point towards the infinity end of the scale. When the apparatus or circuit to be tested is connected between the two push-button terminals in the sides of the tester, seen in fig. 1, and the generator handle is turned, currents pass through both the circuits, the position depending on the ratio between them, which is governed by the resistance under test. Any variations in the testing voltage will affect both control and deflecting coils equally, and as the resistance under test is connected in series with the deflecting coil only, it alone will be responsible for the position of the pointer on the scale.

9. The instrument should be held with the dial horizontal when in use. The leather "test-and-carry" case in which it is supplied can be adjusted with a strap to hold the instrument in the flat position while slung over the operator's shoulder, leaving both his hands free. The case has a window over the scale, holes cut to allow cable connection with the push-button terminals, and allows for the handle of the generator to be turned with the instrument still strapped inside the case, as shown in fig. 3. Type A testers are now being called in and modified to type C (*see* para. 11).

Type B

10. This tester is similar to type A in all respects except that the generator develops a pressure of 250 volts at a handle speed of 160 r.p.m. This type was originally supplied for use in American aircraft, but is now entirely superseded by type C.

Type C

11. Type C is again a modification of type A. The instrument is fitted with a voltage limiter which provides that the pressure shall be 250 volts at a handle speed of *not less than* 160 *r.p.m.* Above this speed, a silicon carbide resistance unit shown in the circuit diagram in fig. 4 keeps the voltage steady. Advantages of this voltage limitation are that it is not possible to apply an excessive testing pressure by over-speedy handle-turning, and that a steady reading is obtained on the ohmmeter when measuring the capacitance of a load, provided that the handle speed is *above* 160 *r.p.m.* This limited voltage tester is superseding type B for all uses where 250 volts is the highest pressure required, such as the testing of aircraft electrical installations.

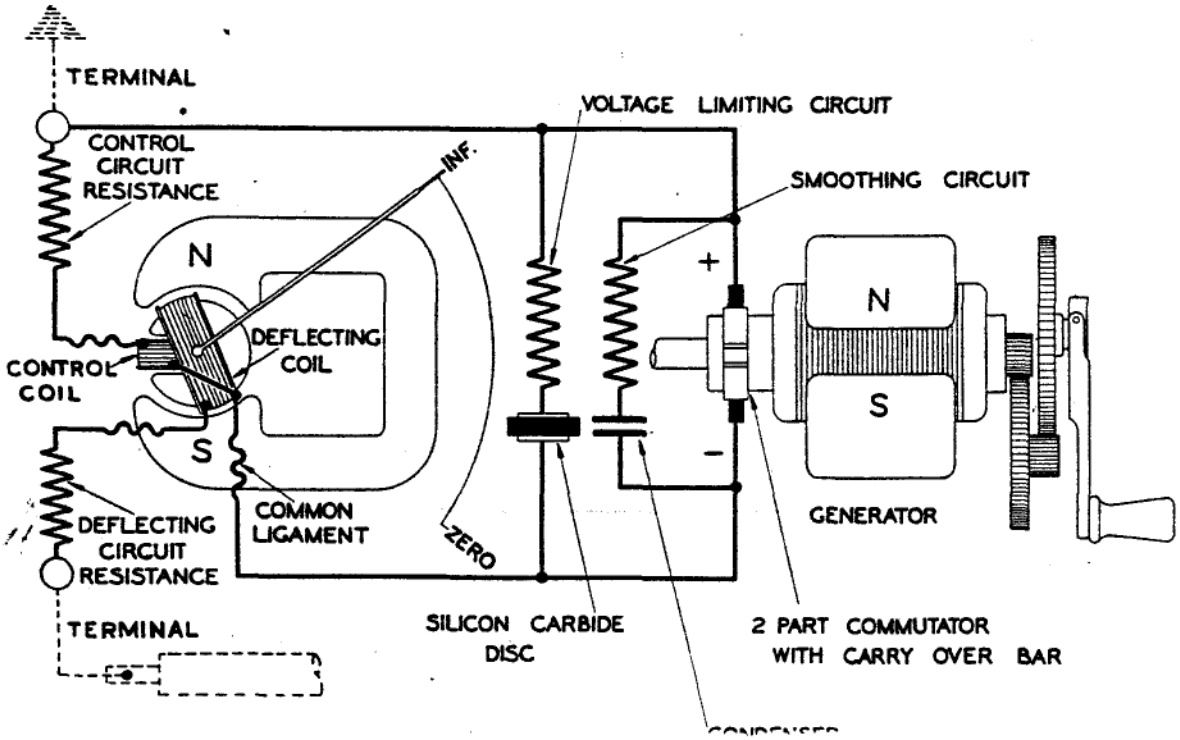


Fig. 4.—Circuit of insulation tester, type C, limited pressure type

Type D

12. This instrument, shown in fig. 5, is of the Record "Minor" insulation tester type. A hand-driven generator and cross-coil type ohmmeter are enclosed in a moulded bakelite case of burr walnut finish, fitted with a carrying handle. Its size is $5\frac{7}{8} \times 3\frac{3}{4} \times 3\frac{1}{2}$ in. and its weight 3 lb. The generator of the variable pressure type with freewheel drive, develops 500 volts at a handle speed of 150 r.p.m. The terminals are screw-type, protected yet accessible, giving a firm grip which will accommodate a wire or connecting tag. This type of tester is now superseding type A in Service supply.

Combined Insulation Tester and Wheatstone Bridge

13. This type of instrument combines the functions of an insulation tester with those of a Wheatstone bridge; that is, it may be used for measuring either insulation or conductor resistance. It consists of a hand-driven generator and a direct reading ohmmeter combined with a variable decade resistance and ratio arms, either in one case or in two readily connected parts. Two types are available, type B and type C.

Type B

14. This Bridge-Meg tester is a combination allowing for the measurement of insulation resistance by direct indication, of conductor resistance by the Wheatstone bridge method, and the tracing of earth faults in cables by the Varley loop method. By turning a single switch three different internal circuits come into action.

15. The Bridge-Meg tester is in a case of aluminium alloy or wood with a lid and base of moulded synthetic resin. It is of robust construction and proof against dust and vermin. A carrying strap is permanently fixed to the case and is adjustable for hand or shoulder carrying, as shown in fig. 6. The weight is $12\frac{3}{4}$ lb.

16. The hand-driven generator of the two pole permanent magnet type has a centrifugal clutch which ensures a constant pressure of 500 volts so long as the handle speed is *not less than* 160 *r.p.m.* The ohmmeter is of the permanent magnet moving coil type described in para. 8. Fig. 8 shows the possible internal circuits of this instrument. On one side of the instrument case is a switch marked for positions of "Meg", "Bridge", and "Varley" testing, while a second switch provides for ratio positions of 1:1, ÷ 10, ÷ 100, × 10, and × 100.

Type C

17. This type, usually known as the Bridge-Megger testing set, is in two parts, the insulation tester and the variable resistance box being separate units. The insulation testing portion, which contains a hand-driven generator and a direct-reading ohmmeter can be used on its own for normal insulation resistance testing; the addition of the variable resistance portion transforms the instrument into a Wheatstone bridge for conductor resistance measurement. These two parts are shown in fig. 7.

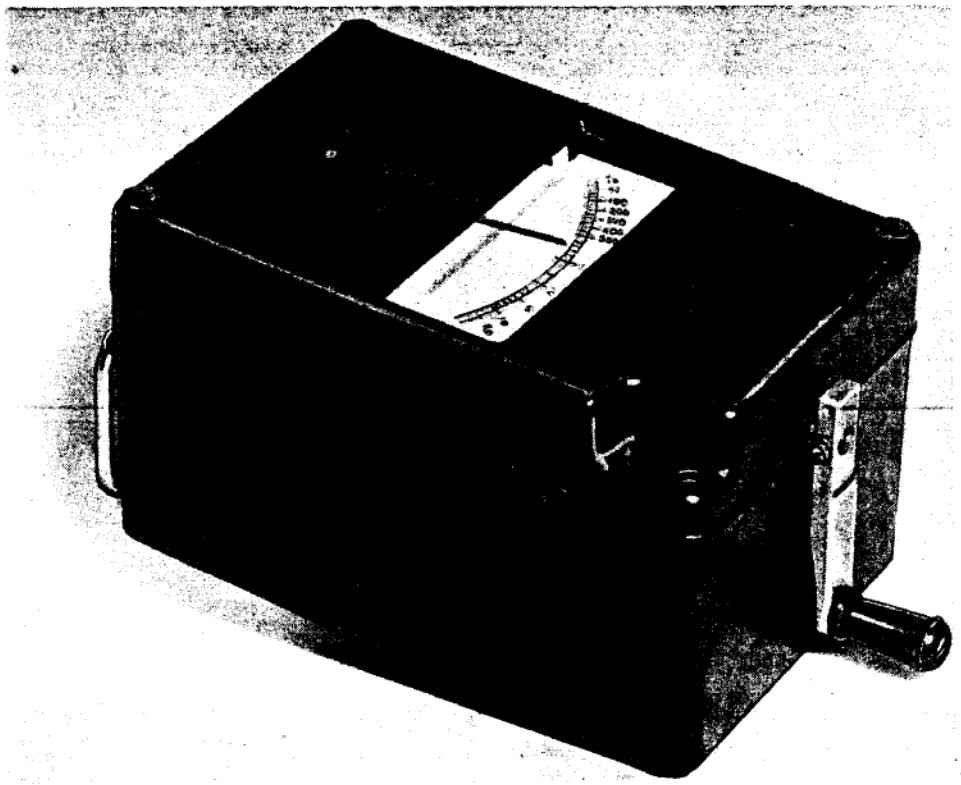


Fig. 5.—Insulation tester, type D

18. The constant-pressure hand-driven generator, of the two-pole permanent-magnet type, develops a pressure of 1000 volts at a handle-speed of 120 r.p.m., and a centrifugal clutch ensures that at or above this speed, the voltage remains constant. The ohmmeter is of the moving coil type fully described in para. 8. The ohmmeter scale on the top of the case is covered by glass and is protected by a hinged metal flap. The handle driving the generator, fixed at one end, can be folded back into a recess when not in use. On the top of the case, which is made of wood, are the ratio switch and change-over switch which are operated when the instrument is connected to the variable resistance box for use as a Wheatstone bridge. The carrying handle, fixed over the scale, is released to swing clear when the instrument is in use.

19. Terminals, for connection to the resistance under test, or to the variable resistance box, are clearly marked with their purpose. An index adjuster is provided by which the pointer may be set to register infinity, and the infinity reading should be checked before each test. This portion of the testing set, enclosed in its wooden box, is about $14\frac{3}{4} \times 7\frac{3}{4} \times 7\frac{3}{4}$ in. and weighs about 23 lb.

20. The wiring diagram in fig. 11 gives the internal connections of the type C resistance tester as used for the Wheatstone bridge method of resistance measurement, and shows clearly how the change-over switch brings into circuit the ratio switch and the variable resistance box. Fig. 10 is a schematic diagram of this Wheatstone bridge test, showing the function of the ratio switch in putting more or less resistance into one arm of the circuit in the definite ratio of 1, 11 and 100. These two diagrams should be studied together, as they are different methods of showing the same test.

21. The variable resistance box, shown in fig. 7, contains a series of bobbin resistances mounted on a panel of moulded synthetic resin material. The ends of each resistance are connected to contacts in the four switches mounted on the top panel. This gives a direct reading in units, tens, hundreds and thousands as each switch is rotated to bring into circuit each resistance bobbin in turn. The whole unit is enclosed in a teak box $10\frac{1}{2} \times 4\frac{1}{4} \times 5\frac{1}{2}$ in.

Safety ohmmeters—current limited type

22. Two types of safety ohmmeters are in service. Type B is used for testing the continuity of the circuit under test—usually a detonator fuze—and type C for determining the insulation resistance of such a circuit. The instrument consists of a hand-driven D.C. generator and direct reading ohmmeter mounted together in a case of black moulded synthetic resin, with a pair of push-button terminals to which the resistance under test is connected. The instrument measures 6 × 4 × 3 in. and weighs 3 lb. A leather test-and-carry case is provided.

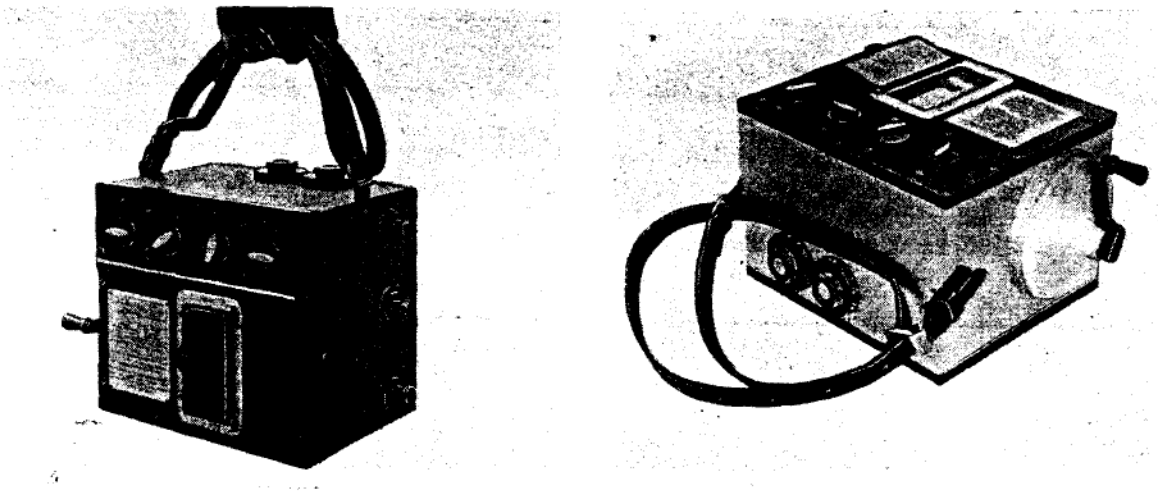


Fig. 6.—Bridge-Meg tester, type B

23. The generator which provides the D.C. testing circuit is of the two-pole permanent-magnet type with rotating armature and commutator, the armature being wound with wire of a high resistance material. The actual circuit is similar to that of the type A insulation tester, but its design is such that even if its brushes are short circuited, the generator cannot give a current exceeding 12 milliamperes even at the excessive speed of 160 r.p.m.: this is an essential safety measure, as the circuit may possibly be in contact with an explosive charge. It is driven by a crank handle through machine-cut double-reduction gearing. The handle folds compactly into a recess in the case when not in use. A free wheel device allows the armature to come to rest slowly when the handle-turning is stopped abruptly, thus relieving the transmission from strain, and ensures that the armature is turned in the right direction.

24. The ohmmeter is of the two-coils permanent-magnet type described in para. 8. Apart from its colour—black instead of mottled red—the case of the safety ohmmeter resembles that of the insulation testers, types A, B, and C. The distinctive calibration of the dials is shown in fig. 9.

Type B

25. In this type the circuit is such that the resistance under test will be connected in series with the control coil, and in parallel with the deflecting coil. This tester is used for determining conductor resistance of 0 to 5 ohms, the current not exceeding 12 milliamperes, particularly in fuze igniters.

Type C

26. In this type of tester, used for testing the insulation of detonator circuits, the control coil is connected across the generator and the deflecting coil is connected in series with the resistance under test. The range is from 0 to 10,000 ohms and infinity, and is so arranged that at infinity the testing voltage is not less than 30 volts.

OPERATION

Insulation resistance testers, types A, B, C, and D

27. Place the tester with the scale uppermost, in such a position that the handle may conveniently be turned without displacing the instrument. Before making any connections, test the instrument by turning the handle, when the pointer should promptly move over the scale towards the infinity mark.

28. Connect suitable leads to the instrument terminals. Taking care that the leads are not in contact with anything, turn the handle again, when the pointer should once more move to the infinity mark. Join the leads together and turn the handle slowly, and the pointer should move across the scale to zero; if these two tests are satisfactory, it may safely be assumed that the instrument will read correctly on all points of the scale. If the test is not satisfactory there is most probably a leak in the leads themselves, and fresh leads must be substituted.

29. When the insulation of the leads themselves is assured, connect the loose ends to the circuit to be tested. Turn the handle at the speed indicated on the dial, and at the same time observe the position of the pointer on the scale. This reading shows the value of the insulation resistance under test.

30. If several successive readings show infinity resistance, touch the further ends of the test leads together while turning the handle slowly to make sure that the leads are not disconnected or broken.

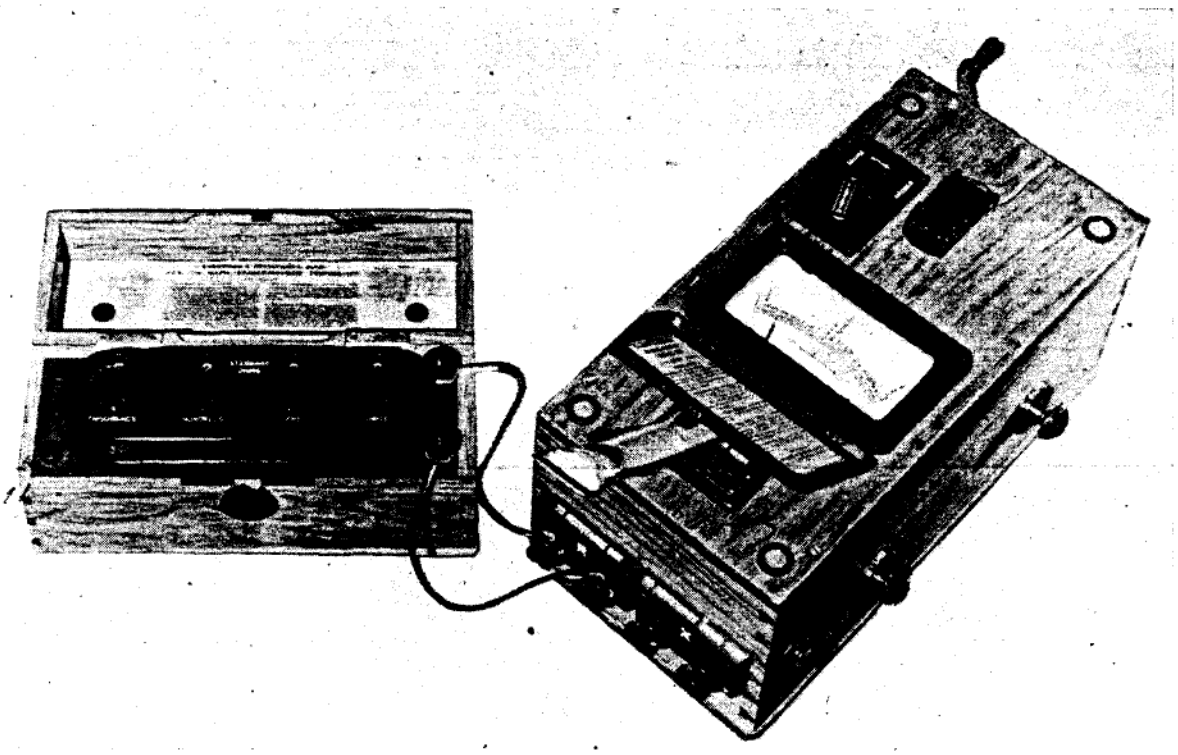


Fig. 7.—Bridge-Megger testing set, type C

31. It will be appreciated that comparison of one reading with another will be of greater value in insulation testing than the absolute value obtained in any one test. Thus, if a record of daily, weekly or monthly readings shows insulation resistance of some item to be between 4 and 5 megohms, a sudden reading of only ½ megohm will suggest the development of trouble at some point which can then be traced and corrected before an actual breakdown occurs.

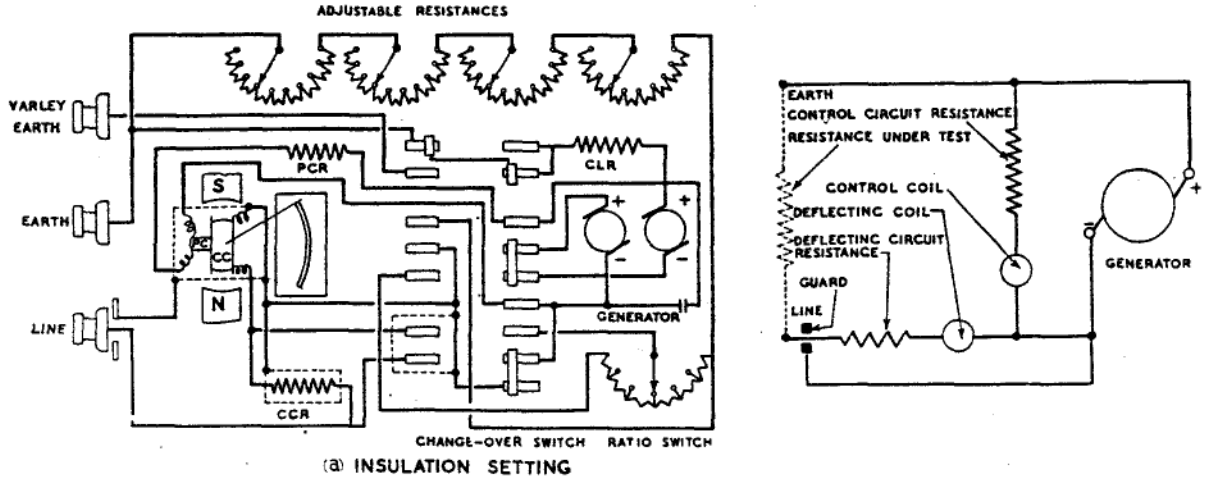
32. When a testing voltage is applied to any system of appreciable electro-static capacity, a current will flow into the system until it is fully charged, even though the insulation is perfect. In this case, the pointer will fall at first, then, when the system is fully charged, will rise to the correct insulation reading.

33. If the handle of the tester is not turned at a constant rate or, in the case of the limited voltage tester if it is allowed to drop below 160 r.p.m., a variable current will result, so that the part under test will alternately be charging and discharging, and the pointer reading will be unsteady.

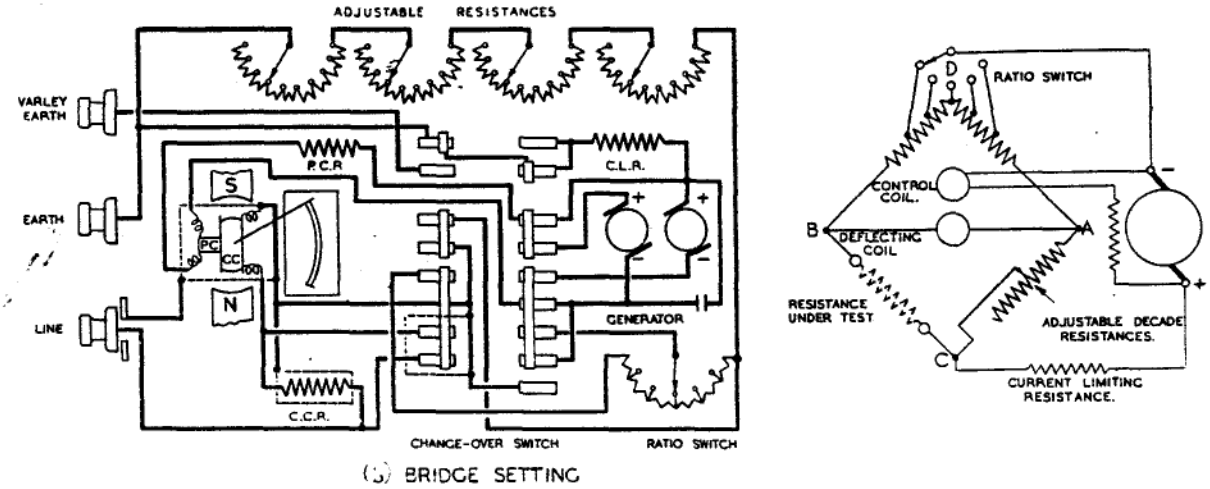
Insulation and bridge tester, type B

34. As described in para. 14, this type of tester has three different testing circuits—insulation testing, resistance measurements, and earth fault location.

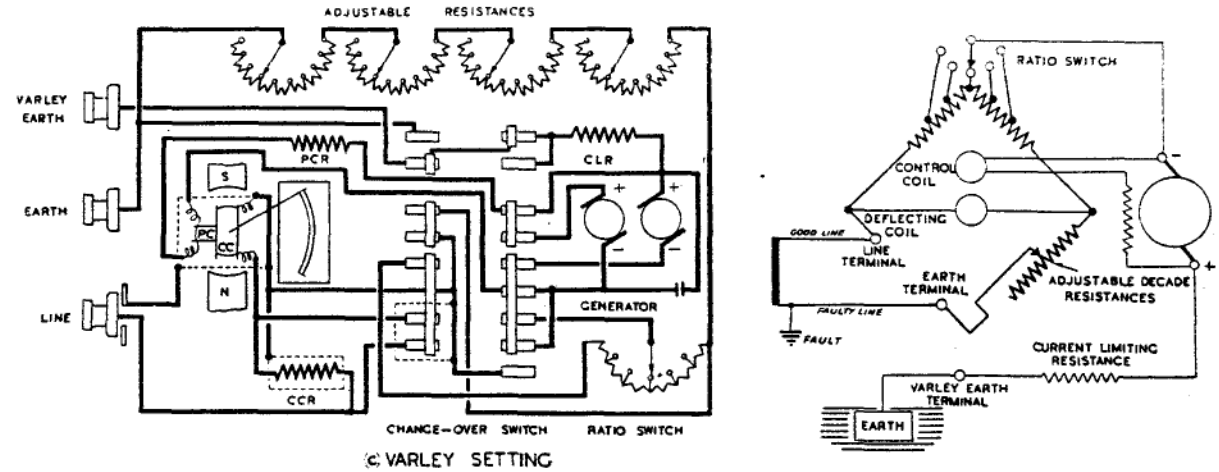
35. *Insulation testing.* Before any test is made, the index should be tested in the manner described in para. 27 and 28, with the change-over switch set at "Meg". If the indicator does not read quite true at "Infinity", slight adjustment may be made by the screw marked "Index Adjuster". Then with the change-over switch set at "Meg", the insulation to be tested is connected between the "Earth"



(a) INSULATION SETTING



(b) BRIDGE SETTING



(c) VARLEY SETTING

Fig. 8.—Schematic diagrams of circuits set up by use of the change-over switch in type B, for "Insulation", "Bridge", and "Varley" settings

and "Line" terminals on the side of the case, shown in fig. 6. The generator handle is then turned at a speed of *not less than* 160 *r.p.m.*, and a direct reading can be taken from the scale, which is marked in thousands of ohms and megohms.

36. *Wheatstone bridge test.* When the switch is turned to the "Bridge" position, the instrument is transformed into a Wheatstone bridge. The new internal arrangement of connections can be followed at (b), fig. 8. The two ratio arms and the adjustable resistance form three arms of the bridge, which is completed by the resistance to be measured. The deflecting coil of the ohmmeter serves as the galvanometer, and the galvanometer control force is provided by the control coil, which is independently energised from the generator terminals. When no current passes in the deflecting coil, the force exerted by the control coil brings the moving system into the position in which the pointer reads infinity, so that the infinity reading corresponds to a balanced condition of the bridge.

37. Connect the resistance to be measured between the "Earth" and "Line" terminals. Set the switch to "Bridge"; turn the ration switch to "1" and all the adjustable resistances to "0". An exception to this last point occurs when testing circuits that might be damaged by excessive current, in which case the "Thousands" resistance should be started at "9" and the hundreds, tens and units

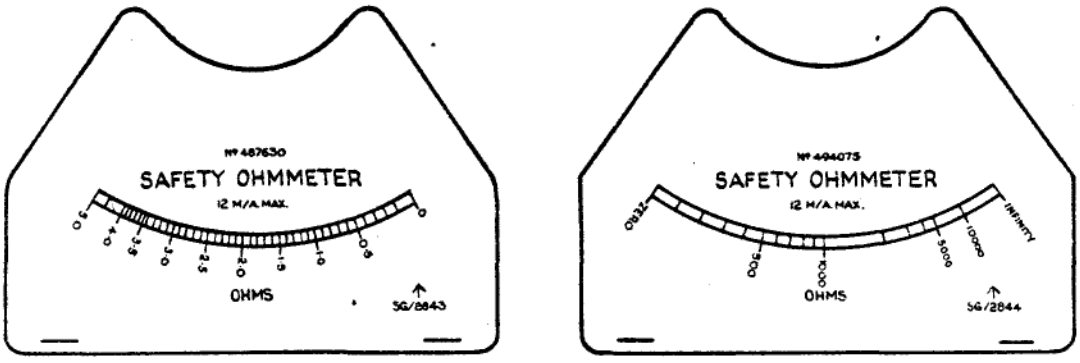


Fig. 9.—Scales of safety ohmmeter, types B and C

at "0". Turn the generator handle while altering the resistances step by step, first the thousands, then the hundreds, tens and units successively until the pointer shows balance by resting at infinity. The generator may be driven slowly until a balance is approached, but if much inductance is present, it should be turned above slipping-speed to obtain constant pressure. When balance is obtained, the value of the resistance under test is shown on the adjustable resistance dials.

38. If the resistance reading is below 1,000 ohms, set the ratio switch to the "$\div$ 10" mark and balance again. The value of the resistance is then equal to the reading of the adjustable dials divided by 10.

39. Similarly, to measure a resistance below 100 ohms with greater precision, set the switch to "$\div$ 100".

40. For resistances above 9,999 ohms, use the "$\times$ 10" ratio setting, or if above 99,999 ohms, the "$\times$ 100" ratio, in each case multiplying the dial readings by the figure on the ratio switch.

41. *Varley setting for earth fault locating.* Fig. 8 (c), gives the schematic diagram of the circuit when the change-over switch is set for the Varley Loop test for locating the position of earth faults on cables, and is suitable for use where the resistance of the loop is not less than 1 ohm. The arrangement is such that one end of the generator is connected to earth, current flowing from it into the bridge network through the earth fault; the good line and the portion of the faulty line beyond the fault are in one side of the bridge, while the portion of the faulty line up to the fault is included in the other side.

42. Connect the faulty line to the "Earth" terminal and the good line, which is looped to the faulty one at the far end, to the "Line" terminal. Connect the "Varley Earth" terminal to a good earth. First set the change-over switch to "Bridge" and measure the total resistance of the loop by the method described in para. 36–40 for the Wheatstone bridge. This resistance, which is termed L, must be expressed in ohms. Thus the reading of the adjustable resistance dials must be multiplied or divided by the factor indicated by the ratio switch. Turn the change-over switch to "Varley" setting, and alter the adjustable resistances until balance is again obtained. This reading is termed R. Then the distance in ohms of the fault from the "Earth" terminal is given by the following formula:—

(i) With ratio switch at "1" when making the Varley Loop test, $\frac{L - R}{2}$

(ii) ,, ,, ,, ,, "÷ 10" when making the Varley Loop test, $\frac{10L - R}{11}$

(iii) ,, ,, ,, ,, "÷ 100" ,, ,, ,, ,, ,, ,, $\frac{100L - R}{101}$

Combined insulation and resistance tester, type C

43. Before use, the tester itself should be checked. With the change-over switch set at "Meg" the handle of the generator is turned slowly before any connections are made, and the pointer should move over the scale to the infinity mark. If it does not do so, the handle should be turned at above the clutch slipping speed while the pointer is moved to the infinity position by means of the knob marked "Index Adjuster".

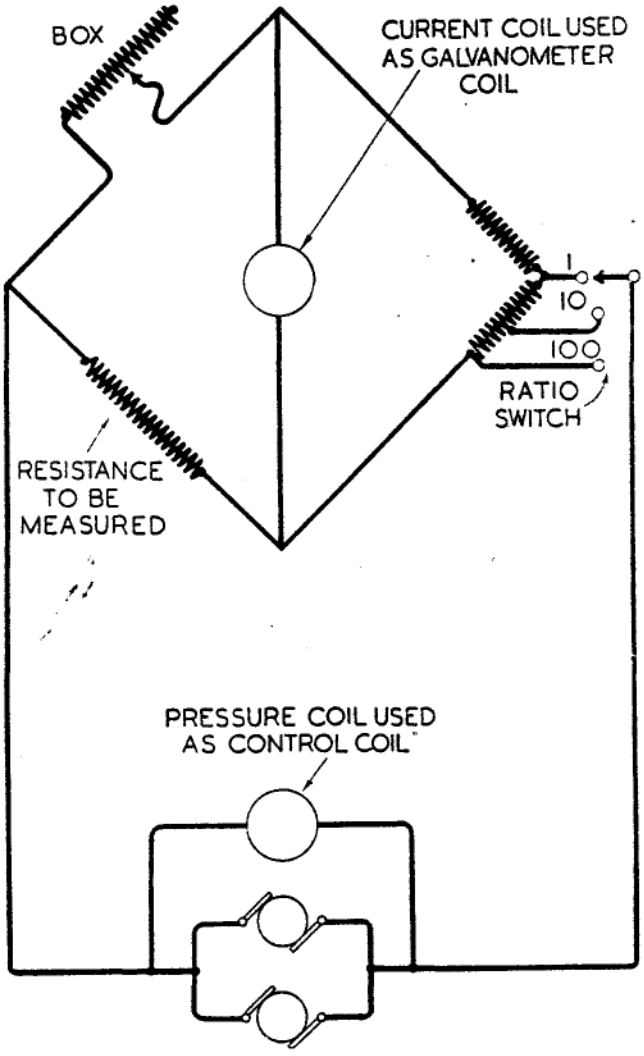


Fig. 10.—Bridge-Megger schematic diagram of resistance measurement

44. *Insulation test.* Procedure for insulation resistance testing is then as described in para. 27–33.

45. *Wheatstone bridge test.* When it is required to measure conductor resistance by the Wheatstone bridge method, the resistance box must be connected to the tester set. Fig. 11 shows the circuit which then comes into use. The resistance box leads are connected to the tester terminals marked R and the resistance under test to the terminals marked X. Fig. 10 is a schematic representation of the same circuit.

46. The procedure can then be followed from the description in para. 36–40.

Safety ohmmeters, types B and C

47. These instruments are extremely simple to use. Connect the two terminals to the resistance to be measured; turn the handle at above 160 r.p.m. and the resistance will be indicated on the scale.

SERVICING

48. All tests should be made on a "dead" circuit. Generally speaking, the testing pressure used should not exceed twice the normal pressure for which the apparatus is designed, but it is laid down that aircraft equipment should be tested at 250 volts, the only exceptions being detonator circuits, wireless circuits or other special equipment.

49. In all types of testers, it is desirable that the instrument be kept away from magnetic surfaces, cable runs, electrical instruments or live circuits while the test is being made, and whenever possible tests should be carried out under cover and in dry atmospheric conditions. Further, it is essential that the tester should be kept steady and so placed that the handle can be turned easily and smoothly without rocking or sliding the tester. NEVER rest the tester on the pole-piece or bed-plate of a dynamo or electrical machine of any nature.

50. The speed at which the handle should be turned is printed on the scale. It should be remembered when using the variable pressure types to test a circuit having much electrostatic capacity that a steady rate of handle-speed as near as possible to the given rate must be maintained to obtain a steady reading on the scale. Excessive speed may produce a pressure high enough to break down the insulation in the circuit or instrument under test. In the limited voltage types, a speed slightly above the given rate will ensure that the pressure is kept steady.

51. Careful observation of the results obtained and comparison with previous figures for the same test will often give the operator a clue as to the condition of the circuit or apparatus under test. For instance, if the insulation is damp, the scale reading will fall as the voltage rises; it may then rise as the insulation dries out, or a complete breakdown may occur. Sudden variations in the readings recorded are often due to intermittent sparking between conducting particles on the surface or sometimes on the body of the insulation of the circuit or apparatus tested.

52. Insulation resistance testers are issued sealed, and beyond keeping them clean and dry and handling them with reasonable care on all occasions, nothing can be done to them in the way of repair or adjustment beyond the small points described in this chapter. They are extremely reliable, and what may appear to be faulty functioning is more likely to be faulty operation.

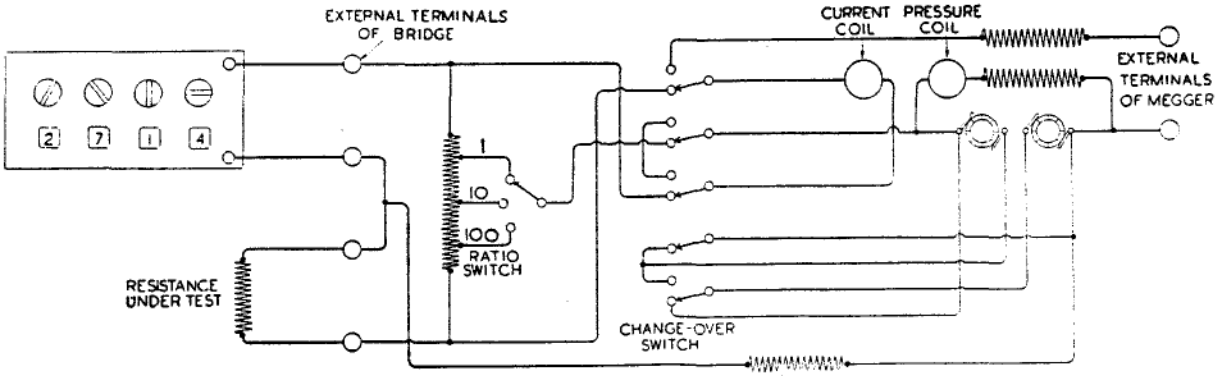


Fig. 11.—Bridge-Megger circuit diagram—resistance measurement

53. The instrument should always be kept in the carrying case provided, as it is unnecessary to remove it from the case when making a test. When it is carried slung from the shoulder, great care should be taken not to knock or jar the tester, which, though robustly constructed, is a delicate mechanism and will be damaged by rough handling.

54. The leads, where provided, are standard length and standard resistance and should be kept dry, free from acute bends, and the insulation kept intact. Any suspicion of break or partial break, any faulty insulation or doubtful fixing to connectors should be given careful attention. Leads cannot be repaired in service, and if a fault or damage should occur they must be returned to stores and a new pair requisitioned.

55. The generators have well-cut gears which run easily in roller bearings. They are protected against the ingress of fine sand and dust, and require attention only at long intervals. This attention cannot be given in Service and if it is suspected that the bearings are not in good order, the instrument must be returned to stores for attention.

56. Before the resistance box is used, the switches should be rotated a few times to ensure the removal of any film of resistance material which may have been deposited by atmospheric conditions.

57. It is advisable to check the accuracy of the testers from time to time by connecting resistances of known ohmic value between the terminals and carrying out the test in the normal way. The readings recorded on the scale of the tester should be correct to within 10%.