DM.19. ISSUE 1.
FEB., - 1949.

NOTE: This Publication cancels leaflet DM.12, Part 1, which is now obsolete.

SMITHS AIRCRAFT INSTRUMENTS LTD.

CRICKLEWOOD WORKS, LONDON, N.W.2.

Installation and Maintenance Instructions

for

Ratiometer Type Thermometers and Combined Temperature and Pressure Indicators

* *For combined instruments this publication should be read in conjunction with publication DM.20.*

THE AVIATION DIVISION OF
S. SMITH & SONS (ENGLAND) LTD.

The information contained in this leaflet which affects the safe operation and maintenance of the instrument(s) has been verified and approved by the Air Registration Board in accordance with Sub-section A.15 of British Civil Airworthiness Requirements.

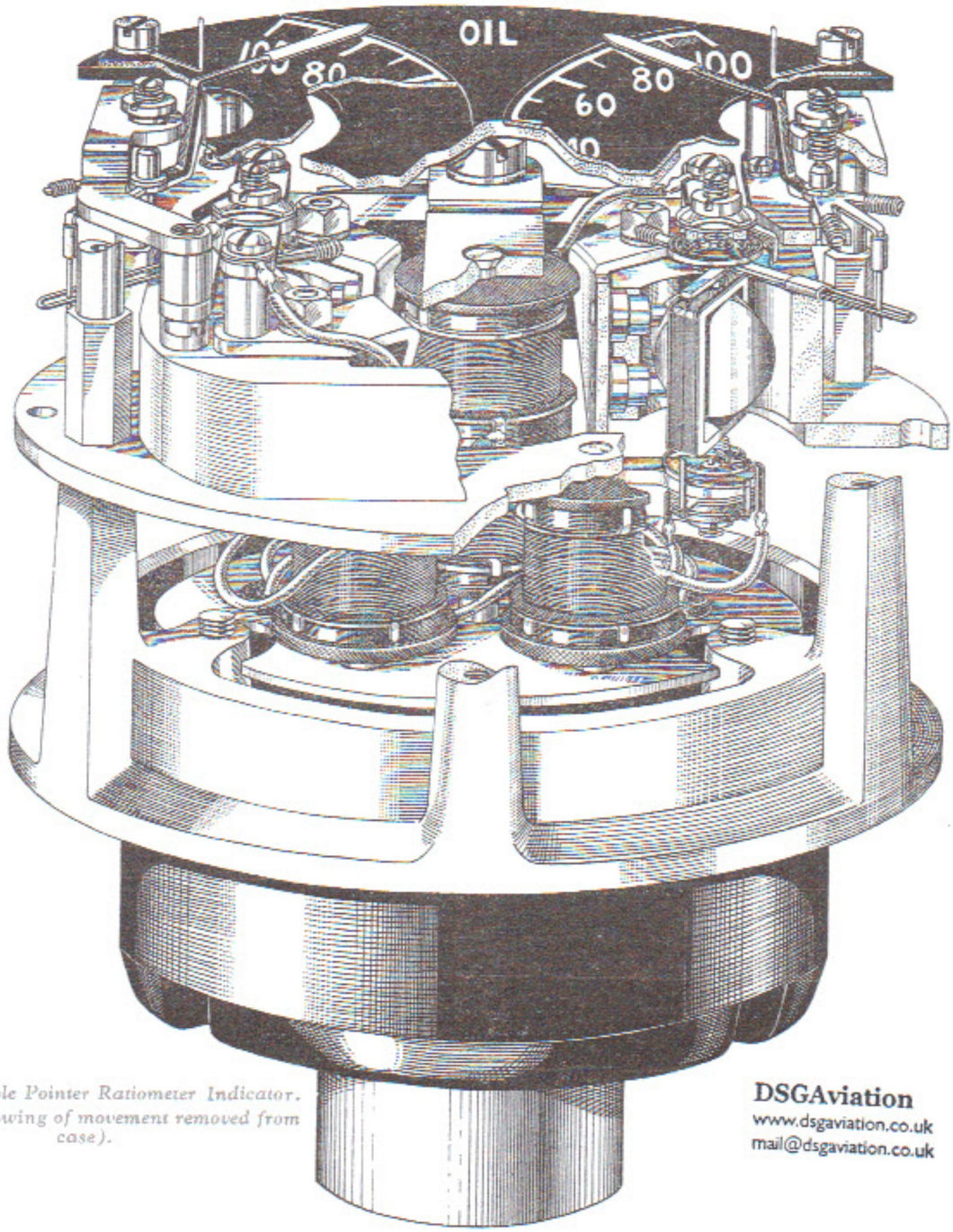
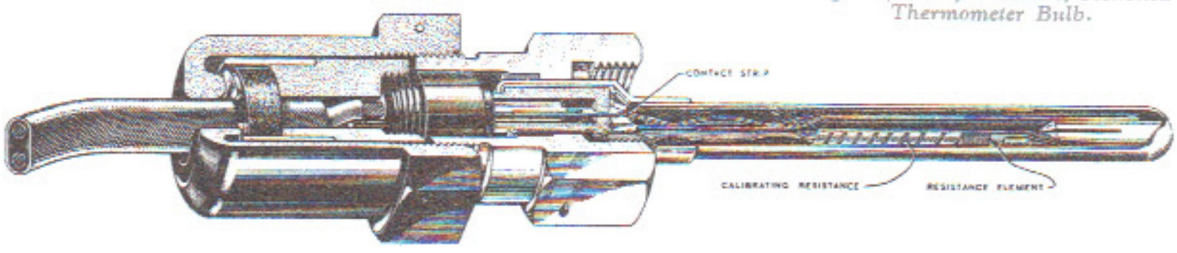


Fig. 1. Double Pointer Ratiometer Indicator. (Sectioned drawing of movement removed from case).

Fig. 2 (below). View of Sectioned Thermometer Bulb.



D.M.19. ISSUE 1
FEB., 1949

SMITHS RATIOMETER TYPE THERMOMETERS AND COMBINED TEMPERATURE AND PRESSURE INDICATORS

Note: This publication cancels leaflet D.M.12 Part 1, Issue 1, which is now obsolete and should be removed from all Manuals.

GENERAL DESCRIPTION

1. Smiths Ratiometer Indicators are remote reading, moving coil instruments used for the measurement of temperature or pressure. The moving element of each indicator consists of two opposed windings pivoted in a non-uniform magnetic field. The arrangement of the windings is such that the position taken up by the moving element, to which the pointer is attached (or mechanically linked), is dependent upon the ratio of the current flowing in one of the windings to that flowing in the other. The construction of the indicator movement is described in para. 6.

2. The circuit is best explained by reference to Fig. 3A in which A is a limiting resistance and B and B_1 the windings of the moving element. These, with their associated calibrating resistances C and C_1, form the two arms of a bridge, the adjustment of which is controlled by an external variable resistance D. The values of the calibrating resistances C and C_1 are set initially so that when equal currents flow through both windings (B and B_1) the pointer takes up a mid-scale position. Any change in the value of D alters the values of the currents flowing in the windings B and B_1, and, due to the graded magnetic field and the crossed windings, the strength of the magnetic field influencing B will differ from that influencing B_1. The moving element therefore takes up a position at which the magnetic torque of B x field strength is equal to the magnetic torque of B_1 x field strength and the system is in a state of equilibrium. The system is designed so as to provide an approximately linear scale and since the movement of the element is dependent on the *ratio* of the currents flowing in B and B_1, the system is theoretically independent of battery voltage. A light control spring is fitted to the movement to bring the pointer off scale in the event of voltage failure. This spring makes the instrument slightly voltage-sensitive.

3. For the measurement of temperatures the external resistance consists of a thermometer bulb with a winding, the electrical resistance of which varies with temperature and it is primarily with this application of the ratiometer instrument that this publication is concerned. The ratiometer may, however, also be used for the measurement of pressures. In this case the pressure medium is made to operate a hydraulic unit mechanically coupled to the brushes of a potentiometer unit. The potentiometer unit is introduced into a slightly modified circuit as shown in Fig. 3B. To conserve panel space ratiometer indicators are frequently made with two separate movements in a single case of international standard dimensions. Both movements may be operated by thermometer bulbs and the dials marked in terms of temperature but dual instruments are also made as combined temperature and pressure gauges with the movements connected, one to a thermometer bulb and the other to a pressure transmitter. For the purposes of description, installation and testing, dual instruments should be regarded as two separate instruments. Information concerning the characteristics and testing of pressure indicating movements of combined instruments and the transmitters with which they are used will be found in publication D.M. 20.

The Thermometer Bulb (Fig. 2)

4. The bulb itself consists of a length of brass tubing closed at one end by a plug carrying a pin projecting into the bore of the tube. The other end is soldered into a hexagonal union nut threaded $\frac{3}{8}$" B.S.P., and terminating in a threaded portion on which a moulded top-cap is fitted. The resistance element is wound on a thin steel tube surrounding the pin in the end of the bulb with

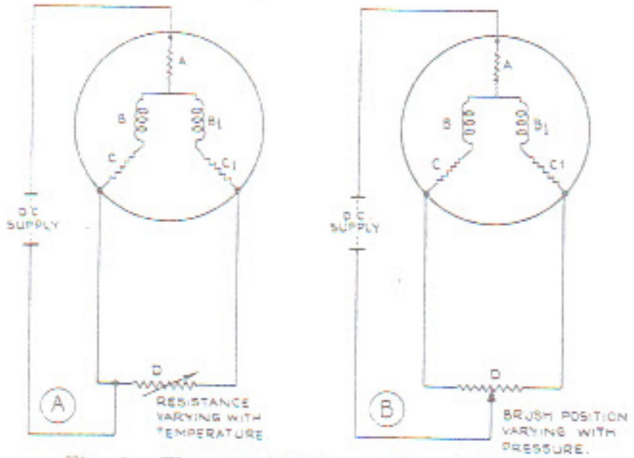


Fig. 3. Theoretical Ratiometer Circuit Diagrams.

a layer of braided glass sleeving interposed. This element is carried at the end of a metal body containing a 2-pin socket. Two contact strips are taken from the sockets and carried down the central former to meet the ends of the resistor winding, a short calibrating resistance being incorporated between one end of the winding and the appropriate contact strip. This calibrating resistance is of Eureka wire, insensitive to temperature changes, and is used to adjust the characteristics of the bulb to a standard law to ensure the interchangeability of units in service. The assembly is completed by a two-pin plug carrying the leads to the indicator, retained in position by the moulded top-cap.

The Indicator (Figs. 4 & 1)

6. The movements fitted in instruments in large and small cases are similar, and have a permanent magnet with circular-shaped pole pieces. The mechanism frame is attached to the magnet and has two jewelled bearings in which the pivots of the moving coil are carried. Projecting from this frame are two short pillars carrying a soft iron core situated in the centre of the coils. The core, as shown in the illustration, is specially shaped to provide a non-uniform magnetic field. Fig. 4 shows the two coils of the moving element at an angle to one another and wound in opposite directions. One end of each coil

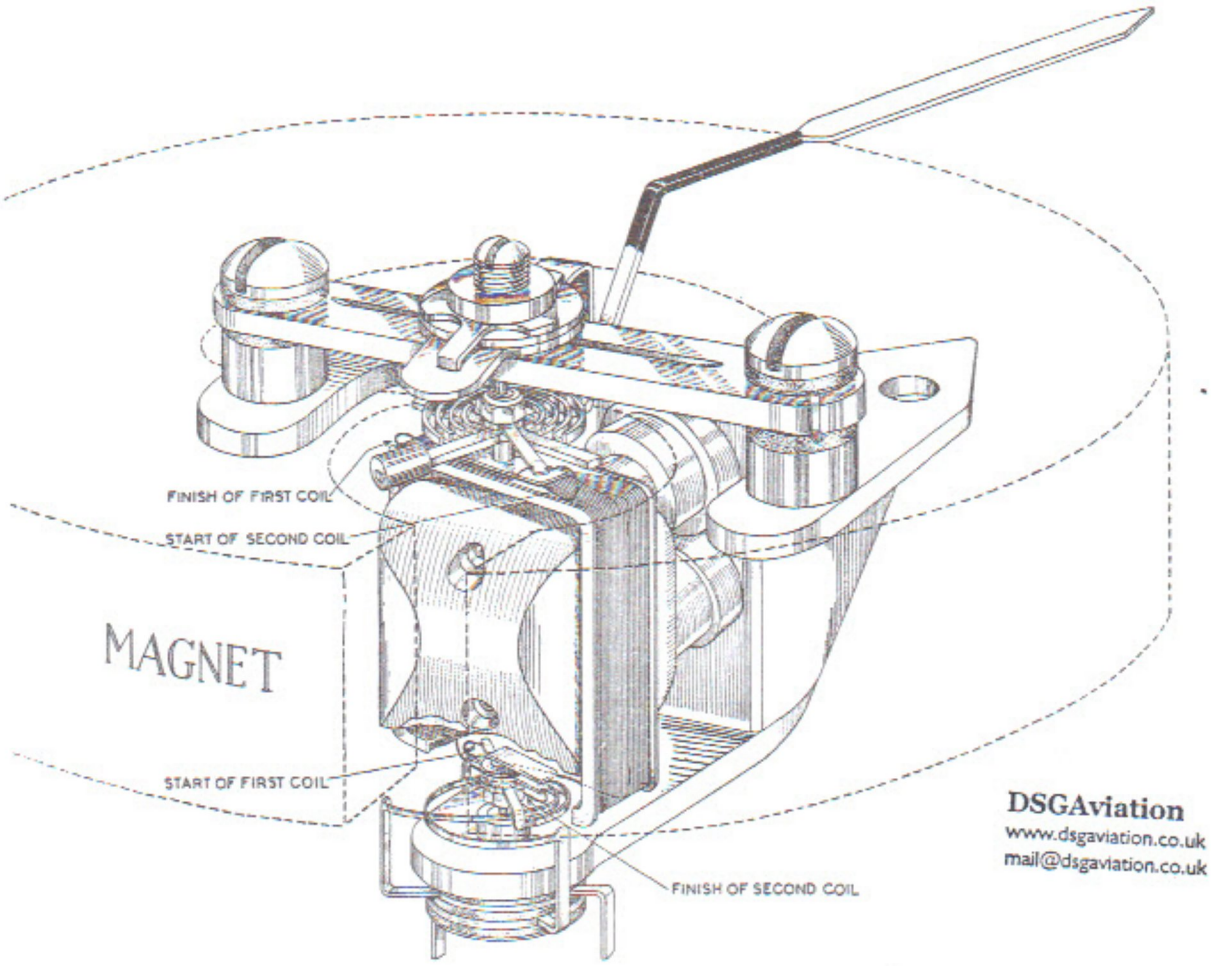


Fig. 4 Details of the movement of a single-pointer Ratiometer Indicator.

5. Two types of bulb are available, *i.e.*, 40 M.V., having a range up to 140° C., and 43 M.V., having a range up to 200° C. All Smiths Thermometer Bulbs are interchangeable and are suitable for use with 12 volt or 24 volt indicators, but obviously it is unnecessary to use a 200° C. bulb with an indicator reading only to 140° C., and similarly, the low-range bulb is unsuitable for the measurement of temperatures beyond its range.

is brought out to a common hairspring which, in addition to returning the pointer off-scale when the windings are not energised, serves as an electrical conductor. The other ends of the coils are connected to the shaped ligaments shown in the illustration. These ligaments are insulated from each other and from the frame, and terminate in tags to which the ends of the calibrating resistances are soldered. The dual instrument (Fig. 1) has two

movements each similar to that shown in Fig. 4, mounted on a common frame with a common magnetic circuit. The instrument pointers, however, are not connected directly to the moving elements, but are operated through linkage mechanisms which magnify the movements of the twin coil assemblies so that the pointers each travel over approx. 180°.

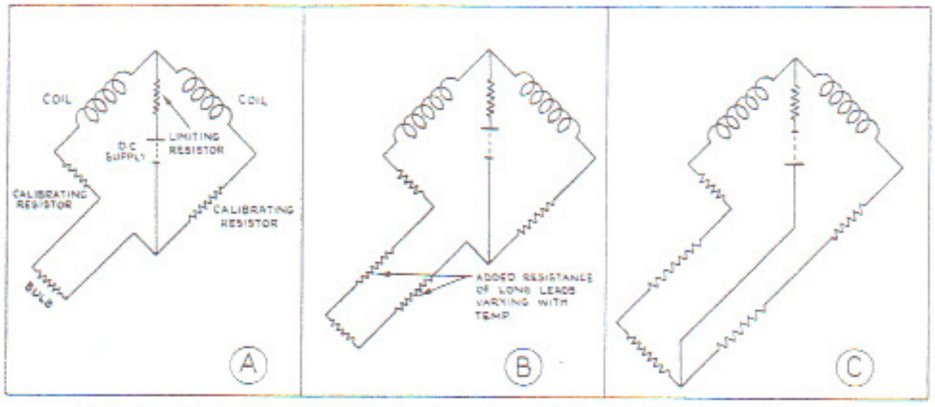


Fig. 5. Theoretical circuit diagrams showing the development of Temperature Compensated leads.

7. In the original circuit as shown in Fig. 5A the D.C. supply is taken to the indicator; the thermometer bulb and the leads between the bulb and the indicator are included in one arm of the bridge. This arrangement has been used for many types of ratiometer temperature indicator but it has been found that on large aircraft where the bulb leads exceed some 20 ft., errors may arise due to changes of the resistance of the leads with varying ambient temperature, as shown diagrammatically in Fig. 5B. To overcome this error, one of the D.C. leads was taken to a point near the bulb, instead of to the indicator (Fig. 5C). In this way, the leads to the bulb appear in two adjacent arms of the bridge and variations in lead resistance due to temperature, being approximately equal in each line, automatically cancel out and do not affect the accuracy of indication. This arrangement (Fig. 5C) has been standardised for the latest types of dual instruments since it is found in practice that dual indicators are most frequently used with long leads. Most of the single instruments are connected as Fig. 5A, but certain single indicators designed for use with long leads are intended for connection as Fig. 5C. A further point regarding dual instruments is that with the combined special instrument code 125 M.V. the D.C. negative lead is taken to the bulb but on later standardised dual types, the positive D.C. supply is taken to the bulb (or transmitter).

8. From the foregoing it will be appreciated that differences exist in the electrical values, the internal wiring and the magnet polarity of ratiometer indicators of different codes and it is important to ensure that when testing and installing instruments, the code is ascertained and the instrument connected accordingly. Wiring diagrams for instruments of all current codes are given on pages 8, 9 and 10.

INSPECTION PRIOR TO INSTALLATION

9. Ratiometer type indicators are delicate instruments and liable to damage by carelessness in storage and transit, and it is recommended therefore, that Indicators and Thermometer Bulbs are functionally tested immediately before installing in aircraft.

10. It is preferable to test the indicator separately for calibration, as described in paras. 19-23 and then carry out a combined check of the indicator and bulb. In this way, any defect which may be encountered may be traced immediately to the appropriate part of the system. If, however, the necessary equipment is not available a satisfactory combined test, as described in paras. 24-26, will suffice.

INSTALLATION

11. All connections between the D.C. supply, the indicator and the thermometer bulb should be in accordance with the appropriate wiring diagram for the indicator code given on pages 8 and 9. Wiring diagrams for combined

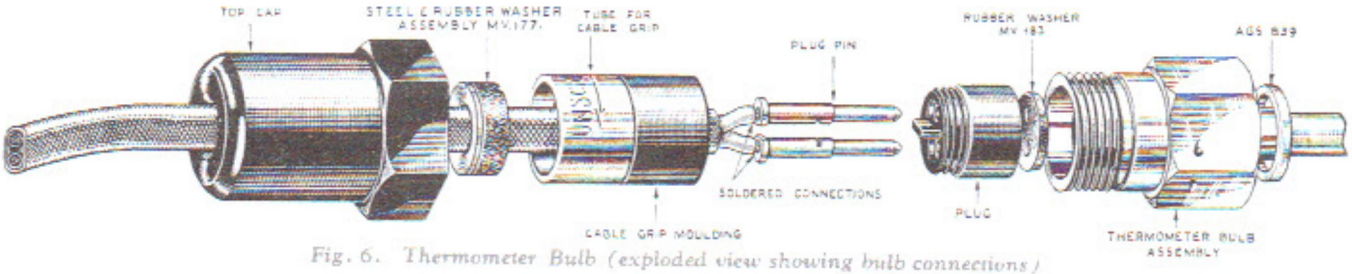


Fig. 6. Thermometer Bulb (exploded view showing bulb connections)

instruments are given on page 10. The order of assembly of the components of the thermometer bulb is shown in Fig. 6, the ends of the cable being soldered to the two contact pins. It is recommended that the rubber washer (Part No. MV. 183) is fixed to the moulding by means of a suitable cement. When the cables have been installed they should be tested for continuity and for good insulation from the aircraft frame.

12. The thermometer bulb is screwed onto the appropriate connection on the engine interposing a washer A.G.S. 839 as shown in Fig. 6 and, after tightening, secured in position with locking wire passing through the drilled hole in the hexagon and round a suitable projection on the engine. Air thermometer bulbs are usually contained in an aluminium plate bolted to the side of the fuselage, but are connected up in a manner similar to that previously described. Details of the installation of pressure transmitters, used in conjunction with combined instruments, will be found in publication D.M.20.

13. Fitting the indicator to the instrument panel necessitates a panel cut-out and four drilled holes as shown in the Installation drawings (pages 11 and 12) and the instrument is secured to the panel, after connecting up the leads, with four 4 B.A. screws which engage the self-locking nuts on the instrument flange.

14. On installation but before the D.C. supply is switched on, the pointer should be off-scale below zero. When the supply is switched on and before starting engines, the pointer should take up a position on the scale according to the temperature of the bulb. Pressure indicators under these conditions should read zero. Oil and Fuel temperature indicators and pressure transmitters should be checked for correct operation during the preliminary engine run.

MAINTENANCE

15. It is recommended that the indicator, the thermometer bulb and, in the case of combined instruments, the pressure transmitter be removed for bench testing at overhaul periods applicable to the engine(s) or airframe. The inspection of single and double pointer thermometer instruments and of the temperature side of combined instruments at this stage should include insulation resistance tests and calibration checks on both the indicator and the resistance bulb. The tests recommended for the pressure side of combined instruments and methods of testing are given under the heading of Maintenance, in publication D.M. 20.

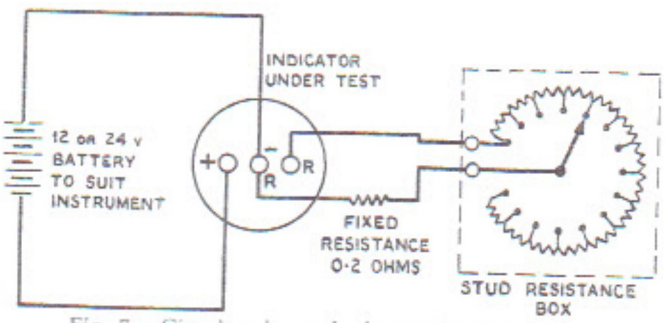


Fig. 7. Circuit to be used when testing Ratiometer Indicators tested in Group 1 (Para. 18)

Insulation Resistance Tests.

16. For these tests, a suitable insulation resistance tester is required (*e.g.*, a "Megger" limited to 500 volts). Applied between either of the two sockets of the thermometer bulb and the metal sheath of the bulb, the resistance at room temperature must not be less than 20 megohms at 500 volts D.C.

17. When making an insulation resistance test on a double pointer indicator, the resistance between any external metallic component and terminal 3 or 4 (plug pin C or D) should first be measured and subsequently between the metallic component and terminal 5 or 6 (plug pin E or F). Single pointer instruments may be tested using any terminal (or any plug pin other than pin B) and the outer magnetic shield. The resistance value in all cases must not be less than 20 meghoms at 500 volts D.C.

Calibration Checks.

18. The introduction of temperature compensated leads and standardised wiring (see paras. 7 and 8) has necessitated the use of two different procedures for testing the calibration of temperature indicators. Indicators can be grouped for testing under their respective codes as follows :—

GROUP 1

Single pointer indicators	Codes : 50 MV., 51 MV., 52 MV., 53 MV., 54 MV., 59 MV., 61 MV., and subsequent single indicators other than those given in group 2 below.
*Double pointer indicators	Codes : 85 MV. and 88 MV.
*Combined Pressure and Temperature Indicators (Temp. Side only)	Codes : 56 MV., 136 MV., 145 MV. and 147 MV.

** NOTE.—When testing the pressure side of the combined instruments or either side of the double temperature indicators listed above it is essential to connect a thermometer bulb or an equivalent resistance to the other side of the instrument. Unless this is done, current will flow through one coil only of the movement*

not under test, causing violent full scale deflection of the pointer which is obviously undesirable.

GROUP 2

Single pointer indicators	Codes 124 MV. and 127 MV.
Double pointer indicators	Codes 125 MV., 149 MV., 157 MV., 158 MV., 176 MV. and subsequent double pointer temperature indicators.
Combined pressure and temperature indicators (Temp. Side only)	Codes 155 MV., 156 MV., 168 MV., 171 MV., and subsequent combined ratiometer indicators.

19. During the tests, indicators should be mounted in the normal position with the dial vertical and should be lightly tapped before taking each reading.

20. Indicators in Group 1 (para. 18) may be checked separately by using a stud resistance box, preferably calibrated in terms of temperature, permitting a series of check readings to be obtained from temperatures well below 0° C. up to the maximum readings on the indicator scale, the whole test procedure being carried out at room temperature. If an accurate stud resistance box is not available, a series of fixed calibrating resistances equivalent to a representative variety of temperatures may be made up and used in turn. The diagram of connections is given in Fig. 7 from which it will be seen that a fixed resistance of 0.2 ohms is placed in series with the stud resistance box or calibrating resistance to represent the average resistance of the twin leads between the bulb and the indicator when installed in aircraft. This fixed resistance may be omitted if the resistance box values or the fixed calibrating resistances employed are increased by an equivalent amount.

21. Instruments in Group 2 (para. 18) may be checked separately in the same manner as that described in para. 20 above, but using a circuit incorporating three separate fixed resistors as shown in Fig. 8.

22. Any thermometer bulb may be checked separately for temperature/resistance characteristics by means of a reference ratiometer indicator (*i.e.*, a master indicator the calibration of which is known) and proceeding as described in paras. 24-26).

23. The table (Fig. 9) gives the resistance value of thermometer bulbs (Codes 40 M.V. and 43 M.V.) at varying temperatures. These values may be used when testing indicators against a resistance box or against fixed resistances.

24. To carry out a combined test of ratiometer temperature indicators listed in group 1 (para. 18) connect as shown in Fig. 7 but substituting the thermometer bulb for the stud resistance box and proceed in the manner described in para. 25 below. To carry out a combined test of instruments in group 2 (para. 18) connect as shown in Fig. 8, and proceed in the manner described in para. 25. In all cases reference should first be made to the appropriate wiring diagram for the indicator code for the actual connections to the indicator terminals.

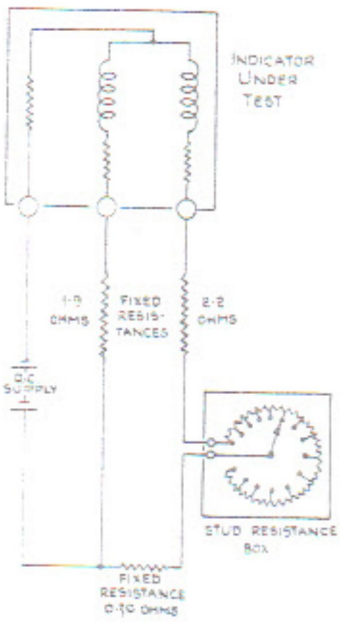


Fig. 8. Circuit for testing indicators in Group 2 (Para. 18)

25. Immerse the bulb in a heated water or oil bath in which an accurate mercury-in-glass thermometer is inserted to measure the temperature. As the instruments are independent of voltage fluctuation, there is no necessity to use a battery giving the exact voltage marked on the indicator case. 12 volt instruments may be tested, using a battery giving between 10 and 14 volts, and similarly, a battery giving between 20 and 28 volts may be used for testing 24 volt instruments.

26. The test is made by heating the water or oil bath to a steady temperature and comparing the indicator readings with those of the mercury thermometer in the bath. It is only necessary for the purpose of pre-installation and serviceability tests, to take readings at two widely spaced points on the indicator scale and the indicator readings should agree with those of the mercury thermometer

Temp. °C.	Ohms.	Temp. °C.	Ohms.	Temp. °C.	Ohms.
−80	58.80	10	94.44	110	145.44
−70	62.28	20	99.00	120	151.20
−60	65.88	30	103.68	130	157.08
−50	69.60	40	108.48	140	163.08
−40	73.44	50	113.40	150	169.20
−30	77.40	60	118.44	160	175.44
−20	81.48	70	123.60	170	181.80
−10	85.68	80	128.88	180	188.28
0	90.00	90	134.28	190	194.88
		100	139.80	200	201.60

Fig. 9. Table of Temperature/Resistance equivalent for Ratiometer Thermometers Indicators and Bulbs.

within the tolerance quoted in para. 27. The indicator should be mounted with the dial vertical during the test, and the instrument should be lightly tapped before readings are taken. The mercury thermometer should be suspended in the bath as close as possible to the thermometer bulb under test. The heated liquid must be constantly stirred to ensure that the temperature measured is equal to that applied to the bulb. The temperature must be maintained at a constant figure for at least ten minutes before a satisfactory check can be made.

TOLERANCES

27. Indicators must be tested at room temperature and at all points on the scale must indicate accurately to within ± 2% of the total scale range.

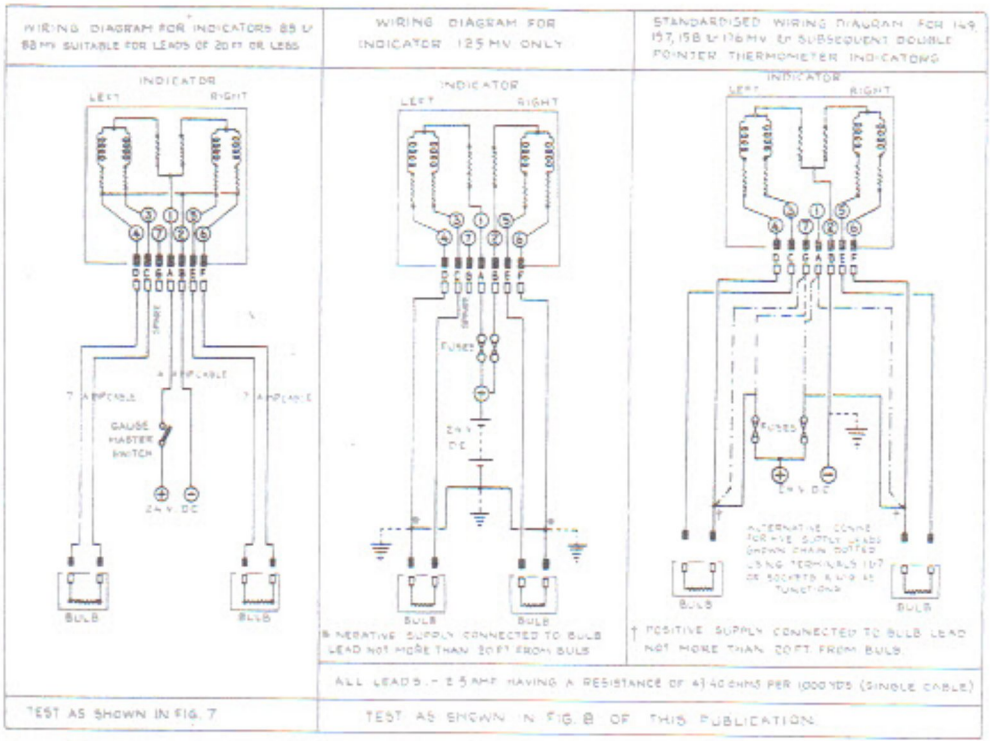
28. The Specification requires the resistance of the bulb to be in accordance with the table (Fig. 9) within ± 0.5 ohms, the checks to be carried out at points between 15° C.-30° C. and between 90° C.-110° C. when passing a current of 5 Ma. The most practical method of carrying out this test is by comparison with a certified substandard bulb and the use of a Wheatstone Bridge circuit. It is found, however, that the temperature/resistance characteristics of thermometer bulbs are not likely to vary from the original calibration unless damage or deterioration has occurred, in which case the error would be of some magnitude.

29. In these circumstances thermometer bulbs may be adequately tested for serviceability by the use of a master indicator (see para. 22). The master indicator should be checked from time to time as described in para. 20.

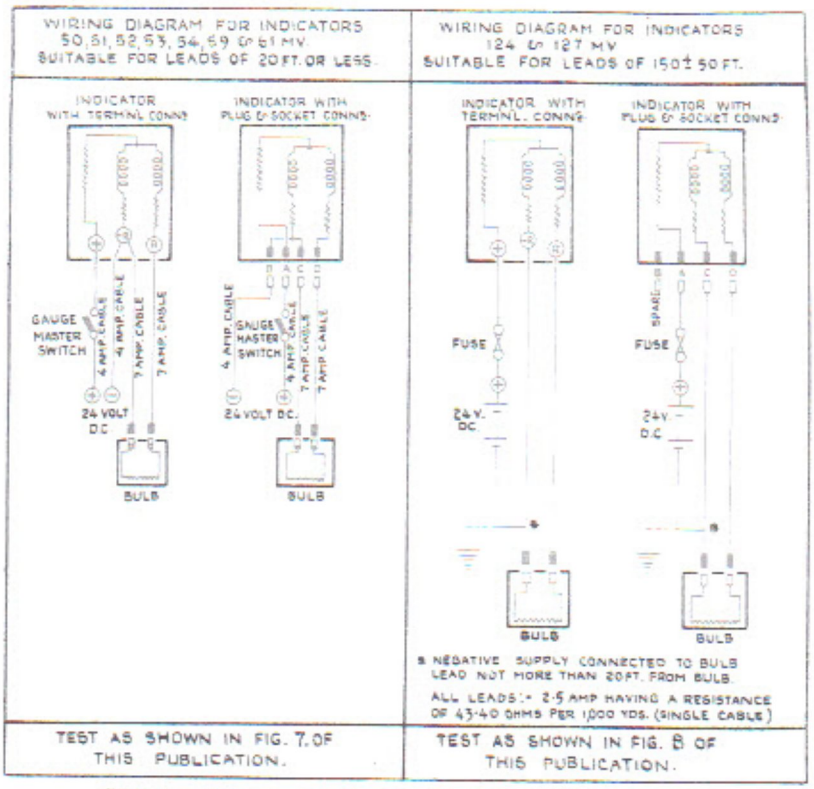
RE-ASSEMBLY OF BULBS AFTER INSPECTION

30. Particular care must be exercised when re-assembling thermometer bulbs with the engine after inspection, to ensure that a new rubber washer (Part No. MV.183) is fitted between the plug and the bulb assembly. The new washer should be cemented in position on the plug before assembly so that it will be withdrawn when the plug is next removed for inspection. It is also recommended that the copper washer A.G.S.839 between the bulb and the union is replaced by a new component to ensure a sound joint.

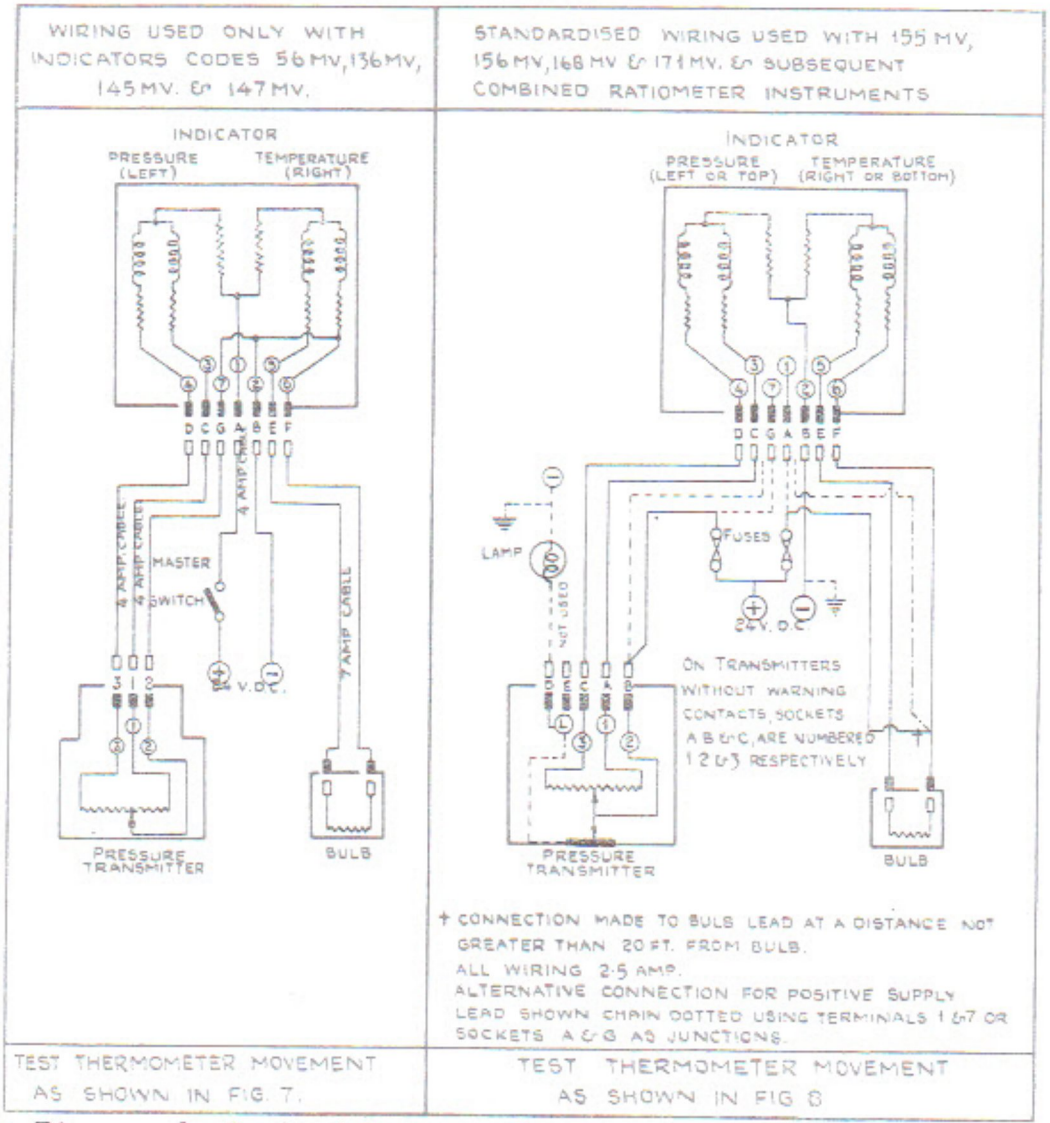
NOTE.—Ratiometer indicators are very delicate instruments and are assembled in an air-conditioned, dust-free atmosphere. They must not, therefore, be dismantled for overhaul unless facilities exist for re-assembly in a similar dust-free atmosphere. In all cases where overhaul is deemed necessary it is strongly recommended that the indicator be returned to the manufacturer or to an authorised repair depot.



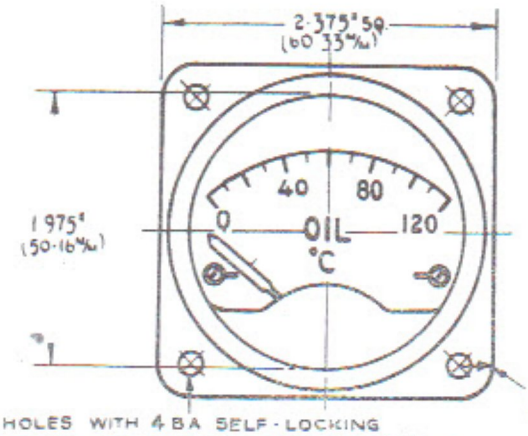
Wiring Diagrams for Double Ratiometer Temperature Indicators.



Wiring Diagrams for Single-Pointer Indicators.

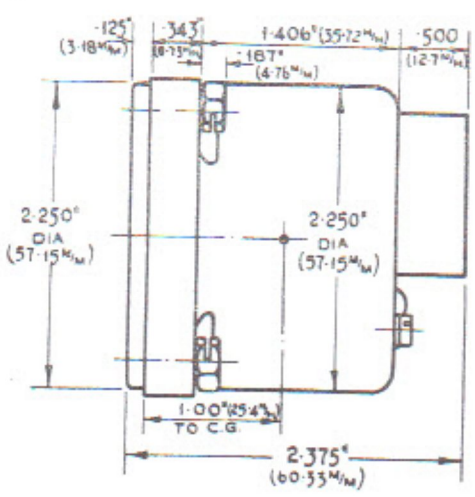


Wiring Diagrams for Combined Ratiometer Type Temperature and Pressure Indicators.

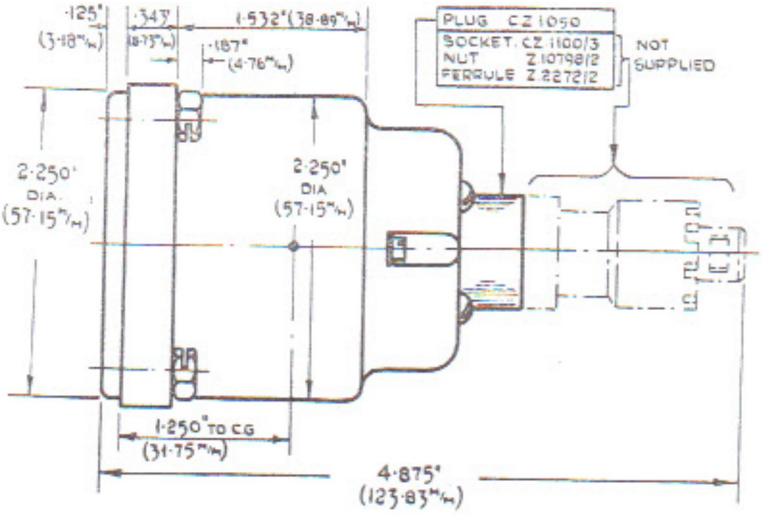


PANEL CUT-OUT
2·281" (57·94 M/M) DIA WITH
4 FIXING HOLES ·161"
(4·09 M/M) DIA (№ 20 DR.)
TO SUIT INSTRUMENT
(HOLES C'SK. 4 B.A.
IF REQUIRED)

4 HOLES WITH 4 B.A. SELF-LOCKING
NUTS EQUISPACED ON 2·625" (66·68 M/M) P.C.D.

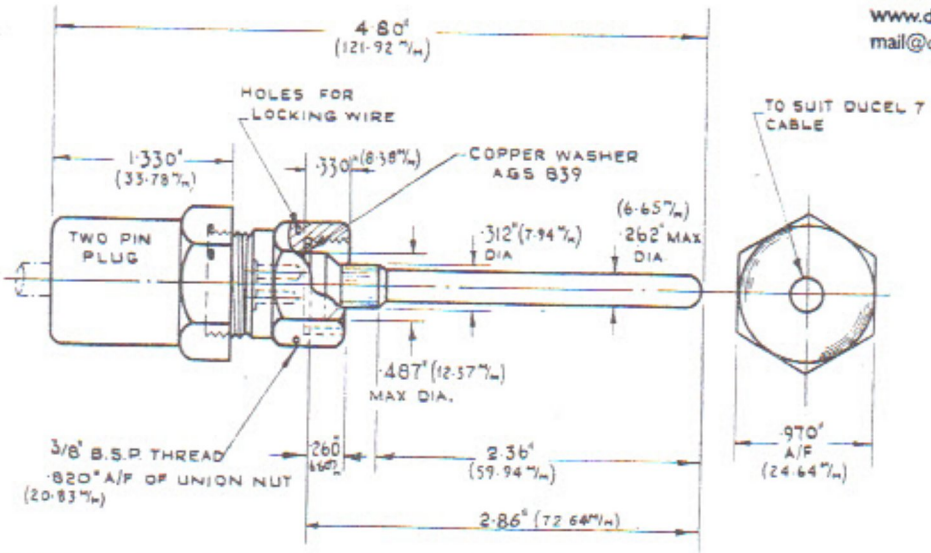


Instrument with Terminal Block

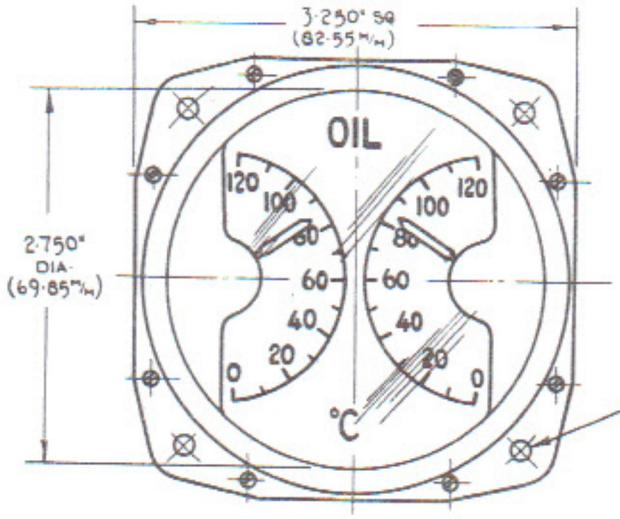


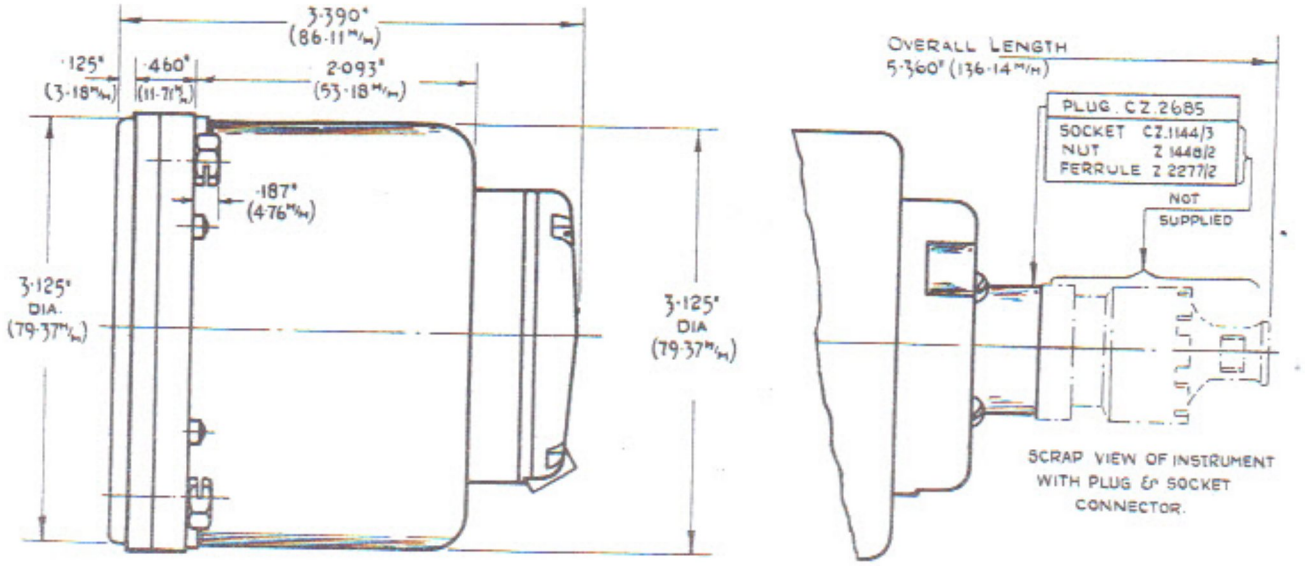
Instrument with Plug and Socket Connection

INSTALLATION DATA FOR SINGLE POINTER RATIOMETER INDICATORS.



INSTALLATION DATA FOR SMITHS THERMOMETER BULBS (40 MV. & 43 MV.)





INSTALLATION DATA FOR DOUBLE-POINTER RATIOMETER INDICATORS.

SMITHS AIRCRAFT INSTRUMENTS LTD.
CRICKLEWOOD WORKS, LONDON, N.W.2.