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TITLE

MACHMETERS

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Mk 1

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Chapter 3

MACHMETERS, Mk. 1 SERIES

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General

1. There are several variations of the Mk. 1 machmeter, and whilst their external appearance may be similar they may be made to different designs whilst conforming to a common specification. In this chapter, therefore, the various instruments of the Mk. 1 series are dealt with separately for each manufacturer.

Machmeters available

2. The following are details of the machmeters in the Mk. 1 series:—

Stores Ref.	Mk. No.	Dial finish	Range	Location of Min. and Max. readings		Scale graduations Min.
				Min.	Max.	
6A/2054	1A	Fluorescent	0·40 to 1·00	7.0 o'clock	6.0 o'clock	0·02
6A/2194	1A*	Fluorescent	0·50 to 1·00	7.0 o'clock	5.0 o'clock	0·02
6A/3154	1B	Fluorescent	0·50 to 1·00	1.0 o'clock	11.0 o'clock	0·02

MACHMETER, Mk. 1A (MECHANISM LTD.)

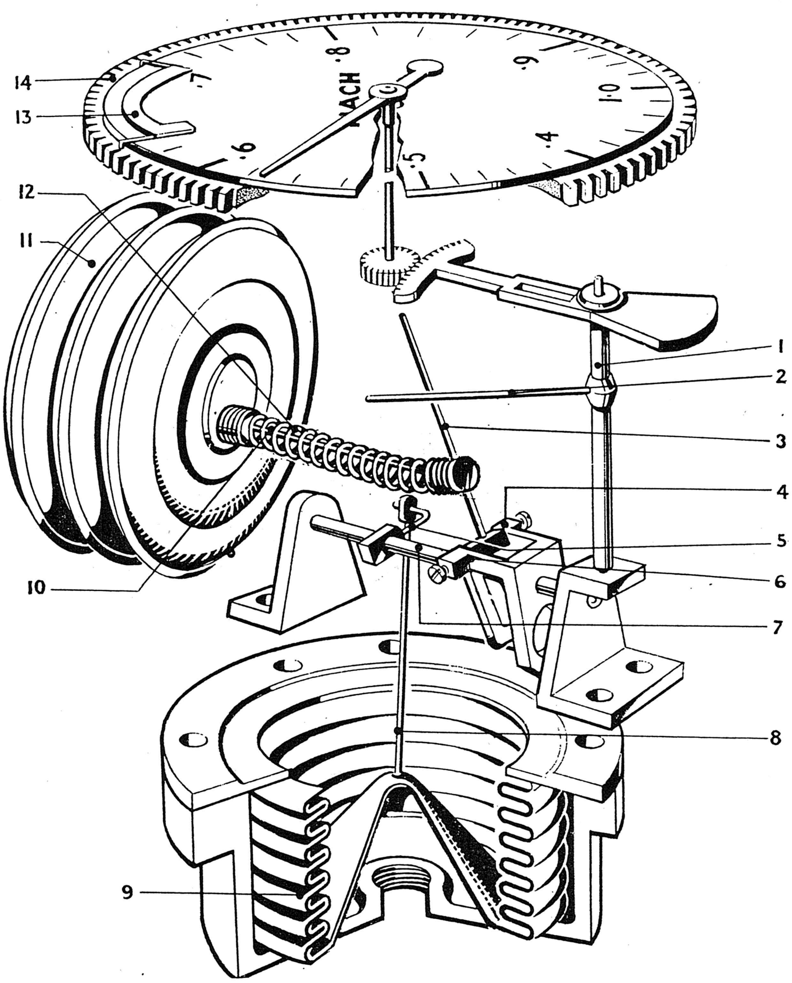
Description

3. The arrangement of the mechanism of the Mk. 1A instrument manufactured by Messrs. Mechanism Ltd. is illustrated in fig. 1. A sylphon (9) is enclosed in a rigid chamber which is connected to air speed (pitot) pressure, and the interior of the case of the instrument is connected to the altitude (static) line. A connecting rod (8) connects the free end of the sylphon to the arm (5) on the main shaft (7), and this shaft carries, at right-angles to its axis, a pair of trunnions (6) which support an arm (3) by way of a block (4).

4. A bank of capsules (11) is evacuated of air and will expand with an increase of height. Movement of these capsules is communicated to the arm (3) by a pin (10). This pin is ball-ended and is located between two hollow bosses, one fixed to the free end of the bank of capsules and the other to the arm (3); a tension spring (12) between this arm and the capsule holds the pin (10) in position.

5. It will be seen that the arm (3) is capable of rotation about two axes, the one about the axis of the main shaft (7) being operated by the airspeed mechanism, and the other about the axis of the trunnions (6) by the altitude mechanism. The upper end of the arm (3) bears on an arm (2), this arm being connected to a quadrant layshaft (1); the arm (2) is slightly bent for the purpose of calibration. The quadrant, fitted to the layshaft, engages with the pinion of the pointer spindle.

6. The combination of the arms (3) and (2) is, in effect, a dividing system which is accurate, provided all angular movements are small, as in this instrument. Referring to the formula in Chap. 2, in which the difference between the pitot and static pressures is to be divided by static pressure, it will be seen that M increases if P-S increases or if S decreases.



1	QUADRANT LAYSHAFT	8	CONNECTING ROD
2	ARM	9	SYLPHON
3	ARM	10	PIN
4	BLOCK	11	CAPSULES
5	ARM	12	TENSION SPRING
6	TRUNNIONS	13	LUBBER MARK
7	MAIN SHAFT	14	TOOTHED PLATE

Fig. 1. Mechanism of machmeter, Mk. 1A (Mechanism Ltd.)

Operation

7. Assuming that a certain air speed pressure has caused a rotation of the quadrant layshaft (1), it will be seen that if this pressure remains constant, a decrease of altitude pressure will cause a further rotation, as required by theory, since the point of contact of the levers (2) and (3) is moved towards the pivot of the quadrant layshaft. These two levers are arranged so that they do not contact each other until a speed of approximately 260 knots (at mean sea level) is attained; this speed is equivalent to a Mach number of 0·4.

8. A lubber mark (13) is fitted and is adjustable as follows. A pinion, housed in the instrument case, is meshed with the toothed plate (14) carrying the lubber mark, the plate being frictionally loaded to, and rotatable around the dial. A screwdriver slot is cut in the top of the pinion, this being accessible from the outside of the instrument case, and rotation of the pinion thus causes the lubber mark to move around the dial.

MACHMETER, Mk. 1A* (MECHANISM) LTD., Type 1415)

9. The machmeter Mk. 1A* manufactured by Messrs. Mechanism Ltd. is illustrated in fig. 2 and 3, and in the following description is considered to be in the vertical position, dial uppermost. The body, or base, of the internal mechanism is a cylindrical shell (16) having a flanged lip at the top for the attachment of the closing plate (17) which carries the main shaft bearing brackets (12) and (27); the closing plate has a central slot in way of the air speed capsule link. The air speed (pitot) capsule is a double bank unit (25) soldered to a threaded and flanged stem (22) which projects through the floor of the body and provides for the attachment of the capsule to the body and the mechanism to the case.

Instrument frame

10. The body closing plate (17), secured to the body with screws, supports three pillars, one of rectangular section (33), and all three pillars are connected at the top by a flat plate (34) on which the pointed pinion is mounted and which provides

PARAGRAPHS 11 TO 22 MISSING FROM ORIGINAL COPY is secured to the bottom of the case for attachment of the static pressure line connector. The pitot and static connectors are marked P and S respectively, and the pitot connection is centrally located.

23. The mechanism is held in the case as described in para. 11, and the case is made pressure-tight when the glass window is fitted. The case has a milled slot on the inside, just above the position occupied by the dial, and a split ring (35) is fitted in this slot. A further ring of angle section (36) sits on the split ring and carries a square-section rubber strip (37) against which the glass window (38) is clamped by the bezel (40). A composition washer (39) is fitted between the window and the bezel, and the case is pressure-tight when the bezel is attached to the case by the securing screws and plate nuts.

MACHMETER, Mk. 1A* (KELVIN AND HUGHES LTD., Type 222/01)

24. The machmeter Mk. 1A* manufactured by Messrs. Kelvin and Hughes Ltd. is illustrated in fig. 4 and is assumed in the following description to be in the normal attitude as installed in an aircraft. Reference to the instrument frame top plate, therefore, will be to the plate forming the front of the instrument frame.

Instrument frame

25. The instrument frame is formed by top and bottom plates (9 *and* 17) connected by three pillars, one of square section (25), one of round section (11) and one of wide, flat section (15), the last being the main post and providing for the anchorage and adjustment of the calibrating spring (14); a central portion of this pillar projects through the top plate. The square-section pillar is spigoted into the end plates and held by screws, but the round-section pillar projects through the top plate (9) to provide support for a secondary top plate (7).

26. The secondary top plate (7) is attached to two studs (30) on the top plate (9) and the extension of the round pillar (11). The sector arbor and pointer spindle are accommodated between the secondary top plate (7) and the top plate proper. The bottom plate (17) is designed to provide for the attachment of the various fittings associated with the air speed nipple secured to the case rear wall.

Air speed capsule

27. The air speed capsule unit (24) is a single capsule anchored to the square pillar (25) by two screws so that adjustment is possible. A copper capillary pipe (21), secured to the lower fitting on the capsule, connects with a series of fittings mounted on the instrument frame bottom plate (17) in such a way that an air-tight connection can be made with the air speed nipple secured to the rear wall of the case. The upper fitting on the capsule takes the form of a stirrup which can support a push-rod.

Air speed linkage

28. The air speed linkage is mounted on the capsule stirrup and consists of a push-rod (23) which carries two brackets, one mounted on the other, the first being capable of vertical adjustment on the push-rod and the second being capable of horizontal adjustment on the first bracket. The second bracket carries an actuating arm (22) through which the capsule movement is transmitted to the resolving shaft and, by virtue of the manner in which adjustments can be made, the amount of movement given to the resolving shaft can be varied to affect the reading of the instrument.

29. The upper end of the push-rod (23) is accommodated in a cup attached to the free end of a calibrating spring (14) which is anchored to the main pillar (15) of the instrument frame. A number of screws (16) in the pillar provide for progressive adjustment of the calibrating spring to increase the resistance to the movement of the air speed capsule, thus altering the range over which the instrument can be set to operate.

Altitude capsule

30. The altitude capsule unit (12) is a double-bank capsule anchored to the round pillar (11) of the instrument frame in a manner similar to that used for the air speed capsule; the capsules are evacuated to obtain a response to atmospheric pressure changes. The acting part of the capsule unit carries a split boss to accommodate a link through which the pulsations of the unit are conveyed to the adjustable arm on the altitude rocking shaft (10).

Altitude linkage

31. The altitude linkage consists of a link (13) attached freely to the capsule unit at one end, and pinned to the altitude rocking shaft at the other, through the medium of an adjustable arm on the shaft. The adjustable arm is shown in fig. 4 adjacent to the link which can be seen close to the split boss on the capsule unit. The arm, shown as a free item in the illustration, is attached to the altitude rocking shaft (10) which pivots between bearings in a bracket fitted to the underside of the instrument frame top plate so that the shaft is parallel to the top plate. The arm is fitted to the upper end of the rocking shaft, as viewed in fig. 4, and a spade fitting is attached to the lower end. The bracket carrying this shaft also accommodates a bearing which supports one end of the resolving shaft.

Resolving linkage

32. The resolving linkage consists of a sliding and rocking shaft carrying two arms, one at each end, and a hairspring. The function of the shaft is to turn in response to movement of the air speed capsule, and to slide in its bearings in response to movement of the altitude capsule, thus resolving the two movements into one which is imparted to the sector arbor.

33. Of the two arms fitted to the shaft, one receives movement from the air speed system and the other actuates the arm on the sector arbor. The precise point on this latter arm at which movement will be imparted is dictated by the altitude unit which, through the linkage described

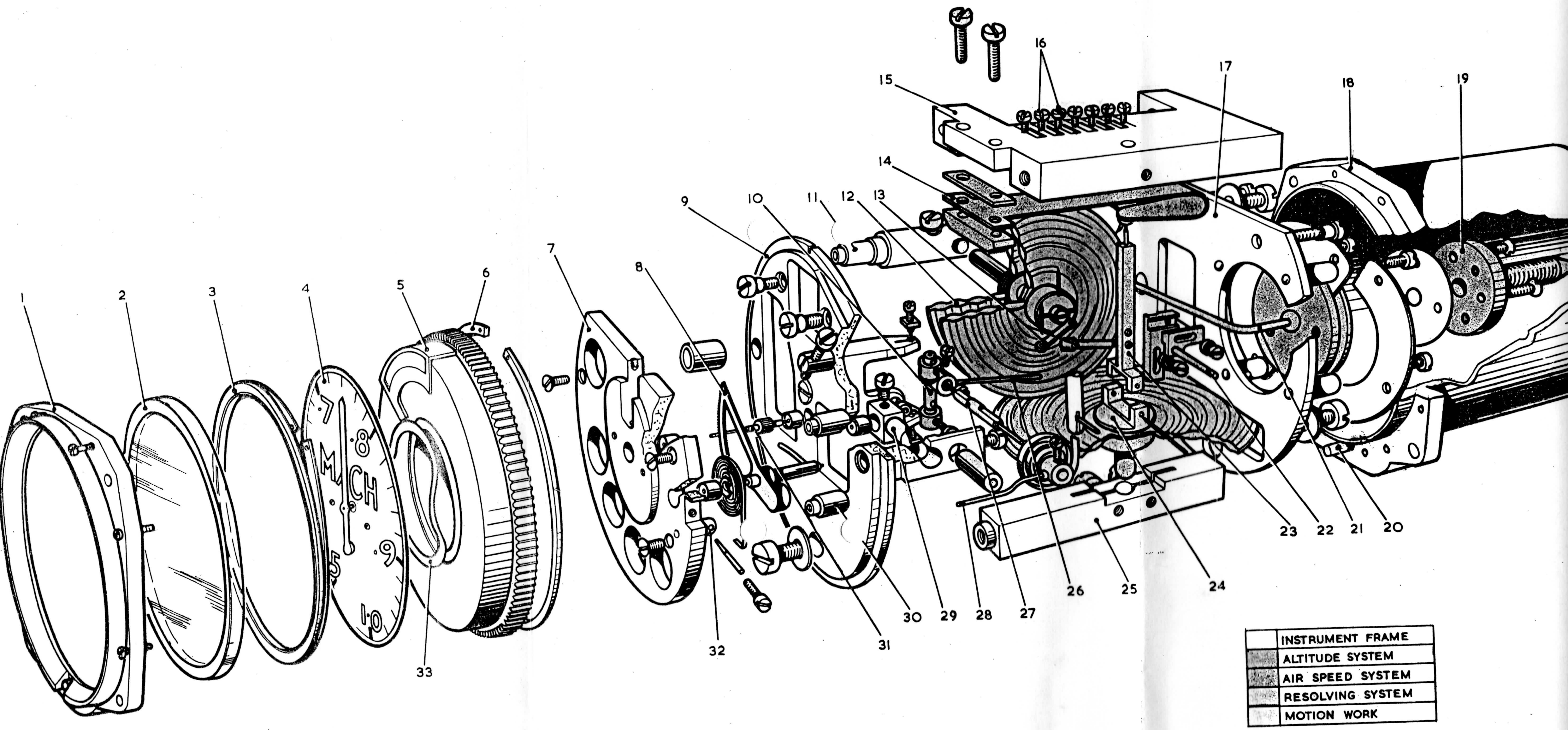


Fig. 4 Exploded view of machmeter, Mk.IA* and IB (Kelvin and Hughes Ltd.)

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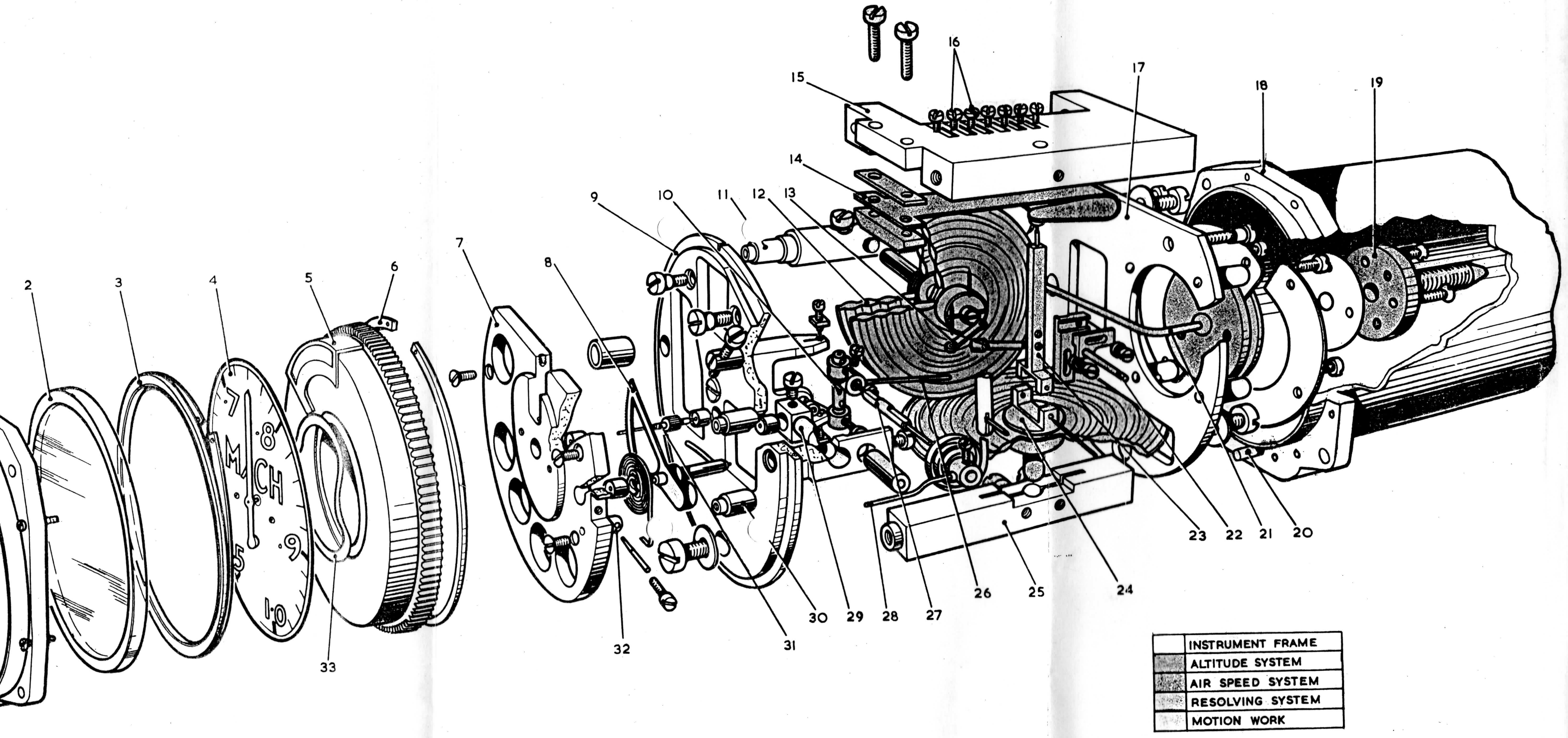

Fig.4

Exploded view of machmeter, Mk.1A* and 1B (Kelvin and Hughes Ltd.)

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(A.L.2, Oct. 56)

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in para. 31, causes the spade to give movement to the end of the resolving shaft, thereby sliding it in its bearings and varying the distance from the axis of the sector arbor at which the movement from the air speed capsule will be imparted.

34. The hairspring ensures that the levers are always in contact, and also maintains a constant end load on the resolving shaft to ensure continual contact with the spade fitting on the lower end of the altitude rocking shaft (10). To do this, the hairspring anchorage post is fitted at an angle of approximately 45 deg. to the axis of the resolving shaft when the post is finally locked in its housing in the main pillar (15) of the instrument frame.

Sector and pointer assembly

35. The sector and pointer assemblies are accommodated between the instrument frame top plate (9) and secondary plate (7). The sector is counterbalanced and is attached to an arbor on which a hairspring is anchored on one side and an actuating arm on the other. The sector engages the pinion of the pointer spindle (31) which projects through a bearing in the secondary frame and carries the pointer. Both sector arbor and pointer spindle turn in adjustable bearings.

Dial plate

36. The dial (*fig.* 2) is engraved for the range 0·5 to 1·0 Mach and, reading clockwise, starts with 0·5 at 7 o'clock. The dial plate is secured by two screws to the instrument frame secondary plate in such a manner that the lubber mark friction plate is trapped when the dial is fitted, and friction loading is applied by a crimped washer (33, *fig.* 4). The edge of the friction plate (5) is toothed to engage the pinion (20) assembled in the instrument case. The outer end of the pinion staff is slotted to facilitate adjustment by means of a screwdriver.

S.A.E. case

37. The S.A.E. $3\frac{1}{4}$ in. case (18) is of black moulded material and has a flanged lip for securing the instrument to the instrument panel. A brass union is fitted to the bottom of the case for the attachment of the static pressure line, and a second fitting (19), to the side of the former, provides for attachment of the pitot line. Both are marked to avoid making wrong connections.

38. The mechanism is held in the case by two snap rings, one to support the sealing ring on which the glass window fits, and the other (6) to hold the mechanism firmly in the case. The latter ring is accessible only after the lubber mark friction plate and crimped washer, etc., have been removed from the case. In addition, the mechanism cannot be removed from the case until the three screws holding the pitot nipple have been removed. Attempts to withdraw the mechanism before these screws have been taken out will result in damage to the capillary tube leading to the air speed capsule.

MACHMETER, Mk. 1B (MECHANISM LTD., Type M.1696)

39. The machmeter Mk. 1B illustrated in fig. 5 and 6 and manufactured by Messrs. Mechanism Ltd. has a mechanism similar to that used in the Mk. 1A* instrument made by the same manufacturer, but the dial has been altered to show the minimum and maximum positions at the top of the instrument, and the pointer pinion assembly has been modified by the introduction of jewelled bearings.

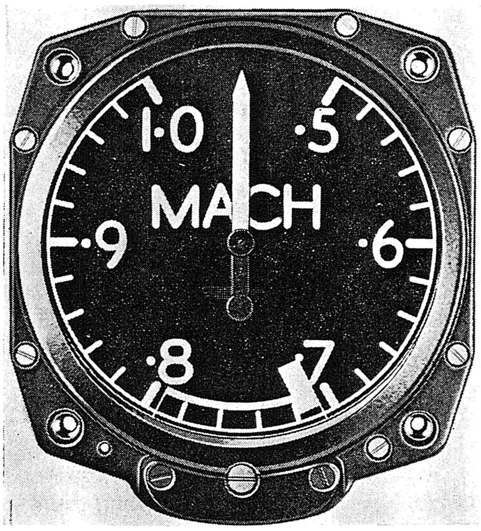

Fig. 5. Machmeter Mk. 1B

40. The dial (*fig.* 5) is engraved for the range 0·5 to 1·0 M, and, reading clockwise, starts with 0·5 at 1 o'clock. The pointer pinion (*fig.* 6) is enclosed in a circular brass housing, the lower half of which is cut away on one side to expose the pinion teeth in the path of the quadrant arm rack. The pinion bottom bearing consists of a ring stone and an end stone at the bottom of the housing, and the top bearing is a ring stone fitted in an adjustable screw locked in the top plate of the housing. The complete assembly is held to the instrument frame top plate by screws, and the pinion spindle extends through the top bearing as a plain tapered shaft on which the pointer is a push fit.

MACHMETER, Mk. 1B (KELVIN AND HUGHES LTD., Type 222/01)

41. The machmeter Mk. 1B manufactured by Messrs. Kelvin and Hughes Ltd. is identical in appearance with that shown in fig. 5, the dial markings having been altered to show the minimum and maximum positions at the top of the instrument, instead of at the bottom as with the Mk. 1A* instrument. The mechanism has not been altered and is identical to that illustrated in fig. 4.

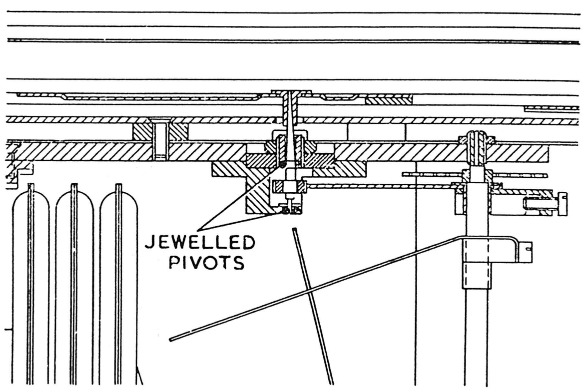

Fig. 6. Pointer pinion assembly Mk. 1B (Mechanism Ltd.)

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Appendix 1

(*Completely revised*)

STANDARD SERVICEABILITY TEST for MACHMETERS, Mk. 1 SERIES

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Introduction

1. The tests detailed in this appendix are to be applied to the above-mentioned instruments prior to installation in an aircraft, and at any time serviceability is suspect. The tolerances specified must not be exceeded.

Test equipment

2. The following test equipment is required:—

(1) Micromanometer, null reading, Mk. 1 (*Ref. No.* 6C/865)

(2) D.P. chamber (*Ref. No.* 6C/1455)

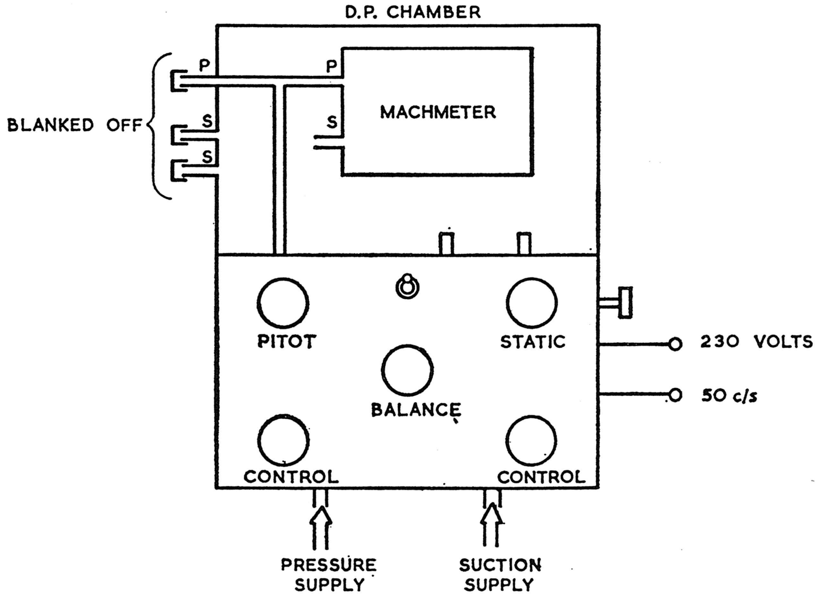

Fig. 1. Layout of test equipment for leak test

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(3) Indicator, air speed, Mk. 15 (*Ref. No.* 6*A*/5967 or 6*A*/5572)

(4) Any altimeter of known accuracy with a range up to 60 000 feet

(5) A locally-manufactured water container.

TEST PROCEDURE

3. Before commencing the testing of the machmeter, carefully calibrate the air speed indicator using the micromanometer as a standard and the data given in Table 2. Compile a ranging chart of exact air speeds obtained at increasing and decreasing pressures, in inches of mercury (London Lab.).

Note . . .
The figures obtained for the ranging chart are to be verified every 14 *days by recalibrating the air speed indicator.*

Leak test—all Mk. 1 series machmeters

4. Set up the test equipment as shown in fig. 1, and make the leak test as follows:—

(1) Set the pitot and static selector valves to A.

(2) Close the balance, pitot and static control valves.

(3) Close and clamp the door of the D.P. chamber.

(4) Switch on the vibrator, and set the pitot selector valve to P.

(5) Slowly open the pitot control valve until the machmeter is reading 0·5 Mach, then close the control valve.

(6) Set the static selector valve to S, then slowly open the static control valve until the machmeter reads 0·52 Mach.

(7) Close the static control valve, and simultaneously start the stop watch. Check that the pointer of the instrument does not fall below 0·5 Mach in less than 15 seconds.

(8) When the test has been completed, switch off the vibrator.

(9) Set the static selector valve at A, and slowly open the control valve.

(10) Set the pitot selector valve at A, and slowly open the control valve.

(11) Remove the machmeter from the D.P. chamber.

Pressure leak test—Mk. 1A* and Mk. 1B machmeter only (*fig.* 2)

5. Set up the test equipment as shown in fig. 2, make the pressure leak test as follows:—

(1) Turn the pitot and static selector valves to A.

(2) Open the pitot and static control valves.

(3) Open both cocks on the micromanometer.

(4) Zero the micromanometer by adjusting the cistern position until the mercury is sighted at the cross wires in the eyepiece, then clamp the cistern in that position.

(5) Using the vernier, make final adjustments to the cistern position.

(6) Turn the manometer main scale to PRESSURE.

(7) Adjust the position of the main scale until its zero is opposite the zero on the PRESSURE vernier.

(8) Close and lock the door of the D.P. chamber.

(9) Switch on the vibrator.

(10) Close the balance, pitot and static control valves.

(11) Turn on the pressure supply external to the D.P. chamber.

(12) Set the static selector valve to P.

(13) Lower the cistern until the zero of the PRESSURE vernier scale is opposite 30·63 in. Hg. on the main scale, then clamp the cistern.

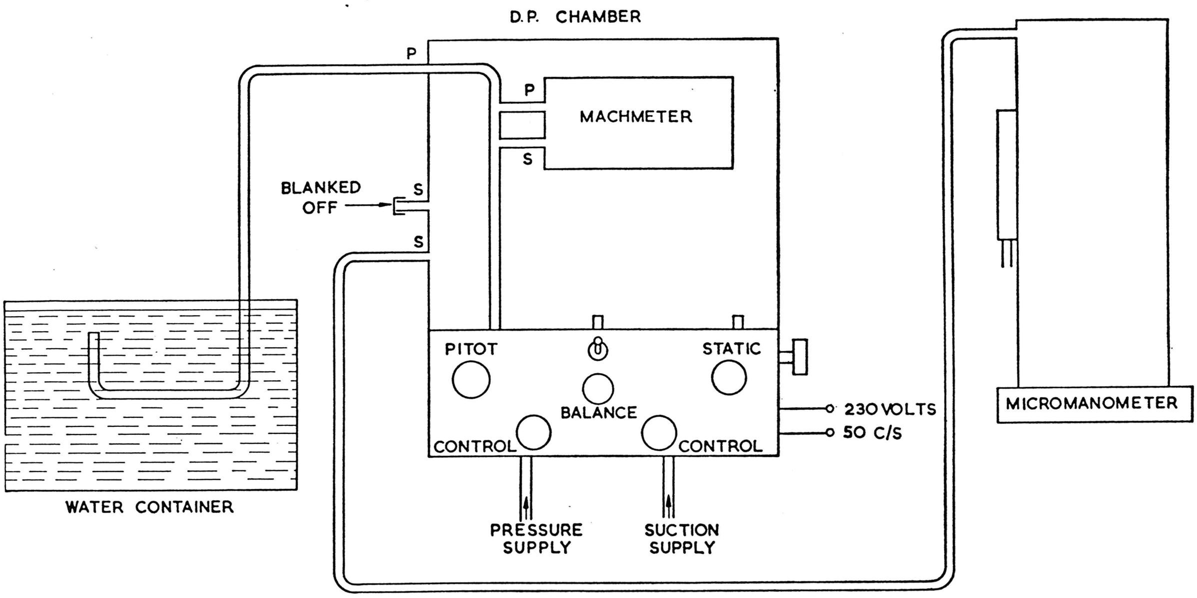

Fig. 2. Layout of test equipment for pressure leak test

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(14) Slowly open the static control valve until the mercury begins to climb up the tube.

(15) Close the static control valve when the mercury meniscus is sighted between the cross wires of the eyepiece.

(16) During operations (14) and (15) check that there is no leakage between zero and 30·63 in. Hg. as indicated by a continuous stream of bubbles from the end of the tube.

(17) After a period of one minute, set the static selector valve to A.

(18) Slowly open the static control valve until the pressure returns to atmospheric. Close the valve.

(19) Remove the machmeter from the chamber.

Ranging tests (*fig.* 3)

6. These tests consist of application of varying air speeds at altitudes of 10 000 and 30 000 feet. Before commencing the tests, set up the test apparatus as shown in fig. 3.

7. Mount the altimeter and machmeter in the D.P. chamber, and connect up the pressure and suction pipes as shown in fig. 3. The purpose of the altimeter is to indicate the approximate altitude when the mercury is not visible in the eyepiece of the micromanometer, and also to provide an immediate indication of loss of pressure.

8. Before commencing the ranging test, adjust the test apparatus as follows:—

(1) Set the pitot and static selector valves to A.

(2) Open both cocks on the micromanometer.

(3) Zero the micromanometer by adjusting the position of the cistern until the mercury meniscus is sighted between the cross wires in the eyepiece, then clamp the cistern. Use the vernier to make final adjustments.

(4) Set the main scale to HEIGHT.

(5) Ascertain the prevailing barometric pressure then adjust the main scale until this value is opposite the zero on the HEIGHT vernier scale.

(6) Lower the cistern until the HEIGHT vernier is opposite 20·62 in. Hg.

(7) Turn the balance control valve to the fully-open position.

(8) Close the pitot and static control valves, then close and lock the chamber door.

9. Test the instrument as follows:—

(1) Switch on the vibrator.

(2) Set the static selector valve to S.

(3) Slowly open the static control valve until the mercury lines up with the cross wires in the eyepiece. Close the valve. The pressure in the D.P. chamber is now equivalent to 10 000 feet.

(4) Close the balance valve.

(5) Set the pitot selector valve to P.

(6) Slowly open the pitot control valve until the air speed indicator reads the corresponding value in knots for the lowest Mach value on the instrument under test. The indicated air speed will be that compiled when the indicator was being calibrated. The approach to the required air speed must be made with care to ensure that the required value is not overshot.

(7) Record the Mach number being indicated, and check that it is within the tolerance shown on the ranging chart.

10. Repeat the operations in para. 9 (6) and (7) until the highest permissible Mach number is reached. Set the pitot selector valve to S.

11. The Machmeter must now be tested at decreasing air speeds, by repeating the operations detailed in para. 9 (6) and (7) with decreasing air speeds.

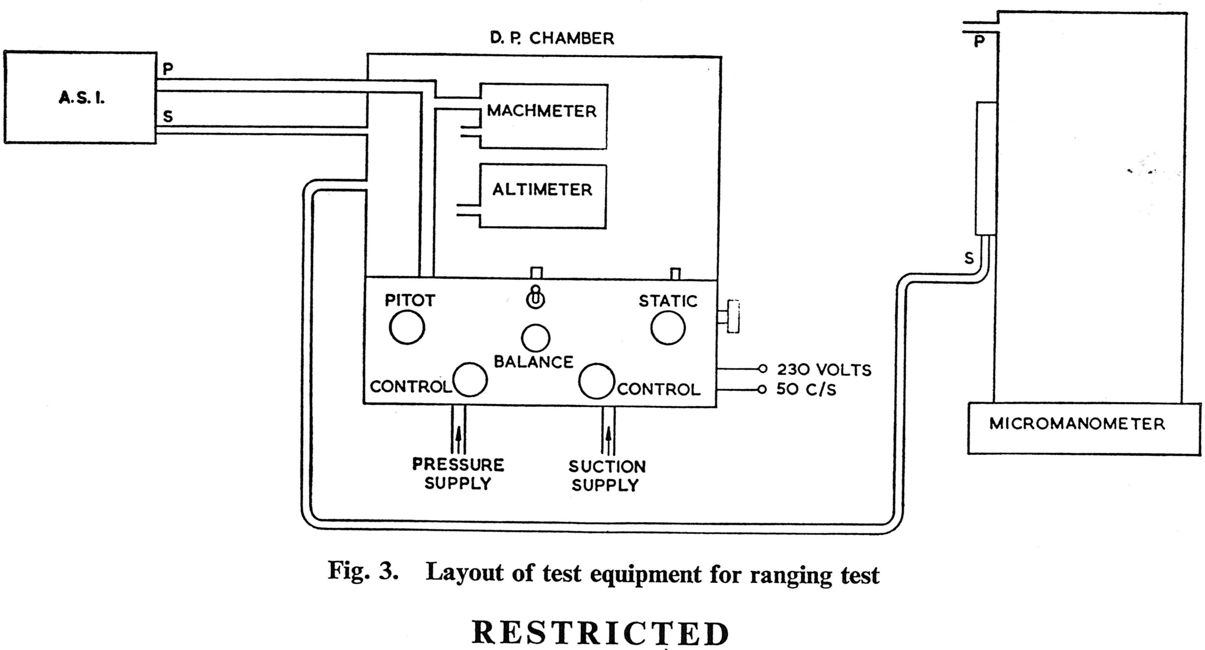

Fig. 3. Layout of test equipment for ranging test

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12. Slowly open the balance valve, then lower the cistern of the micromanometer until the HEIGHT vernier is opposite 8·91 in. Hg. This corresponds to an altitude of 30 000 ft.

13. The ranging tests are to be repeated at this altitude using the operations detailed in para. 9, 10 and 11.

14. After the ranging tests have been completed, slowly open the balance valve. Set the static selector valve to A, then slowly open the static control valve until the pressure falls to atmospheric. The instrument can now be removed from the D.P. chamber.

15. Table 1 shows a suggested chart which can be compiled for the testing of machmeters. The air speed indicator being used as a sub-standard must be calibrated every 14 days. The increasing and decreasing airspeeds listed in columns (2), (3), (4) and (5) would be those obtained during the calibration of the airspeed indicator.

Table 1

Specimen ranging chart

A.S.I. Serial No.:— Tolerance

Date of compilation:—

Mach No. (1)	10 000 ft. Airspeed Increasing (2)	Airspeed Decreasing (3)	30 000 ft. Airspeed Increasing (4)	Airspeed Decreasing (5)	Machmeter, Mk. 1 Serial No. (6)
0·4					±0·02
0·5					±0·01
0·6					±0·01
0·7					±0·01
0·8					±0·01
0·9					±0·02
1·0	NA	NA			±0·02

Table 2

Data for checking sub-standard A.S.I.
(using in. Hg as a reference)

In. Hg	Altitude (feet))	Mach No.	In. Hg	Altitude (feet)	Mach No.
2·40	10000	0·4	1·04	30000	0·4
3·84	10000	0·5	1·66	30000	0·5
5·68	10000	0·6	2·45	30000	0·6
7·99	10000	0·7	3·45	30000	0·7
10·82	10000	0·8	4·67	30000	0·8
14·26	10000	0·9	6·16	30000	0·9
18·42	10000	1·0	7·95	30000	1·0