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CHAPTER 10

MEASURING INSTRUMENTS AND APPLIANCES

LIST OF CONTENTS

LIST OF ILLUSTRATIONS

General

1. The instruments and tools described in this Chapter are in general use throughout the service and, with a few exceptions, present no difficulty in manipulation. Certain instruments demand considerable skill in application, and a short description of each instrument is given to enable personnel to refresh their memories regarding the principles of construction of the instruments before using them. The descriptions and illustrations are not to be taken as authority for dismantling precision instruments. Adjustments should only be undertaken in exceptional circumstances and when experienced personnel and full facilities are available.

2. The accuracy of many contact measurements is mainly dependent upon the human element, i.e. the sense of touch or "feel". The latter can only be cultivated by continual practice in the correct manner of using the instrument. This sense of touch is most prominent in the finger-tips and therefore it is essential that all measuring instruments are held by the fingers wherever possible and in such a way that the finger tips are employed to bring the instrument in contact with the item being measured. It is important to remember that gripping an instrument tightly will greatly reduce the sensitiveness of the touch.

3. Some precision measuring instruments resemble each other in construction but, although they provide they same degree of accuracy, are graduated differently. It is essential that the operator observes certain precautions before using such instruments in order to avoid serious errors when interpreting the scale readings. As an example, some vernier calipers have the main scale marked in fortieths of an inch and the vernier scale marked with 25 graduations, whilst other vernier calipers have the main scale marked in fiftieths of an inch and the vernier scale marked with 20 graduations. (See para. 22.)

4. A large number of measuring instruments incorporate sliding members; the accuracy of such instruments depends upon the sliding member and the stationary member remaining parallel, or in some instances at right angles to one another. Burrs are soon formed on the corners of the slides, etc., if these instruments are allowed to come into forcible contact with other tools; this necessitates great care in handling, otherwise the instruments will give inaccurate results.

5. The majority of precision measuring instruments are originally supplied in cases or boxes and it is very desirable that these delicate instruments should be replaced in their respective containers immediately after use. If the instruments are not in continual use, it is desirable to coat them lightly

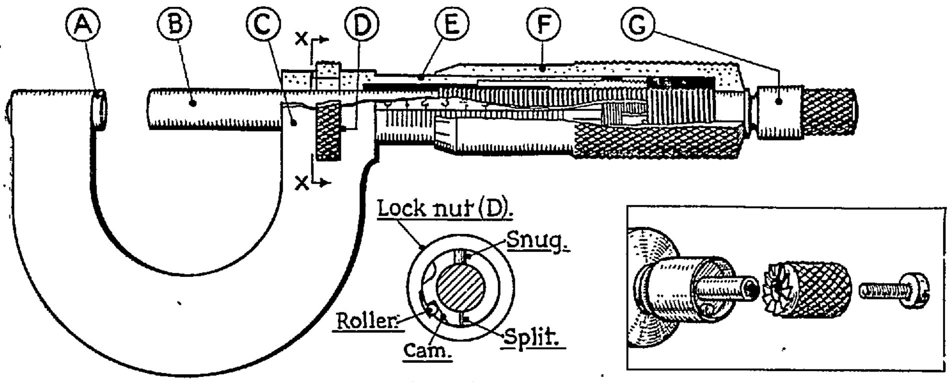


FIG. 1. OUTSIDE MICROMETER.

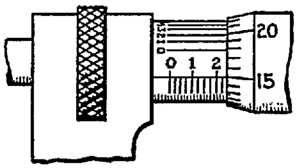


FIG. 2. VIEW SHOWING VERNIER SCALE.

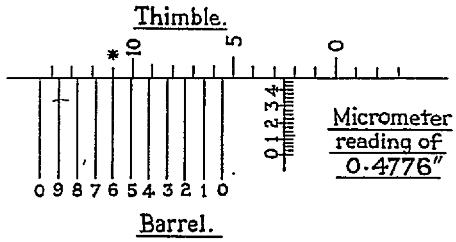


Diagram of vernier scale.

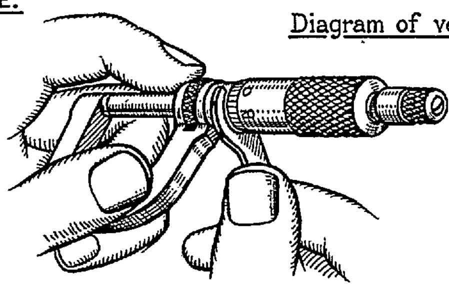


FIG. 3. ADJUSTING MICROMETER.

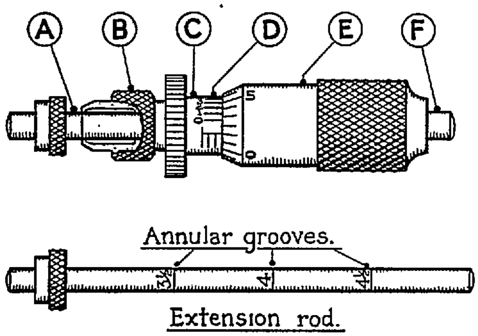


FIG. 4. INSIDE MICROMETER.

Fig. 1 to 4.—Micrometers

with rust preventive or to wrap them in grease-proof paper. The condition of an instrument or tool affects its accuracy; rusty or dirty tools, apart from being unsightly, will not give the same results as those which have been properly maintained. All working surfaces, slides, screws, etc., should be given a few drops of thin lubricating oil to prevent rust occurring and to reduce friction between the working surfaces.

Micrometer calipers

6. The micrometer caliper was originally invented about 1848, and it was first called a "screw caliper". Since that date may modifications have been introduced which have placed this instrument among those universally used where accurate measurements are essential. There are two main types of micrometer caliper, i.e., outside and inside; both types operate on precisely the same principles.

Outside micrometer caliper

7. An outside micrometer caliper is shown in fig. 1 and is used for measuring the external dimensions of an article when the latter is simultaneously in contact with the spindle (B) and the anvil (A). The anvil is mounted in one end of the U-shaped frame (C). The other end of the frame is integral with the barrel (E) on which a thimble or sleeve (F) can slide. Inside the sleeve and fixed to it, is the spindle having a portion of its length screwed with a V-thread of 40 threads per inch. The insi de of the barrel is suitably screwed to form a nut for the spindle which, when the sleeve is rotated, advances or withdraws the spindle to or away from the anvil. By means of a knurled lock-nut (D) the spindle can be locked in any position thereby making the instrument a fixed gauge. By rotating the lock nut, a split bush in the frame is contracted on the spindle, which also keeps the spindle in alignment. The instrument shown in fig. 1 is the English type in which the barrel is graduated longitudinally, in tenths of an inch and further sub-divided into fortieths of an inch. When the thimble is rotated through one complete revolution, the spindle will move a distance equal to $\frac{1}{40}$th (0·025) of an inch, which corresponds to the pitch of the thread on the spindle. The thimble is bevelled at one edge, the circumference of this edge being divided into 25 equal graduations, each fifth graduation being notated 0, 5, 10, 15, 20 respectively. When the thimble is rotated through a single division, the spindle will have moved forward through one-twentyfifth of a revolution or $\frac{1}{40} \times \frac{1}{25}$ of an inch, which equals 0·001 in.

8. It is essential that micrometers should be occasionally checked against the standard test-piece supplied with the instrument, care being taken that the faces of the anvil and the spindle are clean. The test-pieces are hardened and ground to diameters of 1 in., 2 in., 3 in., etc., $\pm$ ·0001 in. according to the size of the micrometer. An alternative method is to close the micrometer, when the zero line on the thimble should coincide exactly with the zero line on the barrel. Slight wear of the screw or nut, or inaccuracy of the instrument, can be generally eliminated by an adjusting device. Some micrometers are provided with a friction sleeve which can be turned by first slackening the locknut to relieve the roller from its cam (see view at X.X.) and then inserting a C-spanner in the recess in the barrel (behind the locknut) and turning the sleeve until the respective zero lines are in agreement—see fig. 3. When using a small micrometer, say one inch, for measuring work, the instrument should be held in one hand so that the first finger and thumb are in contact with the ratchet stop; the frame can be held securely in the palm of the hand by pressure applied by one or more of the remaining fingers, according to the construction of the instrument. This permits freedom of the other hand for holding the work. When measuring larger work, it is desirable that the object should be placed on the bench or marking-out table, or supported in some other manner and thus permit the frame of the larger micrometer to be held by one hand, while the other turns the ratchet stop to obtain the correct measurement. The most satisfactory results are obtained from micrometers having a ratchet stop. This device works on the pawl and ratchet principle (see sketch) and ensures that the object being measured is subjected to a standard gripping pressure. The non-ratchet type of micrometer entails considerable judgment to decide exactly how tightly to screw up the thimble.

9. It is sometimes desired to take readings to a limit of $\frac{1}{10000}$ in. (0·0001) and to do this, a micrometer having a vernier scale is necessary—see fig. 2. As applied to the micrometer, the vernier scale consists of ten divisions on the barrel, the sum of these divisions being equal to nine divisions on the thimble. To read the scales shown in the diagram adjacent to fig. 2:—

(i) Count the number of tenths of an inch on the main scale, i.e. 4 ... ... = 0·400 in.

(ii) Count the number of fortieths of an inch on the main scale, i.e. 3 ... = 0·075 in.

(iii) Count the number of thousandths of an inch on the thimble, i.e. 2 ... = 0·002 in.
The reading less the vernier scale ... ... = 0·477 in.

(iv) Add the vernier reading. It will be observed that the 6th line coincides with a line on the bevel scale. To the reading obtained in operations (i) to (iii) must be added $\frac{6}{10000}$ in. which will make the total reading of the scales in the diagram equal to 0·4776 in. For further explanation of the vernier scale—see para. 23.

Inside micrometer

10. The usual form of inside micrometer is shown in fig. 4. The instrument consists of a barrel (C) with one screwed end, on which is mounted a knurled nut (B) machined to form a split collet, the other end being bored and threaded to take the spindle. The thimble (E) and spindle (A) are similar to those of the outside micrometer, but the outer end of the thimble is machined down to form an anvil (F), the latter being hardened. The extension rods supplied with each inside micrometer are graduated by a series of annular grooves at ½ in. intervals, the latter being machined of a form and depth into which the clamping jaws of the collet (B) can spring. Care must be taken when inserting these rods that they are held by the clamping jaws in contact with the grooves, or the readings of the instrument will be incorrect. If the operation is done carefully, the closing of the jaws will be indicate by a soft click when they have entered the groove. These rods are hardened to obviate wear at their ends. Some inside micrometers are graduated with a vernier scale (D) similar to the outside micrometer and permit readings to be taken with an accuracy of 0·0001 in.

Three-point inside micrometer

11. This instrument, shown in fig. 5, is made in two types, i.e., English and metric and is used for measuring the internal diameters of circular sectioned orifices such as bores of cylinders. Each type of instrument is similar in construction but differs from the usual type of inside micrometer in that it ensures a true measurement of the bore of the orifice being obtained.

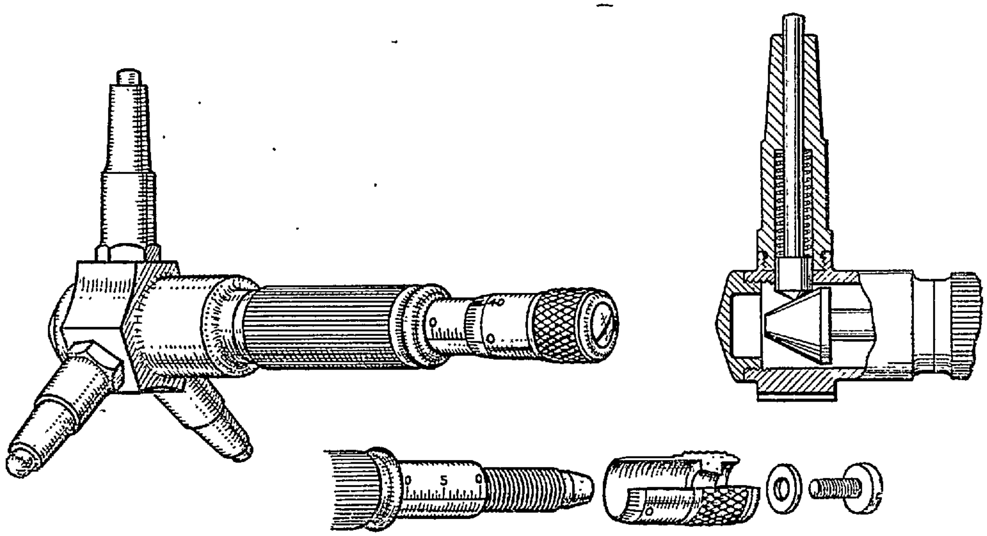


Fig. 5.—Three-point inside micrometer and details

12. The instrument consists of a stock and barrel in which a spindle is advanced or withdrawn by the rotation of a thimble in the usual manner. At one end of the spindle is a hardened cone on which bear the coned ends of three hardened steel plungers, set at 120° from one another and in the same plane. The plungers are kept in contact with the spindle cone by means of springs. As the spindle advances or withdraws an equal amount of movement is transmitted to each of the plungers. In the metric type, each plunger is advanced or retracted 0·25 mm. and as a result, the bore measurement is increased or decreased 0·5 mm. for each complete revolution of the thimble. The circumference of the bevelled edge of the barrel is divided into 50 equal divisions which permits readings having an accuracy of 0·01 of a millimetre to be obtained.

13. The metric type of three-point micrometer has a maximum range of ten millimetres, e.g., from 110 to 120 mm., and the English type has a maximum range of half an inch, e.g., from 2½ in. to 3 in. To provide greater ranges of measurement, alternative sets of plungers are supplied with the instrument and may be substituted for those originally fitted by unscrewing the housings. The plungers of each set are marked with the range of measurement that they cover, and it is essential

that they should be fitted as sets and also that the housings should be screwed up to their shoulders in their proper positions to give correct readings. The markings on the plungers must be taken into consideration together with the micrometer reading when determining the total reading of the instrument.

14. When using the instrument, two plungers are held against the wall of the orifice whilst the other plunger is brought up to the surface under measurement by turning the thimble. The same sense of touch, i.e., "feel" is required for the operation of this instrument as is needed for the more common type of micrometer.

15. Periodic checking for accuracy is desirable; any error can be adjusted by removing the screw at the end of the barrel, which will permit the latter to be removed and re-mounted in another position on its cone. Should the instrument become sluggish in its action, the fault may be rectified by removing the conical nut screwed in the end of the stock and applying thin machine oil or preferably clock or typewriter oil to the coned surfaces.

Cylinder gauge

16. Fig. 6 shows an instrument which is used for measuring the amount of ovality or machining errors in cylinder bores and similar work. The gauge consists of a T-shaped head or anvil in which

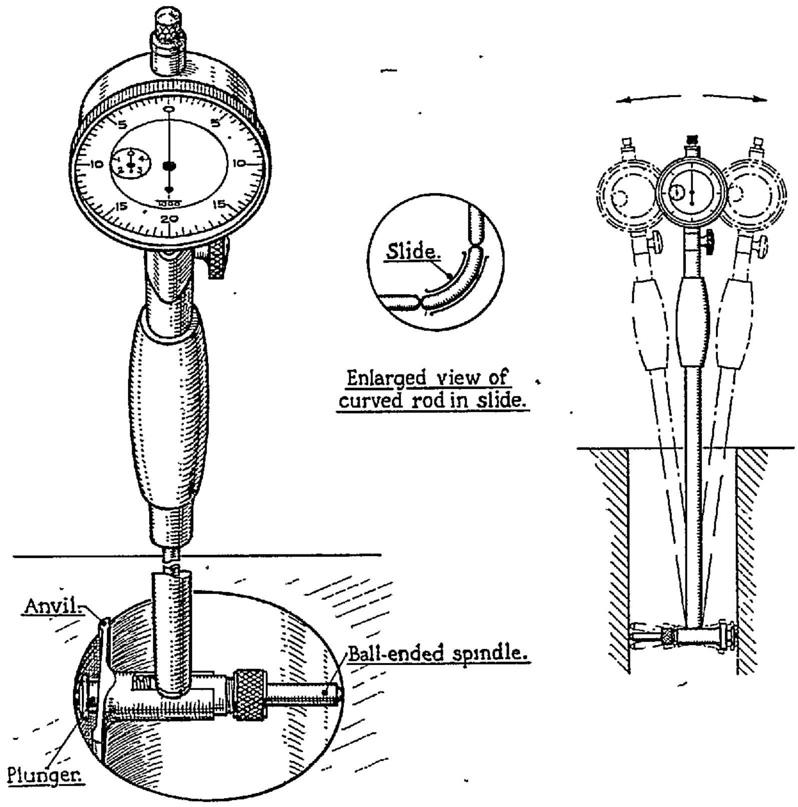


Fig. 6.—Cylinder gauge

a plunger, controlled by a spring, can be moved laterally. Inserted in each end of the plunger are spindles, one of which has a ball point and is located by means of a knurled nut, and the other is moveable and controlled by a light spring acting upon a collar which gives it a sensitive action. This ensures that internal measurements are taken across the diameter, and not across a chord of a circle within the range of the instrument.

17. Mounted at right angles on the plunger is a long hollow stem in which a rod extends throughout its length. The lower end of this rod bears against one end of a small curved rod, and

the upper end provides a point of contact for a dial indicator. The curved rod embraces an arc of approximately 90° and is controlled by a curved slide. The lower end of this rod bears against the inner end of the movable spindle. These three components are maintained in contact with each other by spring pressure, so that the movement is free from backlash and sliding contacts, which may give rise to errors as wear takes place. Any lateral action of the movable spindle will be directly transmitted to the upper end of the long rod.

18. Owing to the use of the curved rod for transmitting the movement, the range of the instrument, without changing the fixed spindle, is limited; the actual amount is approximately $\frac{50}{1000}$ in., or one-twentieth of an inch. Before using the instrument a dial indicator is mounted on the end of the stem, the contact point of the indicator being pushed in until it bears against the upper end of the long rod. A split collar and setscrew is provided to keep the indicator rigid. To permit the instrument to be used over a range of diameters, a set of spindles of various lengths is supplied together with a set of washers.

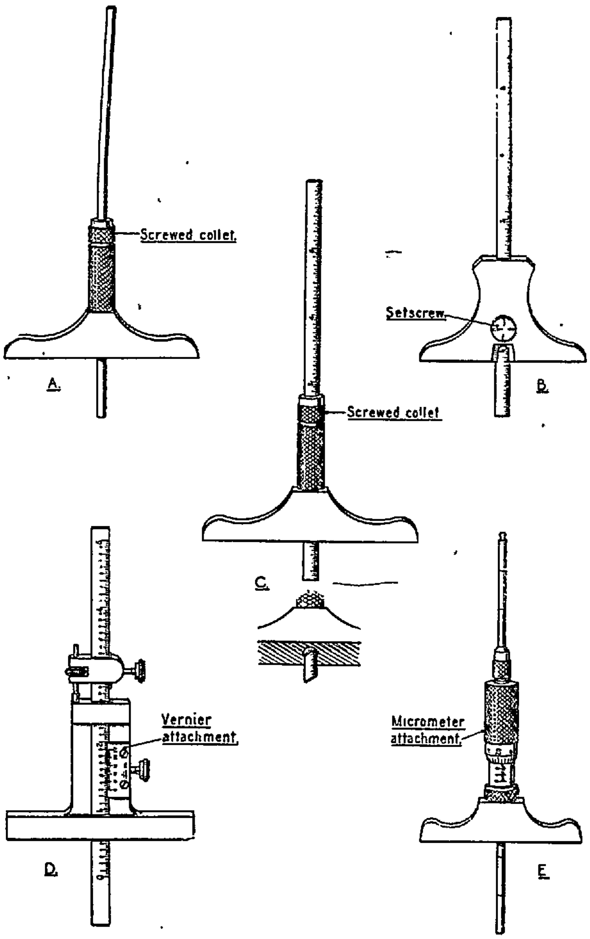


Fig. 7.—Depth gauges

19. *Method of using the instrument.*—First select a spindle appropriate to the bore to be measured and insert it in the end of the anvil. Next, adjust an outside micrometer to the "new size" as stated in the schedule of fits and clearances, if it happens to be an aero-engine part, or to the "lower limit" as stated on the drawing. The contact points of the instrument should then be placed between the jaws of the micrometer so that the spindle of the former is depressed say $\frac{20}{1000}$ in. and the knurled rim of the dial indicator turned so as to be reading at zero. Carefully disengage the micrometer. After this adjustment has been effected, the instrument should be inserted in the bore of the object to be measured, as shown in fig. 6. By moving the instrument up and down the the bore, a fluctuating reading will be observed on the dial according to the irregularities of the bore. A rocking movement should be given to the instrument just before readings are being taken, as shown in the dotted

vernier scale being equal to $\frac{19}{20}$ths. of one division on the main scale, i.e., $\frac{19}{20} \times \frac{1}{50}$th of an inch, the difference between the width of one division on the main scale and one division on the vernier scale is therefore $\frac{1}{1000}$ of an inch. If the zero line on the vernier scale is set exactly opposite to the zero line on the main scale, then the 5 line will be $\frac{5}{1000}$ in. from the 5 line on the main scale. This difference will increase throughout the main scale until the 20 line is exactly opposite the 19 line on the main scale. It is evident that any number of thousandths increase over the zero setting will bring that particular number on the vernier scale into line with a corresponding division line on the main scale.

To explain how to read the vernier, a concrete example is taken—see sketch I of fig. 9:—

(i)	Count the number of inches on main scale, i.e., 3	= 3·000 in.
(ii)	Count the number of tenths of an inch on the main scale, i.e., 5... ...	= 0·500 in.
(iii)	Count the number of fiftieths of an inch ($\frac{1}{50}$ in. = ·02 in.) on the main scale, i.e. 2	= 0·040 in.
	Total	= 3·540 in.

Therefore the jaws of the caliper are opened 3·540 in. plus the vernier reading.

(iv) Use a magnifying glass and carefully ascertain which line on the vernier scale most nearly coincides with a line on the main scale; in the illustration, this is line 6 as marked by the two stars. This represents $\frac{6}{1000}$ths of an inch (0·006 in.) which must be added to the sum of the readings previously obtained. The caliper jaws are therefore opened 3·546 in.

24. Some vernier scales are divided into inches, tenths and fortieths of an inch. The vernier scale in this case has 25 graduations equal to 24 divisions on the main scale. An example of this system of calibration is given in sketch II of fig. 9. The method of reading this scale is as follows:—

(i)	Count the number of inches on the main scale, i.e., 2	= 2·000 in.
(ii)	Count the number of tenths of an inch on the main scale, i.e., 5 ...	= 0·500 in.
(iii)	Count the number of fortieths of an inch ($\frac{1}{40}$ in. = ·025 in.) on the main scale, i.e., 3	= 0·075 in.
	Total	= 2·575 in.

Therefore the jaws of the caliper are opened 2·575 in. plus the vernier reading.

(iv) Add the vernier reading—the 12th line on the vernier coincides with a line on the main scale (two stars mark this position in the illustration) = 0·012 in. The caliper jaws are thus opened 2·587 in.

Universal scribing block

25. This tool is shown in fig. 10, and consists of a heavy base having V-shaped grooves accurately machined in its under surface and at the front end to enable it to be used against circular work as well as on flat surfaces. Two small push pins are fitted in the base which on being pressed downwards protrude through the bottom face so that the base can be located against a machined edge. A rocking bracket is pivoted to a spindle on the top of the base. The bracket, which is retained in a groove machined in the upper face of the base, can be raised or lowered by means of an adjusting screw fitted at the end of the bracket. A stiff spring is placed under the bracket, at the rear end, to prevent undesired movement. Mounted on the bracket is a rotating head having a spindle at one end and a screwed portion and knurled nut at the other end. Fitted on the spindle end is a sliding sleeve. A hole is drilled through the head and sleeve to take a long spindle. It will be observed that when the knurled nut is tightened up it draws the spindle through the sleeve thereby clamping the long spindle. A sliding attachment comprising a clamp, screw and nut is mounted on the spindle and a double pointed scriber passes through the clamp. The scriber is locked in a manner similar to the arrangement on the rocking bracket. For small work the spindle may be removed and the scriber inserted in its place. It will be seen that the scriber can be set in any position within the range of the tool. Fine adjustment is provided by the adjusting screw.

V-blocks

26. There are numerous types of V-blocks in use throughout the service, many of which have been made locally to suit special requirements—see sketches I and II of fig. 11. In this A.P., other forms of V-blocks may be suggested which can be made up by units to assist them in carrying out a specific operation. V-blocks are made of close grain cast iron. The standard V-block is shown in sketch III of fig. 11. All standard V-blocks are originally made in pairs, and it is essential that they should be suitably marked to avoid mixing.

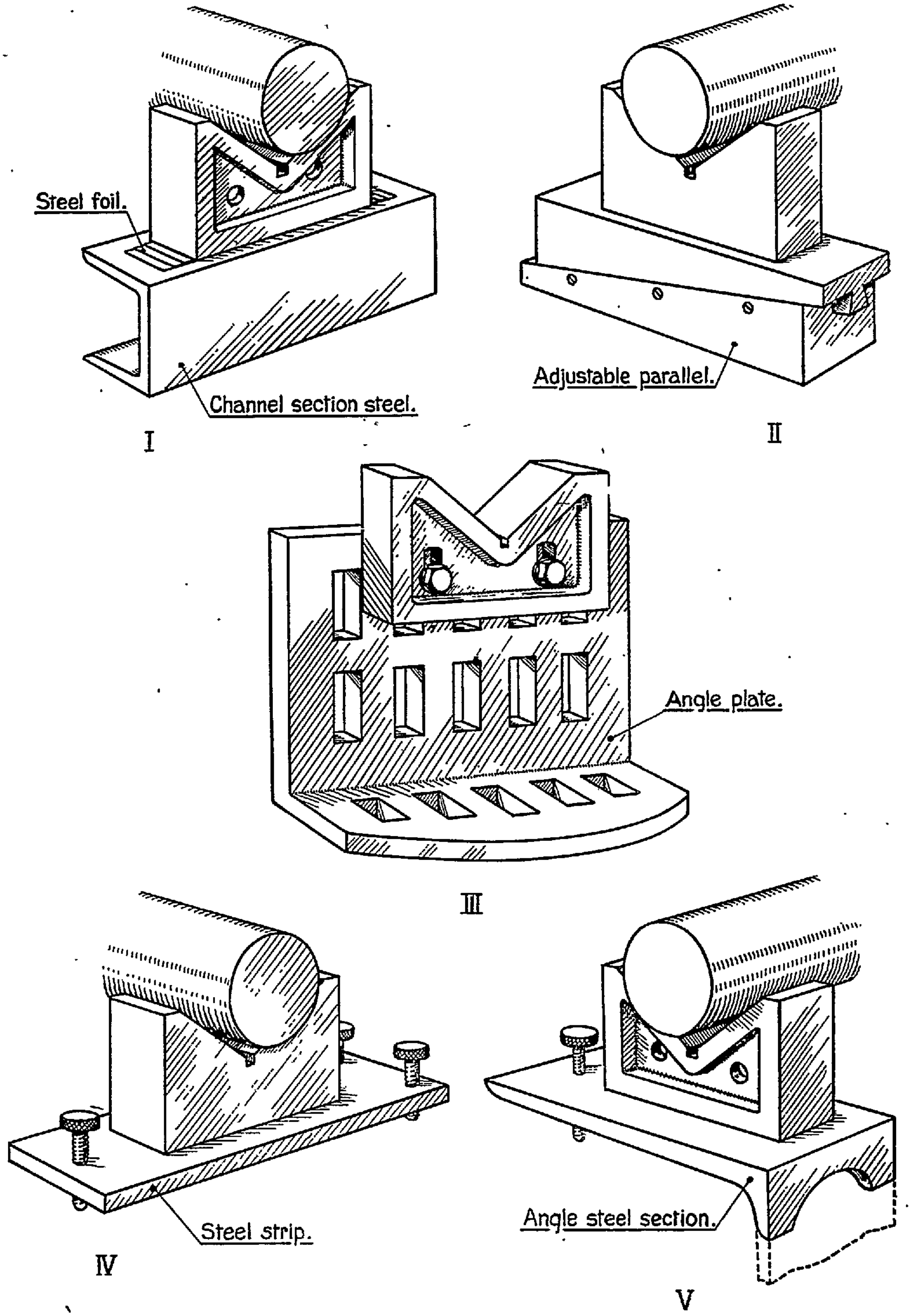


Fig. 12.—V-Blocks—methods of adjusting height

illustrations, but the instrument must be vertical when the reading is taken. The readings should be taken at several points around the circumference of the bore to ascertain the amount of ovality present.

Depth gauge

20. Depth gauges are used for measuring the depths of holes or recesses which cannot be conveniently measured with a steel rule. There are several types of depth gauges, their construction varying according to the degree of accuracy required—see fig. 7.

(i) *Type A.*—This tool embodies the principle of all depth gauges and comprises a steel stock having a hardened and ground flat face. The stock is drilled at right-angles to the face for the reception of a sliding steel rod, the latter being clamped in any desired position by a screwed collet. This tool is chiefly used for making comparisons between the depth of of holes or recesses, where the actual dimensions need not be ascertained.

(ii) *Type B.*—This tool is very similar to the previous type except that a narrow steel rule is fitted instead of the rod which can be clamped in position by a set-screw. The degree of accuracy depends upon the graduations on the rule.

(iii) *Type C.*—This type is similar to type A except that the narrow steel rule passes through a barrel in which a light spring tends to force the rule downwards, e.g., to the bottom of the hole. The barrel can rotate, which permits holes or recesses cut at an angle to be measured. A screwed collet locks the rule when required.

(iv) *Type D.*—This tool is fitted with a vernier scale and is capable of being used for very accurate work. The gauge can be employed to measure recesses with a degree of accuracy of 0·0001 in. The method of reading a vernier is described in para. 23.

(v) *Type E.*—This tool has a micrometer barrel attachment mounted on the stock. The tool shown in the illustration has three extension rods, any one of which can be inserted in the end of the spindle of the micrometer. This tool can be used for measuring very deep recesses or holes with an accuracy of 0·001 in. For method of reading a micrometer—see para. 7.

Vernier height gauge

21. This instrument is shown in fig. 8; it consists of a base having its upper and lower faces ground parallel to each other, and a steel rule graduated in inches, tenths and fortieths mounted at right angles to the base. One scale of the rule is used for internal measurements and the other scale, engraved on the reverse side, for external measurements. To provide for this condition the "internal" scale commences with the one-inch line instead of the usual zero line. Integral with the movable jaw is a vernier attachment similar to that described in para. 23. The movable jaw is machined parallel on both sides, and being at right angles to the main scale allows the instrument to be used for internal and external measurements. When the jaws are in contact the distance between the base and the outside of the movable jaw is exactly one inch—hence the difference in the starting points of the two main scales. An extension arm chamfered to a sharp edge is provided for clamping on the movable jaw. By this means, the instrument is instantly converted into a form of scribing block, in which the chamfered edge of the arm can be accurately set to any desired height for the purpose of scribing lines on work or for checking positions on a component.

Vernier caliper

22. The vernier caliper is shown in fig. 9 and is a combination of a graduated rule and two jaws, one jaw being integral with the rule and the other being movable. The movable jaw is provided with an attachment which enables it to slide on the edges of the rule and permits it to be located in any desired position by means of a setscrew. The illustration shows a form of this tool in which the main scale is divided into inches, tenths and fortieths of an inch and the vernier scale divided into 25 divisions. In order that this tool may be used for internal and external work, the jaws are machined to a definite width, e.g., $\frac{1}{4}$ in., and the back of the slide is marked with a scale allowing for the width of the jaws. Two small holes (marked X in the illustration) are drilled on the main scale and the slide attachment as an aid when setting dividers to an accurate measurement.

The vernier scale

23. The vernier scale, shown in sketch I of fig. 9, is mounted on the saddle piece of the caliper and slides over a main scale divided into $\frac{1}{50}$ths of an inch. The vernier scale is divided into 20 equal parts, each fifth division being numbered 0, 5, 10, 15 and 20 respectively. The total length of these 20 divisions is equal to the length of 19 divisions on the main scale. Each division on the

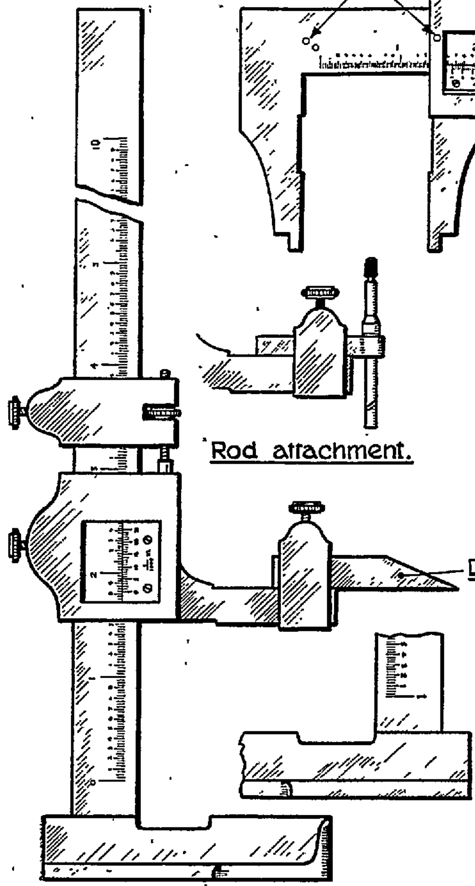


FIG. 8. VERNIER HEIGHT GAUGE.

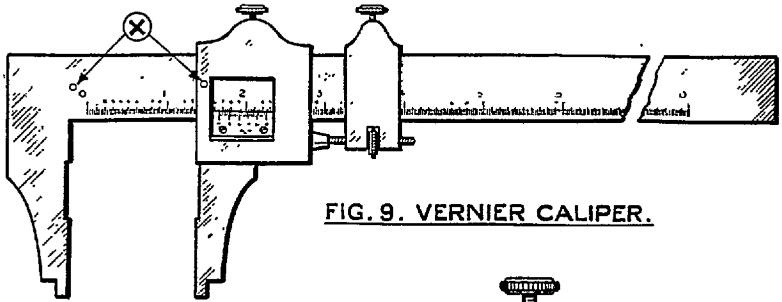
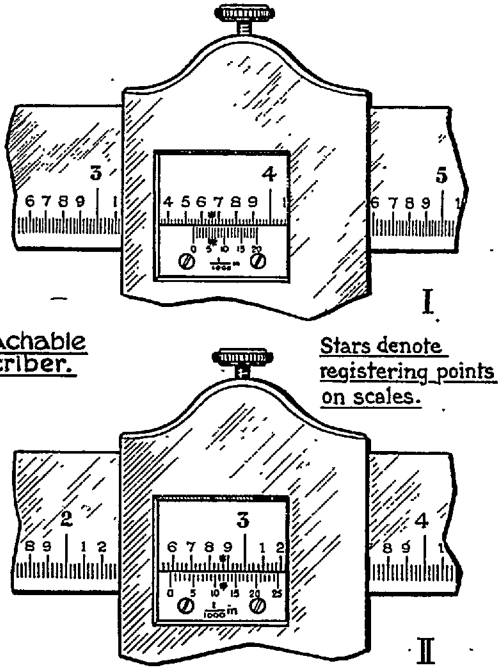


FIG. 9. VERNIER CALIPER.



Vernier scales.

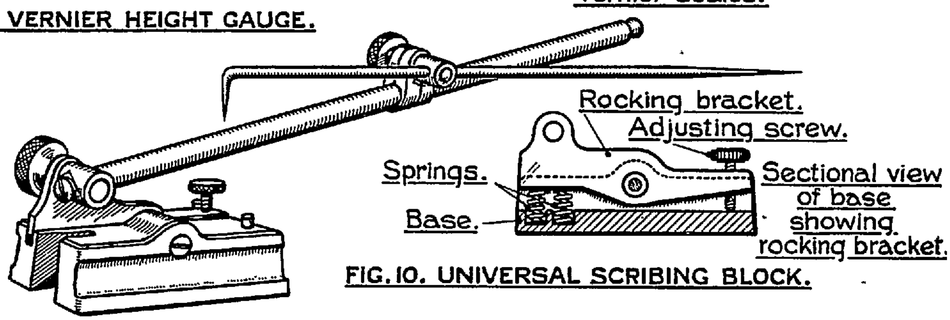


FIG. 10. UNIVERSAL SCRIBING BLOCK.

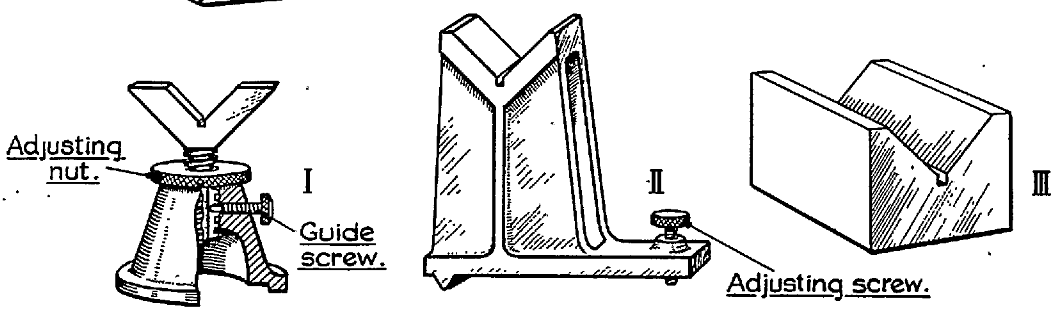


Fig. 8 to 11.—Height gauges, calipers, scribing and V-blocks

27. A useful form of V-block available for service use is known as a drill block. These blocks are made of cast iron and have grooves machined along each side for the reception of a steel clamp, the latter being used when it is necessary to secure a round object within the "vee" of the block. Overtightening the clamp screw should be avoided.

28. It is essential that all pairs of V-blocks should be periodically checked for accuracy both in the "vee" and the external surfaces. The "vee" should be machined centrally at 90 degrees, and the outside surfaces should be square with one another so that they may be used as parallel packing blocks if desired. When reconditioning these tools it is advisable to carry out the various operations simultaneously on each block of a pair; this can be done by securing the two together. If it has been found necessary to remove the markings in order to obtain a true surface or for any other reason, the blocks should be re-marked.

29. It is often necessary to mount a shaft or other circular object upon a pair of V-blocks so that the axis of the shaft is parallel to the upper surface of the marking-out table and at such a height that the shaft can be freely rotated. Several improvised rigs are shown in fig. 12, the equipment employed being generally available in all service workshops.

Parallel strips

30. These tools are generally made of pieces of hardened cast steel and are accurately machined in pairs, each strip having its opposite sides parallel to each other. The pairs are marked to denote their respective sizes to avoid having to measure them each time they are required for use. Parallel strips are employed beneath machined or ground surfaces for the purpose of raising them to a suitable height or to align the underside of a finished surface to an accurate surface such as a table or a plate.

Limit gauges

31. To permit interchangeability in the manufacture of similar components and to ensure parts being measured with the same degree of accuracy, various types of gauges are employed similar to those shown in fig. 13, these being known as plate, gap, plug, and ring gauges. In engine repair work it is often necessary to measure a number of components of a similar type to ascertain their degree of serviceability or selective assembly, and in some cases it is impracticable to use a precision instrument for the purpose. The first three types of gauge mentioned are usually double-ended, one end being slightly larger and the other end slightly smaller than the standard dimension. Plug gauges made under these conditions will permit the smaller end to enter a recess but the larger end will not enter—hence the popular name of "Go and not go" gauges. Plug gauges usually have two flat sides which enable them to be used for ascertaining whether a bore has been incorrectly machined or has worn oval. It is often necessary to ascertain the amount of wear or ovality of a component which has been used as a bearing or bush, e.g., valve guide or an aero-engine. The correct measurement across the axes of the component can be obtained by using a plug gauge having a cross-section as shown at A. The length of the gauge should be such that it will pass completely through the bore. The plate or gap gauge is made so that the larger end will pass over a given dimension but the smaller end will fail to do so. If a plug gauge (double-ended) is made say one inch in diameter plus 0·001 in. at one end and minus 0·001 in. at the other end, the difference between the two dimensions is known as the *tolerance*. The larger dimension is referred to as the *high limit*, and the smaller dimension as the *low limit* of the gauge.

32. In practice these gauges are made either in cast steel and then tempered, or in mild steel and then case-hardened, after which they are ground and lapped. It is usual for double-ended gauges of these types to have one end longer than the other in order that the operator may immediately know which is the "Go" or "Not-go" end without having to examine the dimensions engraved on the gauge.

33. From the above it will be appreciated that properly dimensioned gauges will save considerable time when measuring machine parts. The extent to which such gauges may be made up by Units will depend upon the facilities available. Gauges are generally placed under three classes:—

(i) *Working gauges.*—Those which are used in the workshops during the manufacture of the component.

(ii) *Inspection gauges.*—Those which are used for checking the component after manufacture, e.g., in the View Room, or for checking a component for size ovality and wear, e.g., an engine part removed for examination, etc.

(iii) *Master gauges.*—Those used for checking the accuracy of gauges (i) and (ii).

34. Temperature plays an important part in the size of a gauge, and as far as possible they should be made and retained in a temperature of approximately 68° F. (20° C.), this being the common or average working temperature to which the gauges are ordinarily subjected in practice.

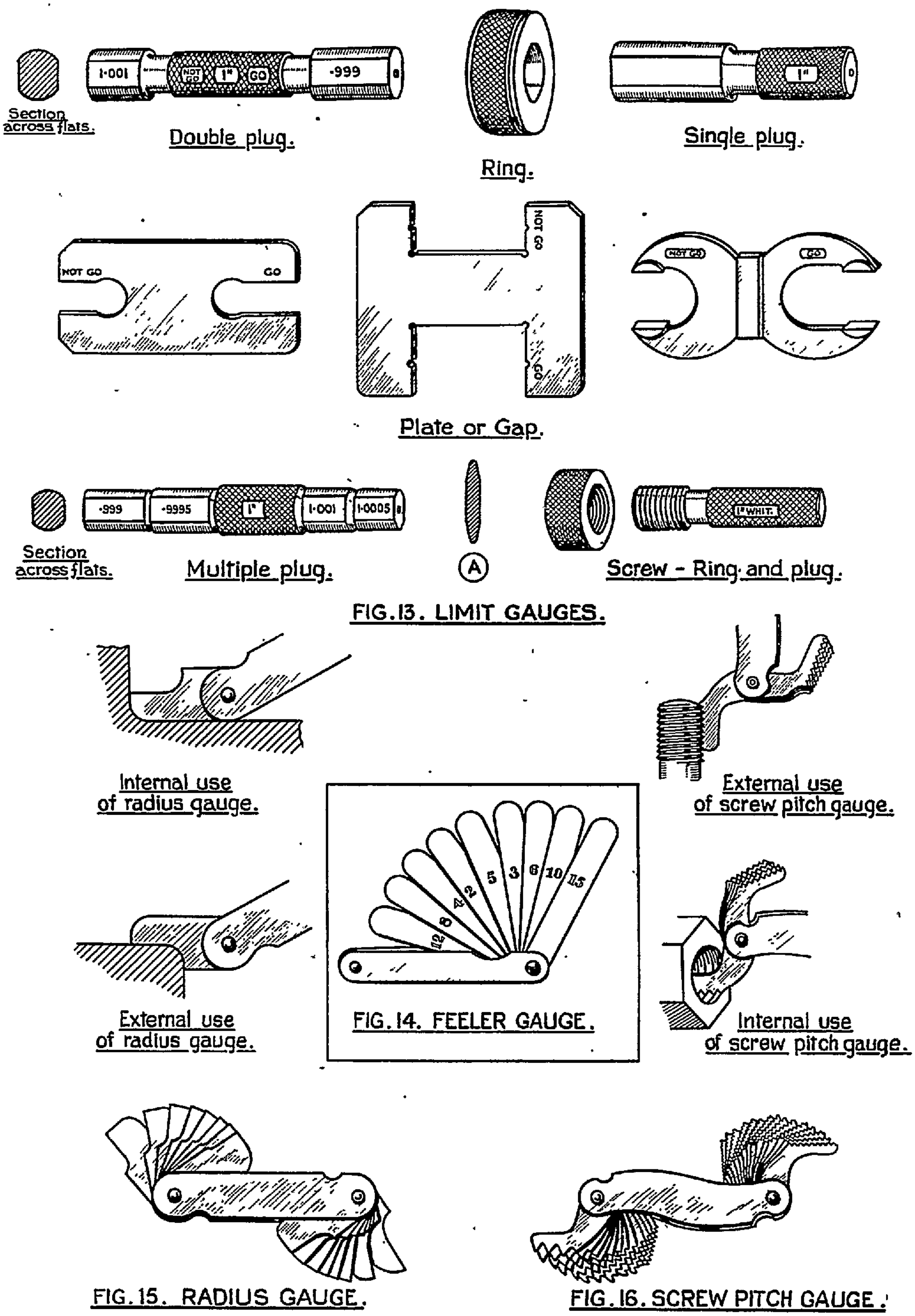


Fig. 13 to 16.—Miscellaneous types of gauges

Feeler gauge

35. The feeler gauge, sometimes called a thickness gauge, is shown in fig. 14 and consists of a number of leaves of thin steel which have been ground to definite thicknesses. Each leaf is suitably tempered and is marked with a number representing the thickness of the leaf in thousandths of an inch. The leaves are held in a metal case thereby protecting them from kinks. Any leaf can be removed by unscrewing the screwed pivot stud. Two types of this gauge are supplied for service use, (i) English—having leaves of thicknesses 2, 3, 4, 5, 6, 8, 10, 12 and 15 thousandths of an inch, and (ii) Metric—having 14 leaves of thicknesses from 0·05 to 1·00 mm. The object of the gauge is to provide a means of measuring clearances between two surfaces. Each leaf may be used singly or in combination with other leaves. Care should be taken to ensure the leaves are free from oil or dirt, especially when they are used in combination.

Radius gauge

36. The radius gauge is sometimes referred to as a fillet gauge, and is used to check the inside or outside radius of a part, e.g., pins, journals and bearings of a crankshaft. Fig. 15 shows a type of radius gauge and its uses. The service patterns are respectively (i) English—having a range of radii from (*a*) $\frac{1}{32}$ to $\frac{1}{4}$ in. and (*b*) $\frac{17}{64}$ to $\frac{1}{2}$ in. and (ii) Metric—having a range of radii from (*a*) 1 to 7 mm. and (*b*) from 7·5 to 15 mm.

Screw pitch gauge

37. A screw pitch gauge, as its name implies, is used for testing the pitch of a V-thread. In gauging a thread, the latter is first cleaned and then held up to the light and the gauge placed in position. The gauge consists of a number of leaves, each leaf being cut with "vees" at a certain number of teeth per inch. Each leaf is marked with a decimal figure which denotes twice the depth of the thread. This assists the operator to determine what size of drill is required to leave a full thread for a screw-cutting tap having the same pitch. The size of drill required will be that of the diameter over the crests of the threads, less this figure. Fig. 16 shows a type of screw pitch gauge and its use when checking the threads of a component. Three types of this tool are available for service use and cover most requirements, (i) British Association, i.e., B.A., (ii) Whitworth—having 30 pitches from $3\frac{1}{2}$ to 60 threads per inch and (iii) Metric—having 17 pitches from 0·5 to 7 mm. together with a centre gauge which can be used when grinding internal and external screwcutting lathe tools.

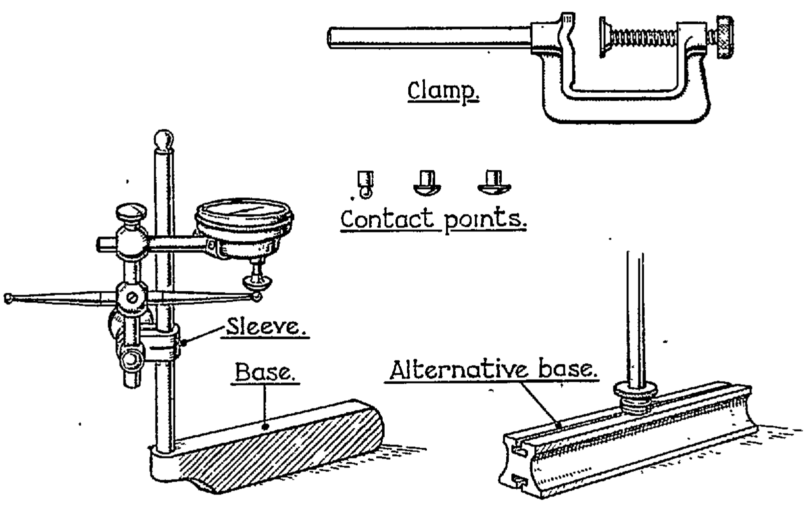


Fig. 17.—Dial test indicator

Dial test indicator gauge

38. This instrument is shown in fig. 17 and is used for determining the degree of accuracy of a flat surface or the truth of a rotating shaft. The instrument can also be used for taking comparative measurements between components. There are several varieties of the instrument but all types are designed to produce similar results. The instrument comprises a base on which is mounted a vertical spindle carrying a clamp or split sleeve. An additional hole is machined in the clamp to take a sliding

post. By tightening up the clamp screw, the clamp is located and at the same time the sliding post is secured. The other end of the post carries an arm on which the dial indicator is mounted. The dial gauge is graduated in thousandths of an inch, the graduations being widely spaced to permit lesser dimensions to be estimated. Some dials are graduated in half and quarter thousandths of an inch, and are generally used in View Rooms for inspection operations and also in the Grinding Bay where the machining limits are very fine; this type of indicator is not in general use in the service. The dial of the indicator may be turned by means of its knurled rim to bring the zero in any position. The contact points of the dial indicator spindle can be removed and different forms of points used. By bringing the contact point against an object with sufficient pressure to move the pointer one complete revolution and then setting the dial at zero, readings can be obtained for one complete graduation of the dial, either to the left or right of the zero graduation. It must be remembered that when circular rotating objects are being tested for alignment in relation to the axis of the object, the actual error will be half that registered on the dial. Fig. 18 shows a dial indicator mounted on a scribing block and illustrates how the dial indicator may be used in the absence of the complete instrument shown in fig. 17.

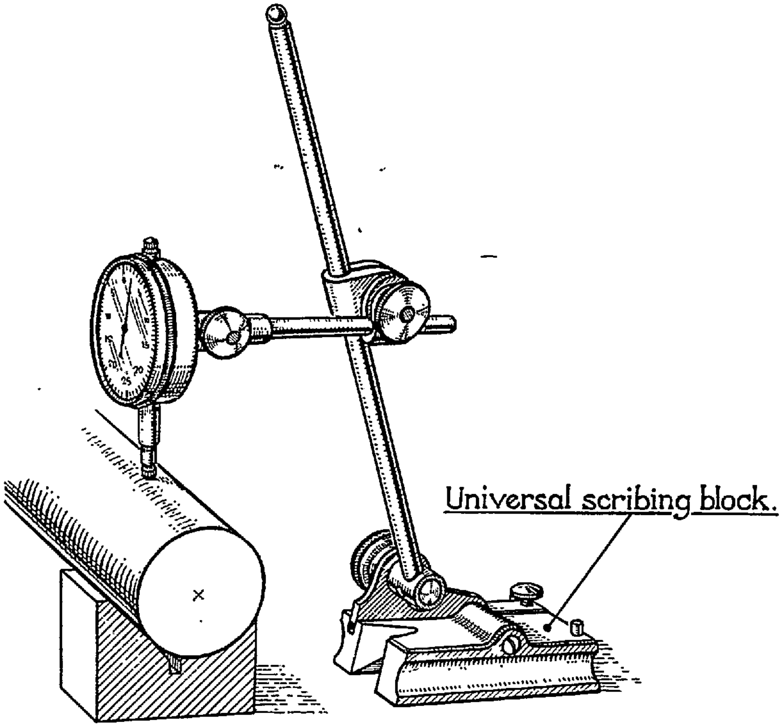


Fig. 18.—Dial indicator mounted on scribing block

Straightedge

39. This tool being made of steel throughout can be relied upon to retain its truth if care is taken during storage and in use. Long straightedges when not in use should either hang in a vertical direction or, if stored horizontally, be supported throughout its length. The tools should also be protected from damage caused by other metal parts coming into contact with them. Straightedges are used for testing the accuracy of long surfaces, and therefore their accuracy is essential. From time to time the tool should be checked for accuracy against a master surface table and any irregularities rectified as necessary. The 4-foot straightedge will be found most useful for all general purposes; straightedges in lengths up to 6 ft. are available. In some trades a wooden straightedge is employed, this tool being made of hard-wood and generally reinforced with metal strips at the ends and in other positions where excessive wear or damage is anticipated. Wooden straightedges are perfectly satisfactory for rigging and similar operations, but it is essential that they should be frequently checked for accuracy.

Parallel mandrels

40. These tools are generally made of mild steel and afterwards hardened; they are then ground to very fine limits. It is most important that mandrels should be used with care and when not in use they should never be allowed to lie haphazard on the marking-out table or bench. Suitably notched

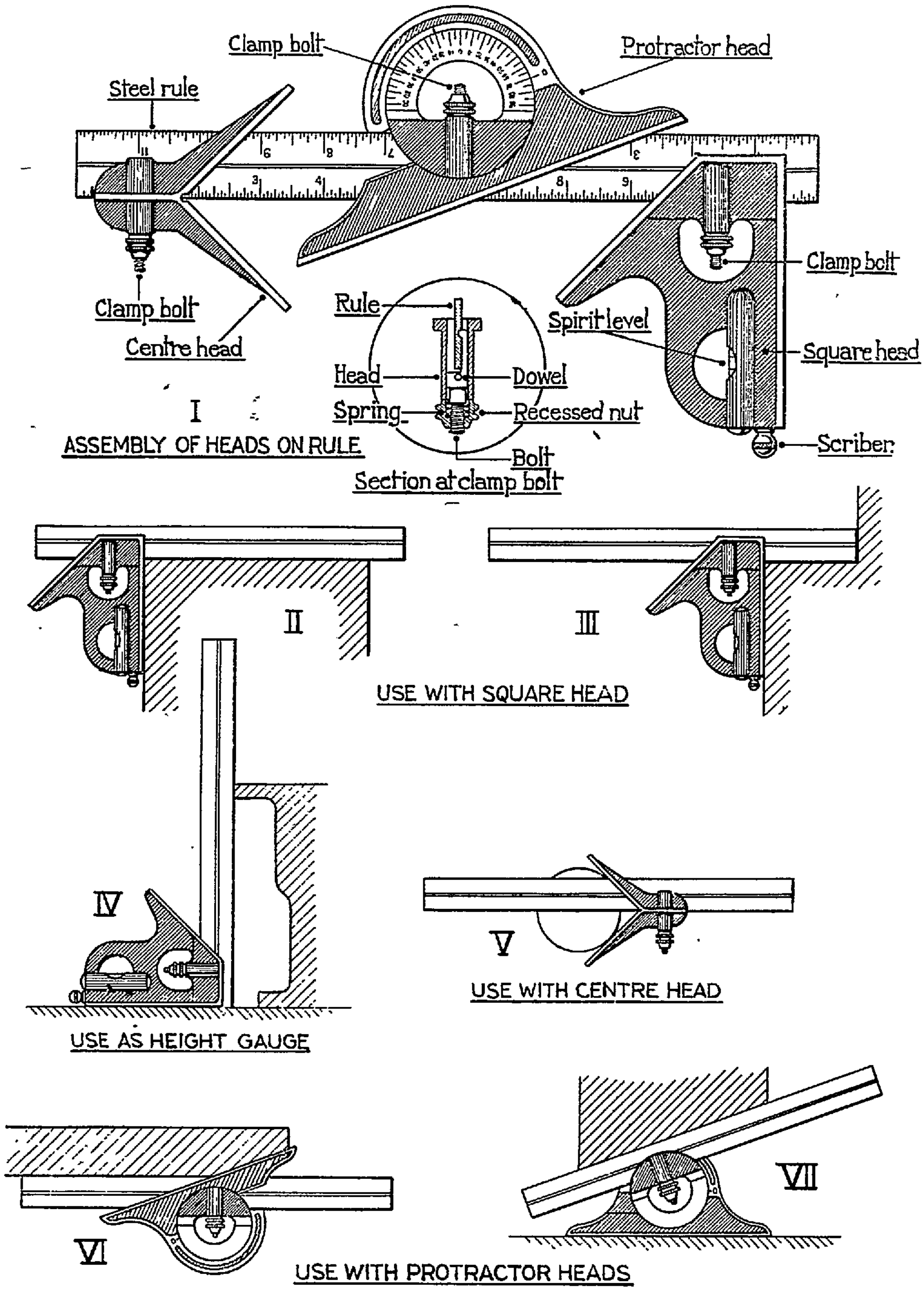


Fig. 19.—Combination set

wooden racks are suggested and the mandrels should always be coated with rust preventive, thick oil or vaseline when not in use, to prevent corrosion taking place on their ground surfaces. Various types of mandrel are in general use in the service and these will be described in connection with the particular operations for which they are used.

Combination set

41. The combination set shown in fig. 19, sketch I, consists of a graduated steel rule and three heads which enable the instrument to fulfil all the requirements of a square, set-square, height gauge, centre square, bevel, protractor, marking gauge and spirit level. The heads are made of cast iron or of malleable iron (drop-forged) and have their working faces ground accurately; the heads are about ½ in. wide. A slot is machined through each head for the reception of the rule and a clamping bolt and knurled nut (carrying a spiral spring) is provided so that the head can be secured in any desired position on the rule. If it is necessary to remove the bolt, care must be taken when replacing it to ensure that the dowel engages in its slot in the bolt hole. When not required, the heads can be removed, but care should be taken in replacing them to ensure that the end of the bolt engages in the concave groove machined in the rule. A brief description of the components is as follows:—

(i) *Steel rule.*—The steel rule supplied with the instrument is graduated in English, metric or combined English and metric measurements. The rule is hardened and this prevents the corners from wearing and destroying the graduations.

(ii) *Square head.*—The square head has one working face machined square and the other working face machined at 45° to the rule. This enables the instrument to be used as an adjustable try-square and a 45° mitre gauge. By sliding the head along the rule the instrument is converted into a set-square. A spirit level is incorporated in this head and is set accurately and secured in a protected position. A hardened steel scriber is also supplied and is frictionally held in a brass bush. Examples of uses with the square head are shown in sketches II, III and IV.

(iii) *Centre head.*—This head is used to determine accurately the centre of the end of a piece of round material—see sketch V. It will be observed that one edge of the rule always passes through the centre of the circular end of the material. The centre point will, therefore, be fixed by the intersection of any number of lines scribed with the centre head in different positions. The end of the bar should always be square before any attempt is made to determine the centre.

(iv) *Protractor head.*—The protractor head, as its name implies, consists of a double protractor reading from 0° to 180° in both directions. The protractor is carried on a revolving turret which can be secured in a similar manner to the other heads. Some protractor heads also incorporate a spirit level which adds to the usefulness of the instrument. The use of this head in conjunction with the rule serves the dual purpose of an adjustable mitre gauge and a bevel protractor. Examples of uses of this head are shown in sketches VI and VII.

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