Basic Mechanical Engineering: Unit - 7
Inspection and measurements
(Part – B)

1 Introduction:

The mass production which characterizes so many branches of modern engineering manufacture would be impossible if component parts could not be produced to close dimensional tolerances to make them interchangeable. It is therefore essential that accuracy required should be built into the machine tools, jigs and fixtures which produce them. Precision measurement is concerned with the precise determination of the linear, angular and non – linear functions of the machine surfaces of the tools and devices used to produce engineering components. Precision measurements must be carried out on both the dies and punches of the press tools used and provided the dimensions are within the limits laid down so that parts produced are acceptable. It has been observed that precision measurements are always required in the manufacture of machine tools such as lathes, milling machines and drilling machines

In quality control, whenever parts must be inspected in large numbers, hundred percent inspection of each parts is not only slow and costly, but in addition does not eliminate all of the defective pieces. Mass inspection tends to be careless; operators become fatigued; and inspection gauges become worn or out of adjustment more frequently. Therefore, we go for sample inspection. The sample must be chosen without partiality. The number of acceptable defective is usually taken as 3 in 1000.

2. **Standards of Measurements**:

These days only two standard systems of linear measurements, English (Yard) and Metric (meter) are in general used throughout the world.

For linear measurements the various standards known are:

1. Linear standard
2. End standard
3. Wave length standard

Depending upon the importance of accuracy required for the work, standards are subdivided into four grades

a) **Primary standards**: This has no direct application to measuring problems encountered in engineering. These are solely used for comparison of secondary standards
b) **Secondary standards**: This has no direct application to measuring problems encountered in engineering. These are solely used for comparison of Tertiary standards
c) **Tertiary** standards: These are solely used for comparison of Calibration standards
d) **Calibration** standards : These are solely used for **Calibration** of Inspection and Working standards

e) **Inspection standards:** These are measuring instruments used by inspection department of any manufacturing establishment. They are in continuous use hence needs to be checked for their accuracy by sending them for Calibration.

f) **Working standards:** These are measuring instruments used by technicians / machine operators of any manufacturing establishment/ tool rooms/ workshops. They are in continuous use hence needs to be checked for their accuracy by sending them for Calibration.

3. **End standards**: In the form of bars and slip gauges, are in general use in precision engineering as well as in standard laboratories such as N.P.L. (National Physical Laboratory). Slip gauges are used in tool rooms, workshops, and inspection departments.

4. **Wave standard:** It is suggested that wave lengths of monochromatic light can be used as natural and invariable unit of length. The seventh General Conference of Weights and Measures in Paris approved the definition of a standard of length relative to the metre in terms of the wave length of the red radiations of cadmium.

5. **Classification of Standards :**
   a) International Standards
   b) National Reference Standards
   c) Plant lab laboratory Reference Standards
   d) Plant working Standards
   e) Shop floor standards
   f) Working Standards

6. **Vernier caliper:** The vernier instruments generally used in workshop and engineering have comparatively low accuracy. The measurement of such instruments does not coincide with the line of scale. The accuracy therefore depends upon the straightness of the beam and squareness of sliding jaw with respect to the beam. To ensure the squareness, the sliding jaw must be clamped before taking the reading. Zero error must also be taken into consideration. Instruments are now available with a measuring range upto one metre with scale value of 0.1 or 0.2 mm. They are made of alloy steel, hardened and tempered (to about 58 Rockwell C), The contact surfaces are lap – finished. In some cases stainless steel is used.

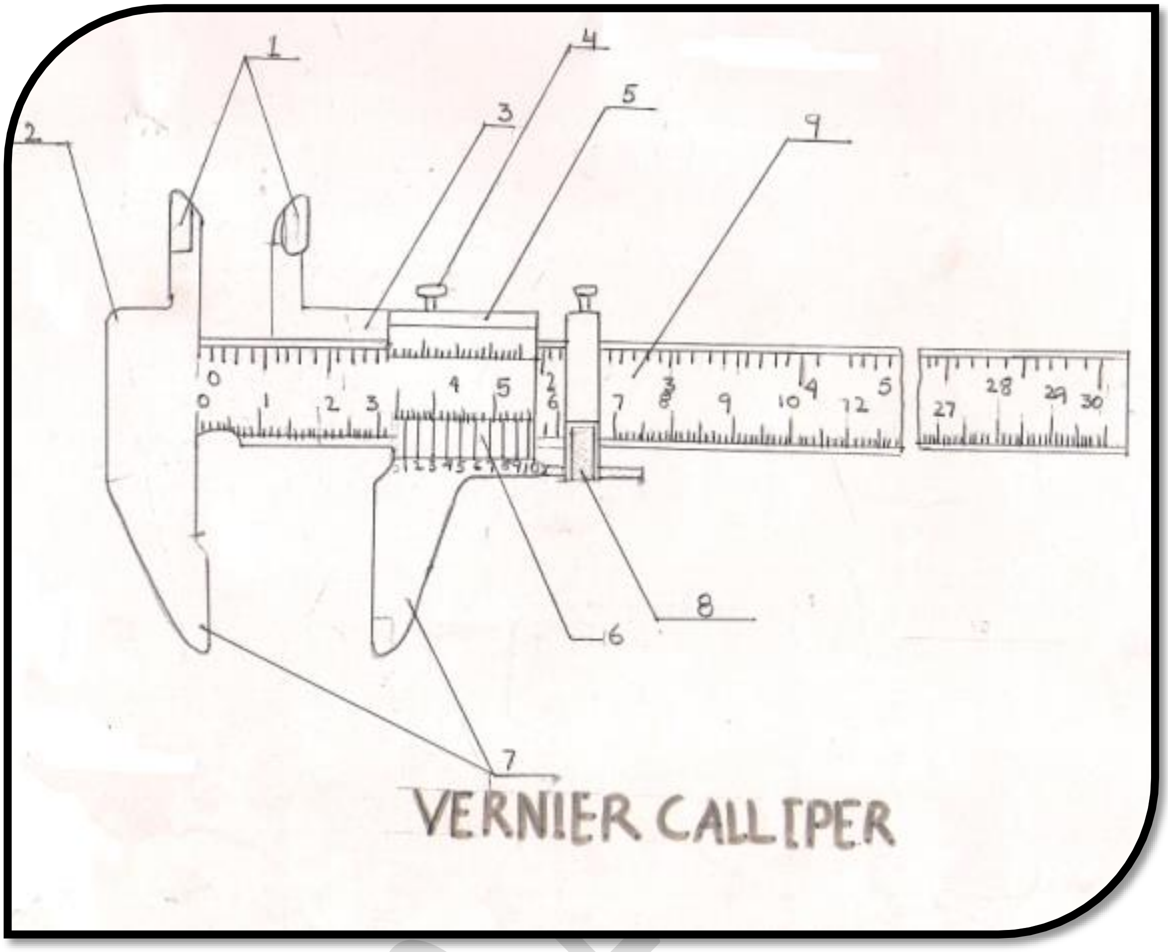


Fig. 1: Vernier Caliper

1.	**Inside Jaws**	**2.**	**Fixed Jaw**	**3.**	**Main Scale**
4.	**Clamping Screw**	**5.**	**Slider**	**6.**	**Vernier Scale**
7.	**Out Side Jaws**	**8.**	**Final Adjustment Screw**		

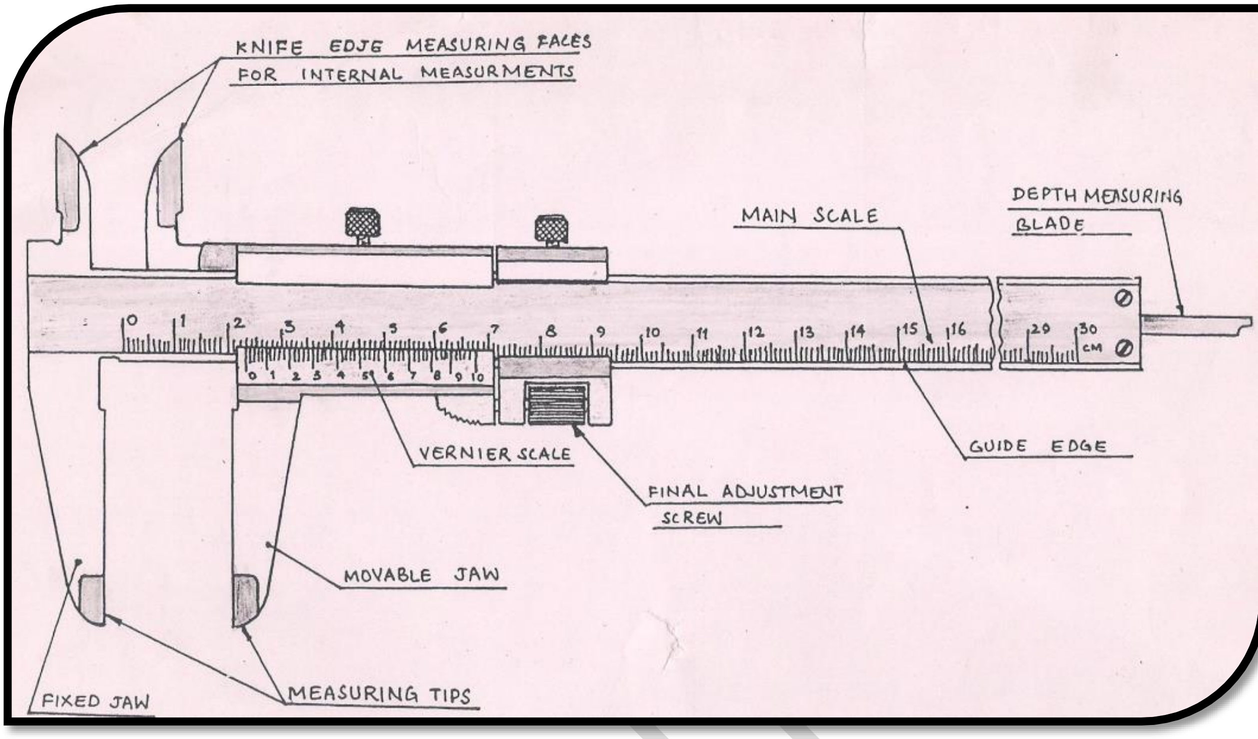


Fig. 2: Vernier Caliper Type A

6.1 **Principle of 0.1 mm Vernier:** The principle of vernier is that when two scales or division slightly different in size are used, the difference between them can be utilised to enhance the accuracy of measurement.

Main scale is accurately graduated in 1 mm steps, and there is another scale which is movable, and also fixed to caliper sliding jaw. The movable scale is equally divided into 10 parts but its length is only 9 mm; therefore one division on this scale is equivalent to 9/10 = 0.9 mm. this means difference between one graduation on the main scale and one graduation on the sliding scale or vernier scale is 1.0 – 0.9 = 0.1 mm. Hence if the vernier caliper is initially closed and then opened so that the first graduation on the sliding scale corresponds to the first graduation on the main scale a distance equal to 0.1 mm has moved. Such a vernier scale is of limited use because measurements of greater accuracy are normally required in precision engineering work.

6.2 Principle of 0.2 mm Vernier:

The vernier scale has main scale graduation of 0.5 mm, whilst the vernier scale has 25 graduations equally spaced over 24 main scale graduations, or 12 mm. Hence each division on the vernier scale = 12/25 = 0.48 mm.

The difference between one division on main scale and one division on the vernier scale

= 0.5 – 0.48 = 0.02 mm

This type of vernier is read as follows:

- Note the number of millimeters on the main scale that are coincides with the zero on the vernier scale.
- Find the graduation on the vernier scale that coincides with the main scale. This figure must be multiplied by 0.02 to give the reading in millimeters.
- Obtain the total reading by adding the main scale reading to the vernier scale reading.

6.3 Types of Vernier Calipers:

According to Indian Standard IS: 3651 – 1974, Three types of vernier calipers have been specified to make external and internal measurements.

Type A: Vernier has jaws on both sides for external and internal measurements, and a blade for depth measurement. **Refer Figure 2 for Vernier Caliper - Type A**

Type B: Vernier has jaws on one sides for external and internal measurements.

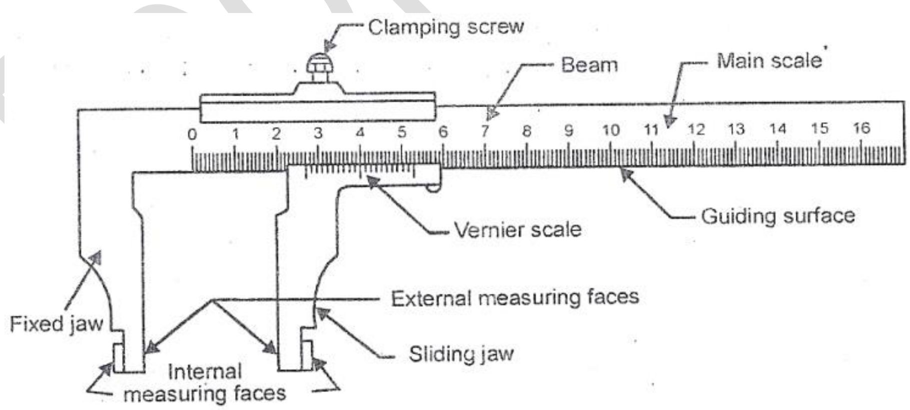


Figure 3: Vernier Caliper - Type B

Type C: Vernier has jaws on both sides for external and internal measurements.

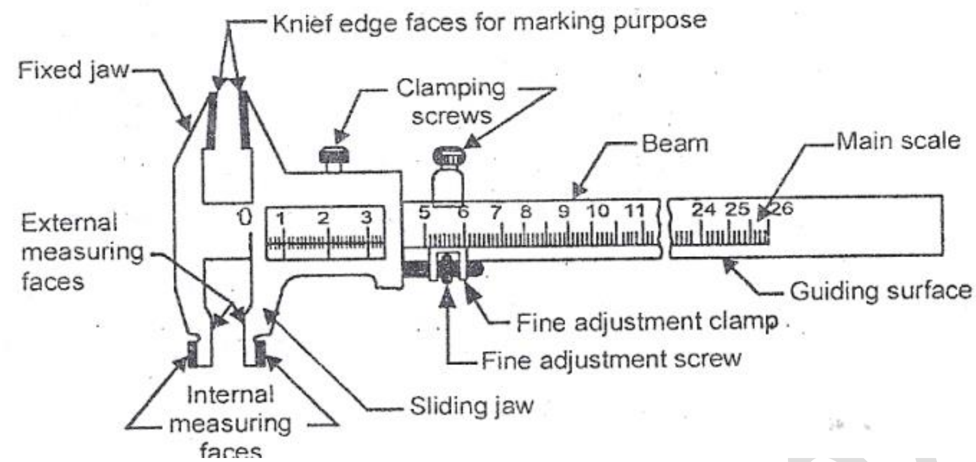


Figure 4: Vernier Caliper - Type C

6.4 **Vernier Height Gauge:** Vernier Height Gauge is mainly used in the inspection of parts and layout work. It may be used to measure and mark vertical distances above a reference surface. Following figure 5(i) shows the vernier height gauge.

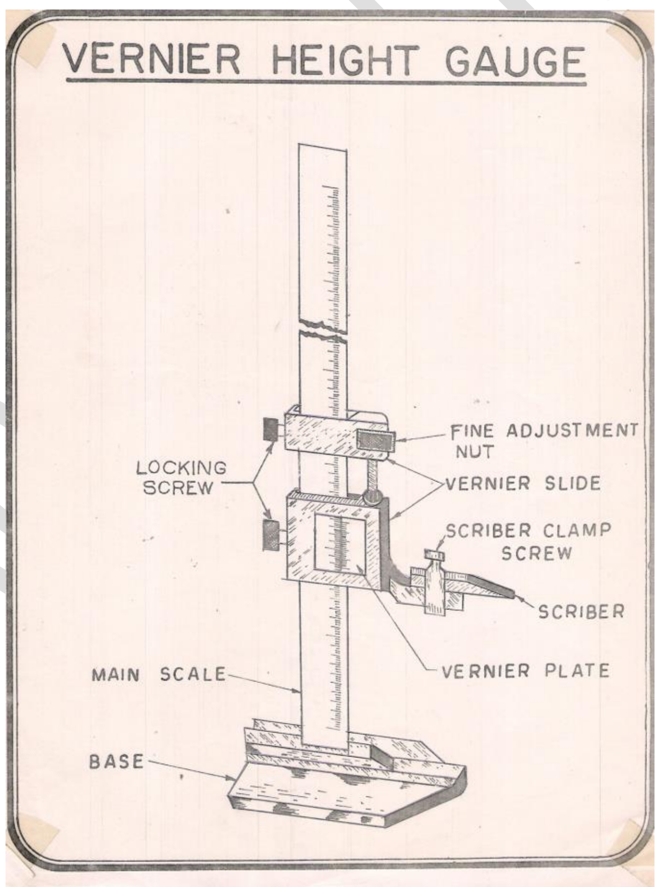


Figure 5(i): Vernier Height Gauge

It consists of following parts:

1. Base
2. Beam
3. Measuring jaw and scriber
4. Graduations
5. Slider

Its working principle is as that of the vernier caliper.

6.5 Precautions:

- While using Vernier Height Gauge, care should be taken to ensure that the base is clean and free from burs.
- It is essential that the final setting of the gauge is made after the slider has been locked to the vertical column.
- Keep the vernier height gauge in its case when not in use

6.6 Vernier Depth Gauge: Vernier Depth Gauge is mainly used for measuring depth of blind holes, recesses and distance from a plane surface to a projection. In figure 5(ii) shows the vernier Depth gauge in use. Its working principle is as that of the vernier caliper.The end of the beam is square and flat, and the base is flat and true, free from curves or waviness

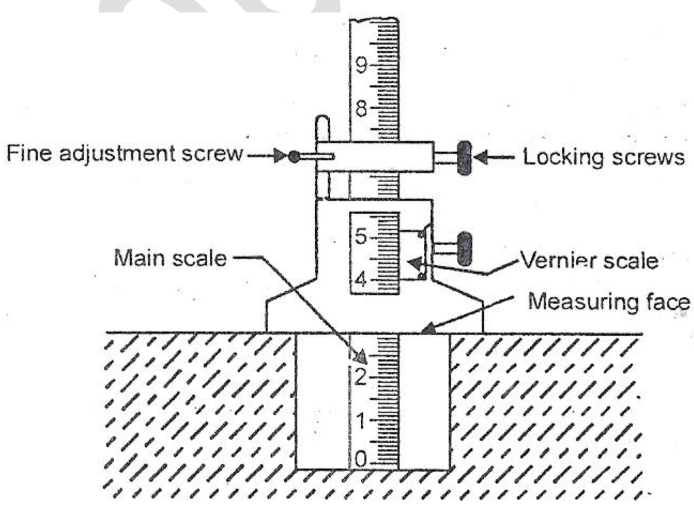


Figure 5(ii): Vernier Depth Gauge in use

7. Micro Meter: Micrometer are designed on the principal of '**Screw and Nut**'

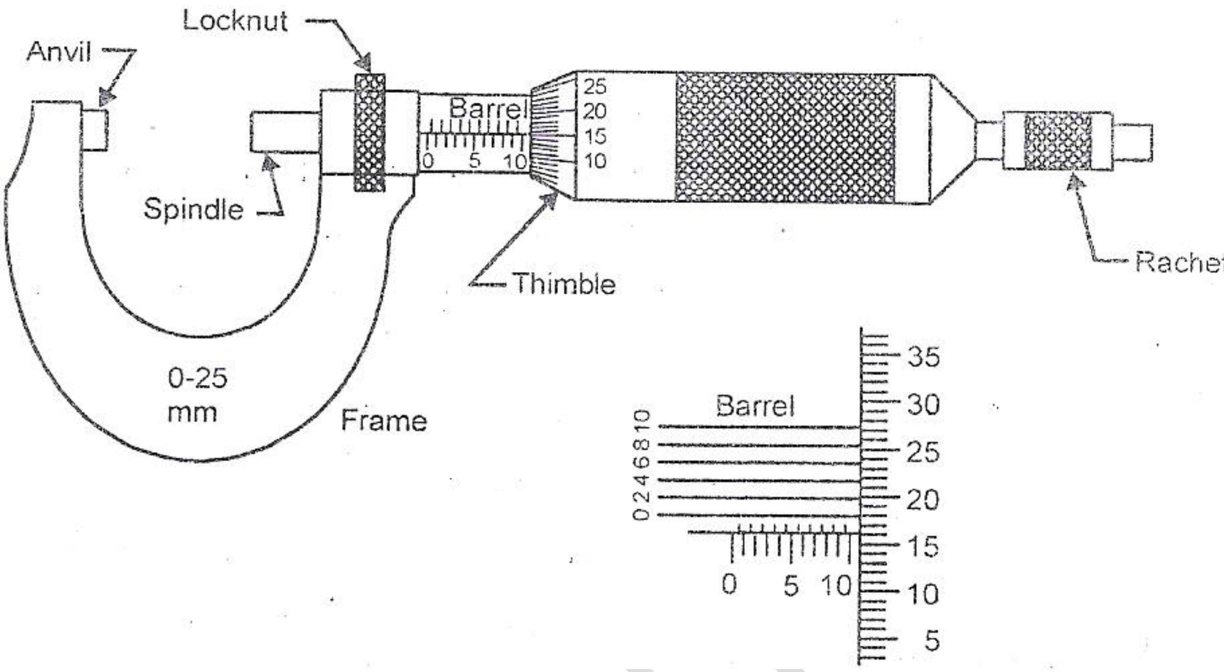


Figure 6: Outside Micrometer

7.1 Description of micrometer:

It consists of the following parts (Refer figure 6): The micrometer requires the use of an accurate screw thread as a means of obtaining a measurement. The screw is attached to a spindle and is turned by movement of a thimble or ratchet at the end. The barrel, which is attached to the frame, acts as a nut to engage the screw threads, which are accurately made with a pitch of 0.05 mm. Each revolution of the thimble advances the screw 0.05 mm. On the barrel a datum line is graduated with two sets of division marks. The set below the datum line reads in milliners, and the set above the line reads in half millimeters. The thimble scale is marked in 50 equal divisions, figured in fives; so that each small division on the thimble represents 1/50 of 1/2 mm which is 1/100 mm on 0.01 mm.

To read the metric micrometer to 0.01 mm, examine Fig. 6A and first note the whole number of major divisions on the barrel, then observe whether there is a half millimeter visible on the top of the datum line, and last read the thimble for hundredths. The thimble reading is the line coinciding with the datum line. The reading for Fig. 6 is as follows:

Major divisions « 10 x 1.00 mm	=	10.00 mm
Minor divisions » 1 x 0.50 mm	=	0.50 mm
Thimble divisions » 16 x 0.01 mm	=	0.16mm
Reading	=	10.66 mm

Since a micrometer reads-only over a 25-mm range, to cover a wide range of dimensions, several sizes of micrometers are necessary. The micrometer principle of measurement is also applied to inside measurements and depth reading and to the measurements of screw threads

• To read the metric micrometer to 0.002 mm, vernier on the barrel is next considered. The vernier shown rolled out in Fig. 6. has each vernier graduation represent two thousandths of a millimeter (0.002 mm), and each graduation is marked with a number 0, 2, 4, 6, 8 and 0 to help in the reading. To read a metric vernier micrometer note the major, minor and thimble divisions. Next observe which vernier line coincides with a graduated line all the thimble. This gives the number of two thousandths of a millimeter to be added to the hundredth's reading. For the cut out in Fig. 6A, the reading is as follows:

Major divisions	=	10 x 1.00 mm	=	10.00 mm
Minor divisions	=	1 x 0.50 mm	=	0.50 mm
Thimble divisions	=	16 x 0.01 mm	=	0.16 mm
Vernier divisions	=	3 x 0.002 mm	=	0.006 mm
		Reading	=	10.666 mm

7.2 Inside Micrometer: These micrometers are used for measuring internal dimensions. The internal micrometer can be a rod provided with spherical anvils as shown in above figure 7. The measuring range of this micrometer is from 25 to 37.5 mm i.e. 12.5 mm. by means of exchangeable anvil rods, the measuring capacity can be increased in steps of 12.5 mm upto 1000 mm.

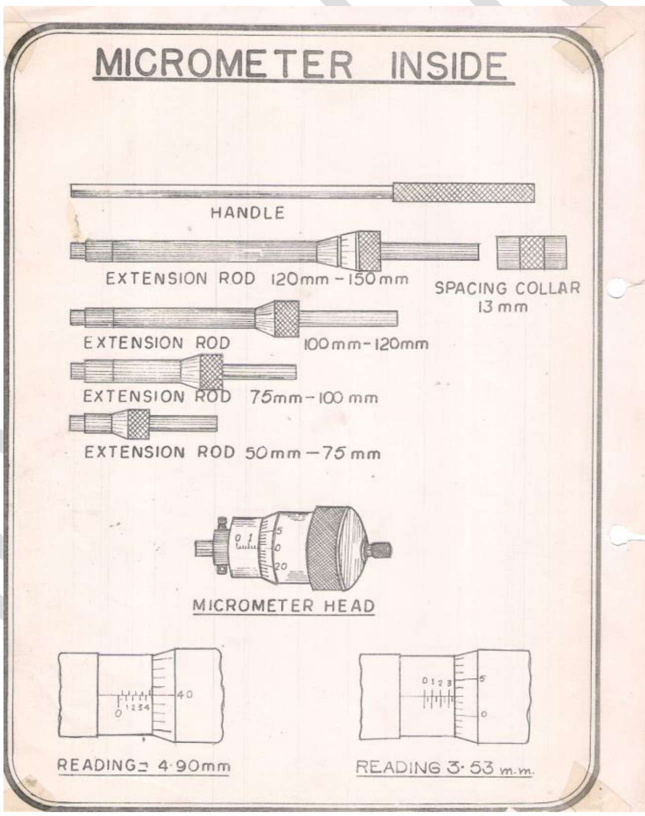


Figure 7: Inside Micrometer

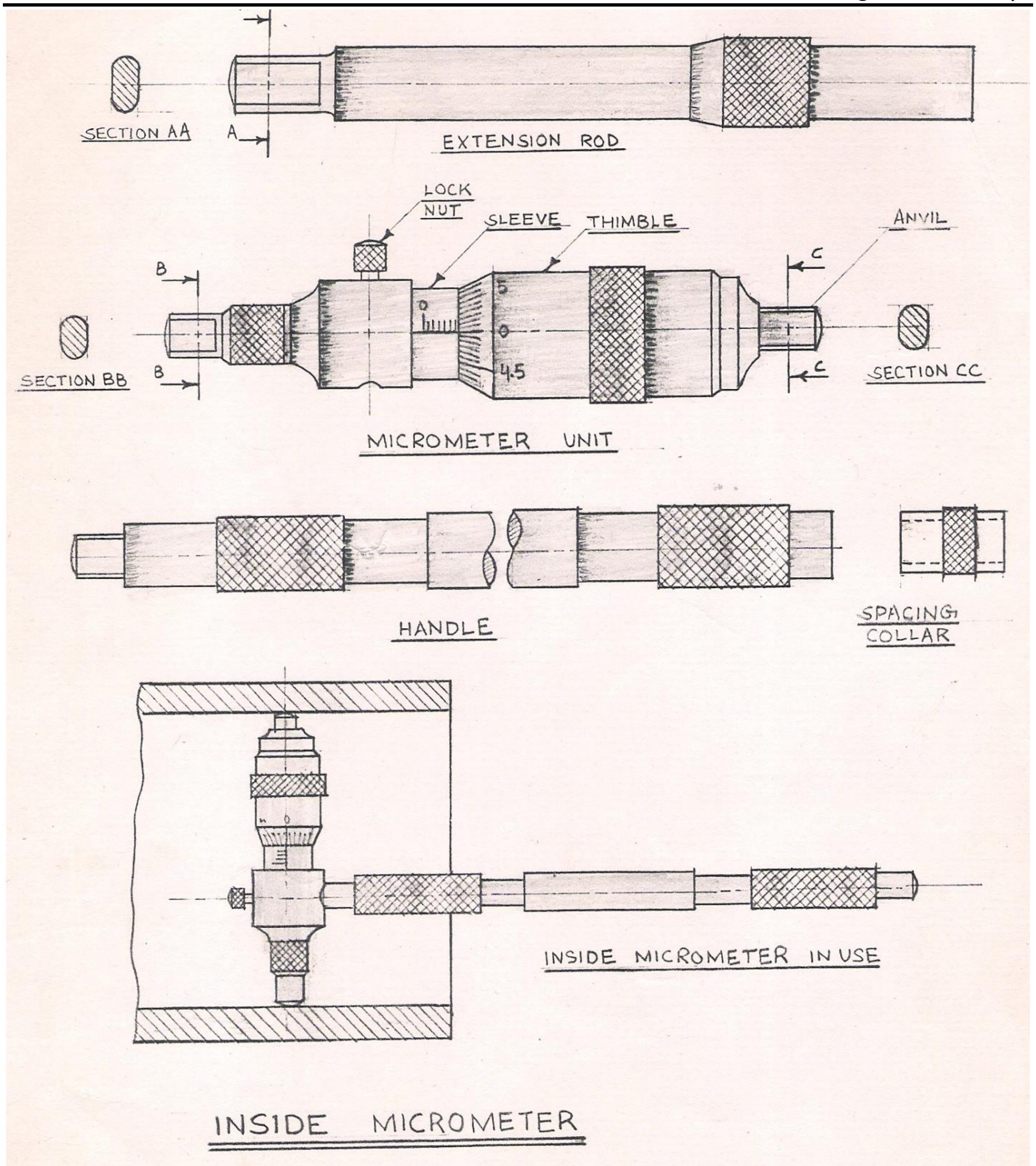


Figure 7A: Internal Micrometer

7.3 Depth Micrometer: It is also known as 'micrometer depth gauge '. The measurement is made between the end face of a measuring rod and a measuring face. Because the measurement increases as the measuring rod extends from the face, the readings on the barrel are reversed from the normal; the start at a maximum (when the measuring rod is fully extended from the measuring face) and finish at zero (when end of the measuring rod is flush with the face)

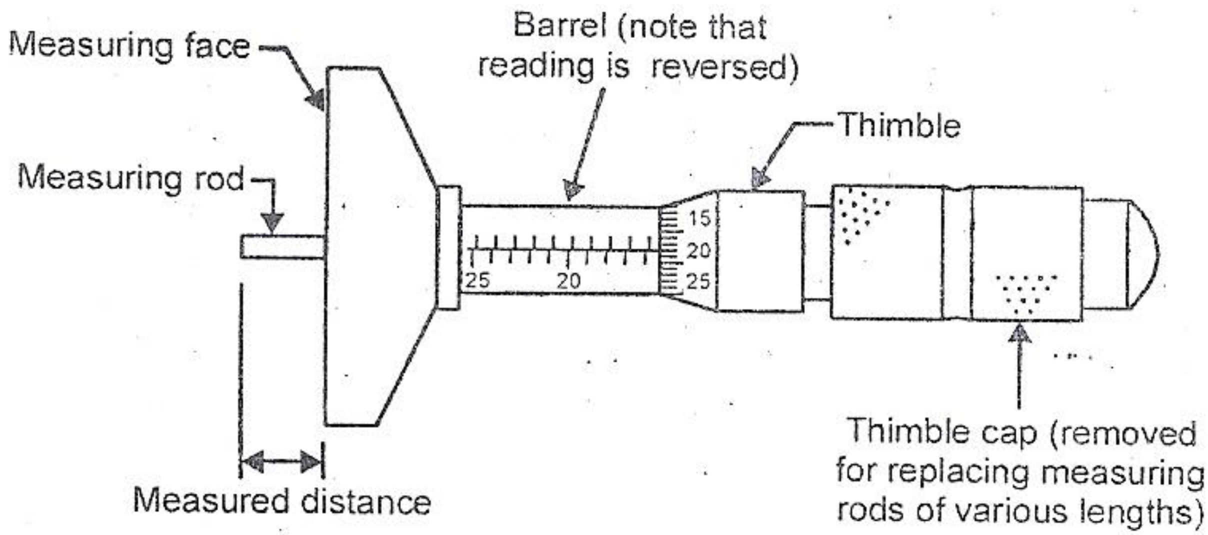


Figure 8: Depth Micrometer

For example, the measurement on the depth micrometer as shown in figure 8 A is: 16 + (18 X 0.01) mm = 16 + 0.18 = 16.18 mm

Measuring rods in steps of 25 mm can be interchanged to give a wide measuring range. The thimble cap is unscrewed from the thimble which allows the rod to be withdrawn. The desired rod is then inserted and thimble cap replaced, so holding the rod firmly against a rigid face.

7.4 Dial Indicators: It is also known as dial gauge or dial test indicators are used for checking flatness of surfaces and parallelism of bars and rods. They are also used for testing the machine tools. They can also be used for measurement of linear dimensions of jobs which require easy readability and moderate precision. Dial gauge is shown in figure 9. It has two pointer arms which are actuated by a rack and pinion arrangement which acts as a mechanical amplifier. The rack is cut in spindle. The spindle is made to come in contact with the work piece. The linear displacement is converted into rotary movement of pointers. The dial is divided into 100 equal divisions, each division represents a spindle movement of 0.01 mm. For 1 mm movement the bigger arm turns through one complete revolution. The smaller arm registers the number of full turns made by the bigger arm.

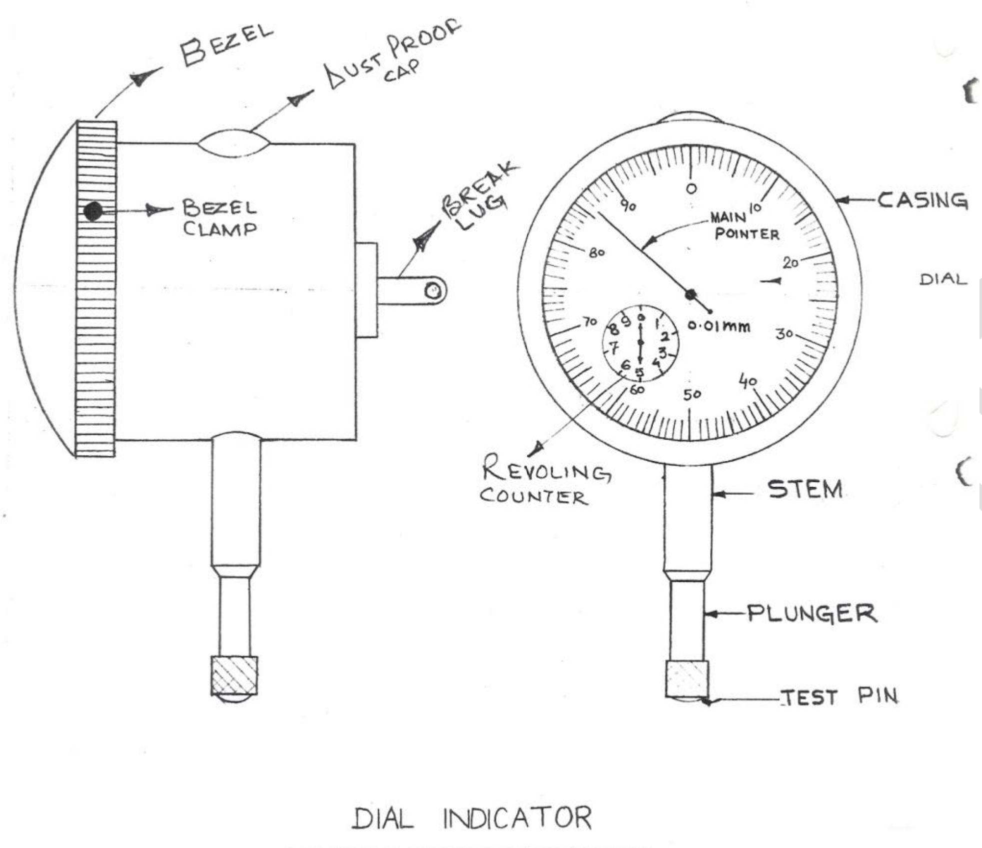


Figure 9. Dial Indicator

8. **limit gauges**:

These are the gauges by means of which a certain dimension or a certain form can be checked for which the gauges are designed or adjusted. For example:

- Snap gauges (Go and Not go gauges)
- Thread gauges
- Taper gauges
- Plug gauges
- Ring gauges
- Length gauges
- Form comparison gauges
- Thickness gauges
- Indicating gauges
- Standard Wire Gauge (SWG)

8.1 Snap gauges :

A Snap gauge, used in the measurement of plain external dimensions, consists of a U – shaped frame having jaws equipped with suitable gauging surfaces. A plain gauge has two parallel jaws or anvils which are made to some standard size and cannot be adjusted (Figure 10: “Go” and “Not Go “gauge with the approximate dimensions for checking a hole $25.50^{+0.00}_{-0.10}\text{mm}$). This type of gauge is being replaced by adjustable gauges which provide means of changing tolerance setting or adjusting to wear. Most gauges are provided with the “Go” and “Not Go “feature in a single jaw (Figure 11: “Go” and “Not Go“ gauge with the approximate dimensions for checking a hole $19.05^{+0.00}_{+0.10}\text{mm}$), such a design being both satisfactory and rapid. These gauges are also known as plug gauges. Other design of “ Go” and “ Not Go “ gauges are shown in Figure 12 and Figure 13

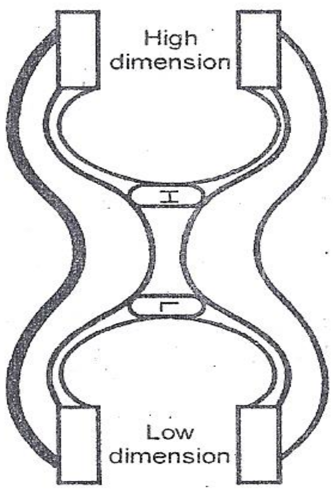


Figure 10: “Go” and “Not Go”

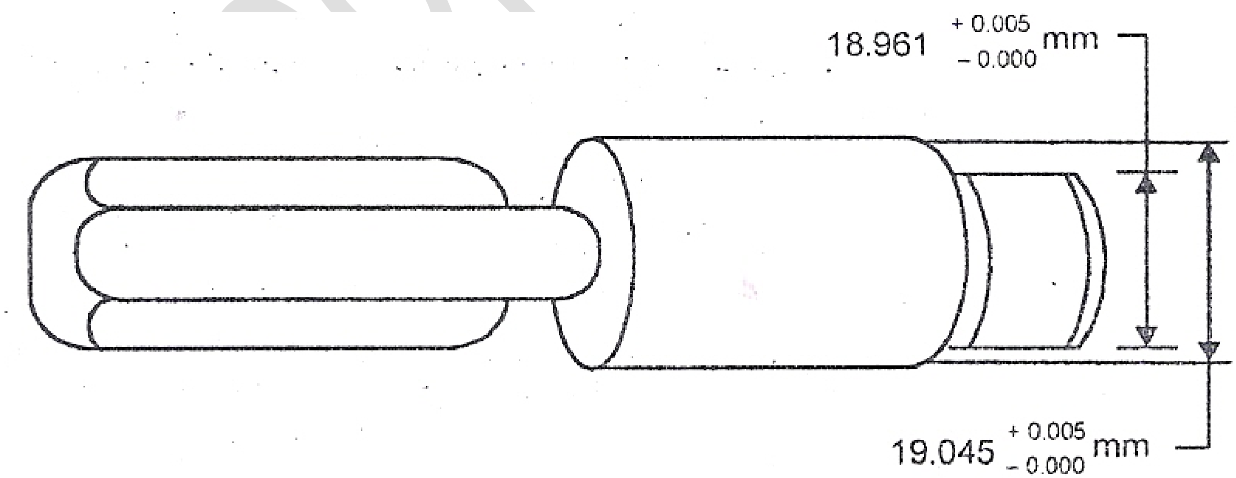


Figure 11: “Go” and “ Not Go”

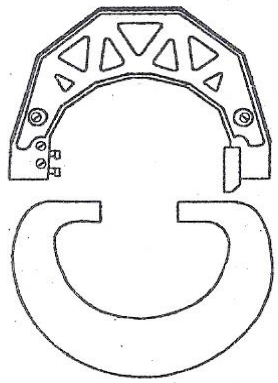


Figure 12: “ Go” and “ Not Go”

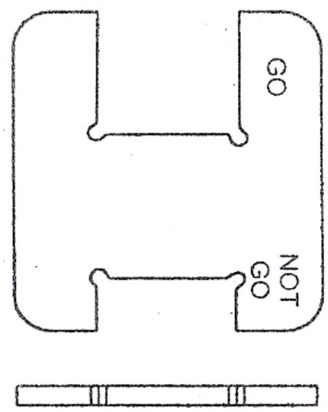


Figure 13: “ Go” and “ Not Go”

8.2 Ring gauges:

Ring gauges are used in pairs, a “ Go” and “ Not Go “ for outside diameters (Figure 14)

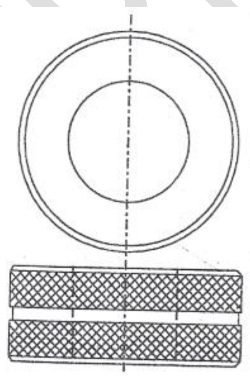


Figure 14 : Ring gauge

8.3 Taper Gauges:

Taper gauge are not dimensional gauges but rather a means of checking in terms of degrees. Their use is a matter more of fitting rather than measuring.

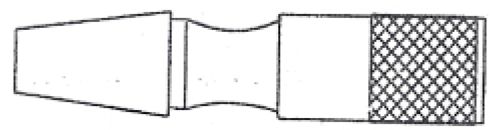


Figure 14(i) : Taper gauge for holes

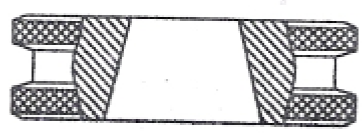


Figure 14(ii) : Taper gauge for shafts

8.4 Thickness or Feeler Gauge:

It consists of a number of thin blades and is used in checking clearances and for gauging in narrow places

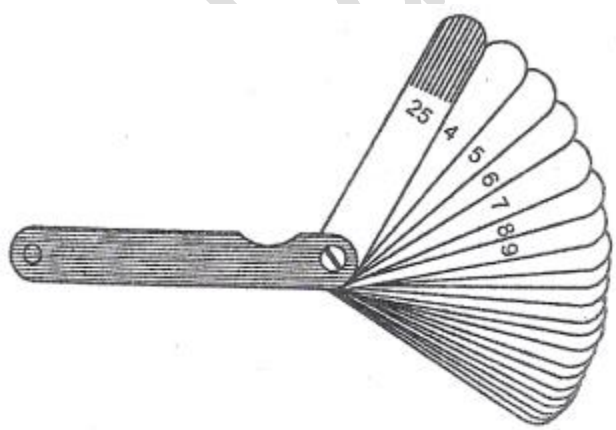


Figure 15 : Thickness or Feeler Gauge

8.5 Slip Gauges:

These are also known as gauge blocks. A gauge block is a rectangular block made up of hardened steel with two opposite faces separated by a defined distances. The faces are ground and lapped to make them flat and parallel within fine limits.

The blocks (Slip Gauges) are produced in sets with which it is possible to build a stack of any required height. The flatness and finish of the surfaces of the block is such that they are made to adhere to each other strongly sufficient enough to keep the stack together during normal use. The process of making the blocks adhere is called ‘**wringing**’. Wringing is done by first very carefully cleaning the faces, placing them in contact as shown in figure 16(i), pressing them together lightly and twisting as indicated by arrows. The two true faces will adhere with very considerable force.

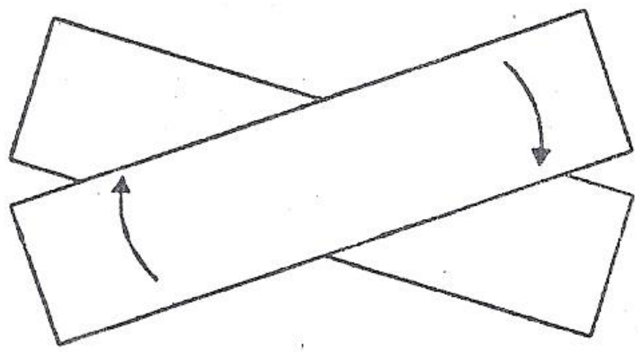


Figure 16(i): Wringing Process

These slip gauges are used along with sine bar for measuring tapers as shown in Figure 16(ii)

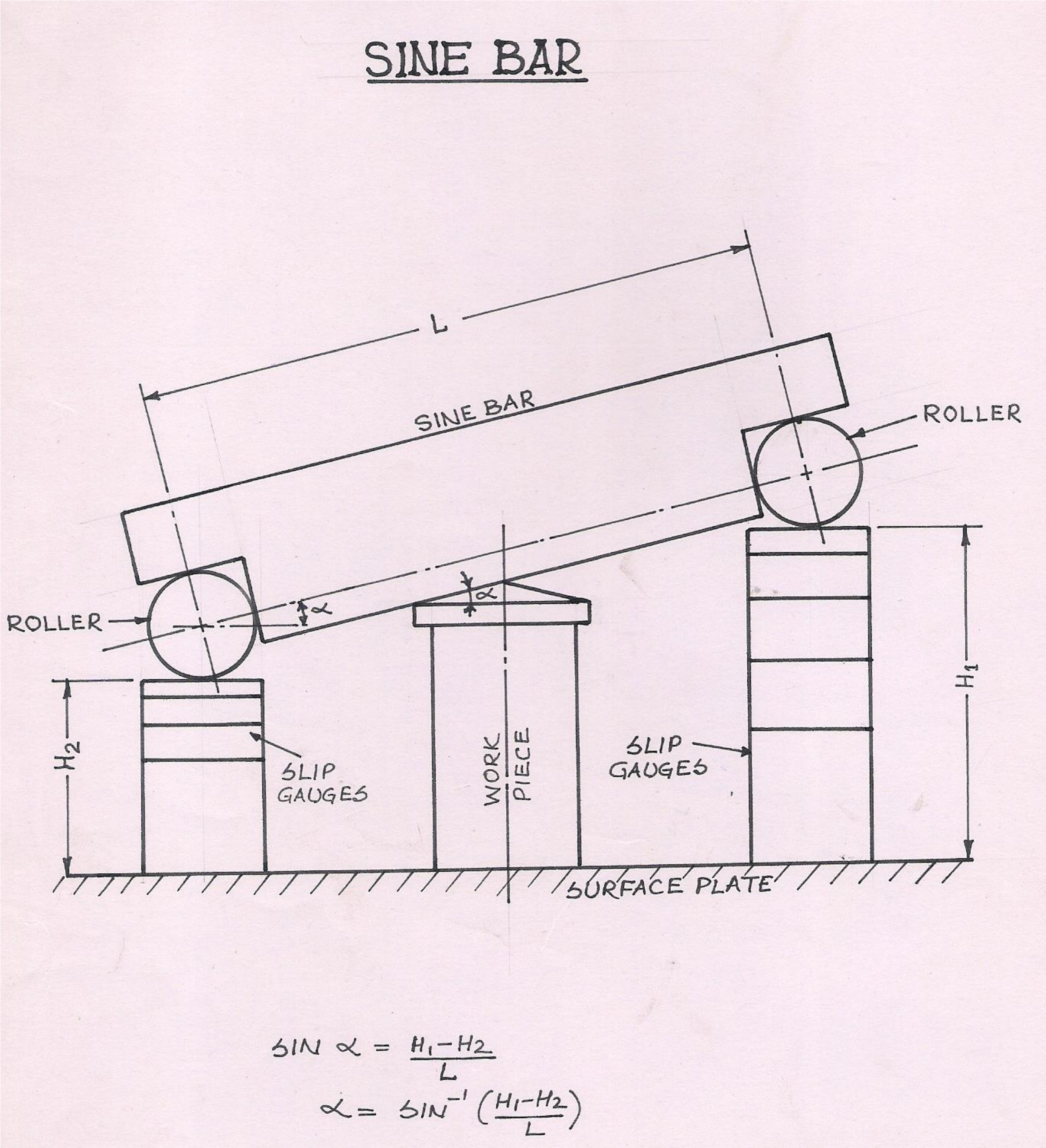


Figure 16 (ii): Sin Bar

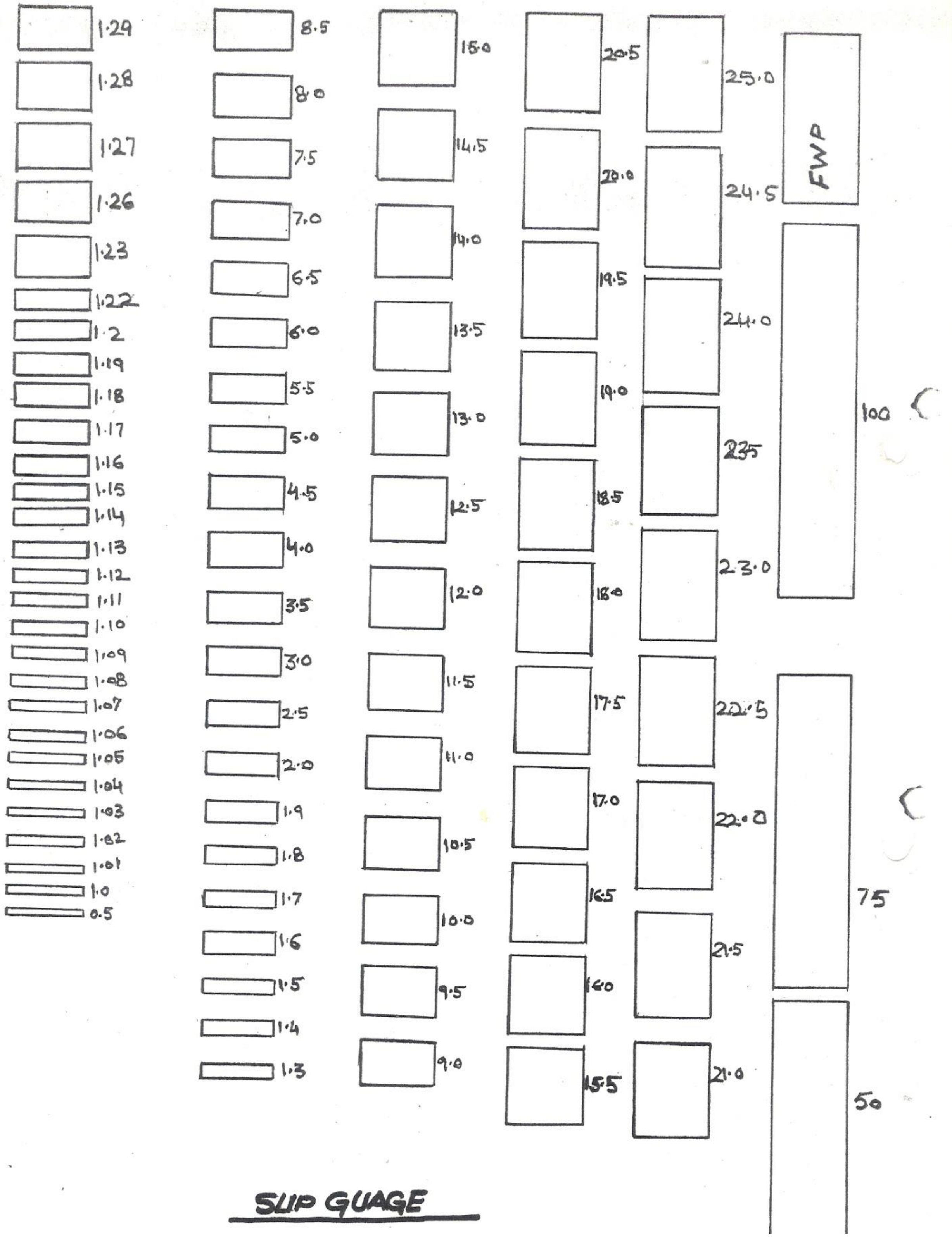


Figure 16 (iii) : Slip Gauge

8.6 Thread Gauge (Screw Pitch Gauge)

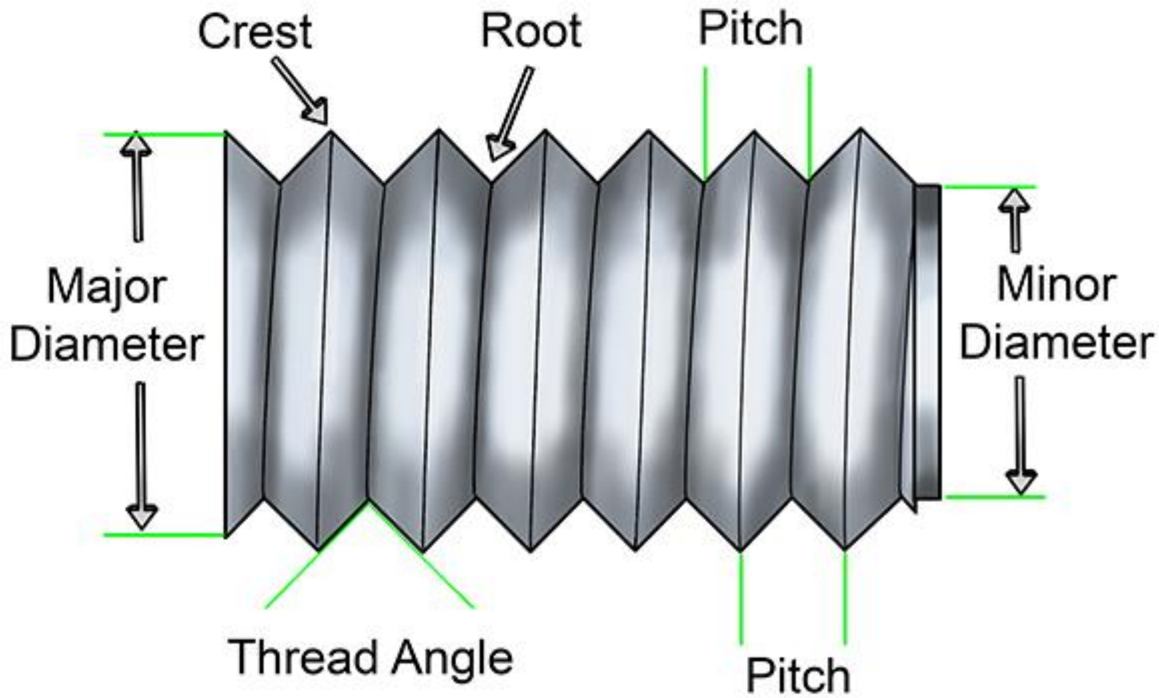


Figure 17: Thread Nomenclature

Thread gauges used to check number of threads on the given threaded portion

Figure 17A: Screw Pitch Gauge

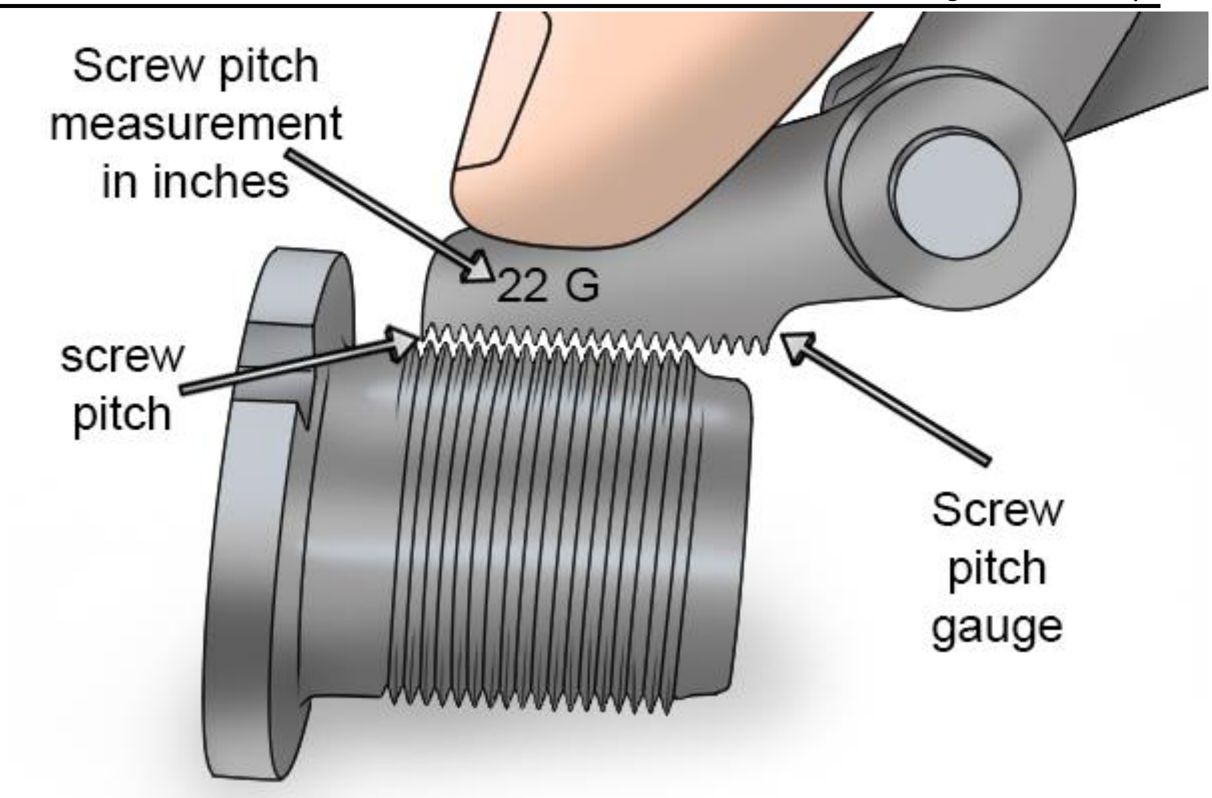


Figure 17B: Screw Pitch Gauge in Use

8.7 Radius Gauge:

Radius gauges used to measure the radius of given curved surface. This gauge has two types of leaves to measure internal as well as external radius of the given surface.

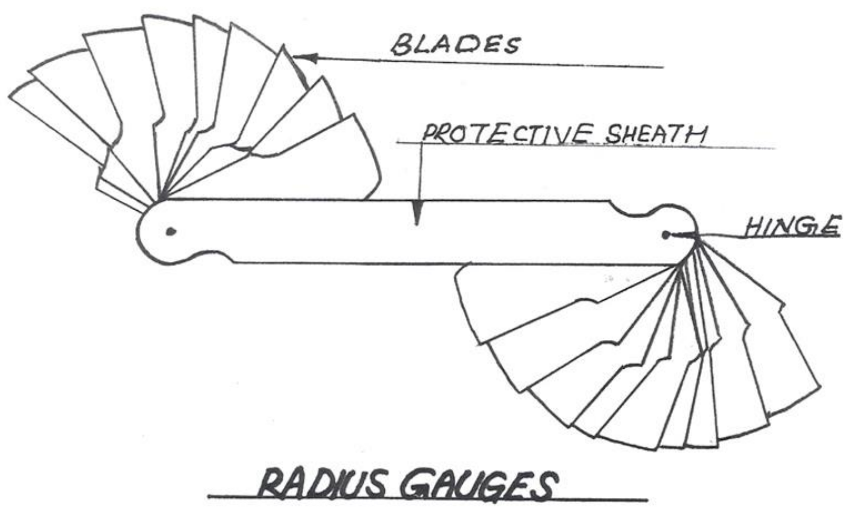


Figure 18 : Radius gauges

8.8 Standard Wire Gauge: This is used for measuring thickness of sheets and also for measuring diameters of wires

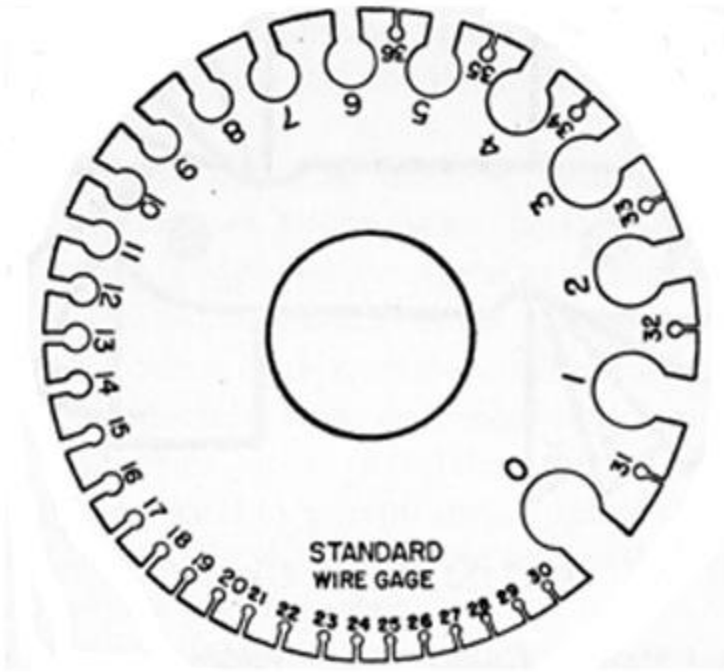


Figure 18: Standard Wire Gauge

SWG Conversion table

SWG	inches	mm	SWG	inches	mm	SWG	inches	mm
7/0	0.500	12.700	13	0.092	2.337	32	0.0108	0.274
6/0	0.464	11.786	14	0.080	2.032	33	0.0100	0.254
5/0	0.432	10.973	15	0.072	1.829	34	0.0092	0.234
4/0	0.400	10.160	16	0.064	1.626	35	0.0084	0.213
3/0	0.372	9.449	17	0.056	1.422	36	0.0076	0.193
2/0	0.348	8.839	18	0.048	1.219	37	0.0068	0.173
1/0	0.324	8.236	19	0.040	1.016	38	0.006	0.152
1	0.300	7.620	20	0.036	0.914	39	0.0052	0.132
2	0.276	7.010	21	0.032	0.813	40	0.0048	0.122
3	0.252	6.401	22	0.028	0.711	41	0.0044	0.112
4	0.232	5.893	23	0.024	0.610	42	0.004	0.102
5	0.212	5.385	24	0.022	0.559	43	0.0036	0.091
6	0.192	4.877	25	0.020	0.508	44	0.0032	0.081
7	0.176	4.470	26	0.018	0.457	45	0.0028	0.071
8	0.160	4.064	27	0.0164	0.417	46	0.0024	0.061
9	0.144	3.658	28	0.0148	0.376	47	0.002	0.051
10	0.128	3.251	29	0.0136	0.345	48	0.0016	0.041
11	0.116	2.946	30	0.0124	0.315	49	0.0012	0.030
12	0.104	2.642	31	0.0116	0.295	50	0.001	0.025

9. **Comparators:**

The comparator is an instrument used for comparing the dimensions of a component with a standard of length.

All comparator consist of following essential parts:

i. A fixed surface from which all measurements are taken.

ii. A very sensitive indicator which will show the movement of a sliding piece usually terminating in an anvil with a curved face.

iii. Some means of setting the curved face at an adjustable distance from surface.

This arrangement is used to measure the difference between the length or diameter of a component and a standard of length, usually made up of slip gauges.

Thus the purpose of a comparator, in general, is to detect and display the small difference between the unknown linear dimension and length of the standard. The difference in lengths is detected as a displacement of a sensing probe. The important and essential function of the instrument is to 'Magnify' or 'Amplify' the small input displacement so that it is displayed on an analogue scale

9.1 Uses of comparators:

Some of the important uses of comparators are given below:

i. To inspect the newly purchased gauges.
ii. In mass production, where components are to be checked at a very fast rate.
iii. As laboratory standards from which working or inspection gauge are set and correlated.
iv. In selective assembly of parts, where parts are graded in three groups depending upon their tolerance.
v. As working gauges, to prevent work spoilage and to maintain required tolerance at all important stages of manufacture.

9.2 Types of comparators

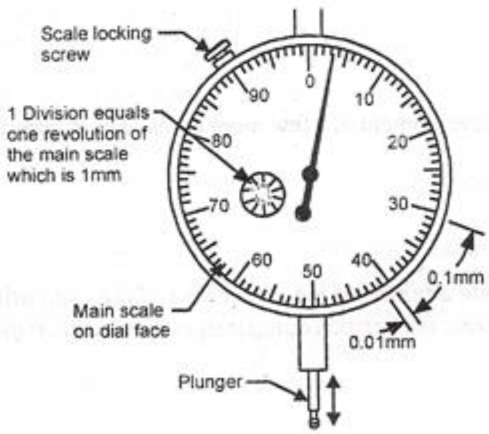
The most common commercially available comparators can be classified into following types:

i. Mechanical comparators
ii. Optical comparators
iii. Electrical and electronic comparators
iv. Fluid displacement comparators
v. Pneumatic comparators
vi. Mechanical - Optical comparators
vii. Electro - Mechanical comparators
viii. Multi check comparators

9.3 Mechanical Comparators:

- Dial indicator
- Reed type comparator
- Sigma comparator
- Johansson comparator
- Eden Rolt Millionth comparator
- Whereas these comparators are used for higher precision work and are costly, most frequently used one is **Dial indicator.** Dial indicator is already discussed in article 7.4 and shown in figure 9 also.

9.4 Dial indicator: Following fig. 19 shows the main features of a plunger-type dial gauge indicator. The main scale is graduated into equal divisions corresponding to a 0.01 mm movement of the plunger. A second but small dial is set in the main dial face to indicate the number of completed revolutions turned through one revolution being equivalent to 1 mm of plunger movement.



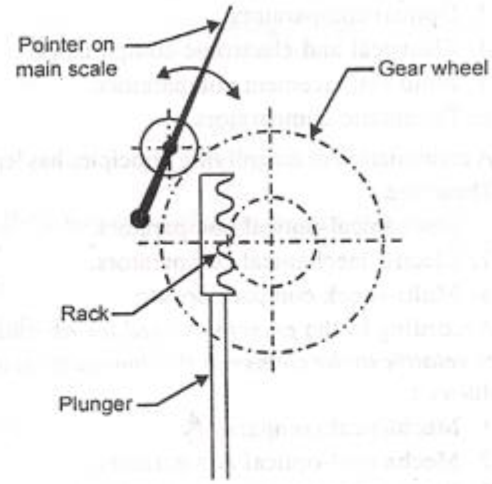


Fig 19: Dial indicator **Fig 20: Principle of Operation of Dial indicator**

To enable the instrument to be zero for any convenient position, the main scale can be rotated and locked into place, using the scale locking screw indicated.

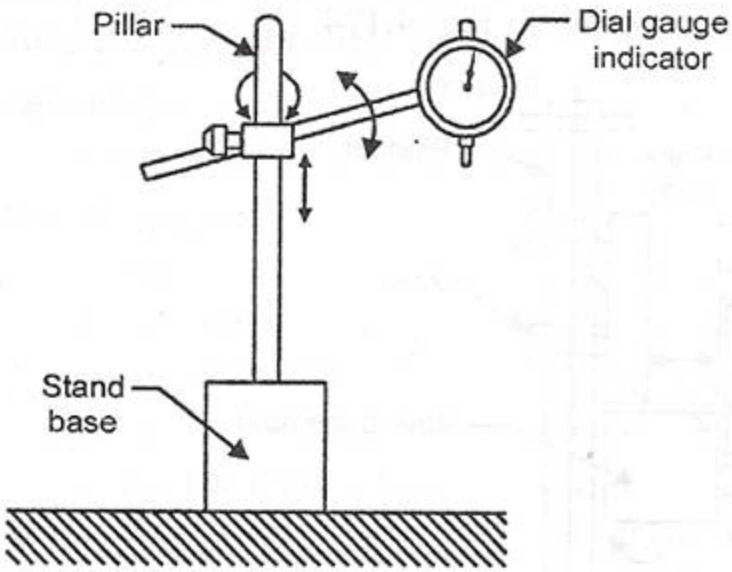


Figure 21: dial gauge indicator fitted to a pillar stand

The principle of operation of the instrument is shown in Fig. 20, where it can be seen that the plunger is attached to a rack. Meshing with a gear wheel, the straight or linear motion of the rack is converted into an angular or turning motion, the movement being magnified by using a large gear in mesh with a small gear wheel. It is the small gear wheel that is fitted to the main scale pointer shown in Fig. 20. The mechanism described above is simple, reliable and very sensitive. However this sensitivity means that great care must be exercised when using a dial gauge indicator.

Fig. 21. Shows a dial gauge indicator fitted to a pillar stand; the stand enables the indicator to be locked in any required position.

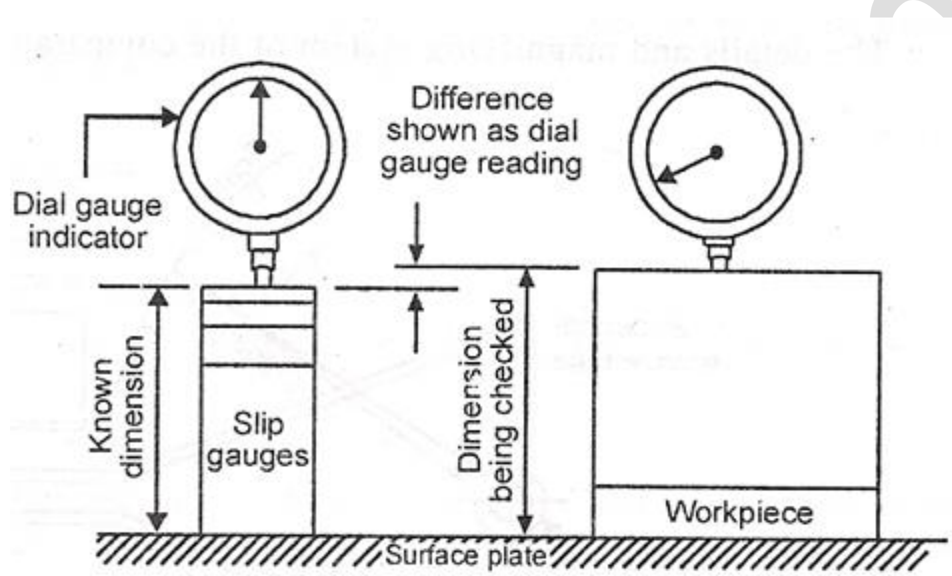


Figure 22: Plunger Type Dial Gauge Indicator in use

Fig. 22 shows a work piece being compared with a known standard, which may be, for example, slip gauges. With the dial gauge indicator placed so that the plunger is ill contact with the reference face, the dial scale can be set to zero and locked. Moving the pillar stand (with the dial gauge indicator fitted to it) across to the work piece, which is positioned on the same flat surface, any difference between the original setting and the face being checked can be read off the main scale.

9.5 Read type mechanical comparator: Fig. 23 shows a Reed comparator which is strictly a mechanical comparator because the linkages required for magnification are purely mechanical amplifiers.

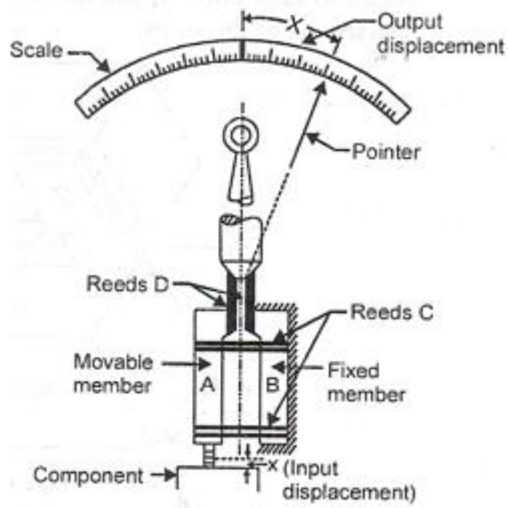


Fig. 23: Reed Type Mechanical comparator

- A comparator has a sensing probe, a spindle, attached to a movable member A.
- Member A moves through a diameter x, the input displacement, with respect to member B which is fixed.
- Member A is constrained by flexture strips or reeds C, to move to $.B$
- The pointer is attached to reed .
- A small input displacement x, produces a large angular movement, X, of the pointer on account of their orientation relative to the motion. The scale is calibrated by means of gauge blocks and indicates the difference in displacement of the fixed and the movable elements. There is no friction and the hysteresis effect is minimized by using suitable steel for the reeds.

Comparators of this type have sensitivities of the order of 0.25 x 10^{-3} mm/scale division. The mechanical amplification is usually less than 100, but it is multiplied by the optical lens system. It is available in amplification ranges from x 500 to x 1000.

9.6 Sigma Comparator: The sigma comparator is an excellent example of very successful instrument in which a high magnification is obtained entirely by mechanical means. Magnification ranges from 300 to 5000. The use of this instrument may be greatly extended by means of especially designed contacts and attachments to include internal diameter of screw threads. The details and magnifying system of the comparator are shown in Fig. 24.

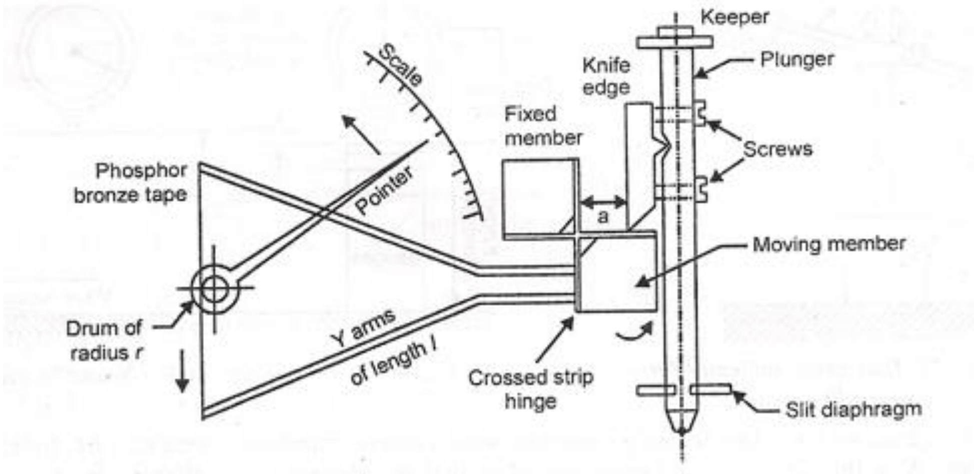


Fig. 24: **Sigma Comparator**

The plunger is mounted on a pair of slit diaphragm to give a frictionless linear motion, has mounted upon the face of the moving member a cross strip hinge (Fig. 25); This hinge consists of the moving component and a fixed member connected by flexible strips alternately at right angles to each other. It can be shown that it would pivot as would a hinge about the line of intersection of the strips.

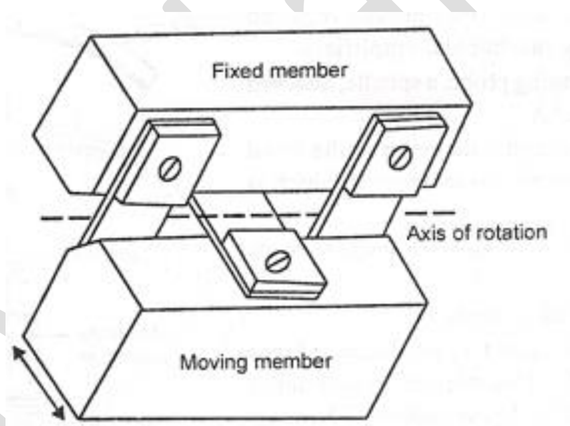


Figure 25: Cross Strip

An arm (which divides into Y form) is attached to the moving member. If the length of the arm is I and the distance from the hinge pivot to the knife edge is a, then first stage of magnification To the extremities of the Y arm is attached a phosphor bronze band or strip which is passed around a drum of radius r attached to the pointer spindle. If the pointer is of length R. the second stage of magnification is !i and the total magnification. The magnification can be changed by tightening one and slackening the other screw attaching the knife edge to plunger and thus adjusting the distance a. Still another way to produce instruments of different magnification is to use drums of different radii r and suitable strip.

Advantage: It has got a bold scale and large indicator pointer.

Disadvantages:

1. Due to motion of the parts, there is wear in the moving parts.
2. It is not as sensitive as optical or other types of comparator due to friction being present in the moving parts.

Some of the important features of a Sigma comparator are:

1. As the knife edge moves away from the moving member of the hinge and is followed by it, therefore, if too robust movement of the plunger is made due to shock load that will not be transmitted through the movement.
2. By mounting a non-ferrous disc on the pointer spindle and making it move in the field of a permanent magnet, dead beat readings can be obtained.
3. The error due to parallax is avoided by having a reflective strip on the scale.
4. The constant measuring pressure over the range of the instrument is obtained by the use of a magnet plunger on the frame and a keeper bar on the top of the plunger. As the plunger is raised the force required increases but the keeper bar approaches the magnet and the magnetic attraction between the two increases. Thus as the deflecting force increases, the assistance by the magnet increases and the total force remains constant.

9.7 Johansson 'Mikrokator' Fig. 26 shows diagrammatically the Johansson 'Mikrokator'. This instrument uses the simplest and most ingenious method for obtaining the mechanical magnification designed by H. Abramson which is called Abramson movement. It works on the principle of a button spinning on loop of string.

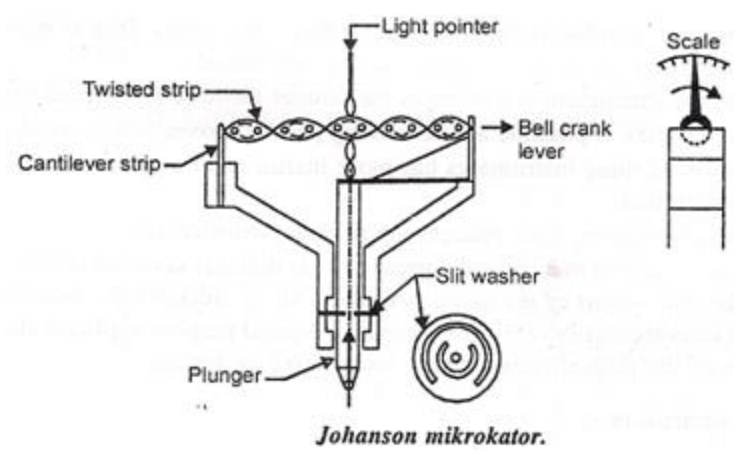


Fig. 26. Johanson mikrokator.

A twisted thin metal strip carries at the center of its length a very light pointer made of thin glass. The two halves of the strip from the center are twisted in opposite directions so that any pull on the strip will cause the center to rotate. One end of the strip is fixed to the adjustable cantilever strip and the other end is anchored to the spring below, one arm of which is carried on the measuring plunger. As the measuring plunger moves either upwards or downwards, the elbow acts as a bell crank lever and causes twisted strip to change its length thus making it further twist or untwist. Thus the pointer at the center of the twisted strip rotates by an amount proportional to the change in length of strip and proportional to the plunger movement. The bell crank lever is formed of flexible strips with a diagonal which is relatively stiff. The length of cantilever can be varied to adjust the magnification of the instrument. Since the centre line of the strip is straight even when twisted, therefore, it is directly stretched by the tension applied to the strip. Thus in order to prevent excessive stress on the central portion, the strip is perforated along the centre line by perforations as shown in Fig. 26. Thus to increase the amplification of the instrument, a very thin rectangular strip must be used. Further amplification can be adjusted by the cantilever strip.

Advantages of mechanical comparators:

1. The mechanical comparators are usually cheaper in comparison to other devices of amplifying.
2. These instruments to not require any external supply such as electricity or air and as such the variations in outside supplies do not affect the accuracy.
3. These instruments usually have a linear scale which is easily understood.
4. These are usually robust and compact and easy to handle.
5. These instruments are suitable for ordinary workshop conditions and being portable can be issued from a store.

Disadvantages of mechanical comparators:

1. These instruments possess more moving parts than other types. Due to more moving parts, the friction is more and subsequently less accuracy is obtained.
2. The range of the instrument is limited as the pointer moves over a fixed scale.
3. Error due to parallax is possible as the moving pointer moves over a fixed scale.
4. The mechanism of these instruments has more inertia and this may cause the instruments to be sensitive to vibrations.
5. Any slackness in moving parts reduces the accuracy considerably.

The major disadvantage of mechanical comparators is that it is very difficult to incorporate in them the arrangement for adjustment of the magnification. This is precisely the reason why electrical and mechanical comparators are increasingly being used for general purpose applications. These comparators +63*3 provide adjustment of the magnification over a wide range as desired.