CHAPTER-1 INSPECTION

PLANNING OF INSPECTION:-

While planning for inspection the following questions are decided before the inspection starts:-

(i) Where to inspect? – Place
(ii) When to inspect? – Time
(iii) How to inspect? – Method
(iv) How much to inspect? – Degree of inspection
(v) What to inspect? – Parameters
(vi) Who should inspect? – Person

Parameters (what to Inspect):-

The first phase of an inspection system is to decide what parameters are to be checked or inspected during the inspection. The parameter may be different for different kinds of jobs. So, the inspectors should be known clearly about the parameters to be checked e.g. diameter, length etc. These make the variation to be studied in case of statistical analysis.

Time of Inspection (When to Inspect?):-

There is no hard and fast rule as when the product is to be inspected but some general rules which may be followed are:

- Inspection should be done at each halt
- Inspection should be done after each operation in the process.

The above rules help in fixing the responsibility for any defective work. This also helps in knowing where the quality is respectively not being followed. Broadly there are three stages of inspection.

- In coming material inspection.
- In process material inspection at each and every stage of halt.
- Outgoing or final inspection.

Person (Who should inspect?):-

Before we start inspection of a product or process, we should appoint the persons for a particular parameters or products. So, that he will be responsible for any discrepancies in the process for that particulars parameter or product.

Place of Inspection (Where to Inspect?):-

The place of inspection largely depends upon the manufacturing conditions, circumstances and plant layout. Generally, three types of location are permitted for inspection. (Floor, centralised, separate room).

(a) **Floor inspection**:- It can be done at the machine itself. In continuous productions industries where every operation is linked through conveyors, it is not advised to carry product at a separate place for inspection. The advantages of it can be enlisted as:

- It saves the transportation of material to inspection room.
- It provides quick inspection service.
- It is best suited for bulky products.

(b) **Centralised/ separate inspection room**:-

In this system the products are brought to a separate inspection room or centrally located inspection counter.

It has following advantages.

(i) Inspection conditions are better because precession instruments can be used.

(ii) More accurate and be used.

(iii) Less chances of inspector being influenced.

Remedial and preventive inspection:-

Major difference between the two is that the latter attempts at prevention, the former on cure. Preventive inspection lays emphasis on removing assignable variables by paying special attention to the possibility of defects and waste is eliminated to the maximum possible extent. Preventive inspection is also known as constructive inspection and has thus the positive approach rather than the negative approach involved in remedial or corrective inspection. Remedial detects parts that are defective, thus it tries to discover defects which have already occurred. It tries to filter the good from the bad ones.

Operative / stage inspection (key point inspection):-

The inspection which takes place at each stage or at end of some functional operations, this inspection automatically fixes the responsibility of a worker or operation which caused the defect. It almost eliminates the need of final inspection and the defective piece is nipped in the bud, thereby eliminating the further wastage and the cost involved.

Incoming or receiving inspection:-

Materials inspection is concerned with the control of a quality of the raw material and purchased parts. It is also known as incoming inspection. It examines everything coming into the plant e.g. materials, parts, assemblies, equipments etc. The received material is generally checked for

(a) Requirement laid down in purchase order.
(b) Damages, corrosion, Cracks etc.
(c) Test report in case of raw-materials.

In case of necessity, the persons of the inspections department inspect the materials at the supplier's plant, before its delivery or even when it is in the process of productions.

In-process Inspection:-

It examines the parts and products in the plant at any stage of manufacturing process. It is mainly used as tool to anticipate and prevent subsequent production difficulties. The objectives of this type of inspections are:

1. Prevention of unnecessary hard work on the assembly floor.
2. Prevention of waste of large amount of material by inspecting mass production operations in the beginning as well as subsequent operations.
3. Prevention of rework on spoiled parts.
4. To ensure against loss of parts while in transit from one process to another.

Final inspection:-

In this type of inspection, the product is checked by appearance. So, that to know that every surface has gone through the required operations or not, before undergoing the appropriate tests or stores. It is a sort of centralised inspection and makes use of special testing instruments.

Factors Influencing the Quality of Manufacture:-

The following nine factors directly affect the quality of products and services.

(i) Market for products, services
(ii) Manpower
(iii) Materials
(iv) Money
(v) Management
(vi) Machines and Method

(vii) Motivations of employees
(viii) Modern information approaches.
(ix) Mounting products needs.

- **Market demand**:- It occurs as per customers demand for a particular products type, quality and quantity.
- **Manpower**:- Both for quality designs and for productions of quality goods, right type of men with required knowledge are essential.
- **Materials**:- Due to pressure on production cost and quality requirements, it becomes necessary to work with wide variety of materials having right specification.
- **Money**:- Increased competition, more mechanisation and lower profit margins have made scrap and rework losses as very serious cost of maintenance & improvement of quality have increased to a great extent. Money crunch touches the quality.
- **Management**: - Without managements interest and active co-operations there can be no adequate quality.
- **Machines and Method**: - Manufacturing equipments have become more complex in order to meet high volume of production and high level of quality goals. The machines and technologies required are highly sensitive to meet quality goals.
- **Motivations of employees**: - A motivated worker can produce better quality products and also he can increase the production rate. The motivation of the employees can be done by financially (Bonus, increments etc).
- **Modern information approaches**: - By implementing modern information approaches to the various production and marketing process the quality of products can be improved.
- **Mounting products needs**: - The right operation at right time in the production process can also improve the quality of products.

Units of measurements:-

The results of a measurement of a physical quantity must be defined both in kind and magnitude. The standard measure of each kind of physical quantity is called a unit.

A considerable number of systems of units have been used at various times during human history. Some systems are of historical interest while others have been used in actual experimental work and have found acceptance in some country.

The international authority on standardisation of names and symbols of physical quantities in metric units has been conference general der poids et measures (CGPM). The system of SI units is based on seven base units and two supplementary units, from which the host of derived unit is obtained.

Base Units

Quality	Unit	Abbreviation
Length	Meter	m
Mass	Kilogram	Kg
Time	Second	S
Electric current	Ampere	A
Temperature	Kelvin	K
Luminous intensity	Candela	Cd
Amount of substance	Mole	Mol.

Supplementary Units

Quality	Unit	Abbreviation
Plane angle	Radian	Rad.
Solid angle	Steradian	Sr.

Some Derived Units

Quantity and Symbol	Derivation	Unit	Unit Symbol
Force F, Weight G	**Mass ×acceleration**	(kg m/s^2)	N
Stress P, Pressure (P)	Force÷unit area	Newton	Pa
Work W, Energy E	**Force×distance**	(N/m^2) Pascal	J
Power (P)	Work÷unit time	(Nm) Joule	W
Velocity (V)	**Distance ÷ unit**	(J/S) watt	m/s
Acceleration (a)	**time**	(m/s)	m/s^2
Frequency (f)	Velocity ÷unit time	(m/s^2)	Hz
	Cycles ÷unit time	(cycle/s), Hertz	

Standards For Measurement:-

We know that measurement is the result of an opinion formed by one or more observes about the relative size or intensity of some physical quantity. The opinion is formed by the observer after comparing the object with a quantity of same kind chosen as a unit, called standard.

- A standard can be defined as "A physical representation of a unit of measurement, a piece of equipment having a known measure of a physical quantity".
  Just as there are fundamentals and derived units of measurement we find different types of "standards of measurements" classified by their function and application in the following categories.

1. According to geographical area of application.
   (a) International standards.
   (b) National standards
   (c) company
2. According to function: Standards for linear measurement.
   (a) Line standard
   (b) End standard
   (c) Wavelength Standard
3. According to importance and hierarchy of standards.
   (a) Primary standards
   (b) Secondary standards
   (c) Tertiary standards
   (d) Working standards.

International standards:-

The international standards are defined on the basis of international agreements. They represent the units of measurement which are closest to the possible accuracy attainable with present day technological and scientific methods. International standards are checked and evaluated regularly against absolutely measurements in terms of the fundamental units. The international standards are maintained at the International Bureau of weights and measure of standardisation (ISO). The adoption of international standards has been essential to ensure interchange ability of components & equipments made in different countries and as a mass of developing and expanding world trade.

National standards:-

The Bureau of Indian standards (BSI) is on the same pattern as British Standards institution (BSI). Its important wing is Indian standards institution (ISI). Its principle objects are

(1) To eliminate the waste of time and material involved in the production of unnecessary variety of pattern and sizes of articles for one and the same purpose.
(2) To set up standards of quality and dimensions and promote the general adoption in Indian standards.
(3) To co-ordinate the efforts of producers and users for the improvement.
(4) Standardisation and specification of engineering and industrial materials.
(5) To simplify production and distribution.

The preparation of standards is the responsibility of the industry concerned and the Indian Standards Institution (ISI) co-ordinates the activities involved. Indian standards are the result of the work of voluntary committees and general agreement of all interested parties before the Indian standards are approved for publication.

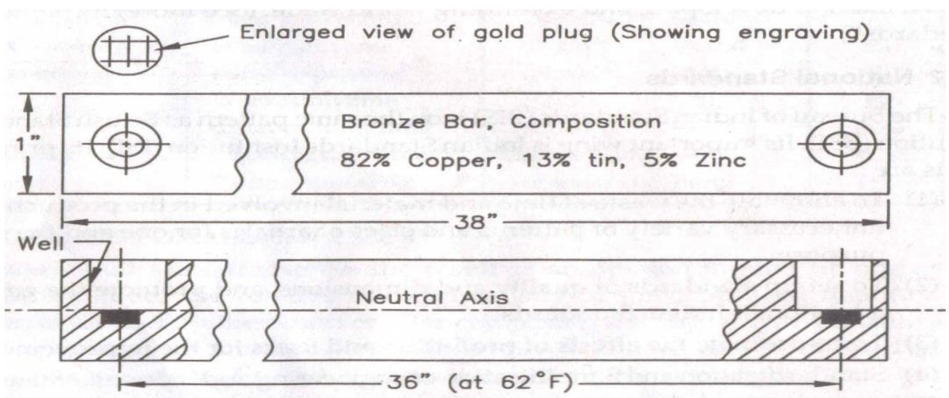
Company standards:-

A company industry standard is maintained between different departments or units for guiding its design principles. There are also agreed upon by different industries for working in association with each other such as by system concerns ancillary units attached by large scale industries.

Line standard:-

According to it, yard or metre is defined as the distance between scribed lines on a bar of metal under certain conditions of temperature and supports. These are legal standards and act of parliament authorities.

(i) Yard:- The imperial standard yard is a bronze bar of one inch square cross-section and 38 inches long.



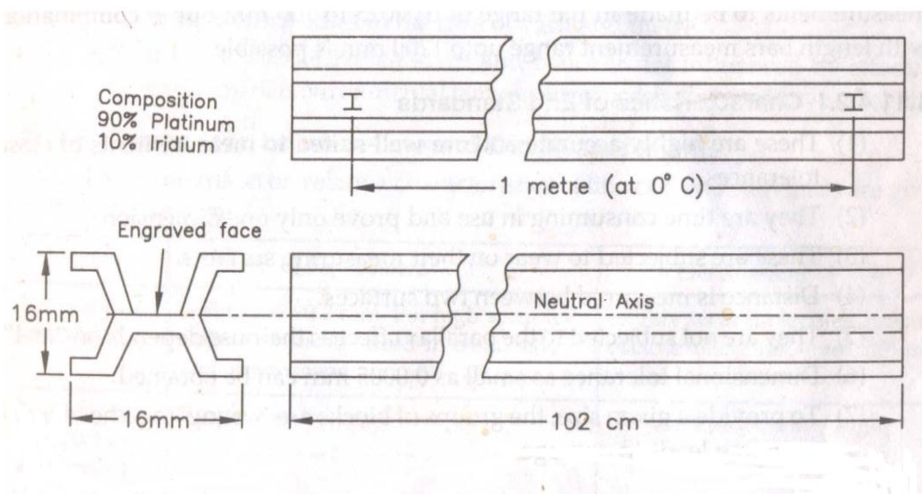
A round recess, one inch away from two ends, is cut at both ends up to central plane of the bar. A good plug 1/10 inches diameter having three lines engraved transversely and two lines longitudinally is inserted into these holes so that the lines are in neutral plane. Yard is then defined as the distance between the two central transverse lines of the plug at neutral axis has the following advantages.

(a) Due to bending of beam the neutral axis remains unaffected.
(b) The plug, being in a well is protected from accidental damage.

The imperial standard yard consist of 82% copper, 12% tin, 5% zinc. though imperial standard yard was widely adopted, yet it is interesting to note that the American standard yard was defined at a temp. at 68˚F and very slightly longer than the imperial standard yard. (1 yard=0.91439841 metre).

(ii) Metre:-

This is the distance between the centre portions of two lines engraved on the polished surface of a bar of pure platinum- iridium alloy (90% pt and 10% iridium). The length of the metre can also be defined as the straight line distance, at 0˚ between the centre portions of pure platinum-iridium alloy of 102cm total length and having a cross-section as shown in figure.



International prototype metre.

It has a shape of winged section, having a web whose surface lines are on the neutral axis. The section chosen gives maximum rigidity and economy of costly material. Overall width and depth are 16mm each. This reference is designated as international prototype metre-M and also it show 1 metre = 39.37014 inch.

Characteristics of Line Standard:-

The characteristics of line standards are:

(i) Distance is measured between two lines.
(ii) Scales can be accurately engraved but it is difficult to take full advantage of this accuracy.
(iii) The scale markings are not subject to wear although significant wear on leading end leads to under sizing.
(iv) A scale is quick and easy to use over a wide range since only one scale is required.
(v) Scales are subjected to the parallax effect, a source of both positive and negative reading errors.
(vi) Scales are not convenient for close tolerance length measurement except in conjunction with microscopes.
(vii) Line standards are not as accurate as end standards.

End Standards:-

A modern end standard consists fundamentally of a block or bar of hardened steel whose end faces are lapped flat and parallel to within a few millionth of a cm. By the process of lapping, its size too can be controlled very accurately. Although from time to time, various types of end bar have been constructed. Some having flat and some spherical faces but the flat & parallel faced bar is firmly established as the most practical method of end measurement.

Slip gauges are also used as end standards of measurement in all metrological laboratories. These are made of high grade cast steel and hardened throughout. Except for applications where microscopes can be used, scales are not generally convenient for the direct measurement of engineering products, where as slip gauges are in everyday use in tool rooms, workshops and inspections departments throughout the world with the set of slip gauges, combinations of slip gauges enables measurement to be made in the range of 0.02025 to 100mm but in combination with length bars measurements range up to 1200mm is possible.

Characteristics of End standards:-

(1) These are highly accurate and are well suited to measurements of close tolerance.
(2) They are time consuming in use and prove only one dimension.
(3) These are subjected to wear on their measuring surfaces.
(4) Distance is measured between two surfaces.
(5) They are not subjected to the parallax effect as their use depends on "feel".
(6) Dimensional tolerance as small as 0.0005mm can be obtained.
(7) To provide a given size, the groups of blocks are wrung together. Faculty wringing leads to damage.

Wavelength Standard:-

Jacques Babinet, a French philosopher, suggested in 1829, that wavelengths of monochromatic light might be used as natural and invariable units of length. Using wavelength of monochromatic lights, the working standard is no more dependent upon the physical standard. Seventh general conference of weight and measurement in Paris approved the definition of a standard of lengths relative to the metre in terms of the wave length of the red radiations of cadmium.

For some times, light wavelength standard had to be objected because of the impossibility of producing pure monochromatic light as wavelength depends upon the amount of isotope impurity in three elements. But now with the rapid development in atomic energy industry, pure isotopes of natural elements have been produced.

Cadmium 114, Krypton 86 and Mercury 198 are possible sources of radiation of wave lengths suitable as natural standard of lengths. Since wavelength standard is not a physical one, it need not be preserved. This is reproducible standard of length and the error of reproduction can be the order of 1 part in 100 million. Kr-86 is the most suitable element if used in a hot cathode discharge lamp maintained at 68˚K temperature. The orange radiation was selected for the measurement. According to this Standard meter = 1659763.73$\times$ wavelength of the radiation.

Advantages or characteristics of wavelength Standard:-

Light as a natural standard has several advantages over the previous standard bars.

(1) It does not change length.
(2) This standard is easily available to all standardising houses, laboratories and industries.
(3) It can easily transfer to other standards.

Comparison Between Line and End Measurements:-

Aspects	Line Standard	End Standard
Accuracy of measurement.	Limited to 0.2mm for high accuracy, scales have to be used in conjunction with microscope.	Highly accurate for measurement of close tolerance, up to 0.001mm
Manufacture & cost of equipment.	Simple & low	Complex process and high
Effect of use	Scale markings not subjected to wear but end of scale is worn. Thus it may be difficult to assume zero of scale as datum.	Measuring faces get worn out to take care of this end pieces can be hardened, protecting type, built in datum.
Times of measurement	Quick and easy	Timing consuming
Errors	There can be parallax errors	Improper wringing of slip gauges may introduce errors. Change in Laboratory temperature may lead to some errors.

Terminology [Limits, Fits and Tolerance]:-

The following terms and definitions are based on these given in IS:919 recommendation for limits & fits for engineering, which is in line with the ISO recommendations.

(a) Basic Dimensions:-

A basic dimension is the dimensions as worked out by purely design considerations. Since the ideal conditions of producing basic dimensions can be treated as theoretical or nominal size and it has only to be approximated.

(b) Shaft:-

The term shaft refers not only to diameters of a circular shaft but to any external dimensions on a component.

(c) Hole:-

This term refers not only to the diameter of a circular hole but to any internal dimensions on a component.

(d) Size:-

A number expressing in a particular unit, the numerical value of a linear dimensions.

(e) Nominal size:-

A nominal size is the size which is used for the purpose of general identification. Thus the nominal size of a hole and shaft assembly is 60mm, even though the basic size of the hole may be 60mm & the basic size of the shaft 59.5mm.

(f) Basic size:-

The basic size is the standard size for the part and is the same for both the hole and its shaft.

(g) Actual size:-

This size is the size of a feature (shaft or hole) obtained by measurement.

(h) Zero line:-

This is the line which represents the basic size. So that the deviation from the basic size is zero.

(i) Limits of size:-

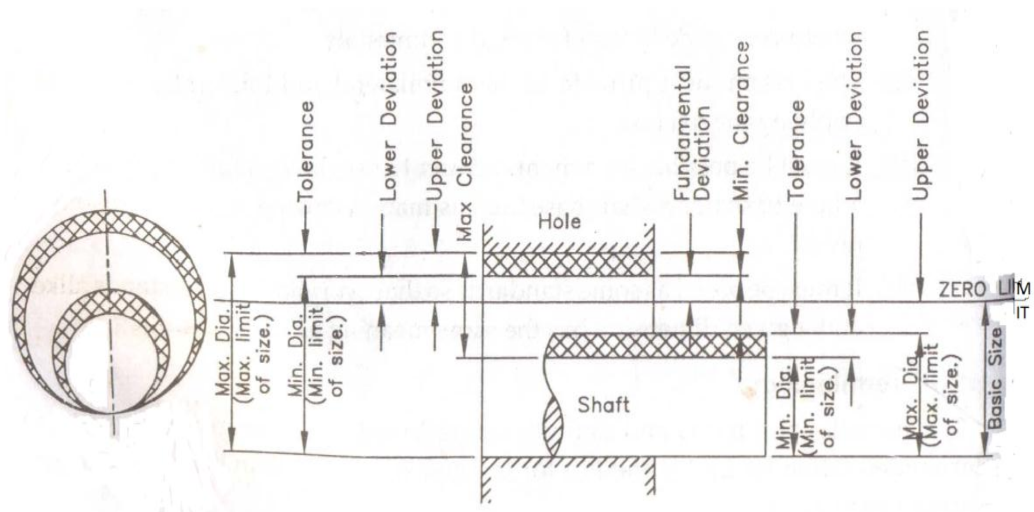
These are maximum & minimum permissible sizes of the part.

- Minimum limit of size:-

The minimum size permitted for the part. It is also known as lower limit.

- Maximum limit of size:-

The maximum size permitted for the part. It is also known as upper limit



(Basic size, Deviation and Tolerance)

(j) Tolerance:-

The difference between maximum and minimum limits of size.

(k) Tolerance size:-

This is difference between the two limits of size.

(l) Grade of tolerance:-

The tolerance grade is an indication of the degree of accuracy of manufacture. It is designated by the letter IT followed by a number. IT01 up to IT16. The large number, larger is the tolerance.

(m) Allowance:-

The intentional difference between the dimensions of the two mating parts is called allowance. It can also be defined as the difference between the maximum shaft and minimum hole size.

(n) Deviation:-

The algebraic difference between a size (actual size, limit of size etc) and the corresponding basic size.

- Upper Deviation:-

  The algebraic difference between the maximum limit of size and the corresponding basic size.

- Lower deviation:-

  The algebraic difference between the minimum limit of size and corresponding basic size.

- Fundamental Deviation:-

  This is the deviation, either the upper or lower deviation, which is nearest one to zero line for either a hole or a shaft. It finds the position of the tolerances zone in relation to zero line.

FIT:- It means a degree of tightness or looseness between two mating parts to perform a definite function.

(i) Clearance fit:-

The difference between the sizes of a hole and shaft which are to be assembled together when the shaft is smaller from the hole. A clearance fit could be obtained by making the lower limit of the hole equal to or larger than the upper limit on the shaft.

(ii) Interference fit:-

The difference between the size of a hole and a shaft which are to be assembled together when the shaft is larger than the hole. It would be obtained by making the lower limit on the hole.

(iii) Transition fit:-

Between these two conditions lies a range of fits known as transition fits. These are obtained when the upper limit on the shaft is larger than the lower limit on the hole, and the lower limit on the shaft is smaller than the upper limit on the hole. It must be realised that transition fits exist only as a class; any actual hole and shaft must assemble with either a clearance or interference fit.

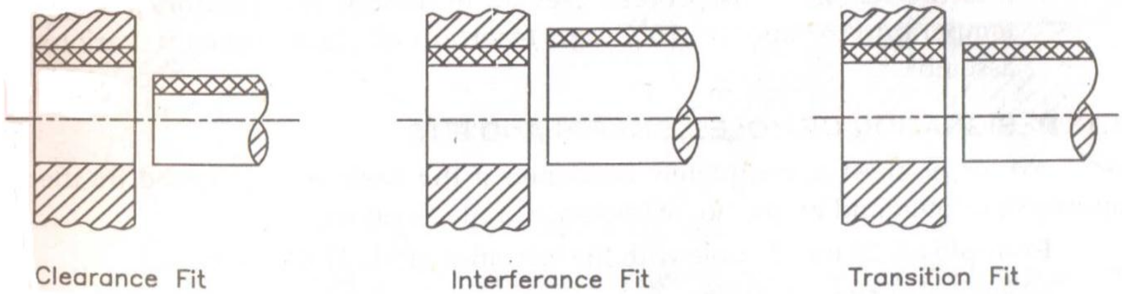


Fig. Types of Fit.

Designation of holes, Shafts and Fits:-

A hole or shaft is completely described if the basic size, followed by the appropriate letter and by the appropriate letter by the no. of tolerance grade is given.

Example:- A 20mm H-hole with the tolerance grade IT8 is given as 20mm H8 or simply 20H8.

A 20mm fit shaft with the tolerance grade is IT7 is given as 20mm f 7 or simply 20f7. A fit is indicated by combining the designation written first, regardless of system (i.e. hole basis or shaft basis).

Ex.- 20H8- f7 or 20H8/f7

Commonly used Holes and Shafts:-

In several engineering applications the fits required can be met by a quite small selection from the full range available in the standards. The holes and shafts commonly used are as follows:

Holes: H6, H7, H8, H9, H11

Shafts: c11, d10, e9, f7, h6, k6, n6, p6, s6

IS: 919 gives the most commonly used holes and shafts up to 500mm, for the purpose of general engineering.

Basis of Fits or Limits System:-

A fit or limit system consists of a series of tolerances arranged to suit a specific range of sizes and functions. So, that limits of size may be selected and given to mating components to ensure specific classes of fit. It has two categories.

(i) Hole Basis System
(ii) Shaft Basis System

Hole Basis System :- Hole basis system is one in which the limits on the holes are kept constant and the variations necessary to obtain the classes of fit are arranged by varying those on shaft.

Shaft Basis System :- Shaft basis system is one in which the limits on the shaft are kept constant and the variations necessary to obtain the classes of fit are arranged by varying the limits on the holes.

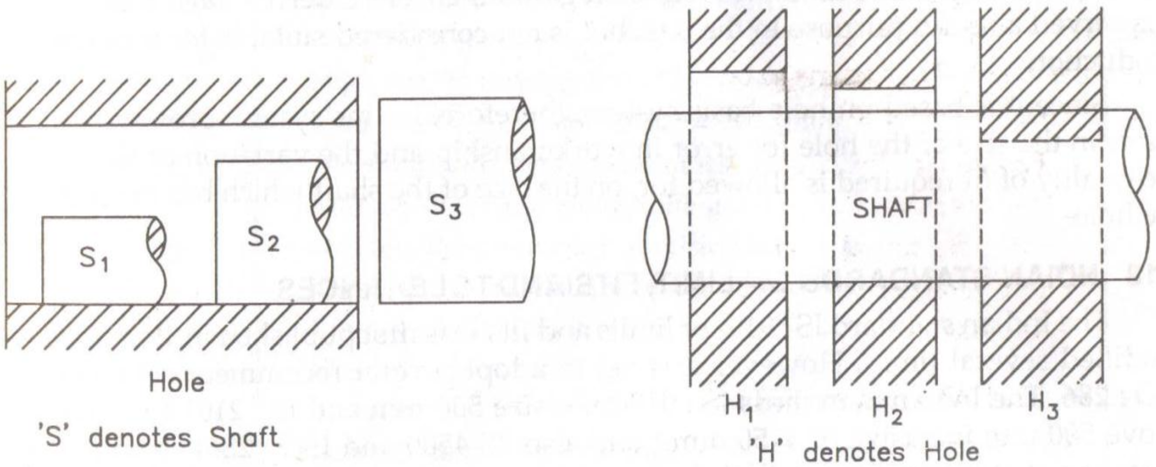
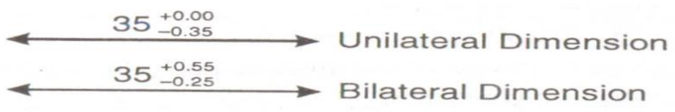


Fig. Hole and shaft basis system.

Unilateral and Bilateral Tolerance:-

A unilateral tolerance is one which allows the variations in only one direction, either plus or minus, from a design size. It is advantageous in the close fittings holes and shafts where the critical size is approached as material is removed step by step during manufacture.



- A Bilateral tolerance is one which allows the variation in both the directions from the design size. The total tolerance is divided in two parts, plus and minus.

Indian Standards on Limit, Fits and Tolerances:-

The Indian Standard IS: 919 for limits and fits was first published in 1963 and modified several times. However it is yet to adopt several recommendations of ISO: 286. The Indian Standards IS: 919 up to size 500mm and IS: 2101 for sizes above 500mm inclusive of 3150mm (and also BS 4500 and ISO: 286) cover the holes and shafts from the smallest size up to 3150mm. For any size over this range, there is wide choice of fits available and for each of the fits there is a series of tolerance grades from very fine to wide tolerances. Either a hole-based or a shaft-based system can be obtained from the standard. It is recommended that a hole-based system should be generally used. A shaft based system may be advisable in some cases.

Total range of 3150mm has been covered in two parts by Indian Standards while sizes up to 500mm are covered in IS:919, sizes above 500 up to 3150 mm are covered in IS: 2101.

ISO SYSTEM OF LIMITS AND FITS:-

ISO system has presently been universally adopted and as a matter of fact IS: 919 is almost in line with this system. While ISO specifies 28 classes of holes designated A, B, C, CD, E, EF, F, FG, G, H, J, JS, K, M, N, P, R, S, T, U, V, X, Y, Z, ZA, AB, ZC and 18 grades of tolerance exactly matching with those of ISO: systems. Similarly ISO has 28 classes of shafts while IS:919 specifies only 25 classes of shaft. Other characteristics such as fundamental deviation and tolerance unit etc. are same in both the systems.

Each of 25 holes a choice of 18 grades of tolerances which are designated as IT 01, IT 0, IT 1, IT 2 upto and including IT 16. The tolerance grade decides the accuracy of manufacture.

The seven finest grades (IT 01 to IT 05) cover sizes upto 500mm and the eleven coarsest grades upto 3150mm. The tolerances in each grade vary over the range of size to produce as far as possible, the same standard of relative accuracy in each size.

GRADES OF TOLERANCES AND APPLICATIONS:-

Following is a very general gradations of tolerance grade and appropriate class of work as per IS:919.

Tolerance Grade	Class of work
01, 0, 1	Gauge Blocks
2	High Quality Gauges, Plug Gauges
3	Good Quality Gauges, Gap Gauges
4	Gauges, Precise Fit produced by lapping
5	Ball bearings, Machine lapping, Fine boring and grinding.
6	Grinding, Fine Boring.
7	High quality turning, broaching, Boring.
8	Centre Lathe turning and Boring , Reaming
9	Worn capstan or automatic lathes.
10	Milling, slotting, Planning, Rolling.
11	Drilling, rough turning, Precision tube drawing.
12	Light presswork, Tube drawing.
13	Presswork, Tube rolling.
14	Die casting or moulding.
15	Stamping.
16	Sand casting, Flame cutting.

Guide for selection for FITS:-

This guide gives recommendations in engineering problems concerned with the mating of a shaft and a hole. The recommendations are also applicable to non-cylindrical fits. This guide also gives the representative usage of various classes and grades to fit. The examples are only of an illustrative character and they do not specify any design details. Fits may be selected on the hole basis system or the shaft basis systems.

An engineer must be familiar with the manufacturing process involved and bear in mind such factors as the length of contact of mating parts, speed, lubrication, temperature, humidity, surface finish, type and quality of the material used for each part and also the forces and loading which are present.

It may be noted that in IS: 919-1963, innumerable number of combinations of shafts and holes may be used for a fit. It should be understood that it is normally easier to produce a shaft with a specified tolerance than a hole with the same tolerance due to the fixed characters of hole producing tools. Therefore, it is the common practice to following only the system of hole basis. However in certain cases when products are made from bright drawn bars, shaft basis system may also be employed and actually which system should be chosen depends upon many conditions.

FOR HOLES

TYPE OF FIT	CLASS OF SHAFT			WITH HOLES			REMARKS
		H6	H7	H8	H9	H11	
CLEARANCE	a b					a11 b11	Large clearance fit and widely used.
	c					c11	Slack running fit
	d		d8	d8, d9, d10	d8, d9, d10	d9	Loose running fit
	e	e7	e8	e8, e9			Easy running fit
	f	f6	f7	f7, f8			Normal running fit
	g	g5	g6				Close running fit or sliding fit, also spigot and location fit.
	h	h5	h6	h7, h8, h9		Nil	Precision sliding fit also fine spigot and location fit.
TRANSITION	js	js5	js6	js7			Push fit for very accurate location with easy assembly and disassembly.
	k	k5	k6	k7			Light keying fit(true transition) for keyed shafts, non- running locked pins etc
	m	m5	m6	m7			Medium keying fit.
	n	n6	n6	n7			Heavy Keying fit (or tight assembly mating surfaces).
INTERFERENCE	p	p5	p6	p7			Light press fit with easy dismantling for non-ferrous parts. Standard press with easy dismantling for (ferrous and non-ferrous parts assembly).
	r	r5	r6	r7			Medium drive fit with easy dismantling for ferrous parts assembly. Light drive fit with easy dismantling for non-ferrous parts assembly.
	s	s5	s6	s7			Heavy drive fit for ferrous parts permanent or semi-permanent assembly standard press fit for non-ferrous parts.
	t	t5	t6	t7			Force fit on non ferrous parts for permanent assembly.
	u			u7			Heavy force fit or shrink fit.

FOR SHAFTS

TYPE OF FIT	CLASS OF HOLES			WITH SHAFTS				REMARKS
		h5	h6	h7	h8	h9	h11	
CLEARANCE	A						A11	Large clearance fit widely used.
	B						B11	
	C						C11	Slack running fit
	D		D9		D10	D11	D11	Loose running fit
	E		EB		E8	E9		Easy running fit
	F		F7		F8	F8		Normal running fit
	G	G6	G7					Close running or sliding fit, also spigot and location fit.
	H	H6	H7	H8	H8	H8,H9	H11	Precision sliding fit also fine spigot and location fit.
TRANSITION	JS	JS6	JS7	JS8				Push fit for very accurate location with easy assembly and disassembly.
	K	K6	K7	K8				Light keying fit (true transition) for keyed shafts, non-running locked pins etc.
	M	M6	M7	M8				Medium keying fit
	N	N6	N7	N8				Heavy keying fit (or tight assembly of mating sources).
INTERFERENCE	P	P6	P7					Light press fit with easy dismantling for non-ferrous parts. Standard press fit with easy dismantling ferrous and non-ferrous parts assembly.
	R	R6	R7					Medium drive fit with easy dismantling for ferrous parts assembly. Light drive fit with easy dismantling for non-ferrous parts assembly.
	S	S6	S7					Heavy drive fit for ferrous parts permanent of semi-permanent assembly standard press fit for non-ferrous parts.
	T	T6	T7					Force fit on ferrous parts for permanent assembly.

Some characteristics of various grades of holes basis system, are discussed as holes.

H5: This grade can be obtained by precision boring. The international grinding or honing.

H6: This grade can be obtained by precision boring and honing or by hand reaming.

H7: This can be produced by grinding broaching or careful reaming.

H8: This can be produced by boring or machine reaming.

H9: This grade is mostly used for non-circular fits and can be obtained by boring and reaming.

H10: This grade is not used for diameter. It is used for milled widths and drilled holes.

H11: This grade two being very coarse is never used in fits. It is useful only for coarse drilled or punched holes.

Table shows that for class of shaft

a, b, c, d, e, f, g, h	Clearance fit
js, k, m, n	Transition fit

Maximum metal condition:-

It corresponds to conditions when a part has maximum amount of metal i.e. corresponding to high tolerance of shaft and low tolerance of the hole. In certain cases its use allows an increase inn the specified tolerance if it is indicated that the tolerance appeals to the features at its maximum material conditions. The maximum material principle takes into account the material depends of tolerances of sizes from, orientation and for location and permit additional tolerance as the considered feature depends from its maximum material condition.

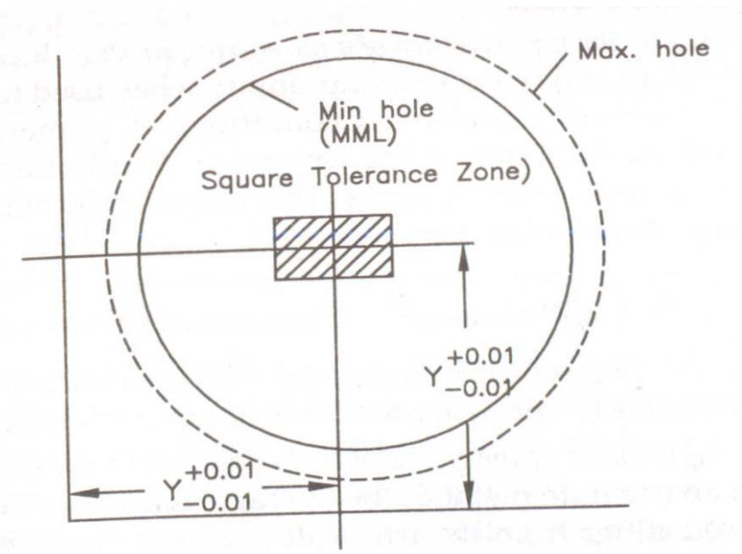
Minimum metal condition:-

It is also known as least material limit. It corresponds to minimum size of shaft and maximum size of hole. M.M.C (Minimum Metal Conditions) has special importance with regard to geometrical tolerance as it critically affects the interchangeability of manufacturing parts which are to be assembled together.

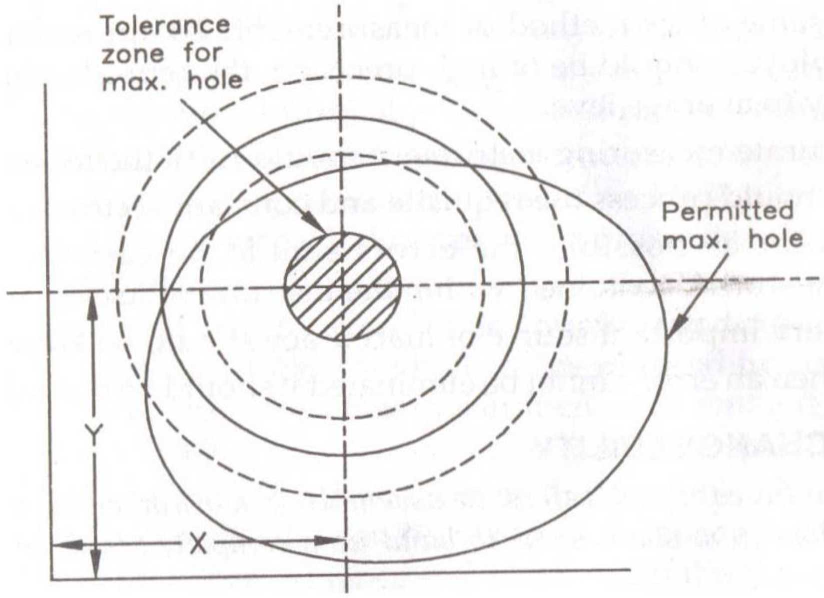
Positional Tolerance:- It represents a conventional method of giving a positional tolerance which has been used since very long time. In this case of the hole illustrated, it will been seen that the tolerance zone for the hole centre is square, if the tolerance or ordinates were not equal, the zone would be rectangular. Thus, the permissible error in the position of centre varies with the direction of error and in the example shown will vary between 0.02 to 0.28mm. This may sometimes be justified and be exactly what is required but, in most cases, the designer merely wishes to restrict the amount by which the hole may vary from its true position irrespective of direction.

The method of tolerancing shown in figure provides a circular tolerance zone for the centre and consequently permits the same error in any direction. Although various circle shown in the diagram tends to create a little confusion, but a careful study will show how such tolerancing allows a larger positional error for a hole that is not on MML. There is an ever-increasing trend of specifying positional tolerances in modern machine tool industries.

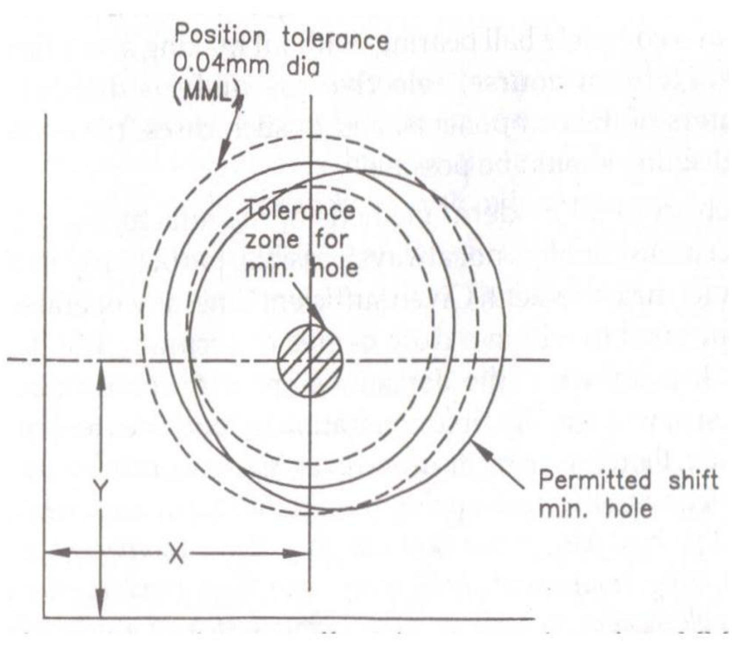
The primary reasons for this is that high speed assembly machines can jam if parts do not fit, as 100% guaranteed fit between the mating parts is prepared for lowest manufacturing cost and positional tolerancing is one of the several ways of dimensioning which can ensure this positional tolerancing does not allows tolerances to accumulate and, therefore provides more usable tolerances.



(a) Square tolerance Zone produced by co-ordinate tolerances.



(b) Circular tolerances zones showing effect of variation of size from NMLC.



(c) Circular tolerance zone showing effect of variation of size from MML.

INTERCHANGEABILITY:-

(i) Interchangeability refers to assembling a no. of mating components taken at randomly from stock, so as to build up a complete assembly without fitting or adjustment.

(ii) One of the objects of interchangeability is to make it possible to replace a worn part, such as a complete ball bearing, without making any adjustment to the old or new parts. Here, of course, selective assembly is difficult except by actual manufactures of the components and in such cases it is necessary that absolute interchangeability should be possible.

(iii) The object of all modern methods of manufacturing is to produce parts of absolute accuracy. But it is not always possible, particularly in mass production, to keep the exact measurement. Given sufficient time, any operation could work to and maintain the sizes to within a close degree of accuracy, but there would be small variations.

(iv) It is known if the deviations are with the certain limits, all parts of equivalent size will equality fit for operations in machines and mechanisms. Certain deviations are, therefore, recognised and allowed to ensure interchangeability of mating parts, coupled with the derived degree of tightness or looseness on assembly. When a system of this kind has been worked out, so that one component will assemble correctly with any mating component, both being chosen at random, the system is called on interchangeability system, sometimes called a limit system or a system of limits and fits.It is by interchangeable spare parts, that various machines, machine tools, tractors, motor cars, aeroplanes and many others can be dismantled for replacement of worn parts in service conditions in the field, and also in many local workshops with l

CHAPTER:- 2 MEASUREMENT AND GAUGING

<u>Principle of gauging:-</u>

A gauge is a tool or instrument used to measure or compares a component. Gauge is used to determine whether a size of some component exceeds or is less than the size of the gauge itself.

The true value of a gauge is measured by its accuracy and service life, which is turn, depends on the workmanship and materials used in it's measure. The wear and tear can takes place while using the gauges, so the proper material should be selected. High carbon and alloy tool steels have been the principal materials used for many years. These materials can be accurately machined to shape and they should be respond readily to heat treating operations which increases their hardness and abrasive resistance. Steel gauges are subjected to some distortion because of the heat treating operation and their surface hardness is limited. These objections are largely overcome by the use of chrome plating or cemented carbides as the surface material. Chrome plating permits the use of steels, since wear resistance is obtained by the hard chromium surface. This process is also widely used in the reclaiming of the worn gauges. Cemented carbides coating, applied on metal shanks by power metallurgy techniques, provide the hardest wearing surface obtainable.

<u>Principles of mechanical measuring instrument:-</u>

In modern industry, for increasing the accuracy of the measuring instruments, some mechanical means of magnification have been adopted.

These methods are

- (i) Lever method
- (ii) Vernier method
- (iii) Screw and screw nut method.

(i) <u>Lever method:-</u>

It is the principle of ordinary magnifying lever. The lever is supported on a knife edge support. When a distance l is measured by the indictor, the magnification ratio is given by :

a/b = Reading on the scale/ b sinα

= a. α/ b sinα

Where α= angle of displacement corresponding to the measured distance l.

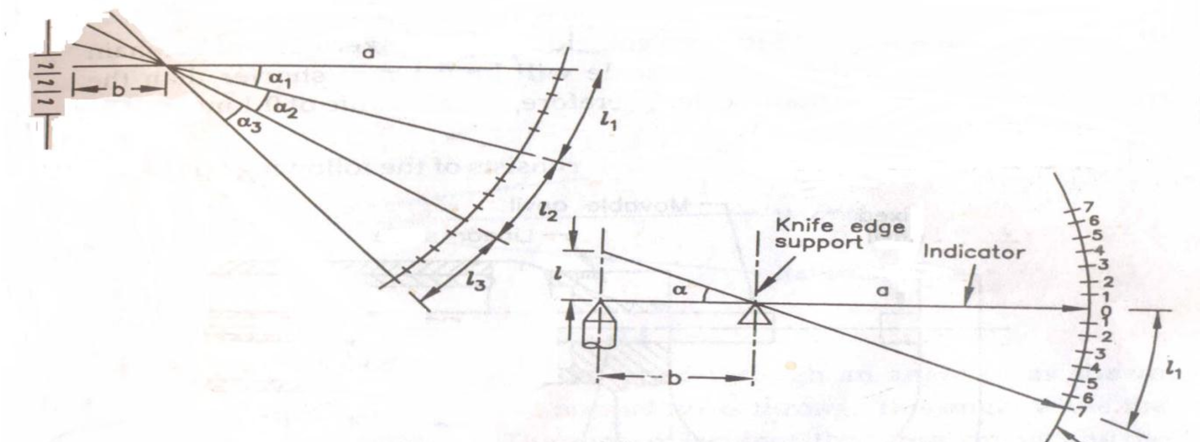


Fig. Magnifying lever method.

It may be noted that the magnification ratio increases by increasing the displacement angle α. Thus for equal distance l, there will be unequal displacement angle α. Thus for scales will have unequal divisions. To dominate this, the angular measuring range of the system must be mader relatively small. In this method the magnification is practically limited to 10:1 because of greater friction involved in pivots and bearing of the system for greater magnifications.

(ii) <u>Vernier method:-</u>

In this method, a vernier is used. It is an additional scale which is used in a place of a pointer or indication line on the movable member and it enables the main fixed scale to be read to a smaller value. Figure shows the principle of vernier method.

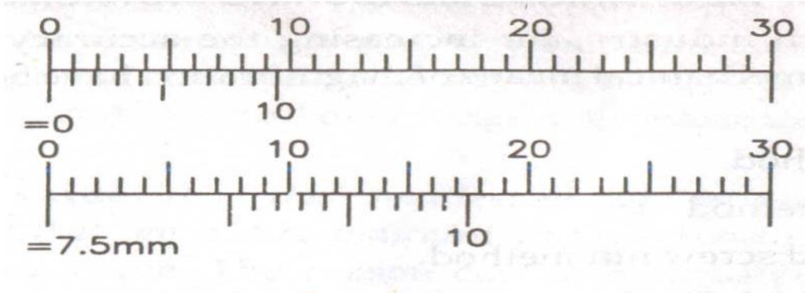


Fig. Principle of Vernier method.

In the vernier method, if the graduations of the scale are in cm and each is divided into 10mm, then readings taken by such as a scale will be accurate with in 1mm. If a sliding vernier is provided, whose scale length equals 9mm but is divided into 10 equal divisions then the difference between the scale divisions of the vernier and that of the main scale will be [10-(9/10)] = 0.1mm. if the vernier scale is set in such a way that it’s zero coincides with zero line of the main scale, the first line on the vernier, scale will be 0.1mm shorter than the corresponding line on the main scale. Therefore a scale value of 0.1mm can be achieved by using a vernier.

(iii) Screw and screw nut method:-

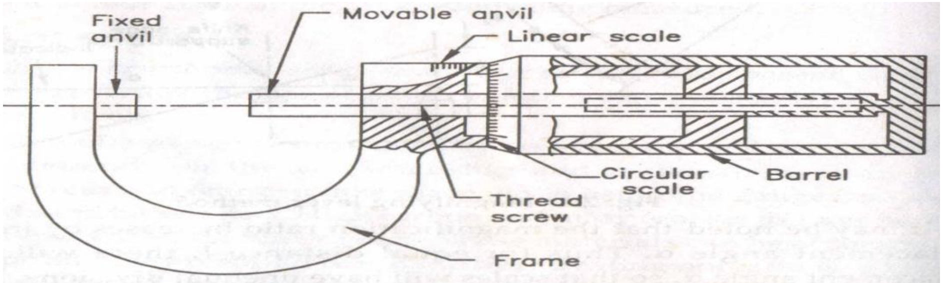


Fig. Screw and Screw Nut method.

(a) Fixed frame:- It has two contact members or anvils. One anvil is fixed and the other is movable.
(b) Movable anvil:- It is provided with a threaded part and can be advanced by means of a barrel nut.
(c) Barrel nut:- The periphery of the barrel nut is graduated (circular scale) and it's reading can be taken opposite to a fixed pointer.
(d) Scale:- the number of complete terms of the nut is indicated by means of a scale engraved on the plain part. The scale should read zero when both anvils are in contact. The readings of the scale will give the distance between the end faces of the anvils. If P is the pitch of screw thread and N is the total no. of equal division on the barrel nut, then the corresponding axial shift 'a' per movement of one division on the barrel nut is given as the scale value of the instrument by

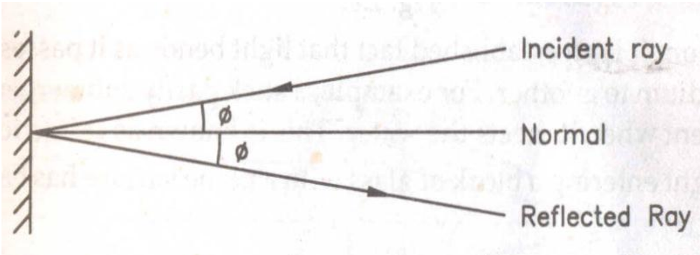
$$\boxed{a = P/N}$$

PRINCIPLES OF OPTICAL INSTRUMENTS:-

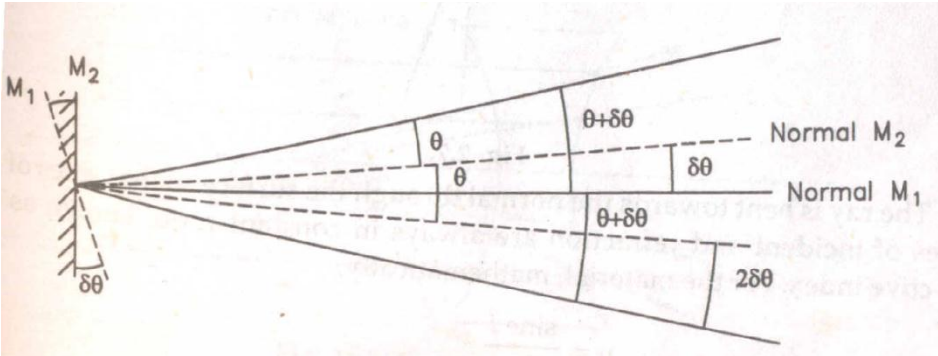
Many modern instruments utilise optical systems in their construction and operation by used for the metrologist to have some knowledge of elementary optical principal as

1. Reflection:-

The figure shows the reflection phenomenon by considering a plane surface. The angle between reflected by ray and the normal to the surface is equal to the angle of incident ray, both rays and the normal being in the same plane. A beam of light is made up of an infinite number of rays which may be treated collectively in a similar way.

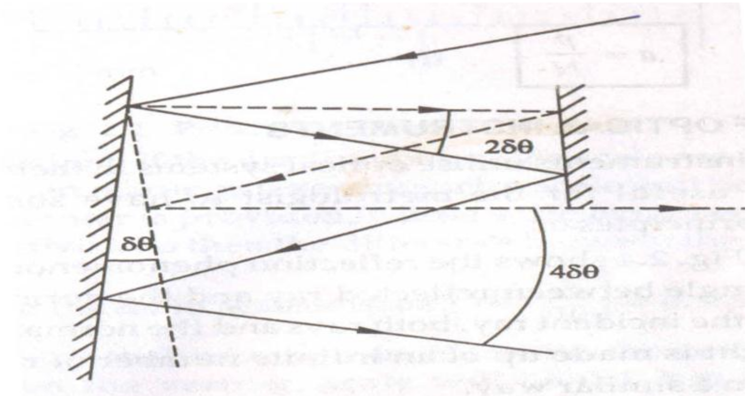


Now, if the reflection surface be fitted through an angle $\sigma\theta$ as shown in figure. It may be seen that the normal turns through this angle while the incident ray remains stationary. The angle of incident and reflected ray's, therefore, changes by $2\,\sigma\theta$.



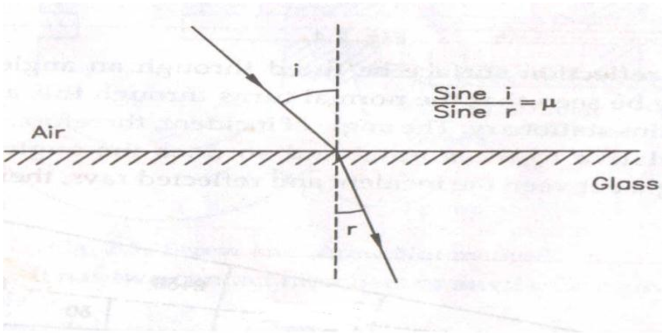
The use of a tilting mirror to magnify small angular movements is, therefore greatly favoured in a number of applications, both in metallurgy and other branches of technology.

If the reflected on the tilting mirror by a second fixed mirror, the change in angle of the reflected ray is then $4\,\sigma\theta$, as shown in figure.



2. <u>Refraction:-</u>

It is an established fact that light bends as it passes from one transparent medium to another. For example, a stick partly submerged in water appears to be a bent when it meets the water. This is known as reflection. A ray of light entering a block of glass with a plane surface has been shows in fig.



The ray is bent towards the normal through the surface, so that sine of the angles of incident and refraction are always in control ration, known as the refractive index. Mathematically

$\mu = sini/sin\, r$ where:- i = Angle of incidence
r = Angle of refraction
μ = Refractive index

It shows a ray of white light passing through a prism and getting refracted. It is separated into it's coloured constituents, the violet light being refracted through a greater angle than the red.

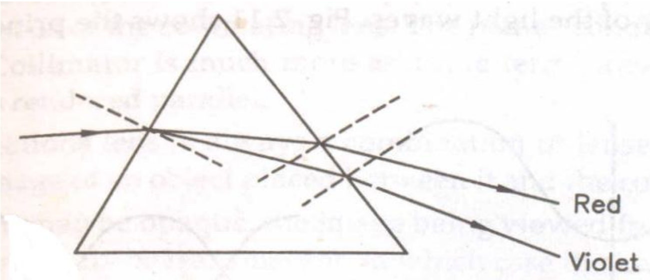


Fig. A ray of light passing through Prism.

These two coloured lies at the extreme of the visible spectrum. The phenomenon indicates that the refractive index is not the same of each wavelength of light.

3. <u>Lenses:-</u>

A lens may be regarded as an infinite number of prismatic units of constantly changing angles which decrease from the edges to the centre.

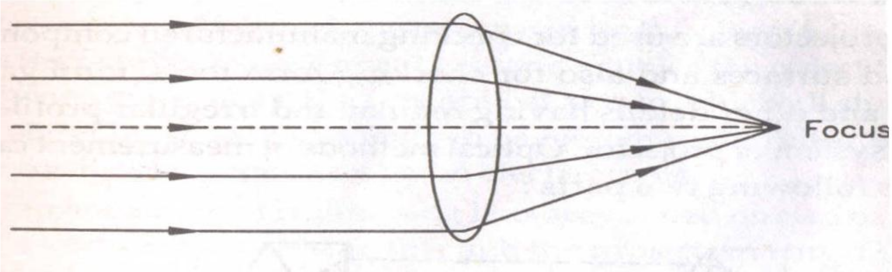


Fig. Convex lens.

- A convex lens is thicker at the centre than at the edges and converges of a parallel beam of light passing through it to a single point, known as the principal focus. A real image is formed on a screen in this case.

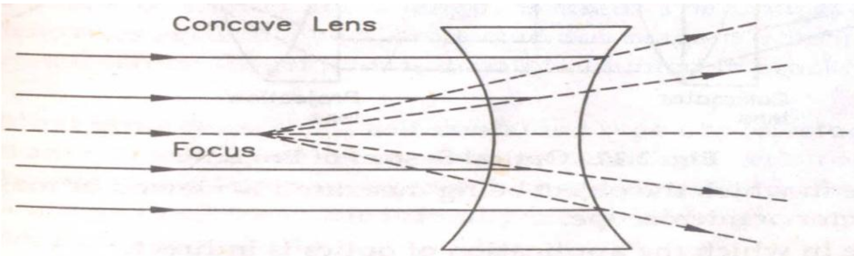


Fig. Concave lens.

- A concave lens is thinner at the centre plan at an edge and diverges parallel light which then appears to come from a focal point behind the lens. A Virtual image is formed on a screen in this type of lens.

4. <u>Interference:-</u>

The wave theory of light is transmitted by electromagnetic vibrations in either. Light may be regarded as a form of energy consisting of transverse electromagnetic waves of very short amplitude and it's colour depends upon the frequency of the light waves. It shows the principle of optical interference.

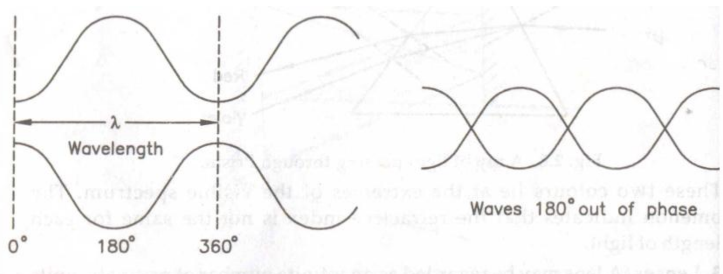


Fig. Principle of Optical Interference.

Principle of electrical and electronics measuring instruments:-

Various mechanical parameters like length, mass and time can be measured by electrical means. The main advantage of this electrical principle is, their simplicity and high sensitivity and accuracy. The following are the principles according to which measurements of mechanical parameter is done.

(1) Transformation of energy:-

It is possible to transform any form of energy into electrical energy which can be measured by electrical measuring instruments. It can be possible with the help of transducer.

Generally transducer is a device which converts energy from one form to another. These can be classified as

(i) Mechanical-electrical transducer:-

These can transform a small part of the mechanical energy directly into electrical energy. These can transform a small part of the mechanical energy directly into electrical energy. These are of generator form.

(ii) Energy transducer:-

These are energised by an external source of energy. The energy transformation can be regulated by the mechanical parameters being measured. Photo electric, thermo electric or pure electric transducers can be controlled mechanically.

(iii) Electromagnetic energy:-

These transducers make use of the principle of magnetic induction. The principle of magnetic induction states that the magnitude of e.m.f (e) induced in a coil is proportional to the rate of changes of the flux (Ø) passing through it. i.e.

$$e = -dØ/dt$$

The change of flux with a constant magnetic field can be achieved by two ways.

- By a relative movement between the coil and the constant magnetic field.
- By changing the magnetic resistance. To achieve this mechanical work has to be supplied.

(iv) Electrical energy transducer:-

By the use of mechanical means, the transformation of electrical energy can be regulated and controlled. This transformation is based on 'Induction principle'. The induced e.m.f in a coil can be changed by;

- Varying the voltage of the primary coil.
- Changing the position of secondary coil relative to the primary.
- Changing the frequency of the primary voltage.

(v) Piezo electric transducer:-

The piezo-electric transducers work on the principles of mechanical-electrical energy transformation. These can be used for measuring forces or small displacements. Their use is primary limited to dynamic measurements because the potential developed diminishes under the static measuring conditions. These can be used as surface finish testers, vibrations pickups & as accelerometers.

(vi) Thermo-electric energy transducers:-

A thermo couple is an energy transformer by which the heat energy is converted to electrical energy. This transformation can be regulated or controlled by the mechanical energy. This transformation of heating the junction of two different metals, a potential difference at the cold end can be measured, which depends upon the metals used and upon the temperature difference between the hot and cold junctions. This principle is used for measuring temperature.

(vii) Photo-electric energy transducers:-

In a photo cell or tube light energy can be transformed to electric energy. This transformation can be mechanically controlled by

- Changing the size of the illuminated area.
- Changing the intensity of light.

The various types of photo-electric transducers are:-

(i) Photo emissive tube
  * Vacuum photo tube
  * Gas fitted tube
  * Multiplier photo tubes

(ii) Photo voltaic cells.

(2) Variations of electrical parameters:-

Several physical parameters are related to the electric parameters are related to the electric parameters. The following relationship should be mentioned.

(a) Direct relationship between the mechanical parameters being measured and one of the electrical parameters i.e. dimensions & the capacitance of the condenser.

(b) The mechanical parameter being measured is applied to change a physical parameter, which is turn varies an electrical parameter e.g. the relationship between the strain can be varied by the mechanical parameter being measured.

(3) Electrical measuring strain gauge:-

The strain gauge is measurement transducers for measuring strain and associated stress in experimental stress analysis. Secondly many others detectors and transducers, notably the load cells, torque meters, diaphragm type pressure gauges, temperature sensors and flow meters, employ a strain gauges; used to measure the strain.

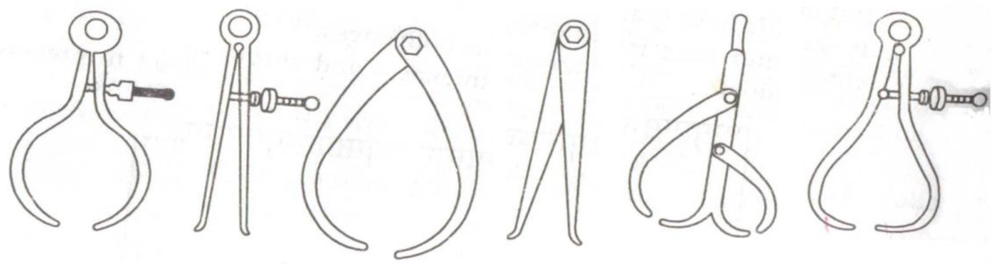
There are three types of strain gauge:-

- Wire wound strain gauges.
- Foil type strain gauges.
- Semi conductors strain gauges.

CALLIPERS:- Callipers are used to make external or internal measurements. A calliper does not have dial or scale to give direct reading. It is used to transfer the measurement from work piece to scale and vice versa. Callipers are of two types:-

- **Outside**:-
  An outside calliper is used to make outside and external measurements, like diameter of sphere, cylinder and thickness of plates.
- **Inside**:-
  An inside calliper is used to make inside or internal measurements like, the inside diameter of a cylinder, groove length.

In modern precession engineering they are not employed on finishing operations where high accuracy is essential, but inn skilled hands they remain extremely useful. No one can prevent the spring of the legs affecting the measurement. Adjustment of the firm joint type can be made only by tapping a leg or the head. Various types of firm joint callipers are shown in the figure.



Vernier callipers:-

The vernier calliper is used for taking both inside and outside measurements. It uses the vernier principle of measuring which was named for its inventor 'pierre vernier' (1588-1637), a French mathematician.

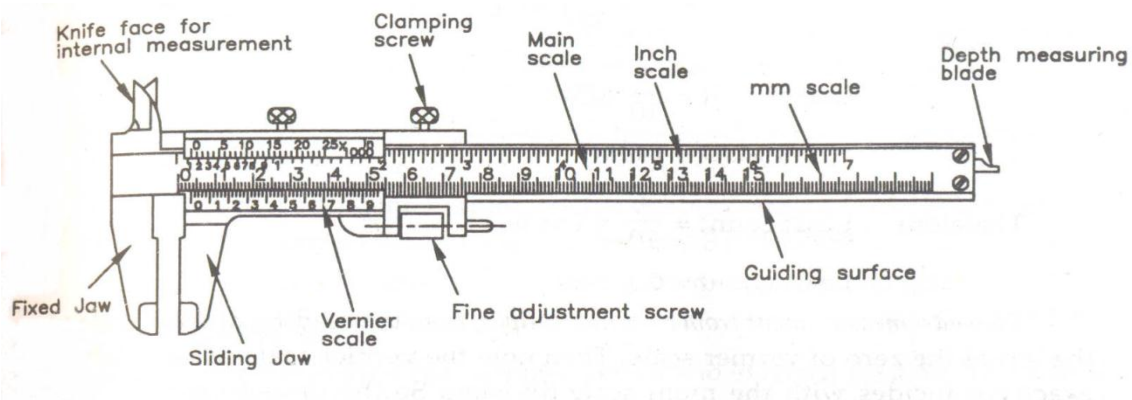


Fig. Vernier Callipers.

- The principle of vernier is that when two scales or divisions slightly different in size are used, the difference between them can be utilized to determine the accuracy of measurement.
- A vernier calliper consists of a graduated vernier slide assembly, screws and adjusting nut. The slide assembly moves as a unit along the beam. The beam is graduated on both sides.
  The vernier callipers are of two types depending on the type of dimension to be measured.
  (a) Outside
  (b) Inside

(a) Outside:- it has a L-shaped frame. The main scale is engraved on this frame one end of the frame contains a fixed jaw which is shaped into a contact tip. A sliding jaw which moves along the guiding surface provided by the main scale is coupled to a vernier scale. The sliding jaw at it's left contains another measuring tip. When two measuring surfaces are in contact with each other, scale shows zero reading. The finer adjustment of the movable jaw can be made by adjusting screw. An outside vernier calliper is precision measuring instrument. The smallest dimensions that can be measure with it is called least count. For example:- Least count to be measured:-- if 10 divisions of the vernier scale co-inside with a divisions of the main scale, then

10 VSD = 9 MSD (VSD= vernier scale division ; MSD = main scale division)

=> 1 VSD = (9/10) MSD

Least count (L.S) = 1 MSD – 1 VSD

= 1 MSD – 9/10 MSD (given)

= [1−(9/10)] MSD

Least count = 1/10 MSD

=> 1 MSD = 1mm

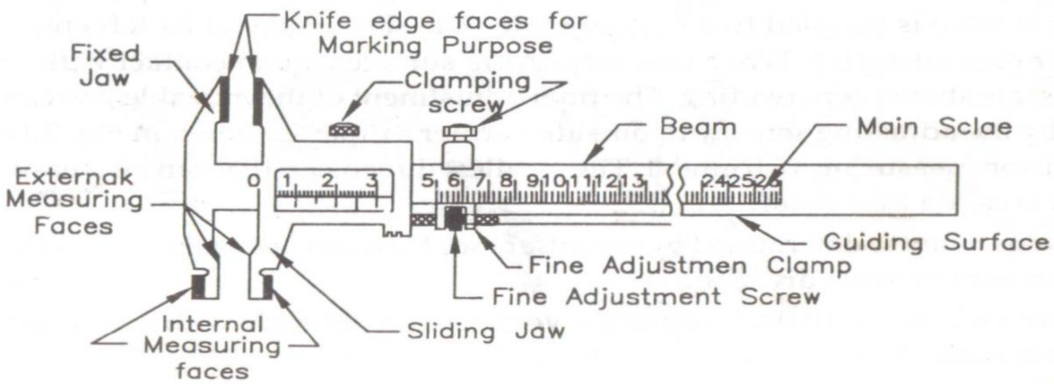
Therefore least count = (1/10) × 1 mm

= 0.1 mm

To read a measurement form a vernier calliper, note the reading of main scale to the left of zero of vernier scale. Then note the vernier scale reading which exactly co-insides with the main scale division. So, the measurement can be defined as

Measurement = [main scale reading to left of zero of vernier scale] + [least count × vernier reading exactly co-insiding with any main scale division]

Inside vernier calliper:-



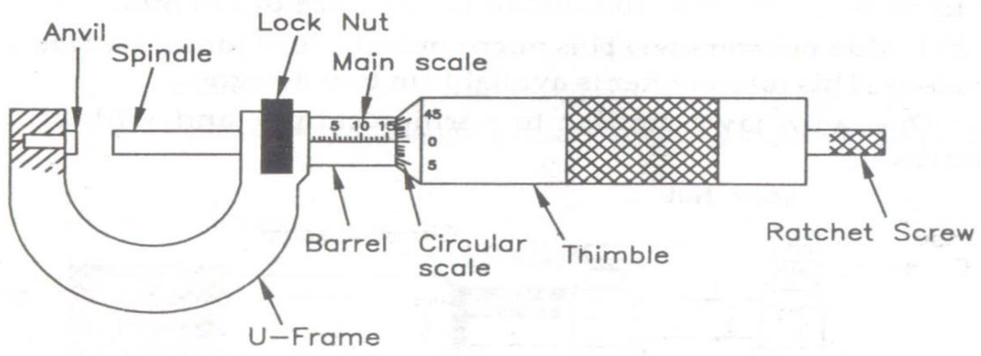
It is used for measuring inside dimensions e.g. internal dia. etc. The various parts of inside vernier callipers are same as that of outside vernier calliper, except that the measuring surfaces are on the outer side of the fixed and moveable jaws. The readings for the internal measurements are obtained by adding the combined width of the internal measuring jaws to the scale reading.

Micrometers:-

A micrometer is used to measure internal and external dimensions, as well as depths and heights. The principle of a micrometer consists of the employment of screw and nut, both having accurately threads. One complete revolution of the screw will advance it, in relation to the nut threads, a distance equal to the lead of the thread.

(i) <u>External micrometer:-</u>

The micrometer screw rotates in a fixed nut & moves in an axial direction relative to the nut. The screw is rigidly attached to the thimble while the fixed nut is fastened to sleeve or barrel. Thus, the thimble rotates and moves axially along the barrel when the screw is rotated. It has a u-shaped frame to the left of which an anvil is attached and to right end, a barrel or sleeve is attached. A spindle passes through the barrel.



A thimble which surrounds the barrel is attached to the right end of the spindle. The unattached faces of the anvil and spindle form the measuring faces of the micrometer. A linear scale with graduations is a millimetre is engraved on the barrel. This is called the main scale. A circular scale is engraved on the bevelled surface of the thimble. This is vernier scale.

Least count of a micrometer = distance moved by screw giving one revolution to thimble/ number of divisions on circular scale.

The screw moves by 0.5mm with one revolution of the thimble and there are 50 divisions on the circular scale, then least count = 0.5/50 = 0.01mm

The micrometer is used as follows

1. Check the zero reading
2. Place the part to be measured in between the measuring faces.
3. Advance the spindle by rotating the ratchet until the beings to slip and click is heard. This indicates that there is no further movement of the spindle.
4. Note the reading both on the main scale and on the circular scale of the thimble. So, reading on the micrometer $=$

[reading uncovered on the main scale] $+$ [least count $\times$no of divisions on the thimble scale which co-insides with horizontal line on the main scale]

- The micrometer is checked and adjusted to zero position by means of gauge blocks, standards or end bars. These are usually available in the ranges of 0 to 25, 25 to 50, 50 to 75, 75 to 100, 100 to 125 and 125 to 150 mm.

(ii) <u>Inside micrometer:-</u>

This micrometer is used for measuring the internal dimensions. This micrometer is available in two designs.

- One with jaws similar to vernier calliper & with scale reading backwards.
- The second is a straight bar with a micrometer is used to measure several interchangeable rods which allows a wide range of measurements. An inside micrometer is shown in figure.

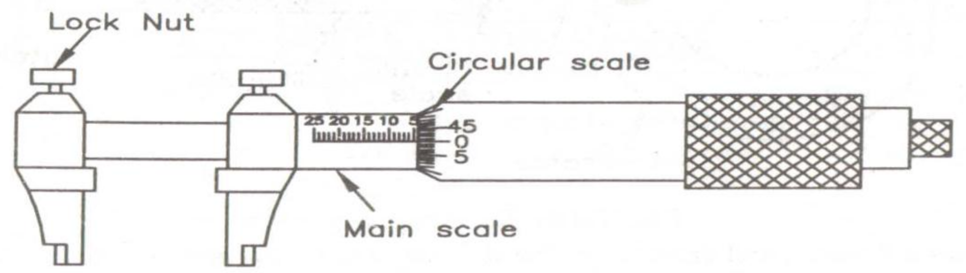


Fig. Inside Micrometer.

(iii) <u>Depth micrometer</u> :-

A depth micrometer is used to measure the depth of a slot or hole. They give the dimensions from the surface to the bottom of a slot or a hole. It has one shoulder which act as reference surface and is held firmly and perpendicular to the centre line of the hole. Here also, for large ranges of measurements, extensions rods can be used. A depth micrometer is shown in fig.

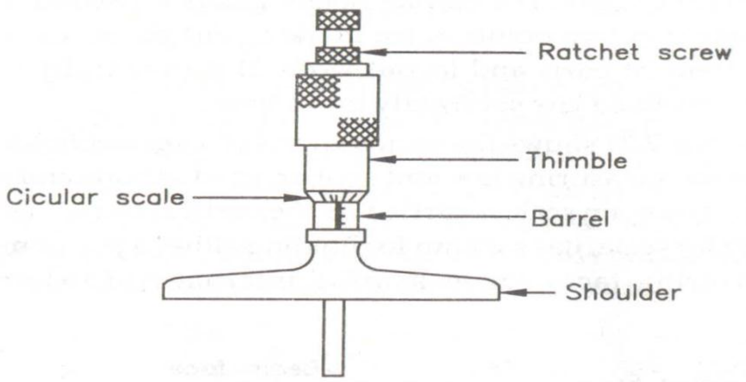


Fig. Depth Micrometer.

<u>Dial indicator:-</u>

It is an instrument used for checking flatness of surfaces and parallelism of bars and rods. It can also be used to measure linear dimensions of work-pieces. It may be of plunger or lever type.

(a) <u>Construction and working of plunger type dial indicator:-</u>

Plunger type dial-indicator consists of a metal case that acts as a rigid frame and protective covering for the instruments mechanism. The case supports a gear train, gear rack, a graduated dial and a transparent dial cover held in a bezel. The main scale of the indicator is graduated into equal divisions corresponding to 0.01mm movement of the plunger. A second but smaller dial is set in the main dial face to indicate the number of complete rotations turned through, one revolutions being equivalent to 1mm of the plunger movement. To enable the instrument to show zero reading for any position, the main scale can be rotated by rotating the bezel.

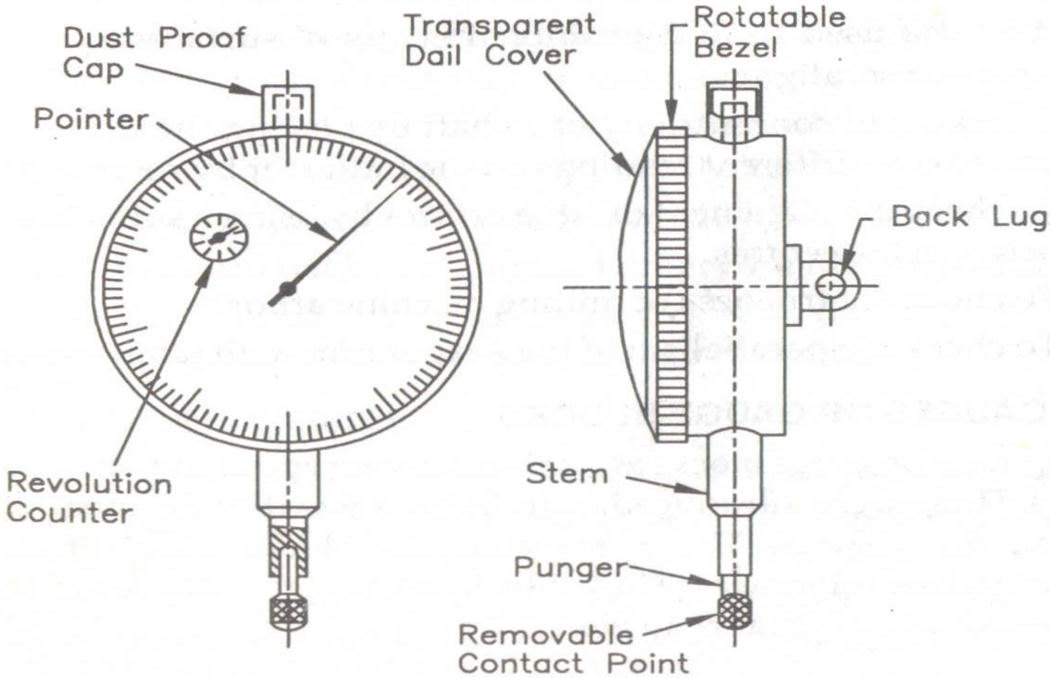


Fig. Plunger type Dial Indicator.

It is simple, reliable & very sensitive. In the plunger type dial indicator, the plunger is attached to a rack. The rack meshes with a large gear wheel, which further meshes with a smaller gear wheel in fig. The plunger is made to come in contact with the work-piece.

The linear movement of the plunger is transmitted to the rack and the linear motion of the rack is converted into rotary motion of the larger gear wheel. This rotary motion is amplified by the smaller gear wheel and is projected on the main scale by the movement of a pointer.

(b) Lever type dial indicator:-

It shows a lever type dial indicator. This type relies on a lever and scroll system of magnification. It has only a limited range of stylus movement, little more than one revolution of the pointer. It is very popular for both inspection and machine setting.

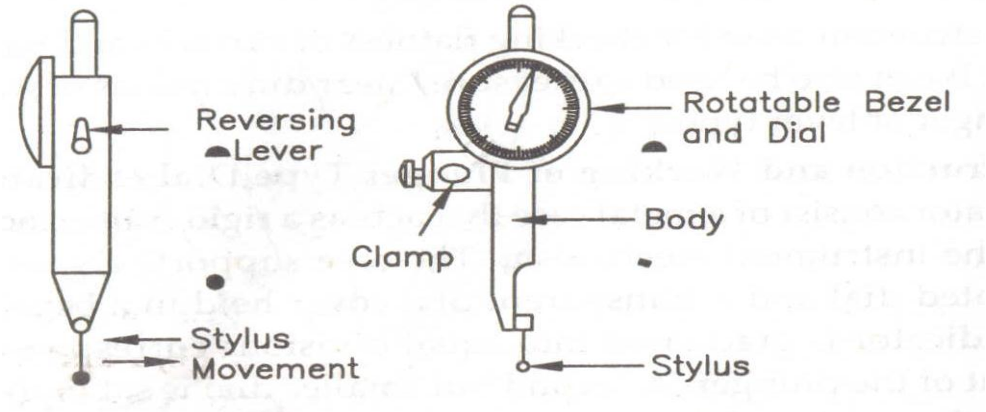
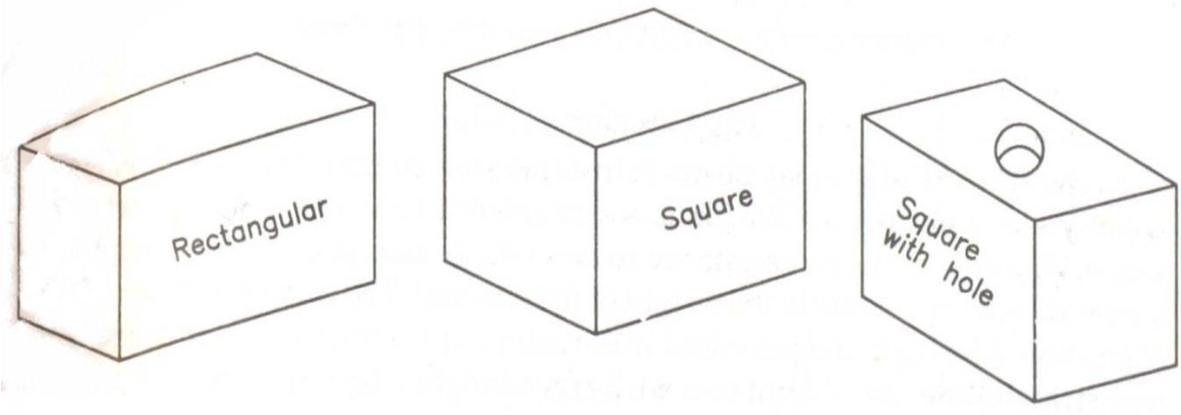


Fig. Lever Type Dial Indicator.

<u>Slip Gauges or Gauge blocks:-</u>

Slip gauges or gauge blocks are universally accepted end standard of length in industry. These were introduced by JOHNSON, a Swedish engineer, and are also called as Johnson Gauges. There are rectangular blocks are suitable hardened through out to ensure maximum resistance to wear. Slip gauge is reference standard of measurement. Instead of lines for references as on a ruler, the slip gauge is made with two reference surfaces. It is a small block of hardened steel carefully machined on the lapping that it has almost an optical finish. Depending upon the shape, the slip gauge can be rectangular, square or square with centre hole as shown in fig.



These are used singly or in combination to check and set micrometers, vernier callipers, snap gauge and indicators. They can also be used directly on work pieces to check centre distances, slot widths etc. Gauge blocks are classified into following grades to allowable tolerance for flatness, parallelism and length, grade 00, 0, 1, 2. Grade 0, 1 & 2 are used for general use. Grade 00 is normally used for calibration purposes. It should not be used in combinations. The contacting surfaces of two blocks should be cleaned by a piece of chamois leather during the joining of blocks. The method of joining gauge blocks together is called wringing.

SUSURFACE CHECKING DEVICES:-

Straight edge:-

This is a measuring instrument having a rectangular (small size) alloy steel strip and an edge perfectly straight within the limits of accuracy. Straight edges are designed for checking straightness and flatness of parts.

The straight edges may be made in either steel or iron. The cast type, which is really a long narrow surface plate, is straightened with a deep web of parabola shape, chosen so that the resistance to bending at each point is proportional to the bending moment due to weight of the material. The accuracy of the straight edge should be high and permissible deviation of the measuring edge from the true straight line should not exceed. Large straight edges should be supported at the points of minimum deflection; these points are usually engraved with arrows on the straight edge.

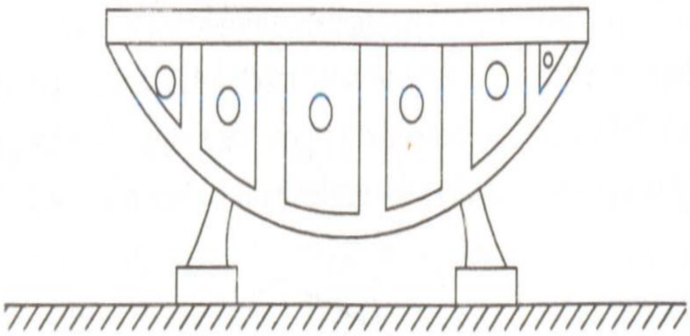


Fig. Straight edge.

Try square:-

(i) It is an instrument employed to see whether a certain angle between two surfaces or features is 90˚ or not. The name try square means that this instrument is not the precise type, through various grades of accuracy are available. It consists of stock and blade, the two making an angle of 90˚ with each other externally as well as internally.
(ii) Two types of try square are commonly used, one with extra thick shock and other without stock. The one without stock is less rigid and so requires thicker blade. The size of square is designed by the length of the blade and the accuracy that is grade.
(iii) The job to be checked is held in the left hand and try square is held in the right hand from the stock. The stock is brought in contact with one surface and blade with the

other surface. The square is checked by seeing through the line of contact of the blade and the surface of the job. If no. of light is passing the angle is correct.

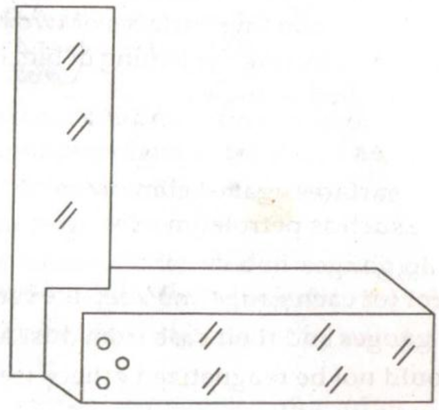


Fig. Try Square.

(iv) If the light passes from the blade near the stock, the angle is more than 90˚ and it from the tip of the blade, the angle is less than 90˚ and it from the tip of the blade, the angle is less than 90˚.

(v) The squares are made of good quality tool or alloy steel hardened and ground and should be free from cracks, flaws and pits. Sharp edges of the try square are removed and it is made smooth and bright all over.

<u>Surface plate:-</u>

(a) The surface plate is a metal plate with an optically flat surface which is used as a plane of reference. The big surface plate generally rests on four levelling screws with the help of which its surface can always kept horizontal. The top surfaces are scraped to true flatness.

(b) The surface plates serve two main purposes. First it is used as a datum plane for taking accurate linear and angular measurement. Secondly, it serves for testing the degree of flatness of other surfaces with the aid of a suitable marking compound.

(c) The surface plate should be made from a material which will provide a high degree of rigidity and freedom from warping and capable of taking a high finish and the surface must be resistant to wear. Most commonly used material for this purpose is either the plain or alloyed close grained cast iron of good quality.

(d) The top of the surface plate must be always dry and clean. After working the plate is cleaned carefully and oiled to prevent corrosion and covered with a wooden shield.

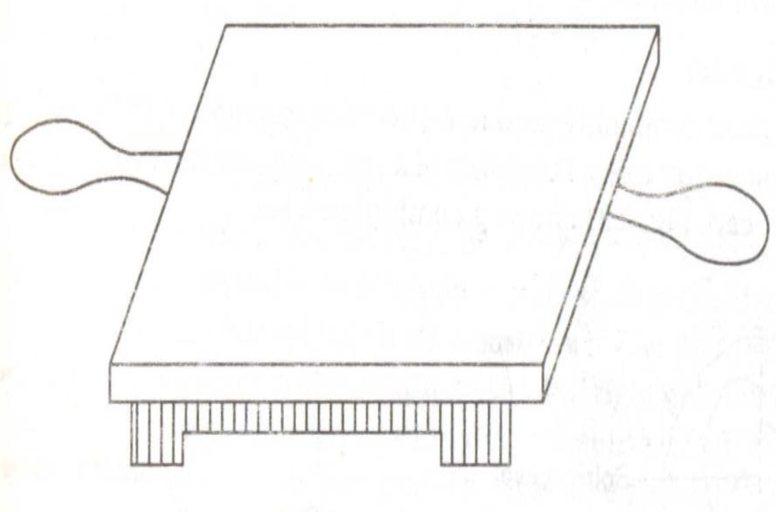


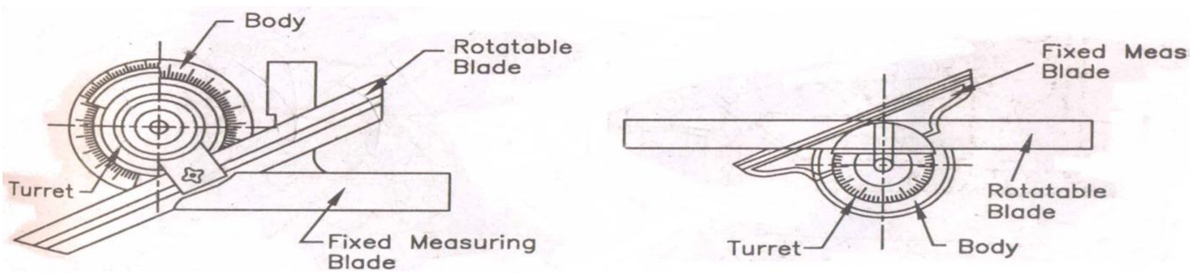
Fig. Surface Plate.

(e) The surface plate is tested for flatness by means of accurate straight edge, feeler gauge or thin paper strips. The straight edge is held against the plate top surface. The clearance between the two is checked with a feeler gauge. Feelers thicker than 0.03 to 0.06mm must not pass under the straight edges.

<u>Protractors:-</u>

It is also known as bevel protector. It is probably the simplest instrument for measuring the angle between two faces of a component. It measure angles in degrees and minutes. These are basically three types:-

(a) <u>Vernier bevel protector:-</u>



Vernier Bevel Protractor.

(i) This figure shows a vernier bevel protector. The bevel protector is an instrument having a main scale graduated in degrees and a sliding blade. The sliding blade is attached to circular plate contacting vernier scale. The vernier scale is also graduated to the right and left of zero upto 60 minutes. The sliding blade can be slide along it's entire length around the centre of the main scale and be clamped. The available size of blade is 150mm, 200mm or 300mm.

(ii) One side of the bevel protector is flat; permitting it to be laid level upon the work. To find out the value of the angle between two surfaces of a component and the working edge of the stock is placed on one surface of the component and the turret the blade is rotated till the working edge of the blade co-insides with the other surface of the component. The turret is fixed and the reading is taken.

(b) <u>Dial bevel protector:-</u>

(i) A dial bevel protector can be measured angle within 5′. In this type of protector, the turret rotates a circular scale that serves as a gear actuating the dial gauge pointer.

(ii) The magnification ratio is made, so that the pointer rotates through one complete revolution of every 10˚ of the turret scale, i.e. for every 10˚ of blades angle movement. The scale of dial gauge is divided into 10 equal divisions, each is subdivided into 12. So that a scale value of 5′ is obtained. The scale of the dial gauge has an opening through which the angles in degrees are read against a fixed mark on the dial.

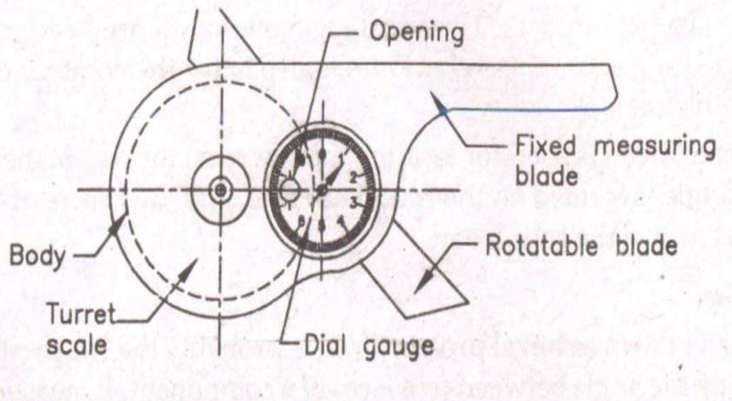


Fig. Dial bevel Protractor.

(c) <u>Optical bevel protector:-</u>

A recent development of the vernier protector is optical bevel protector. In this device, a glass circle divided at 10mm intervals throughout the circle is fitted inside the body. A small microscope is fitted throughout which the circle graduations can be viewed.

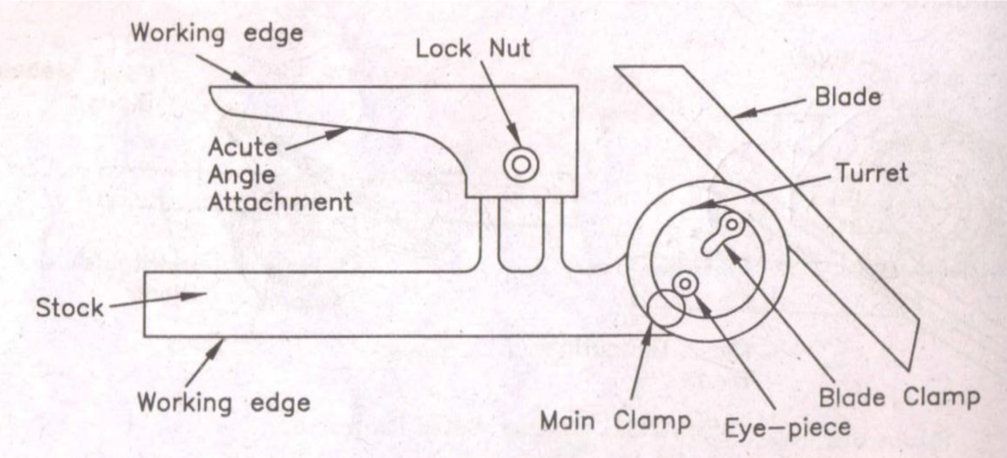


Fig. Optical bevel Protractor.

Sine bar:-

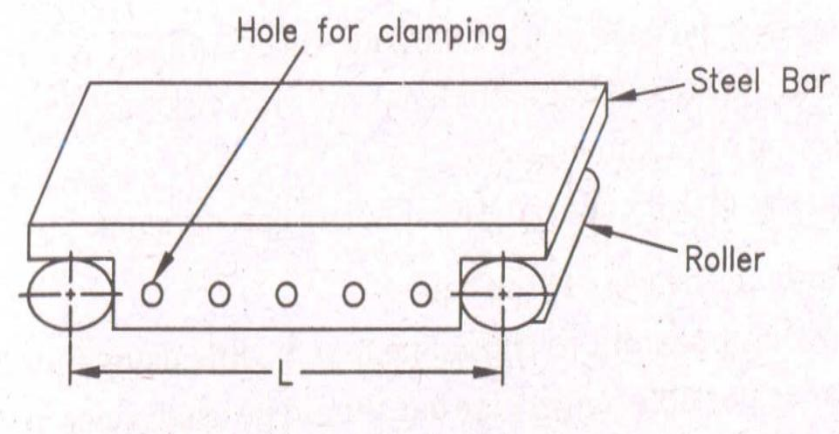


Fig. Sine bar.

(a) Sine bar is an instrument which is used for the measurement of angles with high degree of precision. It is a tool used for accurate setting out of angles by arranging to convert angular measurements to linear ones. Figure shows a sine bar. It consisting a lapped steel bar at each end of which is attached on accurate roller.

(b) The axes of the rollers are mutually parallel and also parallel to the upper surface of the bar. Generally the centre distance between the roller is 100mm or 250mm. The sine bar is specified by the centre distance between the two rollers.

A sine bar is always used in conjunction with a true surface such as surface plate from which measurements are taken. The operation of the sine bar is based on the trigonometric relationship that the sine of an angle is equal to the opposite side divided by the hypotenuse.

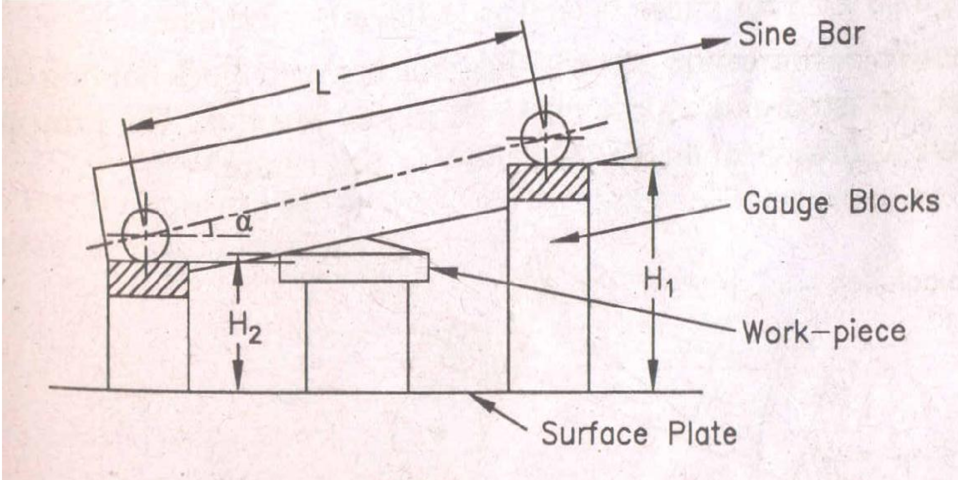


Fig. Sine bar set up for measuring Angle.

∴ $\sin\alpha = (H_1 - H_2) / L$

Application of sine bar:-

(a) Measuring known angles or locating any work to a given angle.
(b) Checking of unknown angles.
(c) Checking of known angles of heavy components.

Clinometers:-

1. A clinometer is an instrument used for measuring angle relative to the horizontal plane. By a simple calculation it is possible to check the angles between two parts of a job even if separated by considerable distances or at different levels.
2. Clinometers are used for checking angular faces and relief angles on large cutting tools and milling cutter inserts. These can also be used for setting inclined table on jig boring machines and angular work on grinding m/c etc.

   The different types of clinometers are:-

   (a) Vernier clinometers
   (b) Micrometer clinometers
   (c) Dial clinometers
   (d) Pendulum clinometers
   (e) Optical clinometers.
3. The most commonly used clinometers is of higher and watt type. The circular glass scale is totally enclosed and is divided from 0˚ to 360˚ at 10' intervals. Sub-divisions of 10' is possible by use of optical micrometer. A coarse scale figured every 10 degree is provided outside the body for coarse work and approximate angular reading.

Talysurf surface Roughness tester:-

It consist various types of parts.

(a) E-shape soft iron head
(b) Stylus
(c) Armature
(d) Cylindrical skid

The stylus is mounted on the armature, which is provided at the central limb of an E-shaped soft iron head.

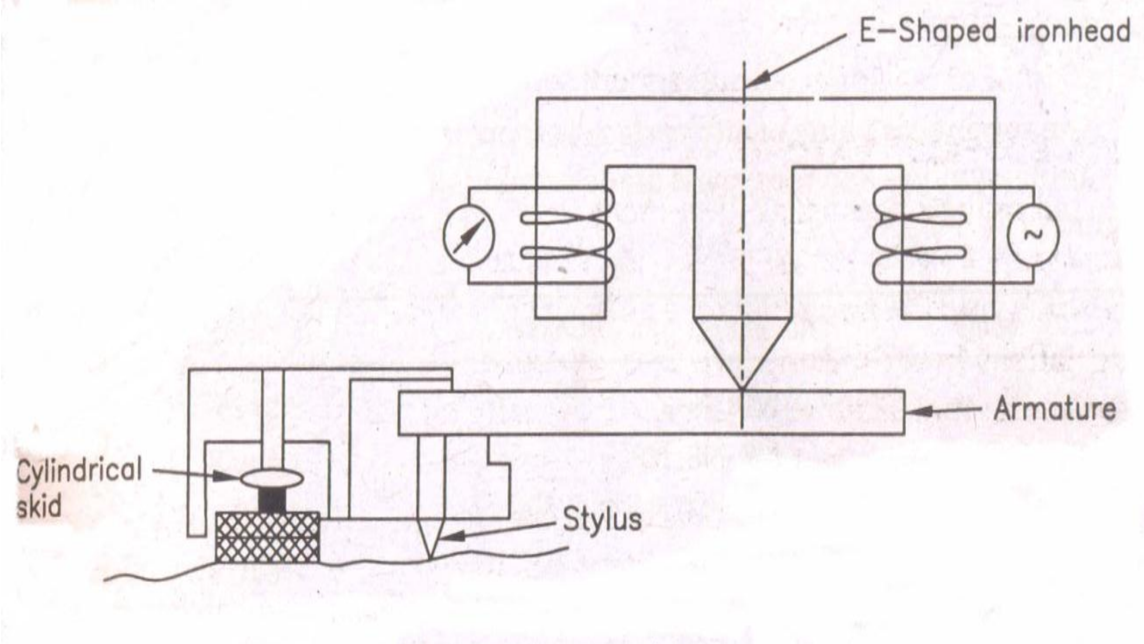
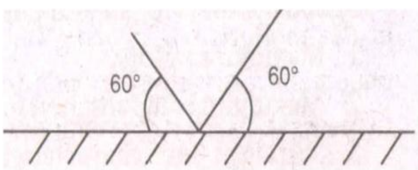


Fig. Talysurf Tester.

The outer limbs of the head are provided with two induction coils and a small air gap is left between the armature and outer limbs of the heads.

<u>Working principle:-</u>

A downward movement of the stylus results in decreasing the air gap of the primary coil and in an equal increase of air gap at the secondary coil. The impedance of the coil will be changed according to the variation of air gap and an additional alternating current flows in the secondary coil whose magnitude is governed by the variation of the impedance of the coil and is proportional to the displacement of the stylus. The position of the stylus, therefore, controls the carrier.



This method of carrier modulation enables the true graphs of the surface texture to be obtained. A cylindrical skid is provided as a datum and a pick up unit is moved across the test surface by means of a motor & a gear box. This provides different measuring speeds. The maximum force of the stylus is 0.1g. The vertical magnification can be varied in steps from 1000 to 50000 times.

Comparators:-

A comparator is a precision instrument used for comparing the dimensions of a component with a standard of length. If thus does not measure the actual dimension but indicates how much it differs from the basic dimension. The indicated difference is usually small and hence suitable magnification device is provided to measure the difference with consistent accuracy. Comparators may operate either on horizontal or on a vertical principle. All comparators consist of following essential parts.

(a) A fixed surface from which all measurements are taken.
(b) A very sensitive indicator which will show the movement of a sliding piece usually terminating in an anvil with a curved face.

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. It eliminates the human element in taking measurements and given accurate results consistency.

Mechanical comparators:-

The mechanical comparators utilize mechanical methods of magnifying; the movement of the contact plunger, their manufacture requires a high degree of skill and accuracy. The usual magnifications of the mechanisms range from about 250 to 1000. The mechanical comparators are of following types.

(a) Dial indicator(dial gauge)
(b) Johansson Mikrokator
(c) Read type mechanical comparator
(d) Sigma comparator

(a) Dial indicator:-

- The simplest type of mechanical comparator is a dial indicator. It consists of a base with a rigid column. An arm is mounted on this column and it carries a dial gauge at its outer end. The arm can be adjusted vertically up and down along the column. An anvil or a worktable is mounted on the base, which provides a reference on which workpieces are placed during measuring operations. Such a simple comparator is ideal for the checking of components with a tolerance of say $\pm$ 0.05mm.

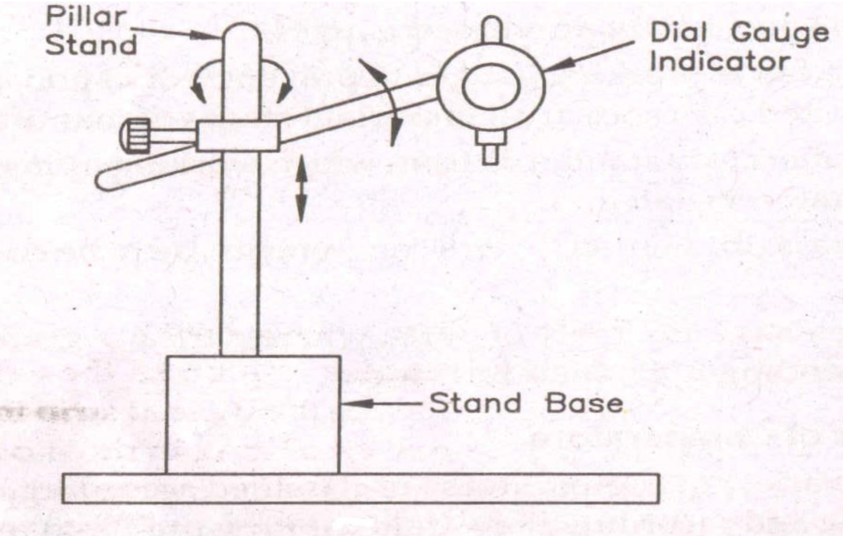


Fig. . Dial Gauge.

- In this, the indicator is set to zero by the use of slip gauges re presenting the basic size of the part. The part to be checked is then placed below the measuring plunger of the indicator. The linear movement of plunger is magnified by means of a gear and pinion train is to be sizeable rotation of the pointer. The variation in dimension of the part from the basic size is indicated on the dial. It is used for inspection of small precision.

(b) <u>Johansson mikrokator:-</u>

- The instrument was invented by C.E Johansson. It is uses a twisted strip to convert small linear movement of a plunger into a large movement of a pointer. It is therefore, also called as twisted strip comparator. It uses the simplest method for obtaining the mechanical magnification designed by H. Abramson which is known as Abramson movement.
- A twisted thin metal strip carries at the centre of its length a very light pointer made of thin glass. One end of the strip is fixed to the adjustable cantilever strip and other end is anchored to the spring elbow, one arm which is carried on measuring plunger. The spring elbow acts as a bell crank lever which shown in figure.

Twisted

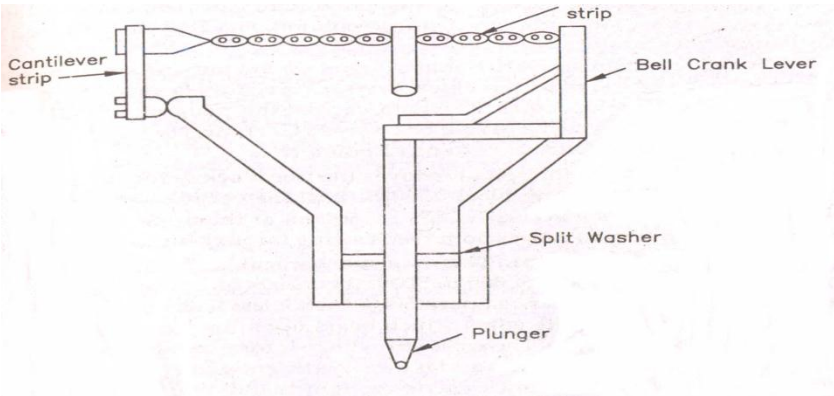
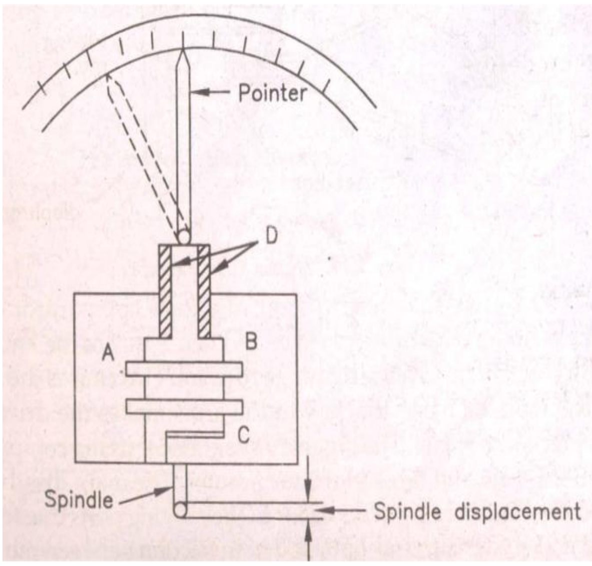


Fig. Johansson Mikro Kator.

- A slight upward movement of plunger will make the bell crank lever to rotate. Due to this a tension will be applied to the twisted strip in the direction of the arrow. This causes the strip in the direction of the arrow. This causes the strip to untwist resulting in the movement of point. The spring will ensure that the plunger returns when the contact pressure between the bottom of the tip of the plunger and the work-piece is not there, that is, when the work-piece is removed from underneath the plunger.

(c) <u>Reed type mechanical comparators:-</u>



- In these comparators, the gauging head is usually a sensitive, high quality, dial indicator. The dial indicator is mounted on a base supported by a sturdy column.
- The read mechanism is frictionless device for magnifying small motions of the spindles. It consists of a fixed block A, which is rigidly fastened to the gauge head case and floating disk B, which carriage the gauging spindle and is connected horizontally to the fixed block by read C. Vertical reads D are attached to each block. Beyond this joint extends a pointer.

- A linear motion of the spindle moves the free block vertically causing the vertical read on the floating block to slide past the vertical read on the fixed block. However, as vertical read are joined at the upper end instead of slipping the movement causes both reads swing through an arc.

(d) <u>Sigma comparator:-</u>

This is a mechanical comparator providing magnification in the range of 300 to 5000. It consists of plunger mounted on two flat steel strings. In these comparators, a frictionless linear movement occurs. The plunger carries a knife-edge which bears upon the face of the mounting block of a cross-strip hinge. The cross strip hinge is formed by pieces of flat steel springs arranged at the right angle and is very efficient pivot for smaller angle or movements. The moving block carries a light metal Y-forked arm. Thin phosphors bronze ribbon is fastened to the ends of the forked arms and wrapper around a small drum, mounted on a spindle carrying the pointer.

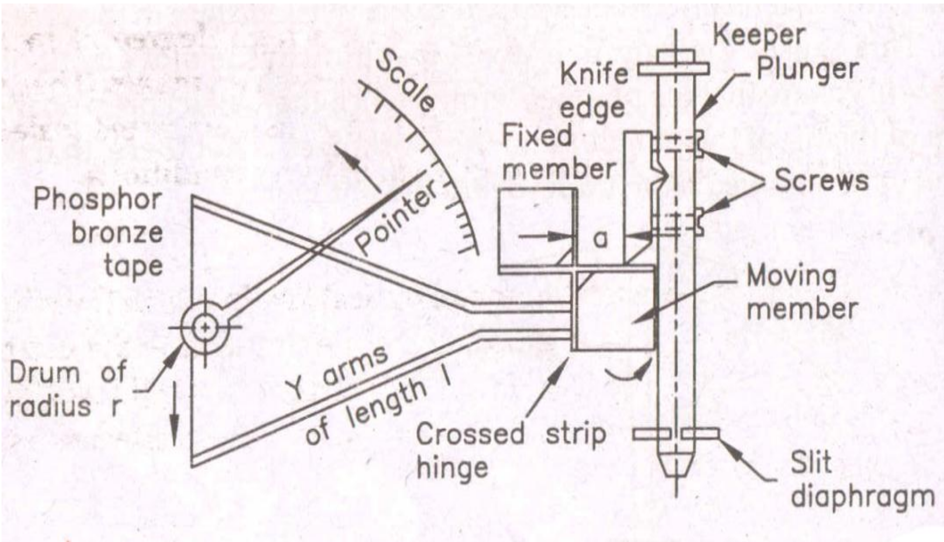


Fig. Sigma Comparator.

<u>Advantages of mechanical comparator:-</u>

- The mechanical comparators are cheaper in comparison to other devices of amplifying.
- It does not require any external medium like electricity or air.
- These instruments usually have a linear scale which is easily understood.
- These are usually compact and easy to handle.
- These instruments are suitable for ordinary workshop conditions and being portable can be issued from a store.

Disadvantage of mechanical comparator:-

- Due to more having moving parts, the friction is more which reduces the accuracy.
- These instruments are very sensitive to vibrations.
- Any dimensional faults in the mechanical devices used will also be magnified.
- The range of instrument is limited as the pointer moves a fixed scale.
- Error due to parallax is possible as the moving pointer moves over a fixed scale.

Optical comparators:-

Optical comparators are capable of giving a high degree of measuring precision. It has lesser no of moving members which makes it better wear resistance than the mechanical type. The provision of an illuminated scale enables reading to be taken as without regard to the room lighting conditions.

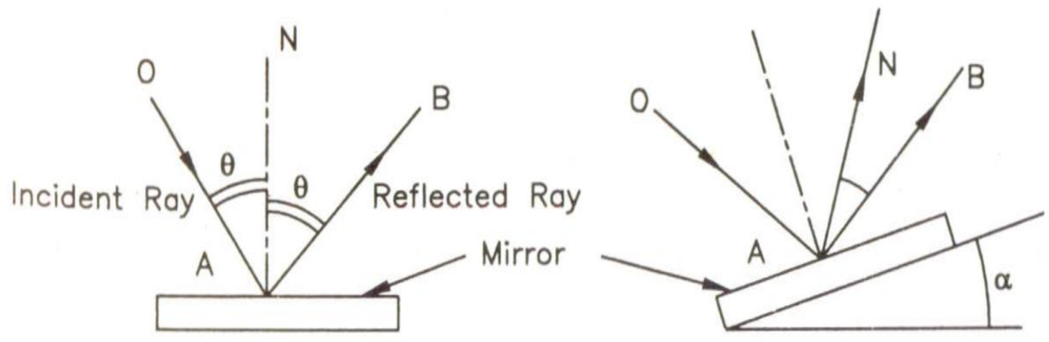


Fig. Optical Principle.

Types of optical comparator:-

(a) Mechanical optical comparator:-

In these comparators, a small displacement of the measuring plungers are amplified first by a mechanical system consist of pivoted levers. The amplified mechanical movement is further amplified by a single optical system involving the projection of an image.

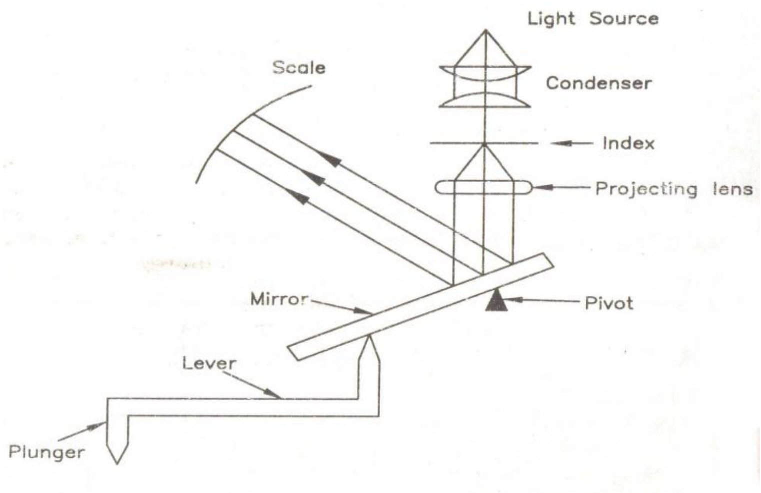


Fig. Mechanical Optical Comparator.

The mechanical system causes a planes reflector to tilt about an axis and the image of an index is projected on a scale on the inner surface of a ground glass screen.

(b) <u>Zeiss ultra opt meter:-</u>

It involves double reflection of light and thus gives higher degree of magnification. The light rays from the lamp fall in the green filter. The green filter filters all and only green light passes to a condenser, which projects it on to a movable mirror M1. It is then reflected to another fixed mirror M2. And then back again to first movable mirror. The objective lens brings to the reflected beam from the first mirror to a focus at a transparent graticule containing a precise scale which is viewed by an eye piece.

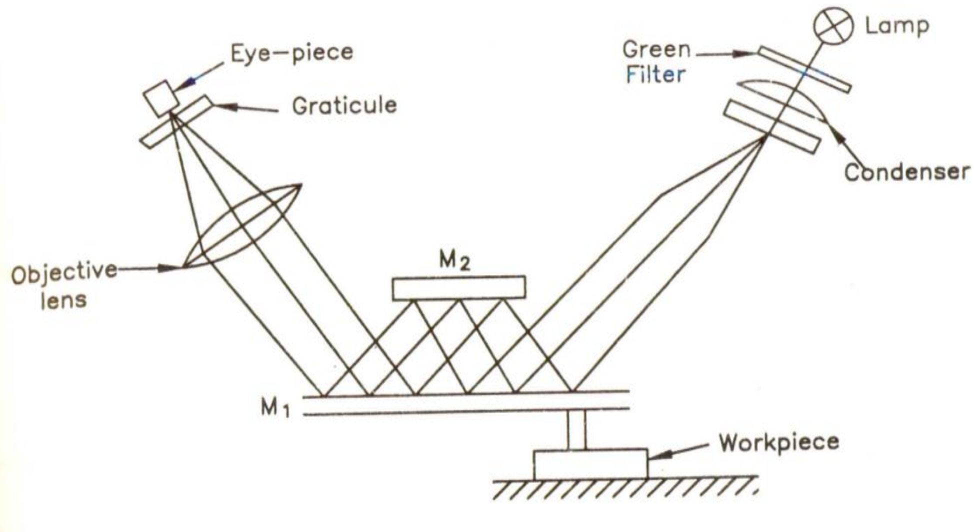


Fig. Zeiss Ultra-optimeter.

(c) Zeiss opt test comparator:-

This is a commercial measuring instrument. It consist of a plunger, tilted mirror, objective lens, prism and observing type of eye piece to provide a high degree of magnification. The mirror is mounted on a knife edge and it can be tilted about this fulcrum by any linear vertical movement of the contact plunger. A beam of light passes through a gratitude suitably engraved with a linear scale. The movement of the mirror causes this scale to move up or down past a translucent screen inside the instrument.

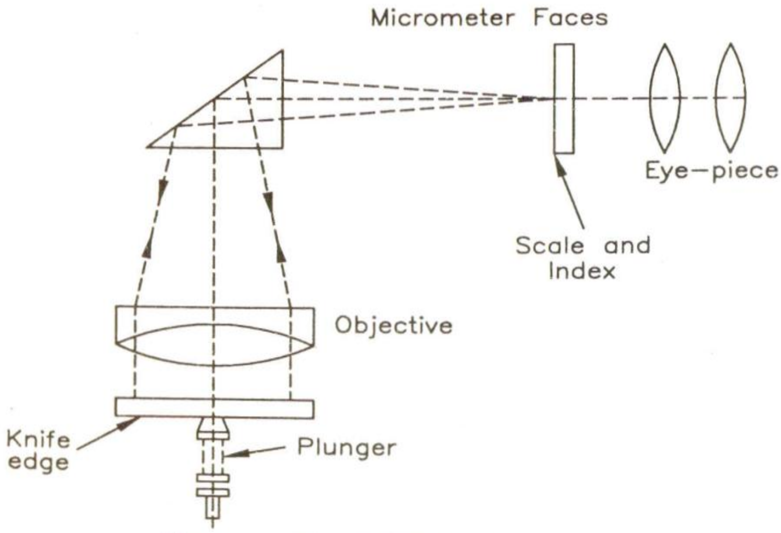


Fig. Zeiss Optotest Comparator.

Advantages of Optical comparators:-

- It gives higher accuracy.
- The scale can be made past a datum line and thus have high range and no parallax error.
- High magnification.
- Optical lever is weightless
- Since scale is illuminated, it enables readings to be taken irrespective of room lighting conditions.

Disadvantages:-

- It depends on external power supply.
- Apparatus is usually bulky and expensive.
- When scale is projected on a screen, the instrument is to be used in the dark room.
- It is inconvenient for continuous use, because the scale is to be viewed through eye piece.

ELECTRICAL AND ELECTRONIC COMPARATORS:-

These comparators are also known as electromechanical measuring system as these employ an electro-mechanical device which converts a mechanical displacement into electrical input signal.

Working principle of electrical comparators:-

These comparators depend on their operation on A.C Wheatstone bridge circuit incorporating a galvanometer. In these comparators, the movement of the measuring contact is converted into an electrical signal. The electrical signal is recorded in terms of plunger movements.

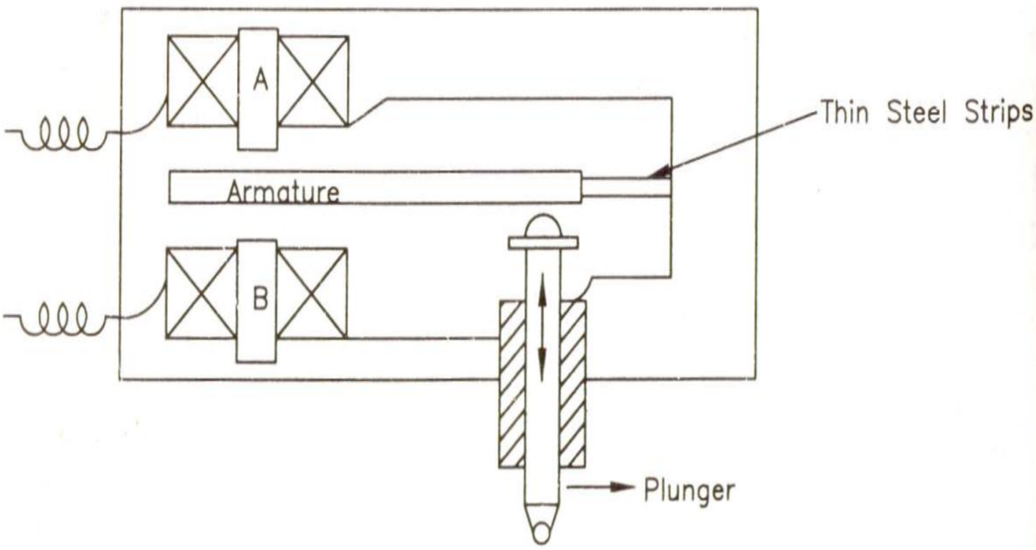


Fig. Principle of Electrical Comparator.

An armature supported on thin steel strips is suspended between two coils A and B. When the distance of the armature surface from the two coils is equal, the Wheatstone bridge is balanced and no current flows through its galvanometer. Slight movement of the measuring plunger unbalance the bridge resulting in the flow of current through the galvanometer. The scale of galvanometer is calibrated to give the movements of the plunger. Various types of electrical comparators are:-

(a) <u>Visual gauging heads:-</u>

The purpose of the visual gauging heads is to give visual inspection of the acceptability of an engineering component with regard to dimension under test. It follows an electrical principle as shown in figure:-

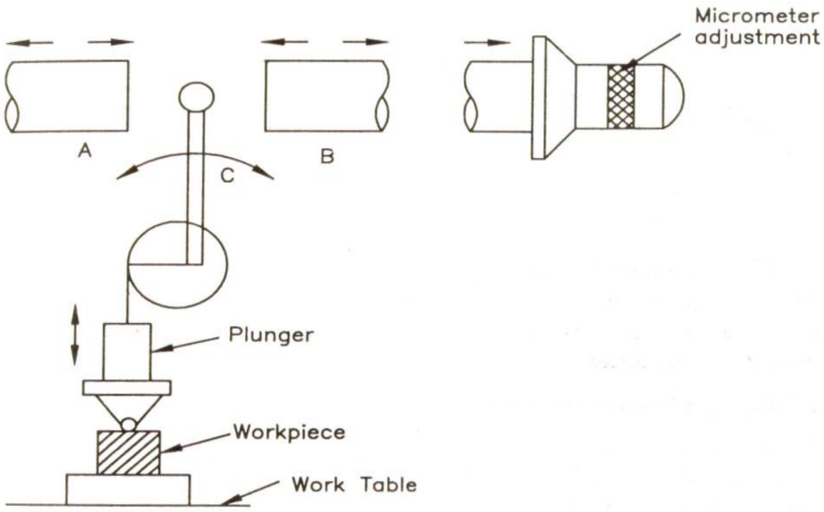


Fig. Visual Gauging heads.

Vertically displacement of an interchangeable plunger causes movement of the rod either to the left or right. A and B are the electrical contacts, which are capable of precise adjustment in the direction of the arrows, micrometer device is available with various detachable plungers, there is practically no limit to the applications of this instrument.

(b) <u>Electricheck gauge:-</u>

Electricheck gauges are simply show whether the dimension of a component falls within a predetermined tolerance range without measuring the actual dimensions. This type of gauge can also used as an automatic check on a m/c in operation to stop the tool when the dimension is out of prescribed limits. This gauge employs read mechanism in its measuring head and reads are caused to bend when the floating block is moved. The bending movement causes the extension arm to break an electric circuit. Electric contacts control signal to indicate whether the dimensions is within the tolerance or not. The gauge has first to be set by precision slip gauges to maximum limits of tolerance.

<u>Working principle of Electronic comparator:-</u>

The electronic comparator is based on the principle of frequency modulation or radio oscillator. In this comparator a special radio-oscillator is used which produces impulses of a definite value at a definite frequency. The frequency is controlled by the measuring head. The measuring head is applied to the part to be measured; the frequency of the instrument oscillator is modified because of the variation of the dimension from that of the present standard. The measuring instrument dial is graduated directly in terms of the physical standards of length which compare with the electronic standards of wavelength. It can be used for external or internal gauging, flatness testing, thickness gauging etc.

Advantages and disadvantages of Electrical and Electronic comparators:-

Advantages:-

- These comparators have less number of moving parts, so the friction and wear is less.
- It has wide range of magnification.
- It is not sensitive to vibrations.
- Easy to setup and operate.
- The instrument is small and compact.
- The indicating instrument need not be placed close to the measuring unit.
- Less error due to sliding friction.

Disadvantages:-

- Fluctuation in the voltage or frequency of the electric supply may affect the results.
- Heating to the coils in the measuring unit may cause zero drift and alter the calibration.
- Cost is generally more than mechanical comparator.

PNEUMATIC COMPARATORS:-

The general principle is to apply a jet or jets of air to the surface being measured, the jet orifices being close to but not in actual contact with the surface. Variations in size affect the aperture of escape of air, and the corresponding variation in back pressure is utilised to indicate the actual dimension.

The response of the comparator working on air flow is quicker than those working on air pressure. But the comparators working on air pressure are more versatile. The various types of pneumatic comparators are:-

(a) <u>Pressure sensitive air gauging:-</u>

The pneumatic gauging is based on Bernoulli's theory. The basic principle of a pneumatic comparator is explained in the figure:-

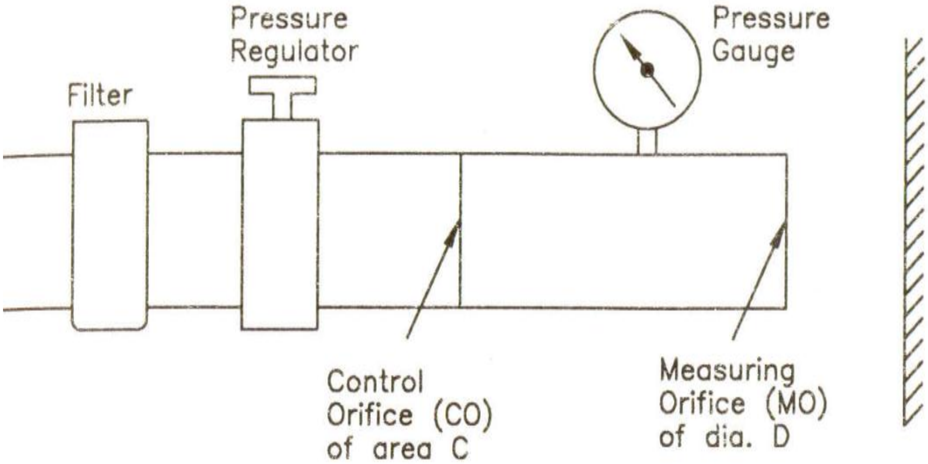


Fig. Principle of Pressure Sensitive Gauging.

The basic principle involved in a pressure sensitive gauging is to be converted changes in length of surface displacement into changes of pressure of air. Air at low but constant pressure is allowed to flow through a control orifice into an intermediate chamber and then to the measuring orifice from where it is allowed to escape into atmosphere. The pressure in the intermediate chamber can be changed by varying the restriction applied to the measuring jet. The change in the intermediate pressure can be calibrated in terms of the changes in the sizes of the measuring orifice which can be the measurement deviation from a standard.

(b) <u>Solex pneumatic gauges:-</u>

This instrument was commercially introduced by Solex air gauges limited. It is generally designed for internal measurement, but with suitable measuring head it can be used for external gauging also.

It uses a water manometer for the indication of back pressure. It consists of a vertical metal cylinder filled with water upto a certain level and a dip tube immersed into it upto a depth corresponding to the air pressure required. A calibrated manometer tube is connected between the cylinder and control orifice as shown in figure:-

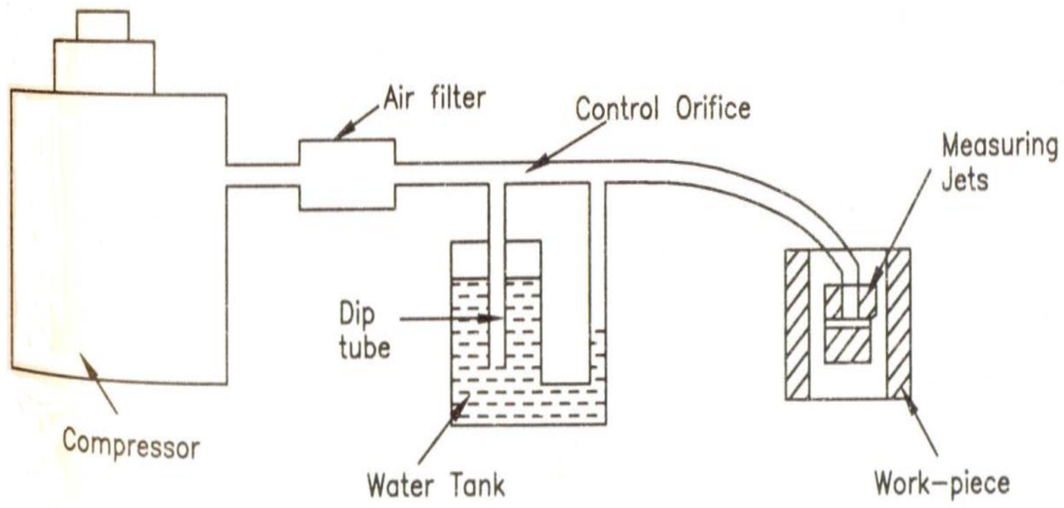


Fig. Solex Pneumatic Gauge.

Thus, the variations in the dimension to be measured are converted into corresponding pressure variations which can be read from the calibrated scale provided with the manometer.

Advantage of pneumatic comparator:-

- It is possible to obtained high degree of magnification.
- The gauging member does not come in contact with the part to be measured.
- It has only a few member of moving parts so these are more wear resistance as compared to mechanical comparator.
- Measuring pressure is very small.
- Single or no. of dimensions can be inspects simultaneously.

Disadvantages:-

- Limited range of measurement.
- Low speed of response.
- The scale is generally not uniform.
- The apparatus is not easily portable.
- Different gauging heads are required for different dimensions.

TOOL MARKERS MICROSCOPE:-

It is also called as tool room's microscope. The tool marker's microscope is an optical measuring machine equipped for external and internal length measurement as well as measurements on screw threads, profiles, curvatures and angles. The main parts of the instruments are:-

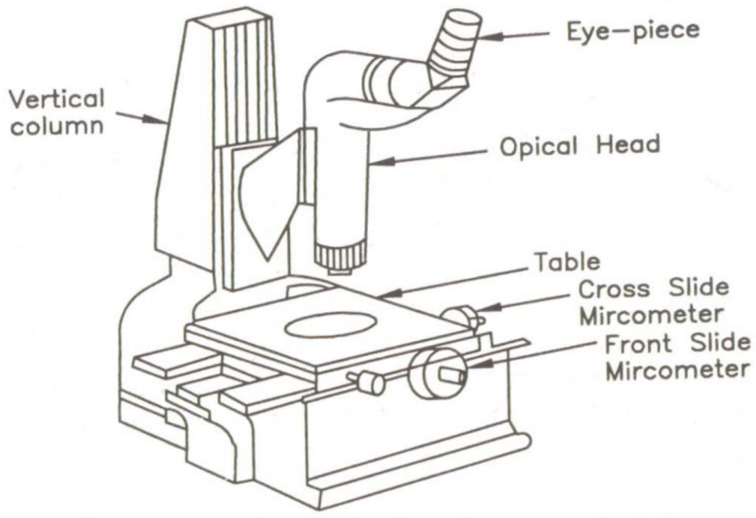


Fig. (*a*) Tool Maker's Microscope.

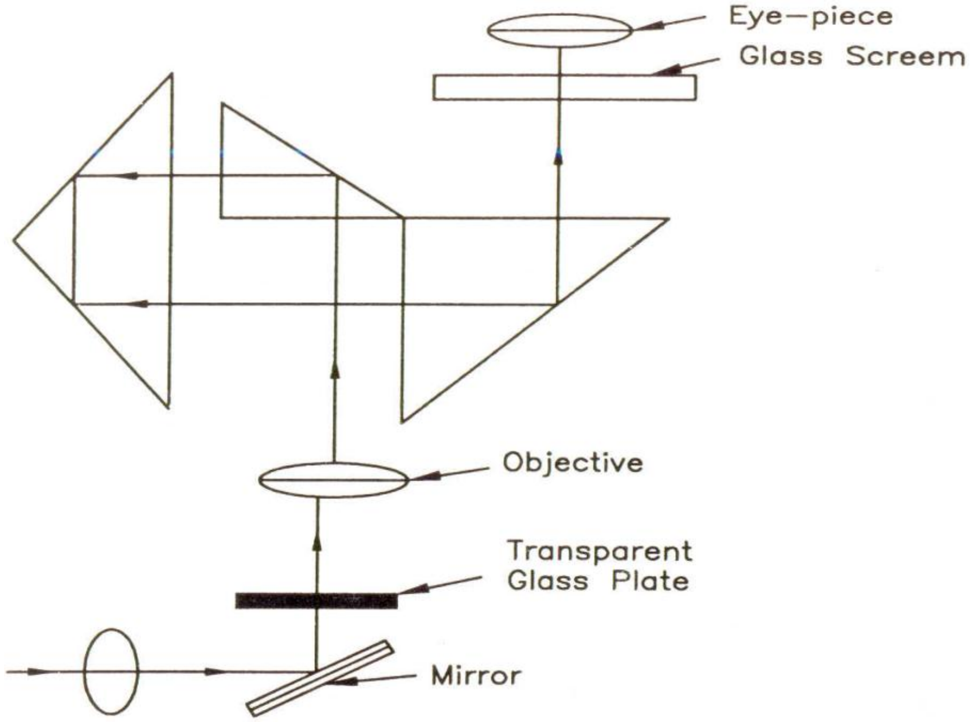


Fig. (*b*) Principle of Tool Maker's microscope.

1. Rotating tables
2. Measuring stage
3. Swing-able head
4. Ocular
5. Projection screen

6. Micrometers
7. Objective lens
8. Prisms

Constructional Detail:-

The microscope consists of a rigid stand on which a swingable head is mounted. The measuring stage moves on ball guide ways by actuating two measuring micrometers arranged perpendicular to each other in the length and cross-section. The measuring range of each micrometer is 25mm and the measuring capacity can be increased using slip gauges.

A rotatable table is provided over the stage, on which the workpiece can be fixed either directly or between centres. This table can be rotated through 360˚ fixed and angular rotation can be read by a fixed vernier to a scale value of 3'.

Working of Tool Maker's Microscope:-

The component being measured is illuminated by the through light method. A parallel beam of light illuminates the lower side of the workpiece which is then received by the objectives lens in its way to prism that defects the light rays in the direction of the measuring ocular and the projection screen. Incident illumination can be tilted with respect to the work-piece by tilting the measuring head and the whole optical system. This inclined illumination is necessary in some cases as in screw thread measurements.

Application of Tool Maker's:-

1. Measurement of angles by using a protractor eye piece.
2. It is used to compare an enlarged, protected image with a scale tracking fixed to the projection screen.
3. It is also used to compare the thread forms with master profiles engraved in the eye piece.
4. The determination of the relative position of various points on work.

Limit Gauges:-

A limit gauge is an instrument by means of which certain dimension or form can be checked for which it is designed or adjusted. It can also be defined as a method used for ascertaining the dimensional accuracy of a component. For small quantities, the direct measurement method can be applied, but for high rates of production, gauges are essential.

These gauges are simple to use and either accept or reject the work-piece being checked by them.

These gauges are of the ‘GO’ and ‘NOT GO’ type. The ‘GO’ sides of the limit gauge should enter the hole or just pass over the shaft under the weight of gauge without using any force. The ‘NOT GO’ side of the gauge must not enter or pass. The three main grades of limit gauges used are:-

1. Workshop limit gauges to be on the machines for gauging the dimensions of the component during production.
2. Intersection limit gauges to be used in the inspection department for checking the component during after production.
3. Reference limit gauges to be used in the metrology laboratory for reference purposes.

<u>Classification of limit Gauges:-</u>

These are 3 types of limit Gauges:-

1. <u>Plug gauge:-</u>

   A plug gauge is an accurate cylinder used for size control of holes. The plug gauges are further classified as:-

   (a) Plain cylindrical
   (b) Cylindrical taper
   (c) Thread plug gauges
   (a) <u>**Plain Cylindrical**</u>:-

   These are of two types Reversible and progressive. Reversible plug gauges have a ‘GO’ plug in one end of the holder and ‘NOT GO’ plug in the other end. The ‘GO’ end should be entering the hole with little or no interference. The ‘NOT GO’ will not enter the hole. On the other hand the progressive gauges have both ‘GO’ and ‘NOT GO’ plugs on one end.

   The ‘NOT GO’ end is not subjected to wear as it seldom enters the hole at the work under inspection. Therefore, its parallel portion is made relatively short in comparison to that of ‘GO’ end. The ‘GO’ end is made 1.5 to 2 times longer than the ‘NOT GO’ end.

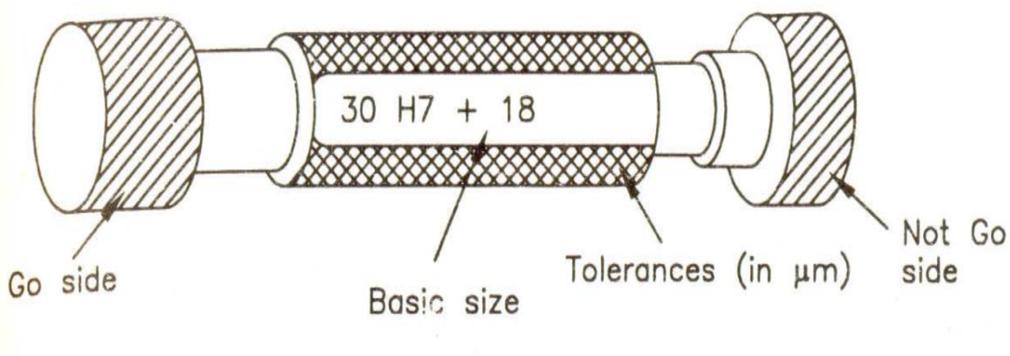


Fig. Plain Cylindrical Gauges.

(b) <u>Cylindrical Taper Gauge:-</u>

Cylindrical taper gauges are used for checking the amount of taper and the size of taper and the size of tapered cylindrical holes such as in drill sleeve and machine tool spindles. The figure shows the testing of a taper by taper plug gauge.

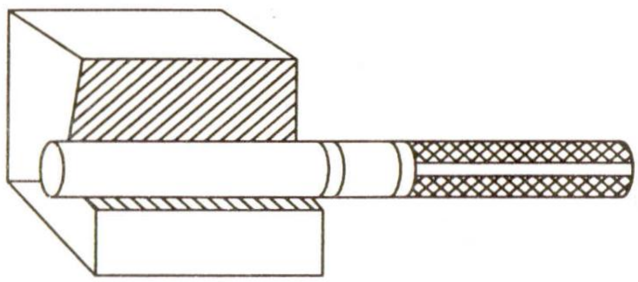


Fig. Cylindrical Taper Gauge.

(c) <u>Thread Plug Gauges:-</u>

This gauge is used for checking external diameters of parts. Ring gauges are classified as plain ring gauge, taper ring gauge and thread ring gauge.

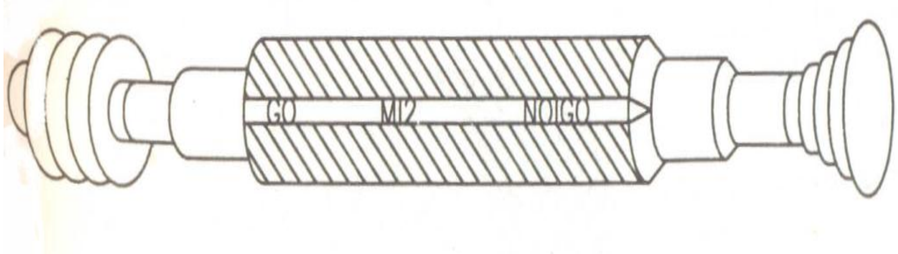


Fig. Thread Plug Gauge.

Plain ring gauges are in the form of cylindrical rings and are used to check external diameters of straight rounds parts. They are made to pairs as shown in figure. The 'NOT GO' ring is used to check the minimum size limit while the 'GO' ring checks the maximum size limit. If both the rings pass over the work-piece, it is undersize. If neither does, the work-piece is oversize.

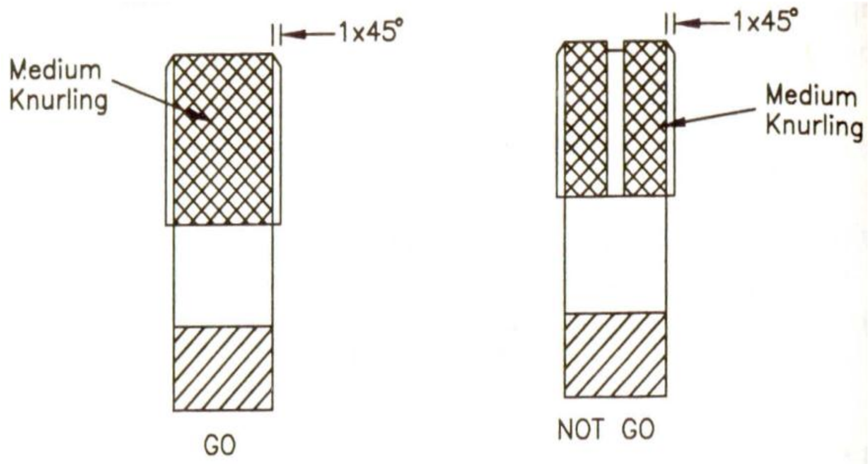


Fig. Plain Ring Gauge.

Taper ring gauges are used for checking the diameter and the amount of taper on parts such as drills, reamers, lathe centres and other tapered products. A taper ring is shown in figure.

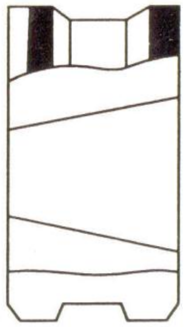


Fig. Tapered Ring Gauge.

Thread ring gauges are used to check the accuracy of an external thread. The set includes a 'GO' and 'NOT GO' gauge. The gauge is used to check the pitch diameter, lead, flank angle, maximum pitch diameter. Figure shows a threaded ring gauge.

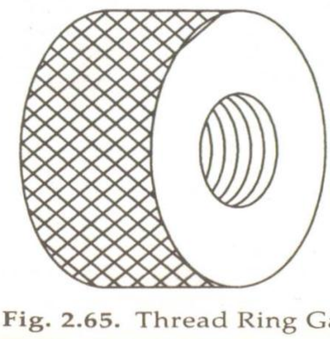


Fig. 2.65. Thread Ring Gauge.

<u>Wire Gauge:-</u>

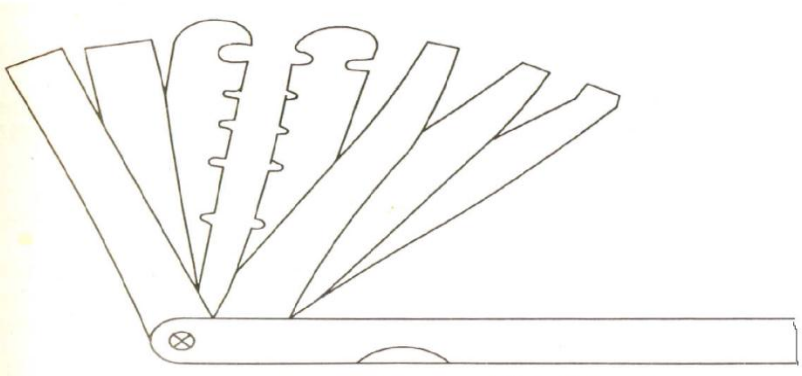


Fig. Wire Gauges.

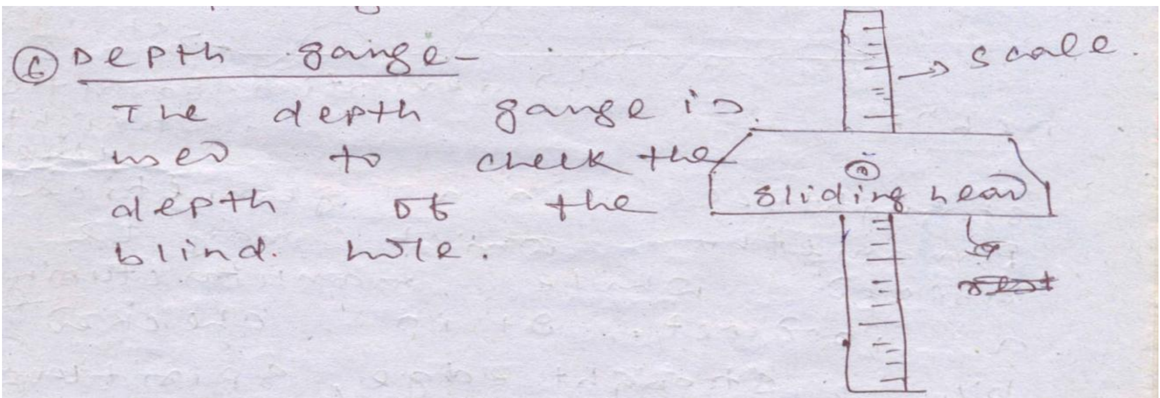
The wire gauge is generally known as engineer’s taper, wire and thickness gauge. It is very handy device which contains leaves for taper measurements, wire diameter measurements and thickness of small gaps.

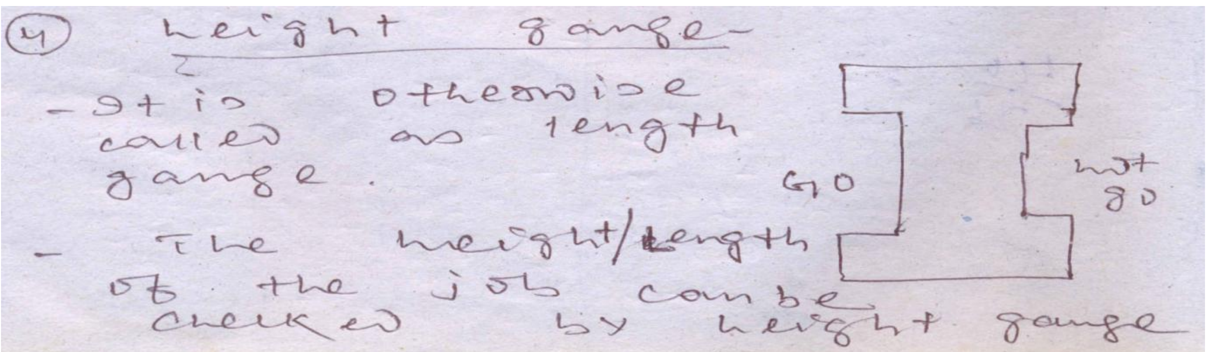
<u>Form Gauge:-</u>

These gauges are used to check the form of the components. These are also known as profile gauges. Profile is difficult to be checked by limit gauges and it is usual practice to use fixed gauges mated to profile for checking profiles.

There are two methods of tolerance the form of profile:-

(a) To provide a tolerance zone within the finished profile must lie. This method provides a uniform metal tolerance normal to profile.
(b) To use ordinates which are provided with individual tolerances. In this method the tolerance, normal to the surface, will vary with the form of the profile.





PROFILE PROJECTORS:-

Profile projector is an optical device which is used to check profile of components having special formed surfaces as gears, screws and those objects having regular or irregular profile. It is an instrument which projects the enlarged shadow of the profile of the workpiece on a glass screen. From this projection of the workpiece, measurements can be made directly or indirectly.

It is highly sophisticated and is versatile optical instrument which is designed as per international standards. It is deal for rapid inspection of linear and angular measurements of small to medium size components as tools, rubber components etc. Its best quality, high resolution optics provides accurate, bright, clear and sharp images.

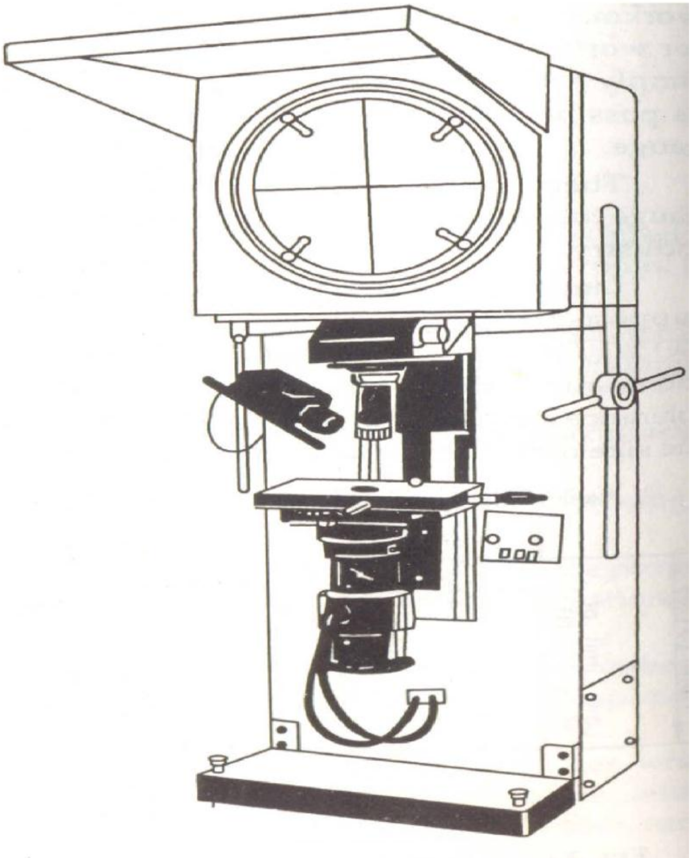
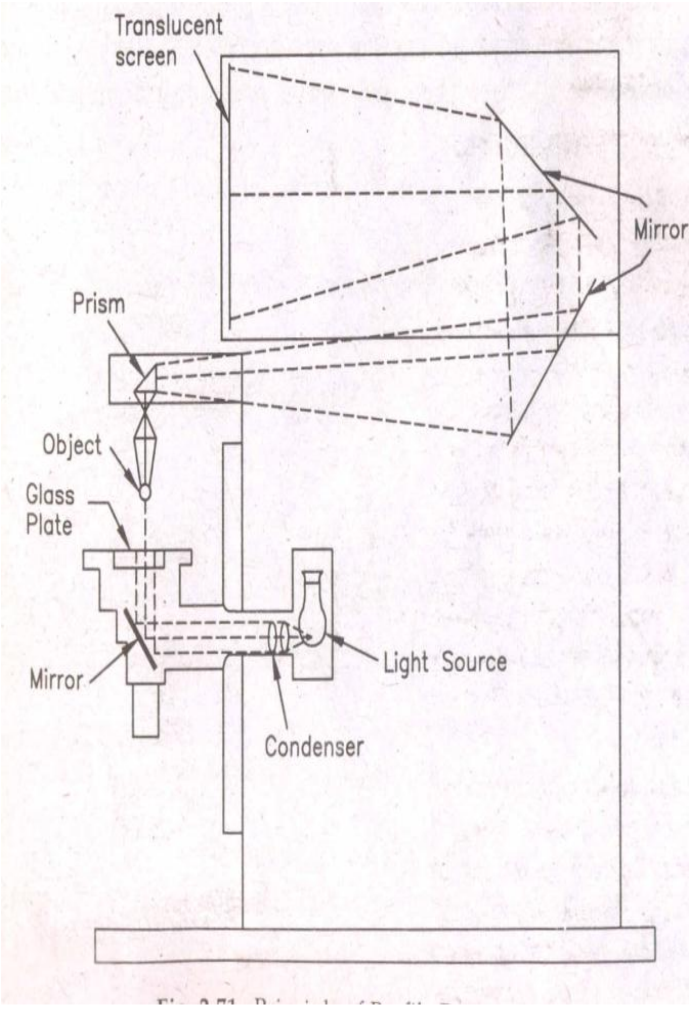


Fig. Profile Projector.

Constructional Details:-

It consists of a halogen of high intensity 24v and 150w. The light source is placed at the principle focus of the collimating lens. The projection lens is a combination of lenses and forms a real image of the object placed between it and collimating lens. The work stage is mounted on ball bearing and is rotatable from0-360˚. The two micrometer are attached to provide motion in X and Y axis directions. The screen is of 300mm diameter & rotatable from0 to 360˚.



Working of Profile Projector:-

The profile projector has a table that can be moved laterally and from front to back. It can be easily elevated or lowered as well as tilted at an angle within certain limits. The work piece is placed on the screen. The movement of the work piece is measured by micrometer or precision gauge blocks are as an indicator. To register the movement of the work piece, the screen of the profile projector is provided with crossed line. Sometimes it is provided with a number of magnifying lenses, so that the images of the screen can be projected as 10, 20, 30 or more times the size of the object.

Advantages:-

1. There will be no fatigue in viewing the image as it is provided on a screen.
2. No special graticules are needed for measurement.
3. The image can be seen by many persons at a time and thus it is helpful for discussing the cause for discrepancies etc.

4. By replacing the screen with a photographic plate, permanent records can be made.

Disadvantages:-

The main drawback of the profile projector is that it is bulky, as the entire magnification is achieved by one lens.

GEAR MEASUREMENT:-

The subject gearing and gear measurement forms a highly specialized field in the transmission of power. The gears are basically used to transmit power from one shaft to another. The various terms related to gear measurement are:-

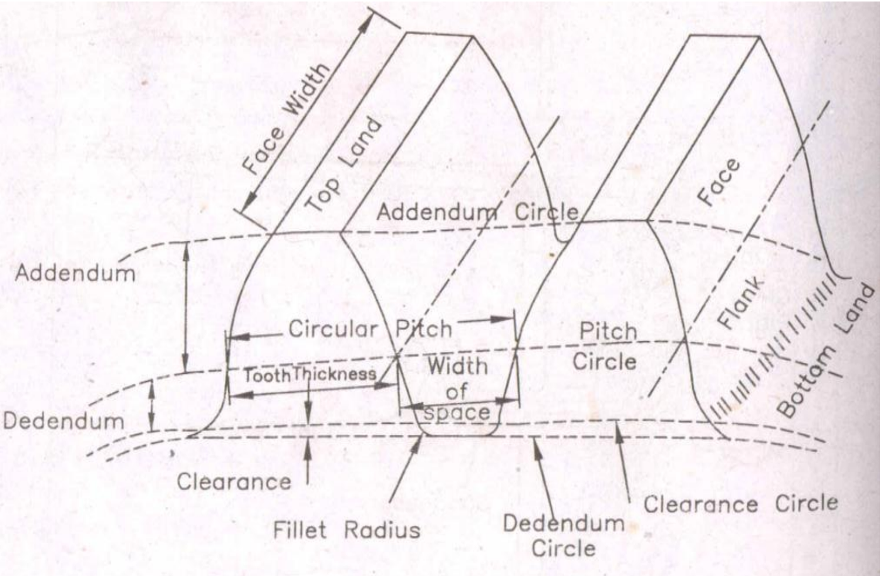


Fig. Gear's Terminology.

(a) Pitch circle:- It is a theoretical circle upon which all calculation are usually based.
(b) Pitch circle diameter:- The diameter of the pitch circle is known as pitch circle diameter.

$$P.C.D\ (D) = (T \times OD) \div (T+2)$$

Where OD = outside diameter, T = no. of teeth.

(c) Tooth thickness:- it is the length of the arc of the pitch circle between opposite faces of same tooth.

(d) Circular pitch:- It is the distance measured on the pitch circle from a point on one tooth to a corresponding point an adjacent tooth. Thus, the circular pitch is equal to the sum of tooth thickness and the width of the space.

C.P = D/T

(e) Module: - it is the ratio of pitch diameter to the number of teeth.

Module (m) = D/T

(f) Diameteral pitch:- it is the ratio of number of teeth on the gear to the pitch diameter. Thus it is the reciprocal of the module.

(g) Addendum:- it is the radial distance between the top land and the pitch circle. It is equal to the one module.

(h) Clearance:- it is the amount by which the width of a tooth space exceeds the thickness of the engaging tooth measured on the pitch circle. It is generally the difference between Addendum and Dedendum.

(i) Dedendum:- it is the radial distance from the bottom land to the pitch circle,

Dedendum = Addendum + Clearance

(j) Working depth:- it is the distance by which a tooth extends into the space of a mating gear and is equal to the whole depth minus the clearance, or twice the addendum.

SCREW THREAD MEASUREMENT:-

Screw threads are helical grooves of various shapes wound around a cylindrical or a conical component. These are used as fastening in the field of engineering. The form or shape of the thread used for different applications depends very much on the purpose of application. The most commonly used forms are metric, Whitworth, acme, buttress and square.

Geometry of screw threads:-

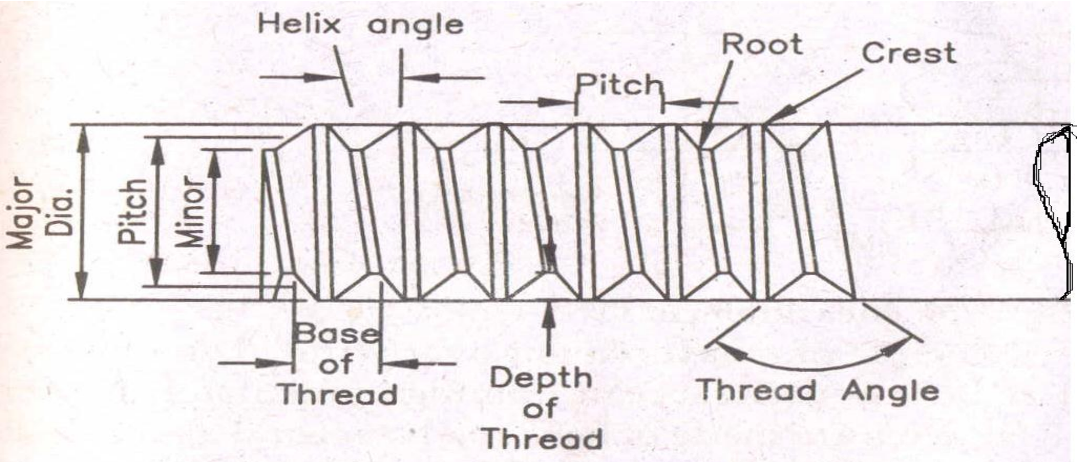


Fig. Screw thread Terminology.

The various terms of the screw threads are:-

(i) **Crest**:- It is the top surface joining the two sides of a thread.
(ii) **Root**:- It is the bottom surface joining the sides of adjacent threads.
(iii) **Flank**:- The surface of the thread which connects the crest with the root.
(iv) **Pitch**:- It is the distance measured parallel to its axis, between corresponding points on adjacent threads.
(v) **Lead**:- Lead of a screw thread is the distance it advances axially in one revolution.
(vi) **Thread angle**:- It is the angle between the sides, measured on an axial plane.
(vii) **Flank angle**: it is the angle between the flank of thread and a plane perpendicular to the axis, measured in axial plane.
(viii) **Major diameter**:- It is the largest diameter of a screw thread on a screw or nut.
(ix) **Minor diameter**:- It is the smallest diameter on the screw or nut.
(x) **Thread depth**:- it is half the difference between major diameter and minor diameter.
(xi) **Effective or pitch diameter**:- It is the diameter of an imaginary cylinder which would passes through the threads at such points as to make the width of the threads and width of the space between the threads at these equal points.

The important element of screw thread which are to be checked are pitch diameter, major and minor diameters, lead and thread angle, number of threads per inch. These tests can be done as under:-

I. Thread per inch or pitch measurement
II. Measurement of effective diameter
III. Thread micrometer

IV. Measurement of major and minor diameter

V. Measurement of thread angle and thread form.

GEOMETRICAL PARAMETERS:-

The increasing demand for product reliability efficiency and accuracy has placed, higher standards in geometric integrity of components and their assembly. The specification of geometrical tolerance in addition to the normal dimensional tolerance is becoming a common practice because;

1. The geometrical accuracy of the component is an important as their size for its correct finding functioning with the mating parts.
2. It is also influence the wear on the moving parts.
3. Proper functioning e.g. slides to move along straight line and spindles to rotate about a fixed axis.
4. For stationary locating parts, the geometrical inaccuracy may affect the class of fits required as the clearance between the mating parts may be changed.

The geometrical shapes deal with various components such as straightness, flatness, parallelism and squareness etc.

Straightness:-

A straight line may be defined as the shortest distance between two points. A line is said to be straight over a given length, if the variation of the distance of its points from two planes perpendicular to each other and parallel to the generation direction of the line remains within the specified tolerance limits.

The tolerance on the straightness of a line is defined as the maximum deviation in relation to the reference straight line in both the directions.

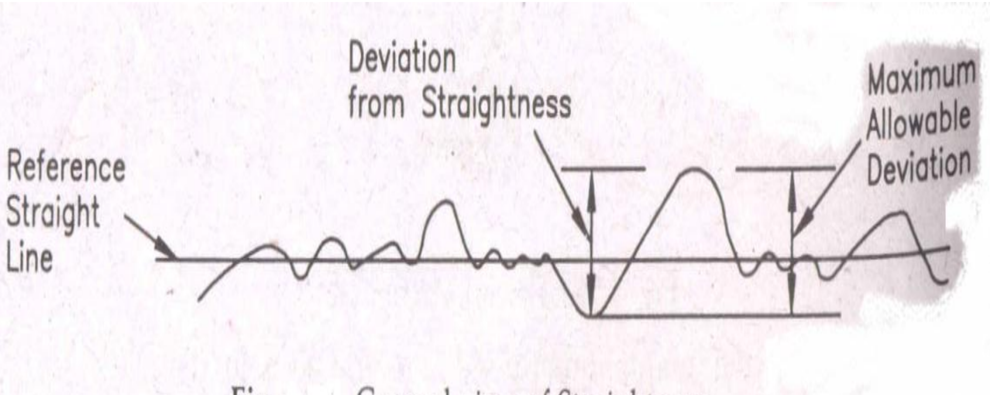
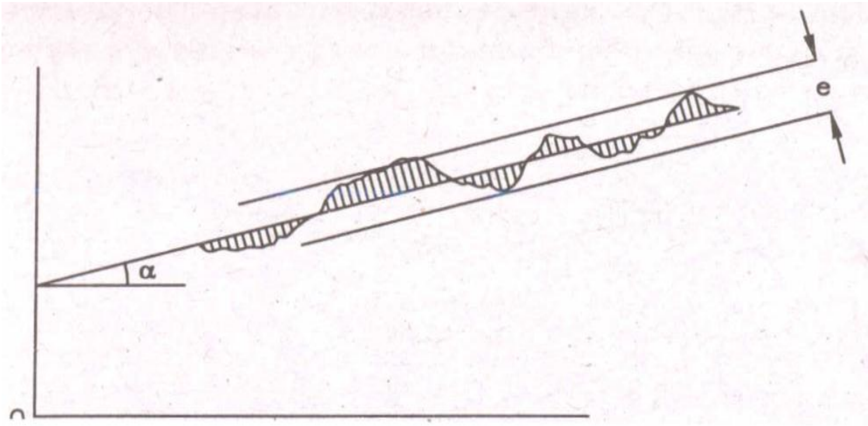


Fig. General view of Straightness.

The straightness error of a line is defined as the distance 'e' between two lines drawn parallel to the mean true line and enveloping the actual contour by passing through the highest and lowest points on the measured line shown in fig.



For measuring the straightness of a line and its error, the following instruments are used:-

(i) Straight edge
(ii) Spirit level
(iii) Auto-collimator

I. <u>Measurement of straightness by straight edge:-</u>

- It is the simplest method of testing straightness of a surface.
- A straight edge is a measuring tool which consists of a length of steel or other suitable material usually of narrow and deep section and varies in length from several millimetres to a few meters.
- A straight edge is supported at the points for minimum deflection on two unequal piles of slip gauges, so, that it is a light inclination to the surface to be tested.
- The distance between the supports is divided into number of equal parts and marked on the straight edge.
- If both straight edge and surface are perfectly straight, the gap at each point will vary uniformly.

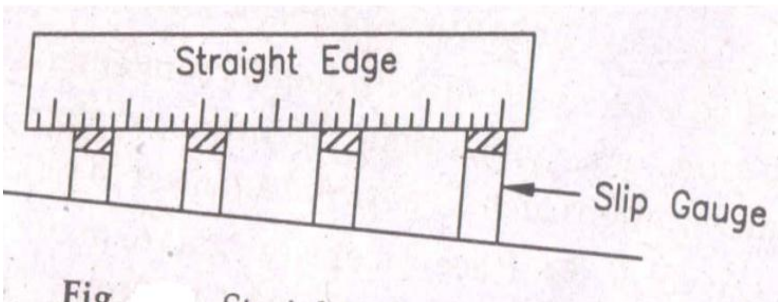


Fig. Straight Edge Method.

II. <u>Measurement of straightness by spirit level:-</u>

- The most convenient method of testing straightness of a surface of any length to a high degree of accuracy is by spirit level.
- A straight line is drawn on the surface whose straightness is to be measured or checked.
- A sensitive spirit level, fitted with two feet at a convenient distance apart is moved along this line in steps. Equal to the pitch distance between the centre lines of feet. For each position, the reading is noted.

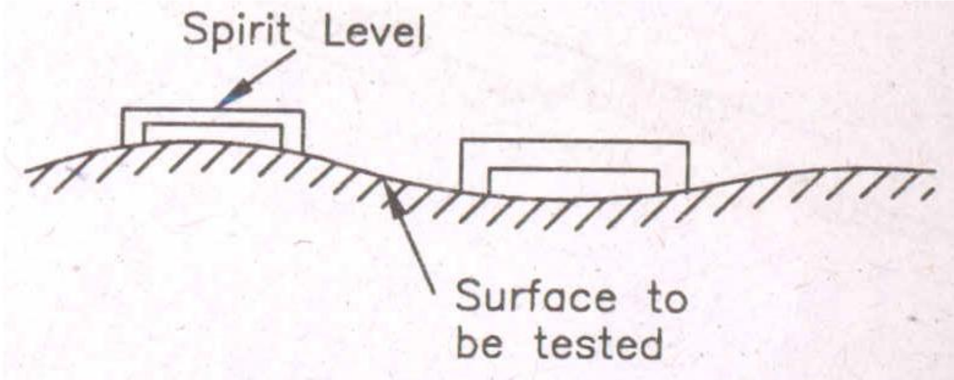


Fig. Spirit Level Method.

III. <u>By auto- collimator method:-</u>

- The main principle of this method is same as that of sprit levels can be used only for the measurement of straightness is horizontal surface while auto collimator method can be used on surfaces of any plane.
- In this method a block fitted at convenient distance apart and carrying a plane reflector is moved along this line in steps of equal to the pitch of the feet. Angular variations at each position are used to plot the graph of errors.

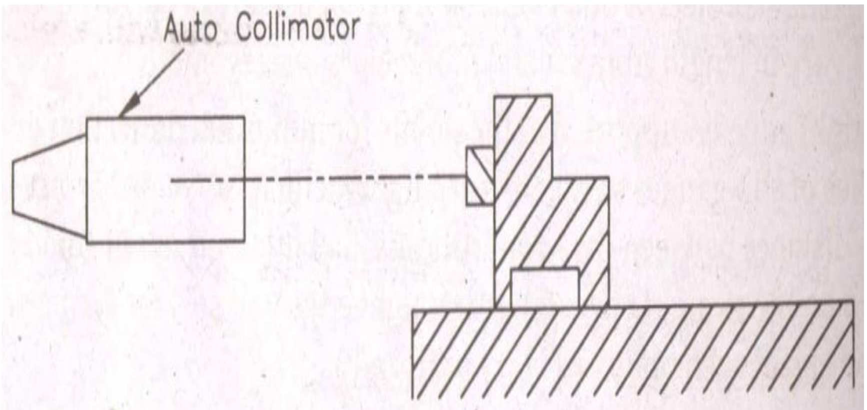


Fig. Auto Collimator Method.

<u>Flatness:-</u>

It may be defined as the minimum distance between two planes which cover all the irregularities of the surface under examination.

The following methods can be used for flatness measurement.

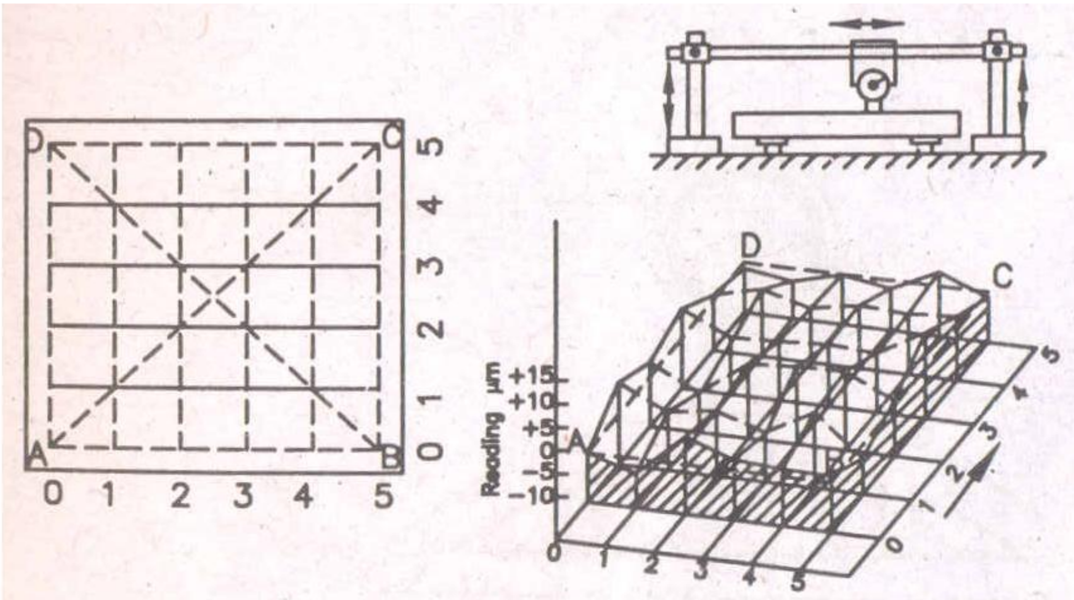
1. Direct comparison
2. Dial gauge
3. Level or auto collimator methods
4. Flatness comparators
5. Liquid method
6. Interference methods

- <u>Direct comparison:-</u>

  It is restricted to relatively small area. The surface to be checked can be compared with a surface plate or tool maker's flat. One of the surfaces is marked with Prussian blue or some other suitable substance, and the surfaces are then rubbed together.

- <u>Dial gauge:-</u>

  To ensure the parallelism, the reading of the dial gauge at each edge of the surface plate should be the same. The dial gauge should be rigidly mounted on the stand to be preventing deformation and deflection of the overhang which can be quite large compared to errors of flatness.



- Level or auto collimator methods:-

  This method is more than elaborate for both straightness and flatness. In this the level or reflector may be guided along the chosen lines by using a straight edge or ordinary rule.

- Flatness comparators:-

  The following two comparators are useful instruments for measuring flatness of surface.

  (i) Beam comparators
  (ii) Bar comparators

  Beam comparators:-

  It consist of a beam having four supports, the two at the centre of the beam being offset from the joining the other two supports. By placing the beam comparators on a surface plate, the initial zero reading of the dial gauge that contacts the surface plate will be lying on the reference true plane of measurement.

  Bar component of comparators:-

  It consists of a bar supported on three fixed points, two at its centre and the third at one end. The measuring anvil of a micrometer or indicator is arranged at the other end of the bar. The measuring anvil should lie on the reference pane containing the other three supporting points, when the micrometer or dial gauge read zero.

- Liquid method:-

  It consist of a trough of liquid, such as mercury or soda solution, supported over the plate, and a form of height gauge with an overhanging micrometer head having a conical point to the spindle. The micrometer head spindle makes contact with the liquid, the exact position of the contact being determined with help of an electrical indicator circuit. Variations in the surface are thus compared with the true plane of the liquid surface.

- Interference method:-

  It is the easiest method to check small lapped surfaces, such as micrometer anvils, block gauges etc. It provides a very sensitive method of measuring flatness on a lapped and polished surface. The flatness of the surface is directly compared with that of a glass plate, known as an optical flat or proof plane. The flatness of such a plate can be produced and measured to an accuracy of a few millionth of a cm. In the interference method, two types of instruments are used

  (i) Optical flat

(ii) Interferometer. [both works on the same principle]

Parallelism:-

Parallelism of lines, axis and planes are frequently dealt with, in metrological work. The terms “lines” and “axis” are used interchangeably. An axis is represented by a cylindrical surface of high precision to form, suitable surface finish and sufficient length. There are many methods to check the parallelism of various surfaces as:-

1. Parallelism of two planes:-

   Two planes are said to be parallel when the distance between them measured from anywhere, remains the same. This is of course an ideal condition and it is very much different difficulties to produce this conditions.

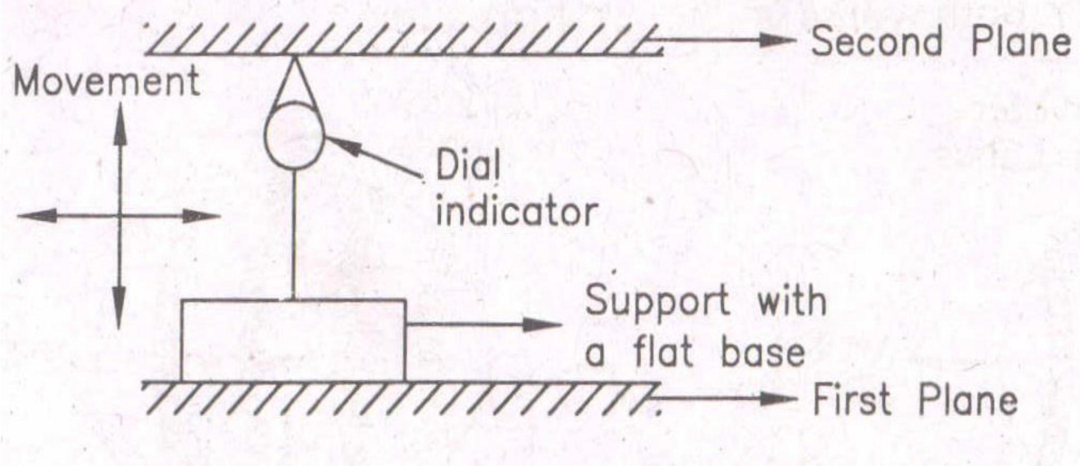


Fig. Parallelism of two planes.

   The above shows the test for parallelism of two planes is carried out in two directions. The dial indicator, which is held on a support with a flat base, is moved in one plane over a given length and the feeler is made to rest against the second plane and the deviations noted down.

2. Parallelism of two axis:-

   Assume that the parallelism of axis of two cylinders is to be tested. The instrument used for the test is dial indicator. It is supported on a base of such shape that the base slides along one of the cylinders.

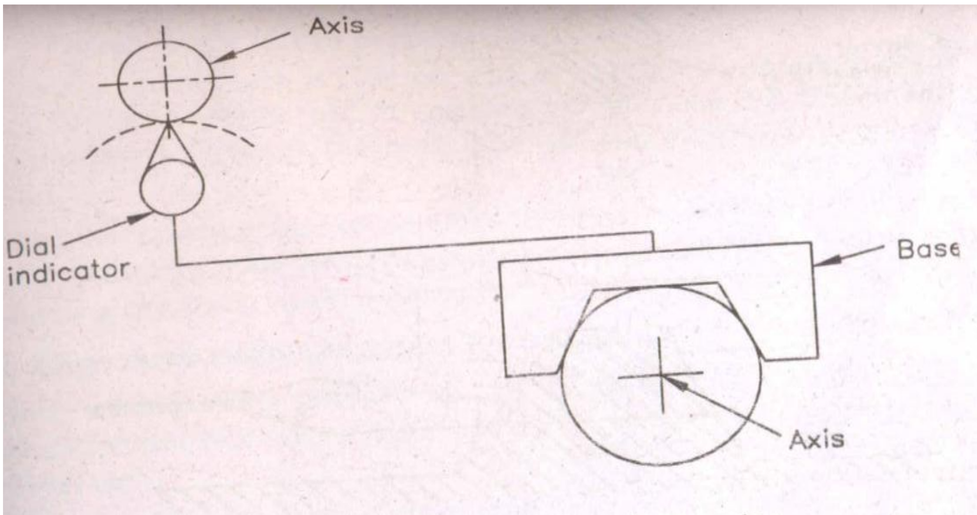


Fig. Parallelism of two axis.

The dial indicator is so that adjusted feeler slides along another cylinder. The maximum deviation between the axes of the cylinders at any point may be determined by gently rocking the dial indicator in a direction perpendicular to the axis.

3. Parallelism of an axis to a plane:-

In this test, a dial indicator is held on a support with a flat base and placed over a plane under test. The feeler of the dial indicator is made to touch the surface of the cylinder representing the axis. The instrument is moved along the plane for a distance over which parallelism test is to be performed.

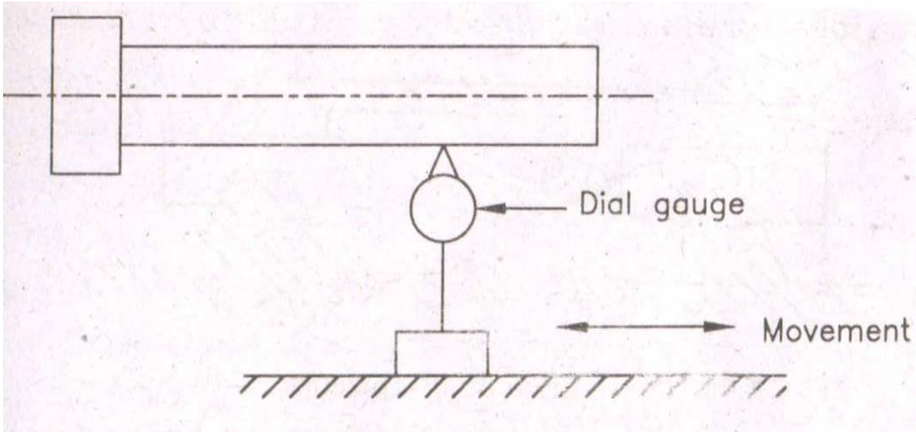
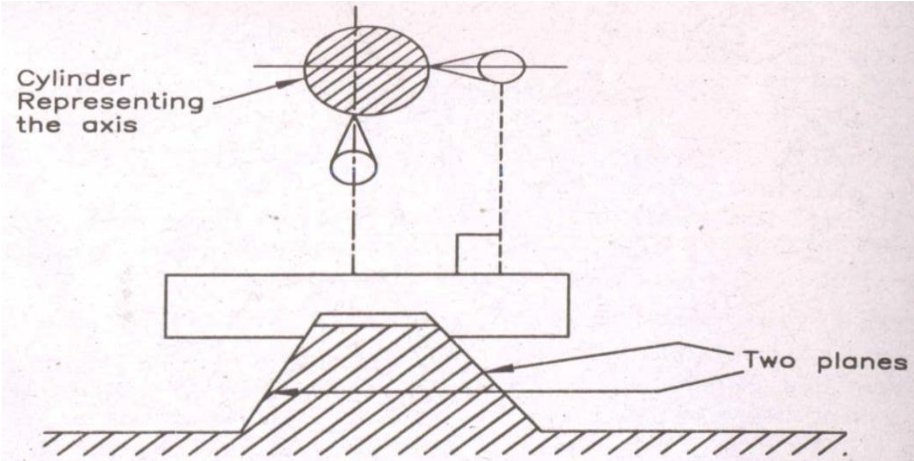


Fig. Parallelism of an axis to a plane.

At each point of measurement, readings of the instrument are noted. If the maximum difference between the several readings taken at number of points does not exceed a predetermined value, the axis can be said to be parallel to the plane.

4. <u>Parallelism of an axis to the intersection of two planes:-</u>

   The instrument setup is shown in figure. And this test is also conducted in two perpendicular planes of the greatest importance.



5. <u>Parallelism of the intersection of two planes to the third plane:-</u>

   This test is similar to the parallelism of an axis to the intersection of two planes as described above. The plunger instead of touching the cylindrical surface, touches the third plane to be tested. The feeler is set at right angles to the plane.
6. <u>Parallelism of two straight lines each formed by the intersection of two planes:-</u>

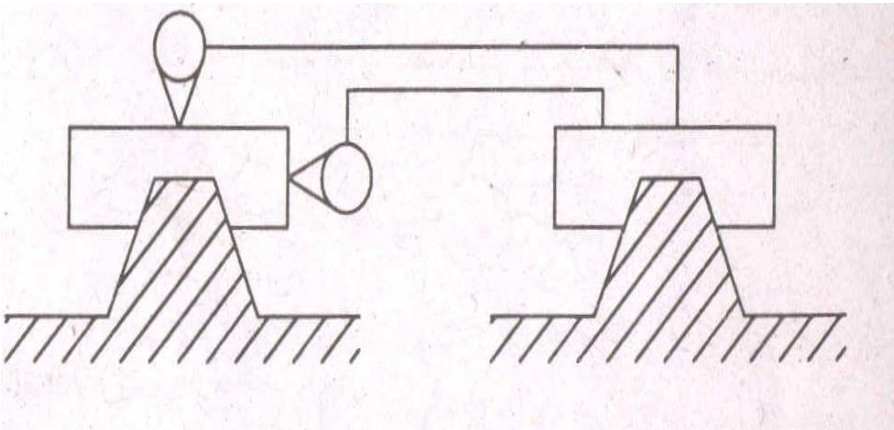


Fig. Parallelism by intersection of two planes.

The above figure shows the setup for checking the parallelism in two perpendicular planes. This setup is recommended only in cases where the distance between two lines is relatively small. Where the distance is large, the V-blocks are covered by a straight edge and check made by a sprit level.

<u>ALIGNMENT TEST FOR LATHE:-</u>

The following alignment tests are conducted on the lathe.

1. Levelling of the installation.
2. Straightness of saddle in horizontal plane.
3. Alignment of both the centres in the vertical planes.
4. True running of taper socket in main spindles.
5. Parallelism of main spindle to the saddle movement.
6. True running of locating cylinder of main spindle.
7. True running of head stock centre.
8. Axial slip of lead screw

(i) Test for levelling of installation:-

(a) In longitudinal direction.

(b) In transverse direction.

Instruments used:- Spirit level, gauge block to suit the guide ways of the lathe bed.

Procedure:- The gauge block with the spirit level is placed on the bed ways on the front position, back position and in the cross wise direction. The position of the bubble in the sprit level is checked and the readings are taken. The setup for testing the bed of a centre lathe is shown in figure.

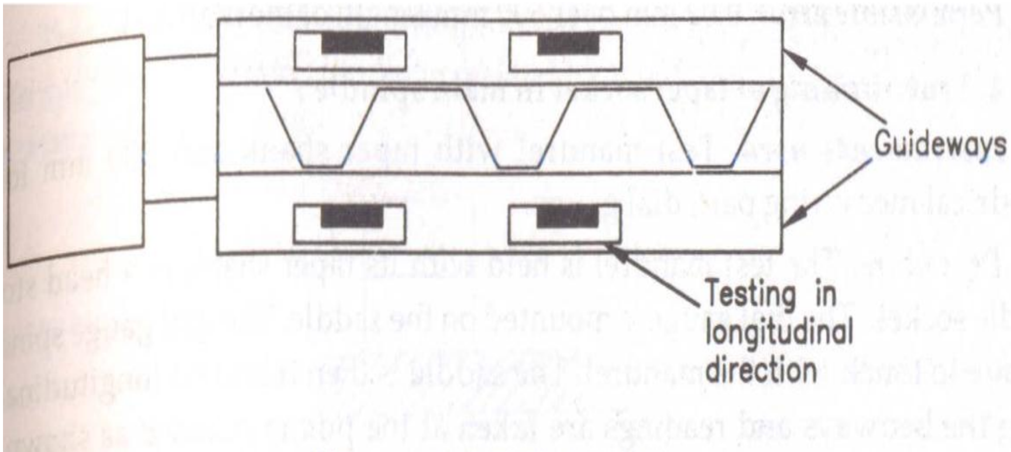


Fig. Level of Installation.

Permissible errors:- Front guide ways 0.02 mm / meter convex only. Rear guide ways, 0.01 to 0.02 convexity. Bed level in cross-wise direction $\pm$ 0.02mm / meter. No twist is permitted. The errors in level may be corrected by setting wedges at suitable points under the support feel or pads of the machine.

(ii) Straightness of saddle in horizontal plane:-

Instruments used:- Cylindrical test mandrel (600 mm long), dial indicator.
Procedure:- The material is held between centres. The dial indicator is mounted on the saddle. The spindle of the dial indicator is allowed to touch the mandrel. The saddle is then moved longitudinally along the length of the mandrel. Readings are taken at different places.

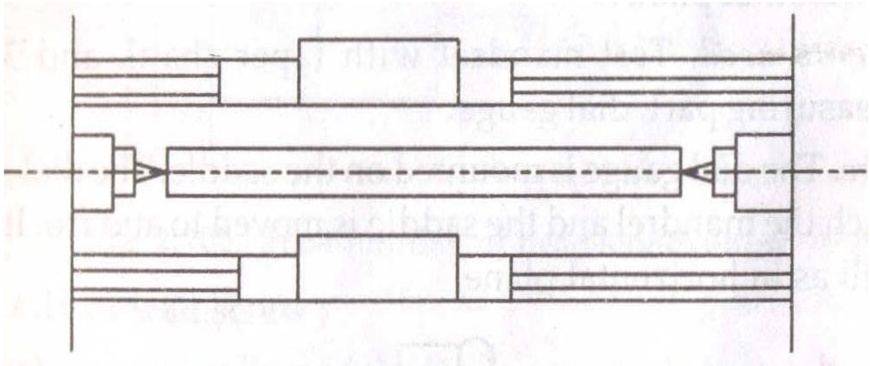


Fig. Straightness of Saddle.

Permissible error:-0.02 mm over length of mandrel.

(iii) Alignment of both the centres in the vertical planes:-
Instrument used:- Cylindrical mandrel (600 mm long), dial gauge.
Procedure:- The test mandrel is held between centres. The dial indicator is mounted on the saddle in vertical plane as shown in figure:-

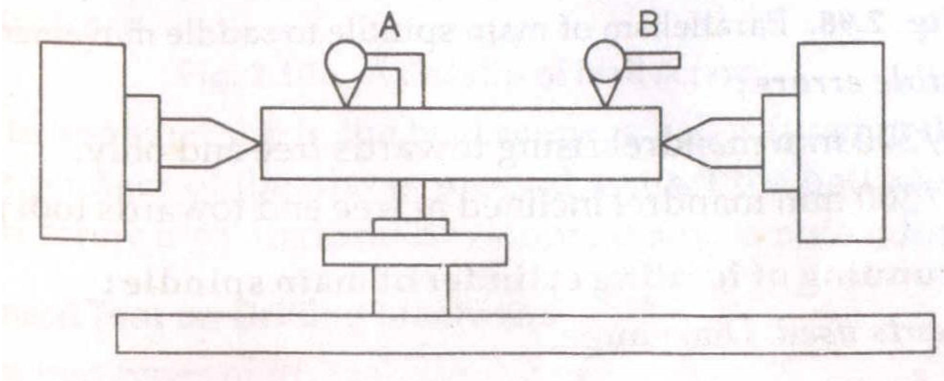


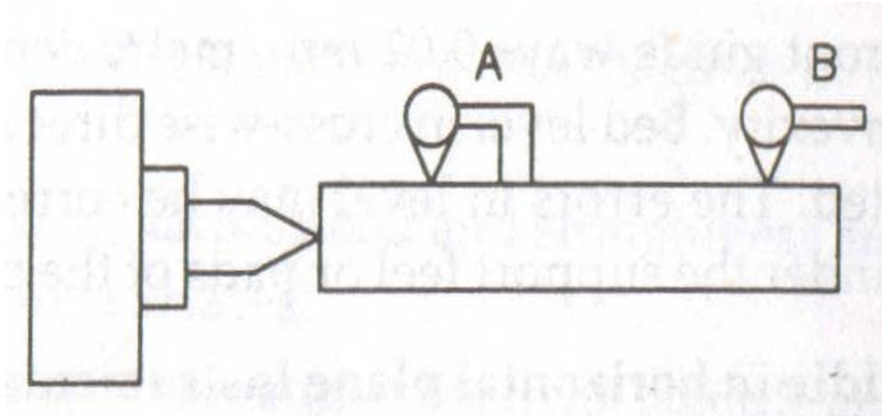
Fig. Alignment for both centres in vertical plane.

Then the saddle along with the dial gauge is travelled longitudinally along the bed ways, over the entire length of the mandrel and the readings are taken at different places.
Permissible error:- 0.02 mm over 600 mm length of the mandrel.

(iv) True running of taper socket in main spindle:-

Instruments used:- Test mandrel with taper shank and 300 mm long cylindrical measuring part, dial gauge.

Procedure:- The test mandrel is held with its taper shank in a head stock spindle socket. The dial gauge is mounted on the saddle. The dial gauge spindle is made to touch with the mandrel. The saddle is then travelled longitudinally along the bed ways and readings are taken at the points A and B as shown in figure.



Permissible errors:- Position A, 0.01 mm; Position B, 0.02mm.

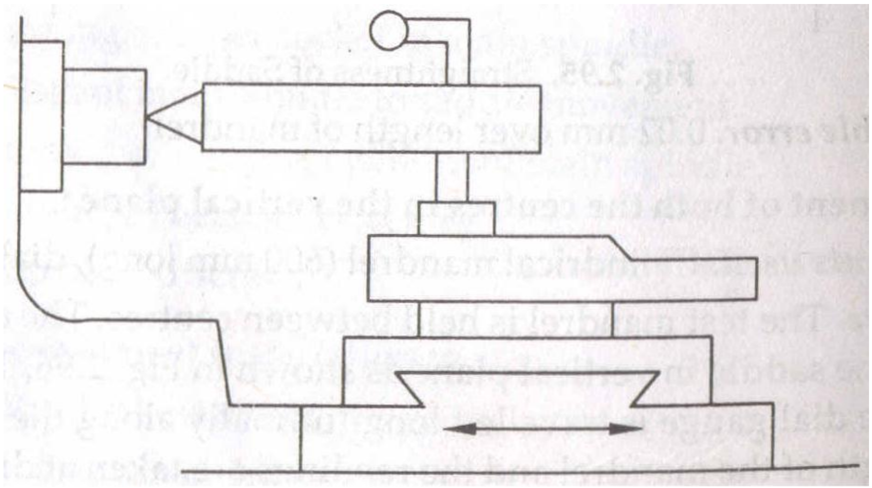
(v) Parallelism of main spindle to saddle movement:-

(a) In a vertical plane

(b) In horizontal plane

Instrument used:- Test mandrel with tapper shank and 300mm. Long cylindrical measuring part, dial gauge.

Procedure:- The dial gauge is mounted on the saddle. The dial gauge spindle is made to touch the mandrel and the saddle is moved to and fro. It is checked in vertical as shown in horizontal plane.



Parallelism of main spindle to saddle movement.

Permissible error.

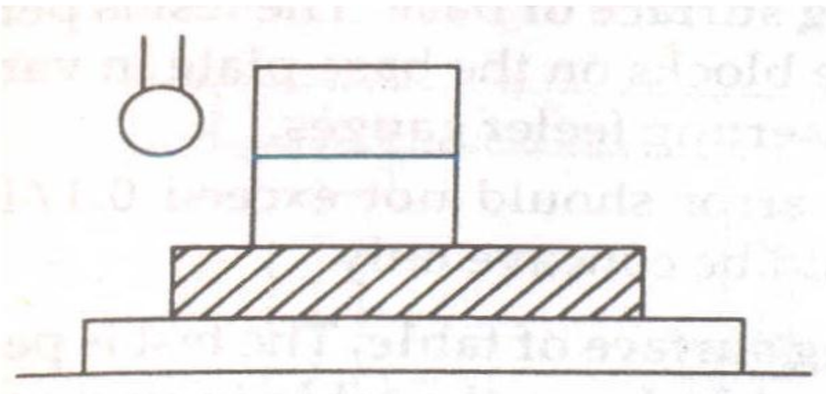
(a) 0.02 / 300 mm mandrel rising towards free end only.

(b) 0.02 / 300 mm mandrel inclined at free end towards tool pressure only.

(vi) True running of locating cylinder of main spindle:-

Instrument used:- Dial gauge.

Procedure:- The dial gauge is mounted on the bed, touching at a point on main spindle. The main spindle is rotated by hand and readings of dial gauge are taken.



Permissible error. 0.01mm.

(vii) True running of head stock centre:-

Instruments used:- Dial gauge.

Procedure:- The live centre is held in the tail stock spindle and rotated. Its trueness is checked by means of dial gauge.

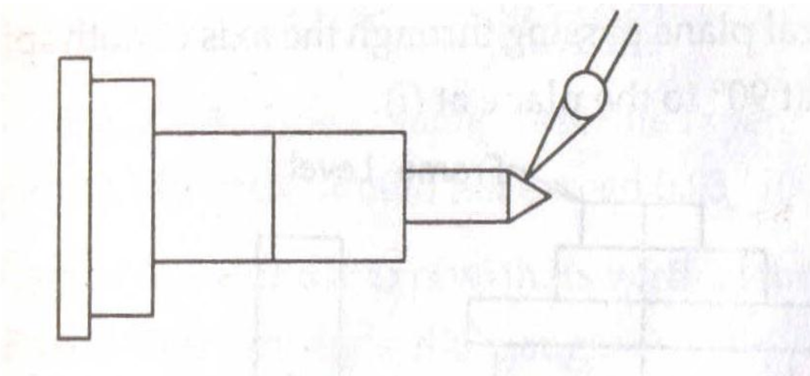


Fig. True running of head stock centre.

(viii) Axial slip of lead screw:-

The thrust face and collars of the lead screw must be exactly square to the screw axis, otherwise a cyclic endwise movement is set up which is of the same nature as the axial slip in the main spindle.

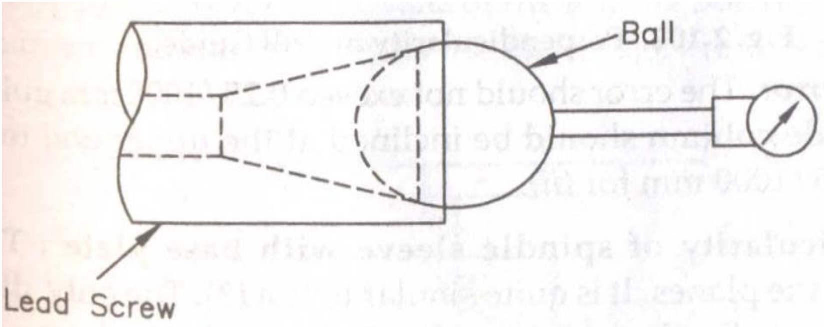


Fig. Axial slip of lead screw.

In order to test axial slip in the lead screw, a ball is fitted in the end of lead screw and the plunger of the dial is pressed against the ball as shown in above fig. The lead screw is rotated and deviation, if any, is noted down.

<u>ALIGNMENT TEST ON DRILLING MACHINES:-</u>

There are two types of drilling machines:-

i. Alignment test on pillar type drilling m/c.
ii. Alignment test on radial drilling m/c.

(i) <u>Alignment test on pillar type drilling m/c:-</u>

(1) <u>Flatness of clamping surface or base:-</u>

The test is performed by placing a straight edge on two gauge blocks on the base plate in various positions and the error is noted down by inserting feeler gauges.

Permissible error:- The error should not exceed 0.1/1000 mm clamping surface and the surface should be concave only.

(2) <u>Flatness of clamping surface of table:-</u>

The test is performed by placing a straight edge on two gauge blocks on the table in various positions and the error is noted down by inserting feeler gauges. In this permissible error is same as in flatness of clamping surface of base (i.e., 0.1/1000 mm).

(3) <u>Perpendicularity of drill guide to the table base plate:-</u>

<u>Instrument used:-</u> Frame level.

Procedure:- The squareness of the drill head guide to the table is tested. The test is performed by placing the frame level on guide column and table and the error is noted by noting the difference between the readings of two levels. The level is measured in two conditions.

(i) In a vertical plane passing through the axis of both spindle and column.
(ii) In plane at 90˚ to the plane at (i)

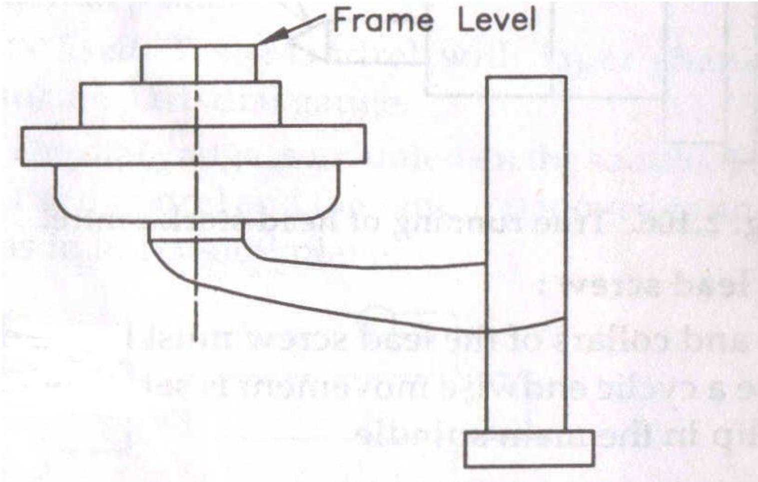


Fig. Perpendicularity of drill Guide.

Permissible error:- The error should not exceed 0.25/1000 mm guide column for (i) and the guide column should be inclined at the upper end towards the front only and 0.15/1000 mm for (ii).

(4) Perpendicularity of spindle sleeve with base plate:-

This test is performed in both the planes. It is quite similar to test (3). The only difference is that frame levels are to be placed on the spindle sleeve and base plate.

Permissible error:- The error should not exceed 0.25/1000 mm for plane (i) and the sleeve should be inclined towards column only, and 0.15/1000 mm for plane(ii).

(5) True running of spindle taper:-

Instrument used:- Test mandrel, dial gauge.

Procedure:- the test mandrel is placed in the tapered hole of spindle and a dial indicator is fixed on the table and its feeler made to scan the mandrel. The spindle is rotated slowly and readings of indicator noted down.

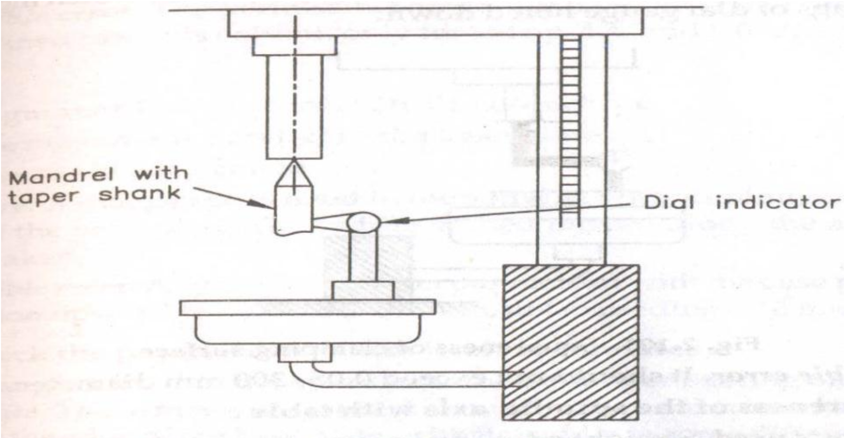


Fig. True running of spindle Taper.

Permissible error:- the error should not exceed 0.03/100mm for machines.

(6) <u>Parallelism of the spindle axis with its vertical movements:-</u>

<u>Instruments used:-</u> Test mandrels, dial gauges

<u>Procedure:</u>- this test is performed into two planes(A) and(B) at right angles to each other. The test mandrel is fitted into the taper hole of the spindle and the dial gauge is fixed on the table with feeler touching the mandrel.

The spindle is adjusted in the middle position of its travel. The spindle is moved in upper and lower directions of the middle position with slow vertical feed mechanism and the readings of the dial gauge are noted down.

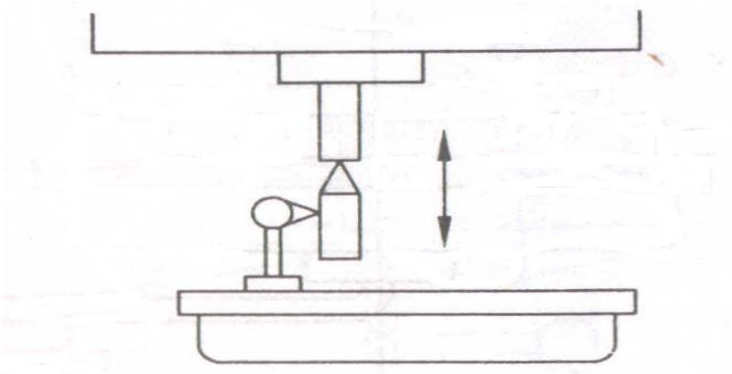


Fig. Parallelism of the spindle.

Permissible error: - 0.03/100mm for plane (A). 0.05/300mm for plane (B).

(7) Squareness of clamping surface of the table to its axis:-

Instruments used:- Dial gauge.

Procedure:- The dial indicator is mounted in the tapered hole of the spindle and its feeler is made to touch the surface of the table. The table is then moved slowly and the readings of the dial gauge noted down.

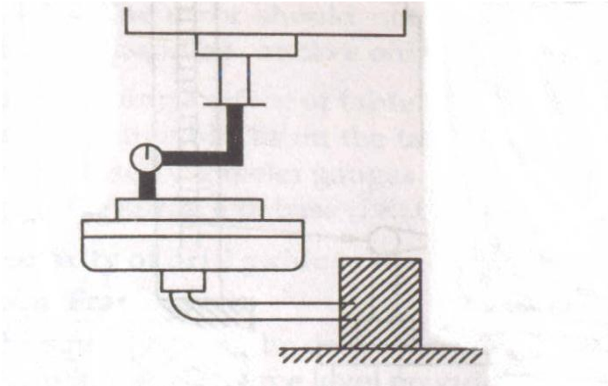


Fig. Squareness of clamping surface.

Permissible error: - It should be not exceed 0.05/300mm diameter.

(8) Squareness of the spindle axis with table:-

Instruments used:- Straight edge, dial gauge.

Procedure:- This test is performed by placing the straight edge in positions AA' and BB'.

- The work table is arranged in the middle of its vertical travel.

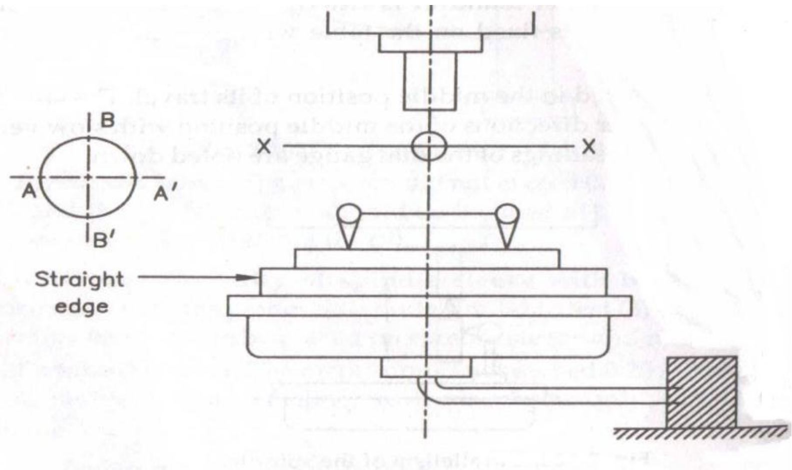


Fig. Squareness of the spindle axis.

The dial gauge is mounted in the tapered hole of the spindle and its feeler is made to touch the straight edge first at A and readings are taken. Then the spindle is rotated by 180˚ so that the feeler touches at point A’ and again the reading is taken. The difference of these two readings is the error in squareness of spindle axis with table. Similar readings are taken by placing the straight edge in position BB’.

Permissible error:- The permissible errors are 0.08/300mm with lower end of spindle inclined towards column only for set up AA’ and 0.05/300mm for set up BB’.

(ii) Alignment test on radial drilling m/c:-

(1) Saddle movement parallel to the base plate:-

Instrument used:- Dial gauge

Procedure:- A dial gauge is fixed to the spindle, with its plunger bearing on the surface of the base plate, the saddle is then moved along the arm and the readings are taken.

Permissible error:- Any deviation from parallelism with the base plate should be on inclination upward towards the column, not exceeding 0.16mm per meter.

(2) To check the parallelism of arm itself as it rotates:-

A dial gauge is fixed in the spindle, with its plunger bearing on the surface of the base plate. The arm is then rotated slowly on the column and the readings are taken near the edge of the base plate, with its saddle in three different positions as shown in fig.

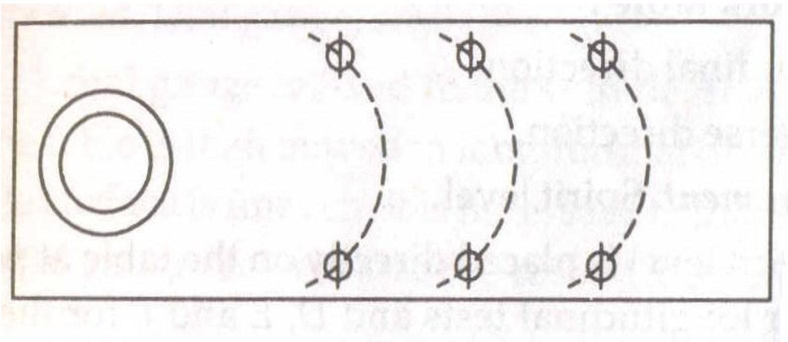


Fig. Parallelism of arm movement.

Permissible error: - 0.16mm per meter.

(3) Spindle and feed movement square with base plate:-
Instrument used:- Dial gauge with suitable attachment for fixing horizontal rod to the spindle.

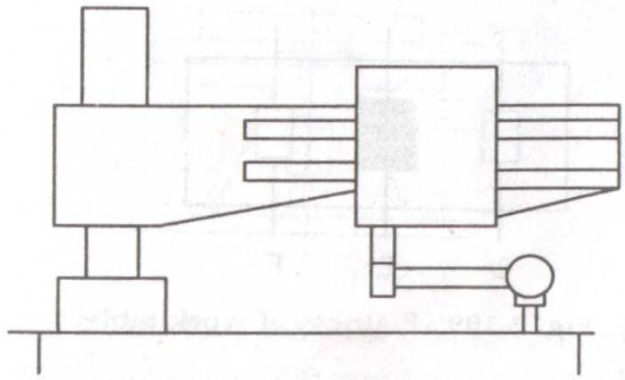


Fig. Squareness of spindle and base plate.

Procedure:- To check the squareness of the spindle, a horizontal rod is fixed to the spindle, with a dial gauge, attached at a radius of about 300mm, as shown in fig. The plunger of the dial gauge is arranged to bear on the base plate and is brought into the two positions shown in the figure by rotation of the spindle. Readings should be taken with the spindle in four different positions, namely near to and remote from the column with the arm first low and then high up on the column.
Permissible error: - in any position, the departure from squareness should not exceed 0.16mm per meter.

(4) Squareness of the feed motion:-
Instruments used:- Dial gauge, true square.
Procedure:- the dial gauge is held in the spindle with its plunger horizontal and rearing on the dial gauge readings, as the spindle is moved up and down, measure the error. The test should be performed with the spindle near to the column and also at the end of the arm.

ALIGNMENT TEST ON MILLING MACHINE:-

(1) Flatness of work table:-
(a) In longitudinal direction
(b) In transverse direction

Measuring instrument:- Spirit level

Procedure:- A sprit level is placed directly on the table at points about 25 to 30 apart at A, B, C for longitudinal tests and D, E and F for the transverse test. After that the readings are noted.

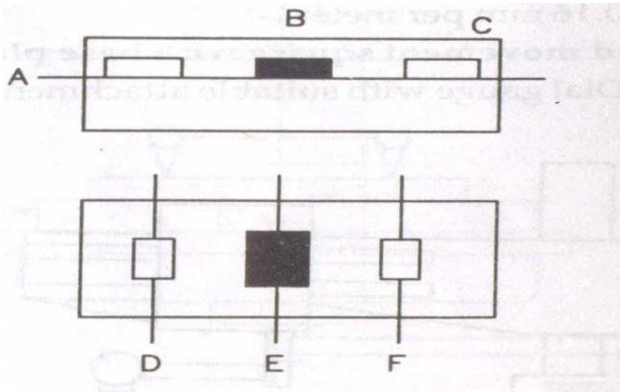


Fig. Flatness of work table.

Permissible error: - Direction A-B-C, $\pm$ 0.04mm

Direction D-E-F, $\pm$ 0.04mm

(2) Parallelism of the work table surface to the main spindle:-

Instrument used:- Dial indicator, test mandrel 300mm long, sprit level.

Procedure:- The table is adjusted in the horizontal plane by a sprit level and is then set in its mean position longitudinally. The mandrel is fixed in the spindle taper. A dial gauge is set on the machine table, and the feeler adjusted to touch the lower surface of the mandrel.

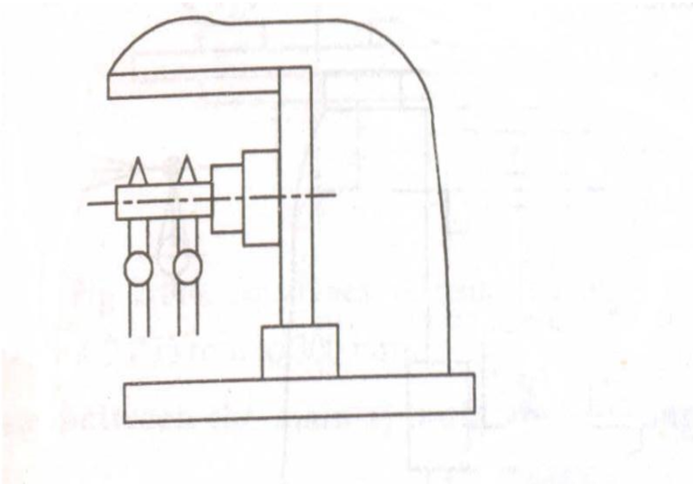


Fig. Parallelism of the work table surface.

Permissible error: - 0.02/300mm

(3) Parallelism of the clamping surface of the work table in its longitudinal motion:-

Instruments used:- Dial gauge , straight edge

Procedure:- A dial gauge is fixed to the spindle. It is adjusted to touch the table surface. The table is then moved in longitudinal direction and readings are noted. If the table surface is uneven, it is necessary to place a straight edge on its surface and the dial gauge feeler is made to rest on the top surface of the straight edge.

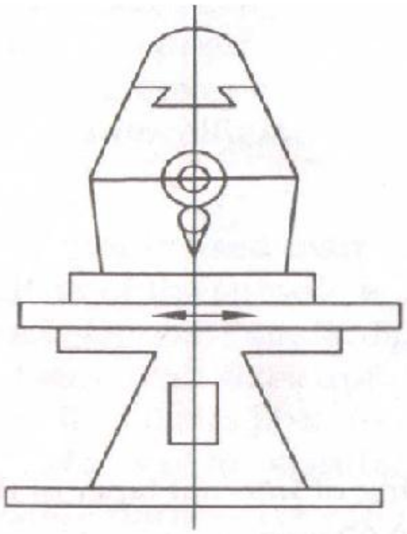


Fig. Parallelism of Clamping surface.

Permissible error:- 0.02 up to 500mm length, 0.03 up to 1000mm and 0.04 above 1000mm length.

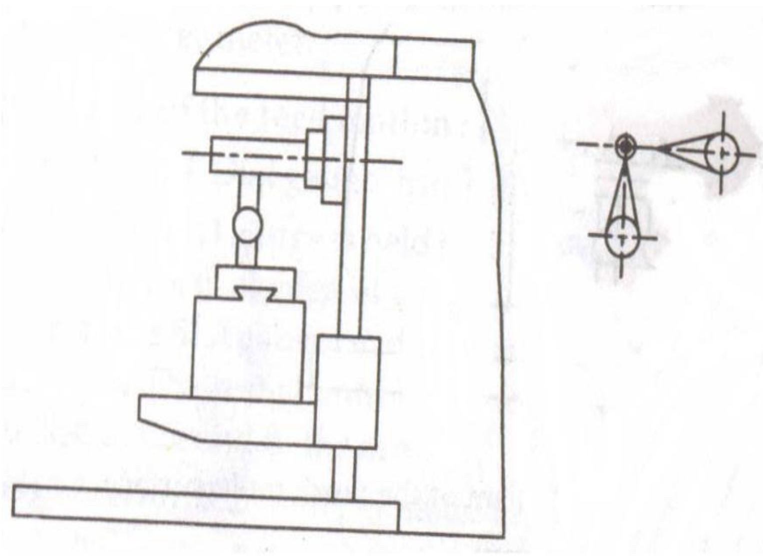
(4) Parallelism of the cross movement of the work table to the main spindle:-

(a) In a vertical plane

(b) In horizontal plane

Instrument used:- Dial gauge, test mandrel with taper shank.

Procedure:- The work table is set in its mean position. The mandrel is held in the spindle. A dial gauge fixed to the table is adjusted so that its spindle touches the surface of the mandrel. The table is moved cross-wise and the error is measured in the vertical plane.



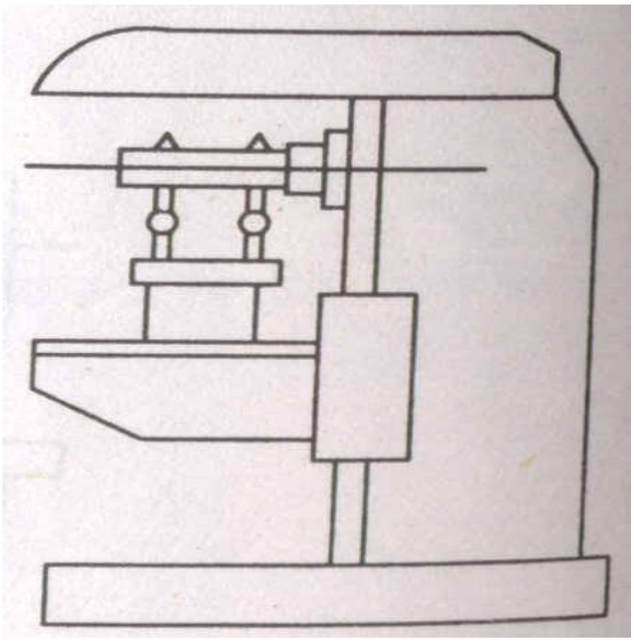
(Parallelism of the cross movement of the work table)

Permissible error: - 0.02 for the overall transverse movement of the work table.

(5) True running of internal taper of the main spindle:-

Instruments used :- 300mm long test mandrel, dial gauge

Procedure: - The test mandrel with its taper shank is held in the main spindle. Dial gauge is kept scanning the periphery of the mandrel. Spindle is rotated and dial gauge readings are noted at different points.



(True running of Internal taper of the main spindle.)

Permissible error :- 0.01 to 0.02mm .

(6) Squareness of the centre T- slot of work table with main spindle:-

Instruments used:- Dial gauge, special bracket.

Procedure:- To check the perpendicularity of the locating slot and the axis of the main spindle. The table should be arranged in the middle position of its longitudinal movement and a bracket in the locating slot. A dial gauge should be fixed in the spindle taper. Observe the readings from the dial gauge.

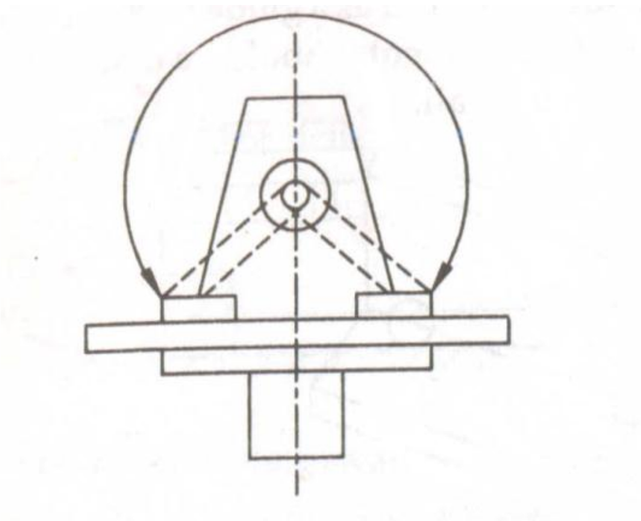


Fig. Squareness of centre T-slot.

Permissible error:- 0.025mm to 300mm.

(7) Parallelism between the main spindle and guiding surface of the overhanging arm:-

Instruments used:- Dial gauge, mandrel

Procedure:- The over-hanging arm is clamped in its extreme extended position. The dial gauge is fixed to the arbour support.

The feeler of the dial gauge is adjusted to touch the top or ride of the test mandrel. The arbour support can then be moved along the over-hanging arm and the deviation from parallelism observed on the dial gauge.

TESTING OF MEASURING INSTRUMENTS:-

It is well known as fact that perfection in manufacturing cannot be obtained. It is for this reason some variation in the form of tolerances allowed on various features of the equipment by all the nation standards.

(a) Micrometer testing:-

It is one of the most commonly used instruments in the metrology. Tolerances for the flatness and parallelism of the spindle end and anvil of various sizes of micrometers are covered by all National standards. As an indication of the amount of tolerance as permitted, the faces of all sizes up-to 225mm must be flat to within 0.001 mm, and parallel to within 0.005mm, in all positions of rotation to the spindle. These figures refer to faces of the standard minimum diameter of 6mm.

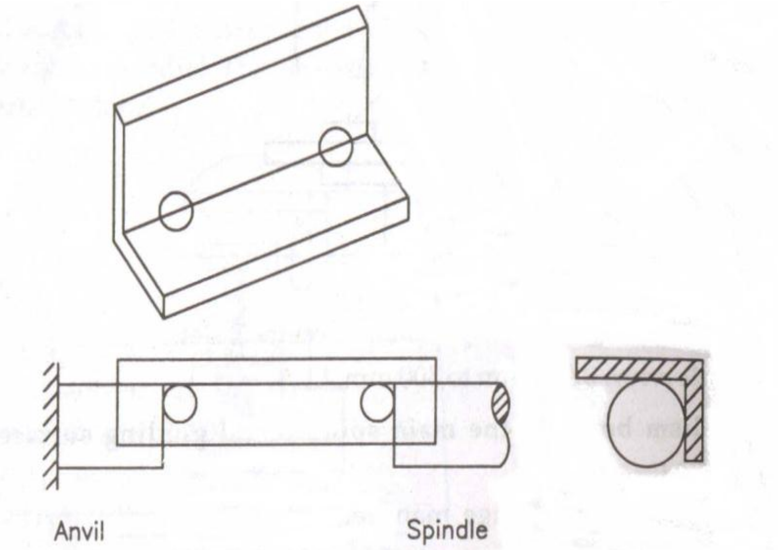


Fig. Test piece for checking parallelism of micrometer faces.

This method can be used to test micrometers larger than 0.25mm by soldering a small ball at each end of a rod of suitable length.

(b) Auto-collimator Testing:-

(i) The accuracy of the scale in an auto-collimator can be checked by arranging the instrument to receive a reflection from a plane mirror mounted on a sine bar reading. Readings are taken as the mirror is tilted by changing the size of slip gauges under the sine bar roller. The sine bar must be at least 250mm long preferably longer. A bar of this length may not be available but a special one can easily be made for the purpose. By using a ball instead of a roller at the end under which the slip gauges will be placed, the necessity for setting the rollers parallel is eliminated and the only features requiring attention are centre distance between the ball and roller and the equality of their diameters.

(ii) The bar and auto-collimator are placed, in line on a good surface table as shown in figure.

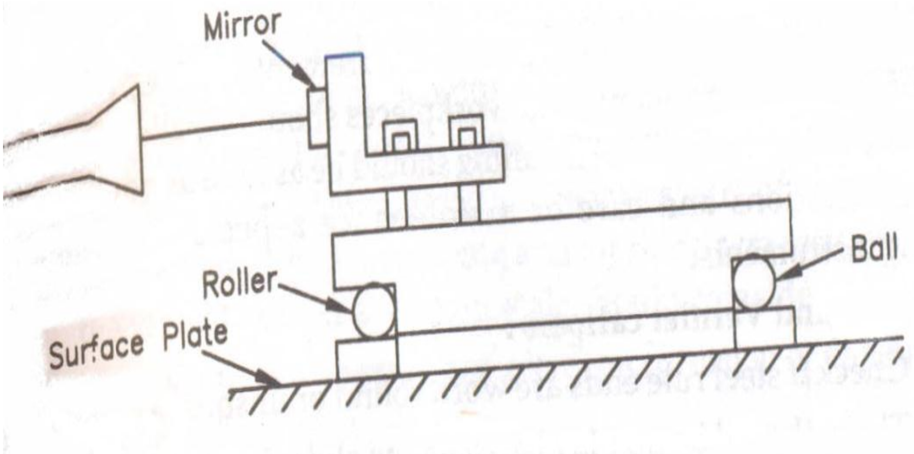


Fig. Testing an autocollimator.

In order to maintain accuracy of measuring instruments following procedure should be followed.

i. Each instrument should be numbered. It serves the easy location of instrument.
ii. A card record should be established for each instrument.
iii. Checking interval should be established.
iv. Some system should be adopted for providing adherence to the checking schedule.
v. The record of the findings of the check should be maintained.
vi. Record of checks should be further studied and analyzed so as to improve upon the system.

MAINTENANCE OF MEASURING INSTRUMENTS:-

The equipments used for precision measurements is designed very accurately and is easily liable to be damaged by even slight mishandling. A great deal of careful handling is, therefore, required. As the standard temperature for measurement is 20˚C, for very precise measurements the instruments and work-pieces should be allowed to attain this temperature before use and the handling should be as little as possible.

(i) Scale and vernier callipers:-

i. Check if steel rule ends are worn round or unsquare before using.
ii. There should be no play between the sliding jaw and the main scale.
iii. The scale should never be laid flat on the part to be measured because by doing so the graduation of the scale is not in direct contact with the surface of the part.
iv. The end of the scale should be never set with edge of the part to be measured because the scale end is usually worn out.

v. When putting any instrument on the table it should be not put violently or with a jerk.

(ii) Micrometers:-

i. Generally appearance and relative movement of moving parts.
ii. Checking initial zero setting for micrometers of size 25-50 mm or more.
iii. Flatness of measuring surfaces.
iv. Error in readings.
v. Parallelness of measuring surfaces.
vi. For every measurement, clean the measuring surfaces of anvil and spindle.

(iii) Height gauge:-

i. To avoid dust and dirt height gauge should be kept in a case.
ii. Check for rocking of base on the surface plate at different points.
iii. While checking longer lengths, the temp. Riser of height gauge by room heating or by hands should be avoided.
iv. The zero error of measuring and marking arm of height gauge should be checked. When measuring and marking arm of height gauge should be rest on a surface plate the zero of vernier and main scale should coincide.
v. There should be no scratches, nicks, no corrosion or damage of any short on the sliding head.

(iv) Depth gauge:-

i. Check that the gauge itself is true and square.
ii. Care should be taken as not to apply too much pressure on the beam or measuring bars as it will have lifting tendency on the slide and results in errors in readings.
iii. Check that the reference surface, on which depth gauge rests is true, flat and square.
iv. While using a depth gauge, pressure the slide firmly on the reference surface keeping several kilogramme of hand pressure on it.
v. While taking the measurement the gauge should not be either tipped towards or backward otherwise errors will produce in readings.

(v) Dial indicator:-

i. Check the accuracy of a dial indicator periodically with the help of slip gauge.
ii. Some initial loading must be given reading.
iii. The plunger of the dial indicator should not be allowed to strike the work with force otherwise the teeth of gears and rack will be damaged.

(vi) Combination set:-

i. The surface should be checked when it clean.
ii. The edge of the scale should be straight.
iii. Before taking reading sprit level should be checked.
iv. Make sure that there are no nicks and scratches on the base of heads.
v. The job should be held in the left hand and the instrument in the right hand.
vi. When checking for squareness and measuring angles, stand facing the surface of light and see the light passing through the scale or base of measuring instrument.

(vii) Gauges:-

i. A plain cylindrical gauge should be cleaned and a thin film of light oil should be applied to the gauging surface before it is used. The work should also be cleaned and the gauge should be aligned with the hole to be measured.
ii. Do not force a snap over work, because forcing will cause the gauge to pass oversized parts. So, the force should be avoided in any gauging operation as it is harmful for both work and gauge.
iii. A gauge should be cleaned after the use prepared for storage.

(viii) Slip gauges:-

i. The gauges should be used only in air conditioned room free from dust and maintained at constant temperature.
ii. The slip gauges are kept in a suitable case in which there is a separate compartment for each gauge.
iii. All the surfaces should be protected against climatic conditions by protective layers e.g. petroleum jelly etc.
iv. Every case should be taken to protect the gauges from getting magnetised; otherwise they will attract metallic dust.
v. If the gauges have been handled for some times, then they would be allowed to settle down the prevailing temperature of the room.
vi. When the gauges are not in use they should be kept only in their case which should be kept closed.
vii. Proper handling care should be there for slip gauges. Otherwise, handling would also corrode high finish of gauges due to natural acid in the skin.
viii. When any gauge is knocked or dropped its edges are most likely to be damaged. Such burrs, may be removed and can be finally washed and cleaned.

So, during the maintenance of measuring instruments, above factors should take into consideration for higher accuracy and life of instruments .

. CHAPTER:- 3 STATISTICAL QUALITY CONTROL (SQC)

BASIC STATISTICAL CANCEPTS:-

For attaining a state of control in a production process the SQC uses the 'Laws of chance' and knowledge of a statistics. It mainly deal with collection, analysis and interpretation of data affected by "Chance variation" for carrying satisfactory (not 100%) inspection of products. The statistics is based on variations as explained below:

Concept of variation:-

Nature itself causes variation e.g. no two men are similar in looks or thinking. So manufacturing processes which are handled and controlled by man are bound to vary. The concept of variation states that however utmost care is taken in getting perfection for manufacturing of two parts, still they will not be perfectly identical. For example, if a skilled labour has to make 100 pieces of some diameter and finish, in the best and constant environment (machine, material and physical conditions), still we will find minute variations in the size or finish of all of the pieces. This is because there are still some factors which are out of his own control. The variations in dimensions can be of three types.

Causes of variations:-

The inherent causes of variations in the manufacturing processes are:

(a) Machine related:

- Machine vibrations
- Tool wear
- Poor maintenance
- Play between nut & screw of machine table
- Improper jigs and fixtures.
- Worn out bearings
- Friction or loss of lubrication,

(b) Operator/environment related:

- Unskilled worker
- Fatigue of worker
- Improper temperatures maintained.

Attributes (Qualities):-

Statistical data needs gathering of characteristic or more information which can be measured or observed. There are two categories of statistical data:

(a) Variables
(b) Attributes.

"Variables" are the quantity characteristics which can be actually measured such as length or mass of an iron bar can be expressed as 5m or 5 kg respectively. The data measured can be continuous in the sense that the mass can be observed in gaps i.e. steps; e.g. number of defectives in a lot can be 1, 2, or 5 or 18 and it cannot be 16.7

"Attributes" are these types of data or quality characteristics which are discrete in nature i.e. the characteristic showing an article/object confirming or not confirming to the specifications (number of defective or not defective).

Frequency:-

The data gathered as statistics in the raw form, which is later grouped and analysed. The grouping of data makes it more meaningful. The repetition of a data, is counted as its 'frequency'. Frequency means how many times a data or value is repeated in a lot.

For counting frequency of a value, the data is tabulated in a sorted order, whether ascending or descending order and then another column of heating 'frequency' is added and as the similar rows (with similar value) are removed, a count is added to the 'frequency' column.

(a) Sorted dimensions of lot of 7 items:-

S. No	Dimensions in mm
1	25
2	26
3	26
4	27
5	27
6	27
7	30

(b) Data grouped & frequency added:-

S.No.	Dimension	Frequency
1	25	1
2	26	2
3	27	3
4	30	1

Therefore, frequency distribution is a tabulation of data obtained from measuring a variable, arranged in ascending or descending order according to its value. The frequency distribution indicates where most of the data are grouped. In the above example, most of the items have dimension of 27mm (3 nos.). In other words, we can say frequency distribution of a set of observations is an arrangement which shows the number of occurrences of values of variable of variable in ordered class.

Another method of reducing data and making it more meaningful is grouping the data for a fixed range interval, which takes into account the error of measuring equipment. For example, in above example, suppose the measuring scale gives or error of 1mm, then the dimensions 27mm can be either 26mm(-1) or 28mm(+1). Thus another way of grouping above can be done by.

Class Interval	Frequency	Mid Point
24-26	3	25
27-29	3	28
30-32	1	31

The main reason for tabulating and grouping the data is to make a sense of variation in data and to analysis it. There are another methods to represent the data for comparing two groups of data ('lot' of values) or interpreting the manufacturing method used, two of them are:

1. Graphical representation of frequency distribution.
2. Quantitative/empirical description of distribution.

1. Graphical representation:-

The graphical representation of data in a ready form for comparison. The popular methods are:-

(a) Frequency polygon
(b) Histogram

(a) Frequency polygon:-

The mid-points of the cells are plotted on the group as dots and are joined with small straight lines. It provides an effective way of presenting a picture of frequency distribution.

(b) Histogram:-

A histogram is essentially a bar chart with bases that represented the mid points of cell values and the height of rectangular bars is proportional to the frequency of the occurrence of mid points. It is an effective tool in an elementary analysis of data. The tabulated data of at least 50 measurements is sorted as discussed in previous article and frequency is polled to study the pattern of variation in lot. For example, if the histogram is symmetrical, it indicates that overall process is normal & the variations are due to chance causes, but if the histogram is uneven & unsymmetrical it shows the unrealistic process variation or so, which needs improvements.

2. Quantitative/ Empirical distribution:-

Although the graphical representation are very useful but they do not give a ready figure for numerical comparison. Therefore, for concise form of representation of data, statisticians have tried to define the central tendency in different terms because most of the data value.

Central tendency:- In order to understand as well as to get a comprehensive idea of the group of figures a terms acting as representative of group is used. The central tendency is the value which represents the most common figure data or a representative value of the lot. The value is called 'central' due to the reason that other values are distributed evenly on both sides of this value.

Measuring dispersion or spread, gives the nature of variation in the data. There are three methods of representing the central tendency.

1. Mean / Arithmetic mean / Average value
2. Median(middle value)
3. Mode

1. <u>Mean:-</u>

Mean or average value generally means the arithmetic mean. It is necessary that all the items in the group should be of the same class. The arithmetic mean of a group should be of the same class. The arithmetic mean of a group of value or figures is determined by the number of items. Let there are be 5 items: 16, 17, 18, 20, 24 then their arithmetic mean will be =

$$\frac{16+17+18+20+24}{5} = 19$$

In general form,

Arithmetic,

$$\overline{X} = \frac{\Sigma x}{n}$$

Where, Σx (sigma x) = $x_1 + x_2 + x_3$ _ _ _ _ _ _ _ _ x

But if the data values are stored and tabulated as in table, so that a frequency (number of occurrences)f, is the attached with each group/class/cell. The X values are the mid points of class of interest. Then

$$n = f_1 + f_2 + f_3 + f_4 + \ldots\ldots f_n$$

and $$\Sigma x = f_1 x_1 + f_2 x_2 + f_3 x_3 + \ldots\ldots f_n x_n$$

so the Mean $$\overline{X} = \frac{\Sigma x}{n} = \frac{\Sigma fx}{\Sigma f}$$

This is also called as average of the frequency distribution.

Example: - The monthly wages of different groups of workers are represented in the following table, find the average of the frequency distribution.

Monthly wages	No. of workers
50-100	2
100-150	5
150-200	8
200-250	7
250-300	3

Solution: The above problem is worked out in the tabulated form as under:

Monthly wages (No. of items)	Mid point (x)	Frequency(f)	fx
50-100	75	2	150
100-150	125	5	625
150-200	175	8	1400
200-250	225	7	1575
250-300	275	3	825
		Σf = 25	Σfx = 4575

In general form,

∴ Average of frequency distribution

$$\overline{X} = \frac{\Sigma fx}{\Sigma f}$$

$$= \frac{4575}{25} = 183.$$

2. Median:-

When different items in a group are arranged in a serial order according to since, the middle item of this serial order according to since, the middle item of this series is termed as median. The median representing the average position is also called the representative of the group. It is not a calculated figure.

(i) If the observations are odd, say 2n+1, then the middle item. i.e. n^{th} item is medium; otherwise if the observations are even i.e. then the average of n^{th} and $(n+1)^{th}$, is the median.

$$\text{Median} = \frac{n\text{th} + (n+1)\text{th}}{2}$$

If the data is grouped in frequency format, then the median is given by an empirical formula.

$$M = L + \frac{\left(\frac{N}{2} - f_{cum}\right)}{f_m} \times i$$

Where m = median

L = Lower value of class having medium

N = Total no. of values.

f_{cum} = Cumulative of medium

i = Class interval

3. <u>Mode:-</u>

It is the most common value is the group occurring or repeating largest no. of times. It is also a representative figure used to indicate a group. In other wards mode is that value of measurement which occurs with the greatest frequency. However the mode if not rigidly defined measure and it appears to be most unstable average.

Taken an example of set of data values

=› 25, 26, 25, 28, 25, 30, 25, 40, 25

Here 25 occurs most time: Mode = 25 but take another example:

=› 25, 26, 27, 28, 26, 25, 30, 25, 28, 26

In this case 25 and 26 occur equal number of times, hence there are two modes 25 & 26.

The empirical formula used for calculation of mode is

$$\text{Mode} = L + \left(\frac{f_2}{f_1 + f_2}\right) \times i$$

Where L= lower limit of class of mode.

f_1 = Frequency of class before the class of mode.

f_2 = Frequency of class after the class of mode.

i = Class interval

<u>Dispersion</u>:-

The average does not provide the extent of variation of the group from it's mean value but gives the general idea about a group from It's mean value but gives the general idea about a group of figure. The extent of variation in the group from the mean value called dispersion gives a better idea of the group.

Range:- Dispersion is measured by finding the difference between the lowest and the highest value in the group. This difference is called range.

Due to pressure of extreme values in the group, determination of range is not helpful and useful. For example the score of a cricketer in the ten matches is 20, 25, 10, 15, 32, 10, 28, 20, 10 with score ranging from 0-100. The total range is (100-0) or 100. This is quite misleading because the range is only based on extreme values.

Whereas, Arithmetic mean is

$$\overline{X} = \frac{20+25+10+0+15+32+100+28+20+10}{10}$$
$$= \frac{260}{10} = 26.$$

Mean deviation:-

It is also expressed in a better way through mean deviation. It is defined as the deviation or vibration of each figure in the group from it's arithmetic mean and all such deviation summed up and divided by the no. of items in the group will give the mean deviation.

Now mean deviation

$$\overline{X} = \frac{\Sigma (x - \overline{x})}{n}$$

When, $\overline{X}$ is the arithmetic mean.

In the above example, $\overline{X} = 26$, $n = 10$

∴ Mean deviation

$$= \frac{1}{10}[(26-20) + (26-25) + (26-10) + (26-0) + (26-15) + (30-26) + (100-26) + (28-26) + (26-20) + (26-10)]$$

$$= \frac{1}{10}[6 + 1 + 16 + 26 + 11 + 4 + 74 + 2 + 6 + 16]$$
$$= \frac{156}{10} = 15.6.$$

The deviation as calculated above is found as difference between $\overline{X}$ & X .

Variance:-

Mathematically, the omitting of the sign difference is incorrect. Therefore to avoid this dependency, the difference are squared up and summed up. The average of the group obtained by dividing the sum of the squared up difference by the total number of item is called variance.

∴ Variance = $\frac{\Sigma (X-\bar{x})^2}{n}$

In the above example variance

$$= \frac{\Sigma (X-\overline{X})^2}{n}$$
$$= \frac{6^2+1^2+16^2+26^2+11^2+4^2+74^2+2^2+6^2+15^2}{10}$$
$$= \frac{7178}{10} = 717.8.$$

<u>Standard deviation</u>:-

The square root of variance is called standard deviation. It is a best measure of dispersion although it is difficult to calculate. It is denoted by the symbol of σ (sigma).

Mathematically,

$$\sigma \text{ (sigma)} = \sqrt{\frac{\Sigma(X-\bar{x})^2}{n}}$$

For the above example, $\sigma = \sqrt{717.8} = 26.8$

This shows that the dispersion of the group is 26±26.8 or 52.8 and -0.8

<u>Average of sample average</u>:-

In order to find the values of the standard deviations for whole production lot when a number of samples have been collected at random from a production lot with average, $\bar{x}$ calculated.

Separately for each sample, average of the sample average i.e. $\overline{\overline{X}}$ instead of $\overline{X}$ is used for finding out the standard deviation for the lot

Therefore $\bar{\bar{X}} = \frac{\sum x}{n_1}$

Where n_1 = no. of examples

And $\bar{x}$ = average of a saingle sample.

<u>Average of Sample Range</u>:-

In S.Q.C in order to know the range representative of the whole lot, average of the sample range $\bar{R}$ is calculated when a no. of samples haven collected at random from a production ot and a ranges (R) have been calculated separately.

$$\bar{R} = \frac{\sum R}{n_1}$$

Where n_1 = no. of sample

Example:-

Five thermostatic controls are used to determine the temperature of an oven. The measure values are 342^0, 338^0, 3444^0, 335^0 and 336^0. These values constitutes first sub group for certain control chart.

Compute the arithmetic mean, median, standard deviation, range and variance of the sub groups.

Solution:- Arithmetic mean $\bar{X} = \frac{342+338+344+335+336}{5}$

$$= \frac{1695}{5} = 339^{\circ}$$

Arranging in ascending order these values are 335°, 336°, 338°, 342°, 344°

Median = central value = 338°

Range -= Largest value – smallest value = 344 – 335 = 9

Standard deviation $=\sigma$ = $\sqrt{\frac{(335-339)^2+(336-339)^2+(338-339)^2+(342-349)^2+(344-339)^2}{5}}$

$= \sqrt{\frac{16+9+1+49+25}{5}}$

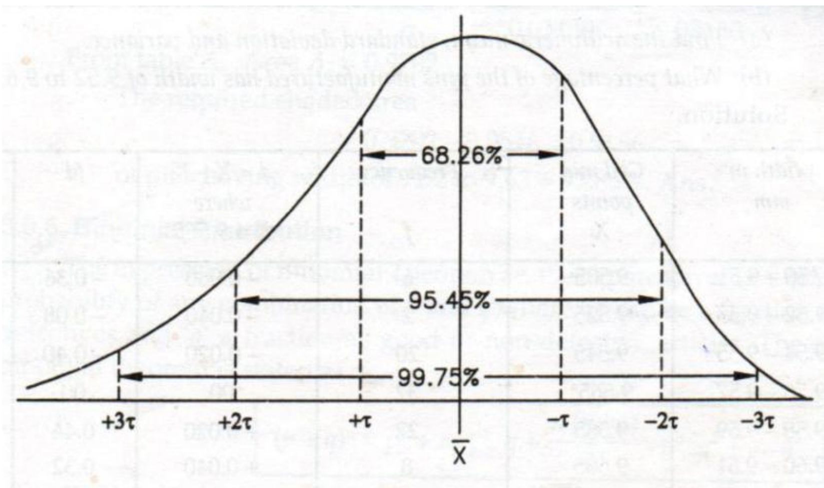
$= \sqrt{\frac{100}{5}}$

= 4.475

Variance σ^2 = $(4.475)^2$ 20. **Ans.**

<u>Normal distribution curve</u>:-

In case of variation due to chance factors, the normal curve which is a graphical representation of a frequency distribution indicates the distribution of the characteristics among the whole production lot because it is a bell shaped symmetrical curve. It extends from $-\infty$ to $+\infty$. The area contained in each column of the histogram is proportional to the frequency with in its cell. For controlling the construction of the normal curve, there are two statistical controls (Average) and σ (sigma), the standard deviation. The no. of cells



Normal curve.

For quality control techniques the most useful curve is the normal curve. It is estimated that σ (sigma deviation) covers 68% of the normal curve; 2σ covers 95.45% of the total area and 3σ covers 99.75%. In case, 3σ is applied as deviation on either side of average ($\bar{X}$) than 99% of the area will be covered up by the control limits. Further, the control on the process beyond this is not economical. Hence, 3σ limits basis of SQC.

Mathematical, normal curves can be represented by

$$y = \frac{1}{\sigma\sqrt{2x}} \cdot e^{i} \quad \text{where} \quad i = \frac{(x-\overline{X})^2}{2\sigma^2}$$

$\overline{X}$ = Average of lot

σ = Standard deviation.

Characteristics of normal distribution:

- The normal distribution is bell shaped and symmetrical when shown generally graphically.
- A population of infinite size is represented by it.
- The magnitudes of range involved is from minus infinity to plus infinity, in case its mean ($\bar{X}$) is shown as zero.
- The mean and standard deviation of the normal distribution can completely describe its curve or can give predictions of the lot.

Example. A machine shop produces steel pins. The width of 100 pins was checked after machining and data was recorded as follows:

Width in mm	Frequency	Width in mm	frequency
9.50-9.51	6	9.58-9.59	22
9.52-9.53	2	9.60-9.61	8
9.54-9.55	20	9.62-9.63	6
9.56-9.57	32	9.64-9.65	4

(a) Find the arithmetic mean, standard deviation and variance.
(b) What percentage of the pins manufactured has width of 9.52 to 9.63

Width in mm	*Cell mid points X*	*Frequency f*	$d = X - K$ *where* $K = 9.565$	*fd*	fd^2
9.50 – 9.51	9.505	6	– 0.060	– 0.36	0.0216
9.52 – 9.53	9.525	2	– 0.040	– 0.08	0.0032
9.54 – 9.55	9.545	20	– 0.020	– 0.40	0.008
9.56 – 9.57	9.565*	32	00	00	00
9.58 – 9.59	9.585	22	+ 0.020	0.44	0.0088
9.60 – 9.61	9.605	8	+ 0.040	0.32	0.0218
9.62 – 9.63	9.625	64	+ 0.060	0.36	0.0216
9.64 – 9.65	9.645	4	+ 0.080	0.32	0.0256
		$n = \Sigma f = 100$		$\Sigma fd = 0.60$	$\Sigma fd^2 = 0.1016$

(*a*) Now, $\overline{X} = K + \frac{\Sigma fd}{n} = 9.565 + \frac{0.60}{100} = 9.571$ (Arithmetic mean)

$$\sigma = \sqrt{\frac{\Sigma fd^2}{n} - \left(\frac{\Sigma fd}{n}\right)^2} = \sqrt{\frac{0.1016}{100} - \left(\frac{0.60}{100}\right)^2}$$

$$= \sqrt{0.00098} = 0.0310 \text{ (standard deviation)}$$

$$\text{Variance} = \sigma^2 = (0.03130)^2 = 0.0009796$$

(*b*) % of pins having width of 9.52 to 9.63.

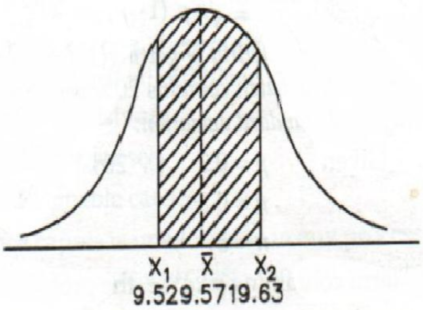


Fig. 3.4.

$$Z_1 = \frac{X_1 - \overline{X}}{\sigma} = \frac{9.52 - 9.571}{0.03130} = \frac{-0.0510}{0.03130} = -1.629$$

From table *A*, Area $A_1 = 0.0516$ ... (1)

$$Z_2 = \frac{X_2 - \overline{X}}{\sigma} = \frac{9.63 - 9.571}{0.03130} = \frac{0.059}{0.03130} = -1.885$$

From table *A*, Area $A_2 = 0.9702$ ... (2)

$\therefore$ The required shaded area

$$= 0.9702 - 0.0516 = 0.9186$$

$\therefore$ of pins having width of 9.52 to 9.63 = 91.86%. **Ans.**

Binomial Distribution:

The expression of binomial theorem i.e. The expansion of $(p + q)^n$ can give the probability of any combination of p & q where p can be a fraction representing defectives and q a fraction as good or non-defective articles. The expansion of binomial theorem is stated as

$$(p + q)^n = p^n + np^{n-1}.q + \frac{n(n-1)}{2!}.p^{n-2}q^2 + ... q^n$$

Each term represents the probability of occurrence of ‘r’ defectives. The general term can be represented as:

Probability of r defectives $= {}^nC_r\, q^{n-r} p^r$;

where $${}^nC_r = \frac{n!}{r!\,(n-r)!}$$

(*i*) The **Average of Binomial Distribution** is given by :

$$\boxed{\overline{X} = np}$$

where $\overline{X}$ = Average number of defectives per sample

n = Size of random samples taken

p = The fraction defective found of sample

(*ii*) The **Standard Deviation** of Binomial is given by

$$\boxed{\sigma = \sqrt{n\,p\,q}}$$

or

$$\sigma = \sqrt{n\,p.\,(1-p)}$$

Example:

Find the probability of getting 1 defective and 4 good items, from a lot having sample size of 5. The batch contains 20% defectives as per Binomial distribution. Also find the average and standard deviation

Solution:

Given: p = 0.2 (∵20%)

q = 0.8

n = 5

Taking the term of containing $p^1.q^4$ i.e. the probability of one defective and four good articles is.

$${}^5C_1\, p^1\, q^4 = \frac{5!}{1! \times 4!} \times (0.2)\ (0.8)^4$$

$$= 0.4096 \ \textbf{Ans.}$$

(*ii*) Average number of defective per ample.

$$\overline{X} = np = 5 \times 0.8 = 0.4 \quad \textbf{Ans.}$$

(*iii*) Standard Deviation

$$\sigma = \sqrt{npq} = \sqrt{5 \times 0.8 \times 0.2}$$

$$= \sqrt{0.8} = 0.894 \quad \textbf{Ans.}$$

Poisson Distribution:

It is applicable, where the probability of failure p is very small. This happens when there are large no. of trials than failure will occur at large intervals only. The larger the value of n and smaller the value of the p, the looser is Poisson Approximation.

The probability of finding 'K' defectives is given by

$$P(k) = \frac{\lambda^k . e^{-\lambda}}{k!}$$

Where K = the no. of defectives to be found

λ = np i.e. average value of expected no. of defectives.

(i) Average of Poisson distribution

$\bar{X}$ = np. = λ

(ii) Standard deviation

$$\sigma = \sqrt{np} = \sqrt{\lambda}$$

Control Charts:

It is the quality of the materials, batches, parts assemblies, during the course of their actual manufacture is the most important activity. The most important tool is control chart designed by Dr. W.A. Shewart's, for this purpose which is used for the study and control of repetitive processes. It is a day to day gr4aphical presentation of the collected information from the production floor. The information pertains to be measured or otherwise judges quality characteristics of manufactured products in always subject to certain variations. In any type of machining operation, there is always some variation from piece to piece which is inherent to any particular scheme of production and inspection.

There are two types of variations exist as

- Variation due to chance causes
- Variation due to assignable causes can be discovered and corrected, it may consists of Variation due to assignable causes can be discovered and corrected, is consisting of
  - Difference in m/c
  - Difference amongst the workers
  - Difference in their relationship to one another

- Improper tooling
- Proper lighting arrangement etc.

A control chart accepts the normal dispersion of variation due to chance causes but eliminates entirely the errors due to assignable causes.

Advantages of control charts:

The control charts have the advantages given as under

1. The control chart gives Indication for the process is in control or out of control
2. It determines process variability.
3. It detects unusual variations taking place in a process.
4. It ensures the product quality level
5. It gives warning in time to rectify the process so that scrap or percentage rejection can be reduced.
6. It gives informations about the selection of process and setting of tolerance limits.
7. It also helps to build up the reputation of the organization through customer's satisfactions due to good quality of the products.
8. The inspection work reduces.

Types of Control Charts:

There are following types of control charts used for quality control,

- Variable charts ($\bar{X}$ and R charts)
- Attribute charts (P, np, C and U chart).

These control charts are based on variables and attributes. The quality can be controlled either through actual measurement or without caring for the actual dimensions of a part. The control charts which are most commonly used are:

1. Control charts for measurable quality char4acteristics (control chart for variables). This includes
2. Control charts for no. of fractio0ns defectives (P-charts)
3. Control charts for no. of defects per unit(C-charts)

S. No.	Variable chart	Attribute chart
1.	**Example,** $\overline{X}$, R σ **charts.**	P, np, C, u **charts.**
2.	**Type of data required :** Variables data (Measured values).	Attributes data (using Go, Not-Go gauges).
3.	**Field of Application** Control of individual characteristics.	Control of proportion of defective or number of defects or number of defects per unit.
4.	**Advantages** (*a*) Provides max. utilisation of information available from data. (*b*) Provides detailed information on processes average and variation for control of individual	(*a*) Data required are often already available from inspection records. (*b*) Easily understood by all persons. Since, it is more simple as compared to $\overline{X}$ and R chart. (*c*) Provides overall picture of quality history.
5.	**Disadvantages** (*a*) They are not easily understood unless training is provided. (*b*) Can cause confusion between control limits and specification limits. (*c*) Cannot be used with Go and Not Go type gauge inspection.	(*a*) They do not provide detailed information for control of individual characteristics. (*b*) They do not recognise different degree of defectiveness.

Interpretations of a control charts

The following interpretations can be made by the study of control charts:

1. If all the point in a chart lie within V.C.L. and L.C.L then the processes is said to be in control indicating presence of chances causes only.
2. If one or more pints lie beyond V.C.L. and L.C.L. then not safe to derive any conclusion about the process control. Thus, a control chart is a graphical representation of the range of expected variability in a production processes. The scale on Y-axis and X-axis should be chosen in such a manner that the chart is narrower than it's length.

(A) $\overline{X}$ -chart:-

The chart is based on the measurements data instead of data that arise simply form classification counting. Sample size can be smaller also. So, it is constructed to show the fluctuations of the means of samples about the mean of the process. This chart will help of the user in tracking down the assignable causes.

The control chart has the following advantages:

1. It shows changes in processes average and is affected by changes in process variability.
2. It is a chart for the measure of control tendency.
3. It shows erratic or cycle shifts in the process.

4. It detects steady progress changes, like tool wear.
5. It is the most commonly used variables chart.
6. When used along with R chart.

- It tells when to leave the process alone and when to check and go for the causes leading to variation.
- It secures information in establishing or modifying processes, specifications or inspection procedure and.
- It controls the quality of incoming material.

7. $\bar{X}$ and R charts when used together form a powerful instrument for diagnosing quality problems.

The control limits of $\bar{X}$ chart are given as :

Upper control limit (UCL) $= \bar{\bar{X}} + A_2\bar{R}$

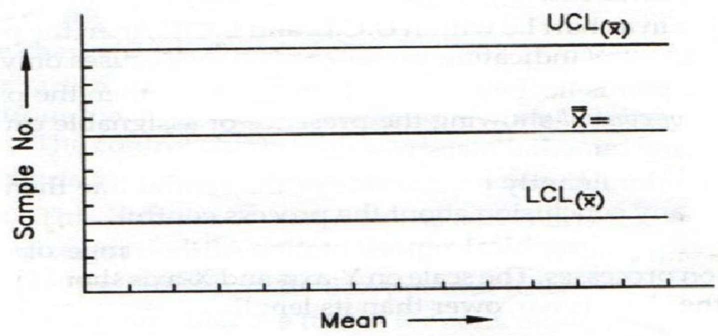
Central line (CL) $= \bar{\bar{X}}$

Lower control limit (LCL) $= \bar{\bar{X}} - A_2\bar{R}$

where, $\bar{\bar{X}}$ = mean (average) of sample means

$$= \frac{\Sigma\bar{X}}{n} = \frac{\bar{X}_1 + \bar{X}_2 + \bar{X}_3 + ... \bar{X}_n}{n}$$

= Arithmetic mean of $\bar{X}_1$, $\bar{X}_2$, $\bar{X}_3$ etc.



R = Range = Difference between the largest observed data and the smallest observed data.

$$= X_H - X_L$$

$$\bar{R} = \frac{\Sigma R}{n} = \text{mean (average) of ranges}$$

$$= \frac{R_1 + R_2 + R_3 + ... R_n}{n}$$

A_2 = Chart factor for mean chart.

(The value of A_2 depends upon the size or the sample and is available in standard table).

(B) R chart :

It is used to show fluctuations of the ranges of the samples about the average range R. This control the general variability of the process and affected by the changes in variability. It is a chart for measures of spread. It is generally used along with an $\bar{X}$ chart.

The control limits for R chart are given as :

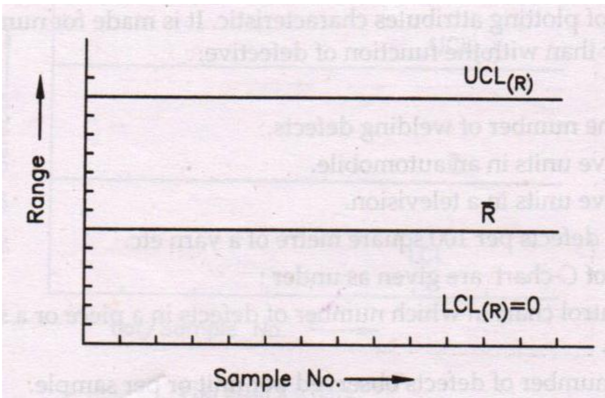
Upper control limit (UCL) $= D_4\,\overline{R}$

Lower control limit (LCL) $= D_3\overline{R}$

where, $\overline{R}$ = Average of sample ranges

D_4 = Control factor for UCL of R-chart

D_3 = Control factor for LCL or R-chart



The value of D_3 and D_4 depends on sample size chosen and their values are available from standard table.

Factors for determining the 3 sigma control limits for $\bar{x}$ and R charts.

Number of observations in sub-group n	Factor for c chart, A_2	Factor for R chart	
		Lower control Limit D_3	Upper control limit D_4
2	1.88	0.	3.27
3	1.02	0.	2.57
4	0.73	0.	2.28
5	0.58	0.	2.11
6	0.48	0.	2.00
7	0.42	0.08	1.92
8	0.42	0.14	1.86
9	0.37	0.18	1.82
10	0.34	0.22	1.78
11	0.31	0.26	1.74
12	0.29	0.28	1.72
13	0.27	0.31	1.69
14	0.25	0.33	1.67
15	0.24	0.35	1.65
16	0.22	0.36	1.64
17	0.21	0.38	1.62
18	0.20	0.39	1.61
19	0.19	0.40	1.61
20	0.18	0.41	1.59

(C) **C -charts**:

It is the method of plotting attributes characteristics. It is mad for no. of defects per unit rather than with the function of defective. For example:

1. In a turn, the no of welding defects.
2. The defective units in an automobile.
3. The defective units in a television.
4. No. of defects per 100 square meter of a yarn etc.

The advantages of C-chart are given as under:

- It is the controls charts in which no. of defects in a piece or a sample are plotted.
- It controls no. of defects observed per unit or per sample.
- Sample size in constant.
- The chart is used where average no. of defective prices in a given sample, c-chart take into account the no. of defects in each defective piece may contain more than one defect.
- Whereas P- chart consider the no. of defectives prices in a given sample, C-chart taken into account the no. of defects in each defective piece or and a given sample. A defective piece may contain more than one defect.
- C-chart is preferred for large and complex pants.
- It has limited use.

The control limits for C-chart are given as:

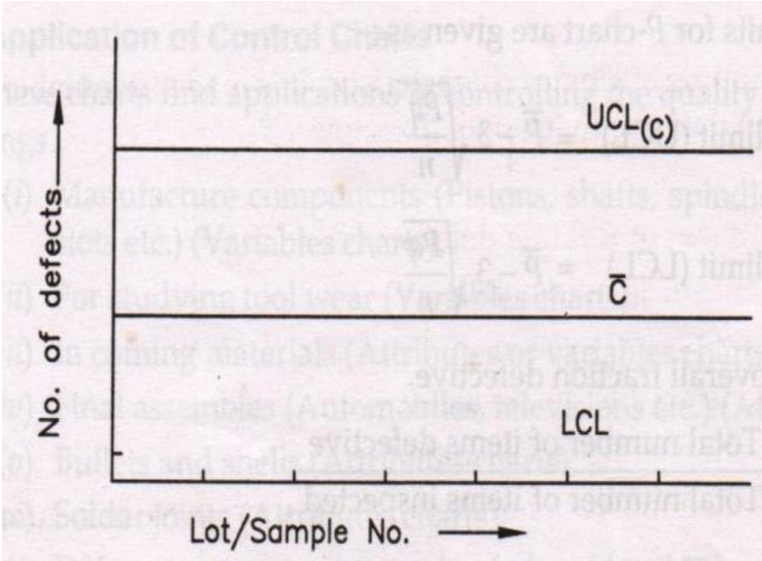
Upper control limit (UCL) $= \overline{C} + \sqrt{\overline{C}}$

Lower control limit (LCL) $= \overline{C} - 3\sqrt{\overline{C}}$

where $\overline{C}$ = average number of defects per sample

$$= \frac{\text{Total number of defects in all the samples}}{\text{Total number of samples inspected}}$$

Lot/Sample Number	*No. of Defects*
1	
2	
3	
4	
.	
.	
.	
.	
.	
$\Sigma n =$	$\Sigma c =$



(D) P- Chart

The chart shows the variation in the fraction defectives of output. It is also known as control chart for 'Go' and Not Go' data. It is a tool for process quality control and hence it is quality control and hence it is quality control by attributes, sometimes it is also known as control chart for attributes.

The P-chart has following advantages given as under:

1. It can be fraction defective chart or defective chart (100p)
2. Each item is classified as good or bad.
3. This chart is used to control the general quality of the component part and it checks if the fluctuating in product quality (level) are due to chance causes alone.
4. It can be used even if samples size is variables but calculating control limits for each sample is rather number some.
   P-chart is plotted by calculating the fraction defective first and then the control limits.

Lot No.	Sample Size (a)	No. of Defects (P)	Fraction Defectives $= \left(\frac{P}{a}\right)$
1			
2			
3			
4			
.			
.			
.			
.			
.			
.			

Total no. of items, n = Total no. of lots × sample size

The control limits for P-chart are given as :

Upper control limit (UCL) $= \overline{P} + 3\sqrt{\frac{Pq}{n}}$

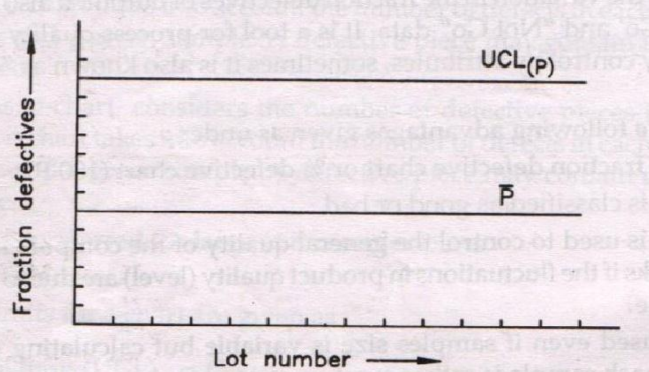
Lower control limit (LCL) $= \overline{P} - 3\sqrt{\frac{Pq}{n}}$

where $\overline{P}$ = overall fraction defective.

$$= \frac{\text{Total number of items defective}}{\text{Total number of items inspected}}$$

$\overline{q} = (1 - \overline{P})$

n = sample size.



The P-chart can also be prepared in the following two forms :

(*i*) Number of defective (np) chart :

$$UCL = n\overline{P} + n \times 3\sqrt{\frac{Pq}{n}}$$

$$LCL = n\overline{P} - n \times 3\sqrt{\frac{Pq}{n}}$$

(*ii*) Present defective chart :

$$UCL = 100\,\overline{P} + 100 \times 3\sqrt{\frac{Pq}{n}}$$

$$LCL = 100\,\overline{P} - 100 \times 3\sqrt{\frac{Pq}{n}}$$

SAMPLING PLANS:-

As a technique of quality control several types of sampling plans are in use. These are as:

(ii) Single sampling plan
(iii) Double sampling plan
(iv) Sequential plan

Single Sampling Plan:-

If a single random sample of a lot is secured and the lot is accepted or rejected on the basis of results discovered in that single sample as detected by the single sampling table, then it is known as single sampling.

For this method, usually four values are to be determined:

N = Lot size

n = sample size

c = acceptance number

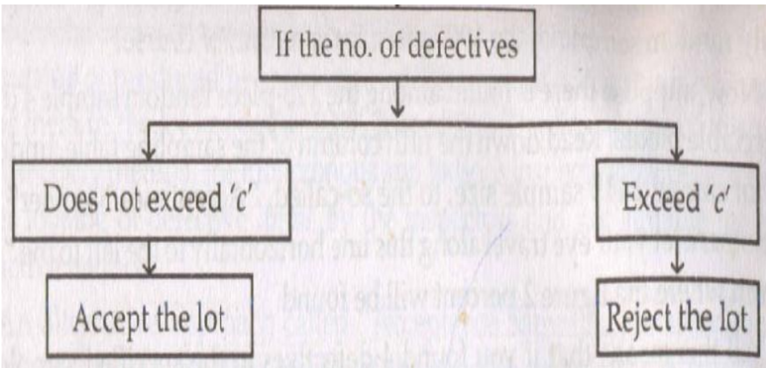
d = number of defectives in a sample.

Now, the acceptance of the lot is calculated as under:

(i) If the $d<c$, than the lot is accepted.
(ii) If the $d=c$, than all the pieces in the remainder of lot be inspected.
(iii) If $d>c$, than the lot is rejected.
(iv) Rejected lots will be returned to the producer and if rectified lot is replaced then the lot will be checked only for those defects causing rejection.

Inspect n jobs

↓



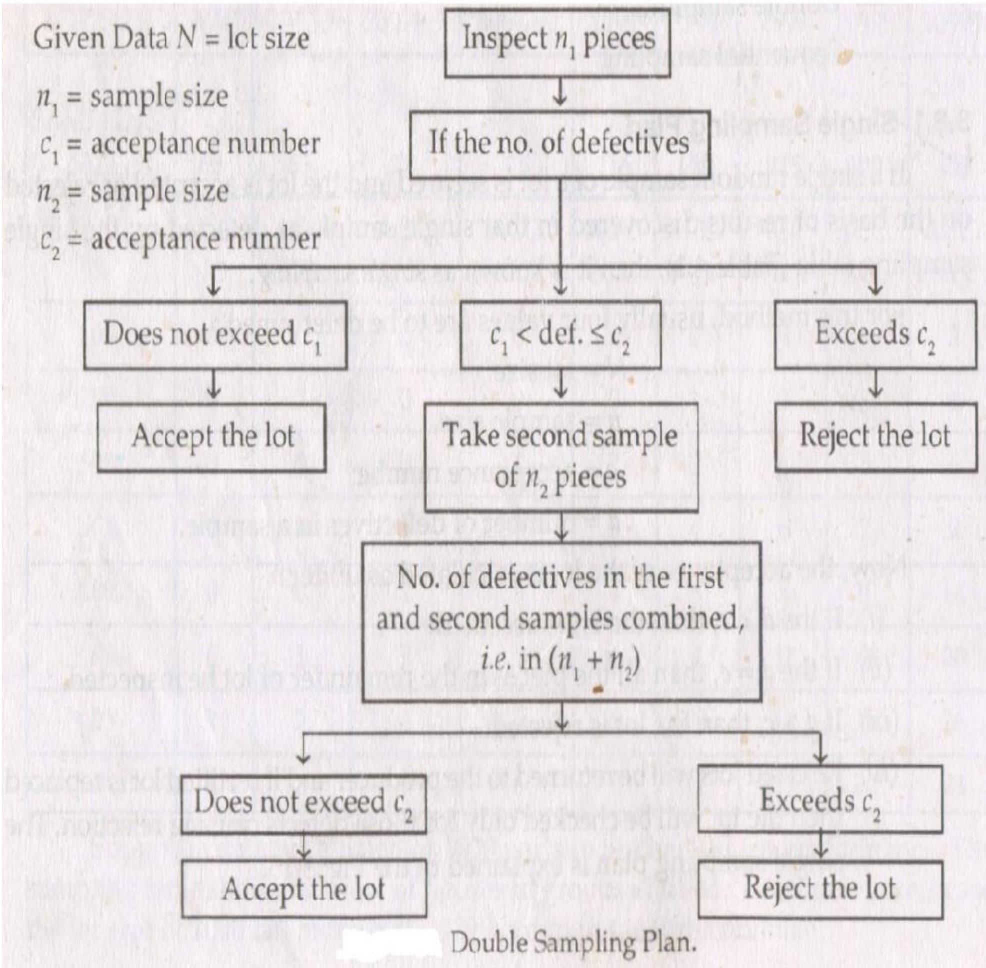
<u>Double Sampling Plan</u>:-

In this plan, the decision of acceptance and rejection of the lot is based on two samples. The lot may be accepted if the one of the samples is good or rejected if the same is bad. If the first sample is neither good nor bad, the decision is based on the evidence of the both samples combined.

The first sample n is taken from lot N. The defective count d_1 is compared with an acceptance number c_1.

If the $d_1 \ngtr c_1$ then the lot is immediately accepted. Otherwise it is next compared with rejection number c_2 if d_1 equals or exceeds c_2 the lot is immediately rejected. A condition found within these margins c_1-c_2 requires that another second sample n_2 be taken from lot N.

The defectives are added i.e. d_1+d_2 and compared as previous for final confirmation.



Double Sampling Plan.

<u>Sequential Sampling</u>:-

Sequential sampling is similar to extended double sampling. Provision is made for taking multiple samples one by one and comparing the accumulated count of defective at each step of the sampling process with a pair of acceptance and rejection numbers.

For example, a segment of a 1 percent A.Q.L. sequential sampling table for lot size 500-1000 appears in below mentioned table.

Sample	Sample size	Combined	Accept	Reject
First	20	20	*	2
Second	20	40	0	3
Third	20	60	1	3
Fourth	20	80	2	4
Fifth	20	100	2	4
Sixth	20	120	2	4
Seventh	20	140	3	4

A random sample 20 pieces is taken from the lot. The asterisk in the table means that the lot for cannot be accepted on the basis of a sample of 20 no matter if it contains no defectives. However, if 2 or more defectives appear in the first sample of 20, the lot may be immediately rejected. Otherwise the second random sampling of 20 more pieces is to be made. If by this time (a total of 40 sample pieces examined) no defectives have been uncovered, the lot may be accepted. If a total of 3 or more defective have been counted among the accumulated 40 piece sample, the lot is to be rejected at that point. but, up to this point, 1 or 2 defectives may have appeared, counts that lie between the 0 or 2 defectives may have appeared, counts that lie between the 0 acceptance figure and the 3 rejection figure. In that event, sampling is resumed by taking 20 more pieces. Eventually, as can be seen, enough successive samples will have been inspected and an accumulation of defectives counted where either an "accept" number or a "reject" number is reached and appropriate action is taken in regard to the lot.

Selection of Sample size:-

(v) As it is usual, the sample size can be anything from 2 to upwards. But for manufacturing processes, minimum sample of size 4 is required to make a normal distribution of sample average.

(vi) Although a larger sample is always preferred to get the surety (≅100%) of quality judgement of 'universe' (lot) on the basis of sample quality. But at the same time considering cost factor associated with increasing sample size, it is also desired to keep the smaller size. This is also true if the inspection involves destructive testing. Hence, a balance between the sample size and cost factor should be made.

(a) Generally a sample size of 2 or 3 is avoided because of the lot (universe) is non-normal. (See art. Normal Distribution), then the 3-sigma limit for group of 2 or 3 is invalid. But on the other hand for group of 4 or more; even if the universe is non-normal, still the distribution of group averages is normal.

Method of taking samples:-

As the SQC rules say, "The samples taken should be random in order to become true representative of the universe". The method should follow the simple rules as:

(i) They should be drawn from the same universe. Because, as the probability defines that if two samples are drawn from two different universes (lots), then the probability of difference is high rather than where one sample is taken from one lot and other sample contains items from both lots.

(ii) All short of items should be tried to be included. Although this is to be avoided while lot formation so as products from different sources (shifts, machines, materials) should be mixed.

(iii) The sample should be random i.e. without any biasing and consideration. The method of selection should be such that gives every number of lots in equal chance of being drawn. One of the methods in industry is to use Table of random Samplings Numbers. Although second rule tries to bias the selection process still the difference looking items should be tried to see the range of variability.

Frequency of samples:-

Mathematically, we have tried to explain the frequency of samples taken in topic of this chapter. But more or less practically the frequency of samples generally depends upon the gut-feeling of the analyst or SQC engineer. He himself judges the ongoing operations wellness and combining it with the 'unit-processing time', he takes decision how frequently the sample should be taken.

For example, if the unit- processing time is one hour and he feels that the process is 'Out of Control' then he may reduce the frequency to a day's sample and the a week's ample and soon.

The only limit for the sample frequency is the limit time for production of at least one sample and obviously the cost of sampling involved (capacity for destructive testings).

Inspection Plan Format:-

In acceptance sampling, the defects are classified as ABC, the following terms:

A – Critical defect, hazardous, unsafe for human life.

B – Major defect, Reduces usability of product.

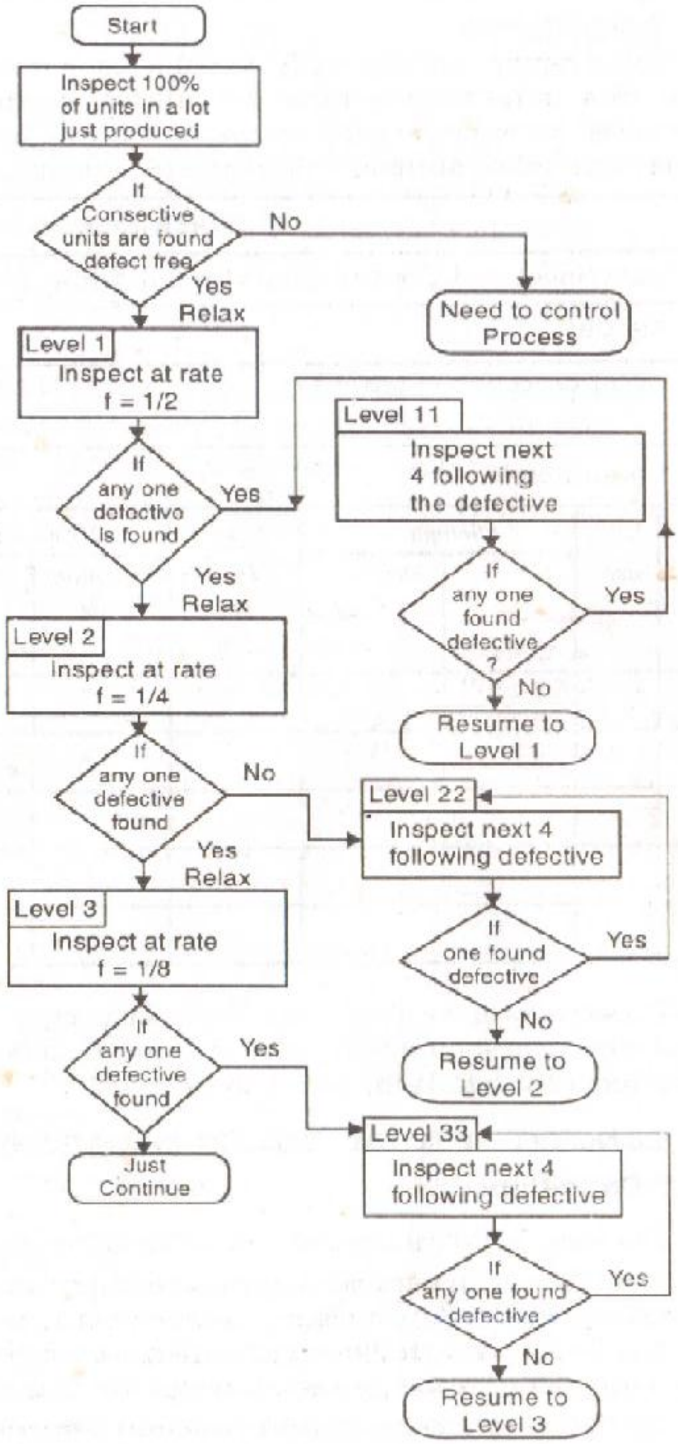
C – Minor defect, has little effect on use or operation.

The IS: 2500 (part-1) – 1973, provides the tables of sampling Inspection Plans for lot-by-lot inspection, when the inspection is done by attributes or by count of defects. It is also describes the procedure and formulae for the construction of your own sampling plans.

This standard states that when the quality of the lot shows significant shifts, it is described to make appropriate changes in sampling plans. The quality of universe should be such that it is necessary to tighten the inspection otherwise if quality improves, the inspection should be relaxed. The criteria as followed are as:

(i) If at least 2 out of 5 consecutive lots are rejected. Then it needs to tighten the inspection.

(ii) Similarly, while on tightened inspection should be changed over to the normal inspection.



A sample inspection plan format

Test Reports:-

The test reports at the end of SQC process provide a systematic record of Quality history of statistical acceptance procedure. A written record tells whether the inspection carried out was nominal, tightened or relaxed inspection. The last report generated should show whether the process is in control and even shows the current quality level. These reports are especially useful when lots are isolated from each other e.g. lots of same units manufactured by different vendors. These test reports help to make decisions regarding the acceptance as well as adoption of which inspection criteria (tight relax, normal) will ensure the quality.

<table>
<tr><th colspan="10">Total Report</th></tr>
<tr><td colspan="10">Data Sheet and Control Chart for Sampling Inspection</td></tr>
<tr><td colspan="10">Vender:</td></tr>
<tr><td colspan="7">Acceptance Level (AQL):</td><td colspan="3">Inspection: (Nor/Relax/Tight)
Procedure</td></tr>
<tr><td colspan="10">Comments:</td></tr>
<tr><td rowspan="2">Date</td><td rowspan="2">Lot Size</td><td colspan="2">I Sample</td><td rowspan="2">% age defective in I</td><td colspan="2">II Sample</td><td rowspan="2">% age defective in II</td><td rowspan="2">Action For lot</td><td rowspan="2">Control Scheme For samples</td></tr>
<tr><td>Sample size</td><td>Defective</td><td>Sampling size</td><td>Defective</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

These reports are also useful, when inspectors are reluctant to openly discuss that whether a lot should be rejected or requires taking a second sample, than written quality record suggests the action to be taken.

Concept of Total Quality Management (TQM):-

Definition:- The term TQM can be defined in the following ways as

1. TQM is an integrated organisational approach in delighting customers (both external and internal) by meeting their expectations on a continuous improvement in all products, services and processes along with proper problems solving methodology.
2. The TQM refers the control of all transformation processes of an organisation to best satisfy customers need in the most economical manners.
   The management can ensure this through:-
   (i) Team effort
   (ii) Satisfying work the emotional and intellectual needs of workers.

(iii) Satisfying the needs of better working conditions.
(iv) Constant improvement in industrial relations climate in the organisation.
(v) Installing motivation system to include collective achievement and quality excellence.
(vi) Integration and co-ordination of activities of various departments such as product design, Research and development, Production, planning, manufacturing / Processing, Technical services, sales etc. to attain the desired goals economically.
(vii) Maintaining a sound quality system to ensure each task is performed correctly.

Dimensions of TQM:-

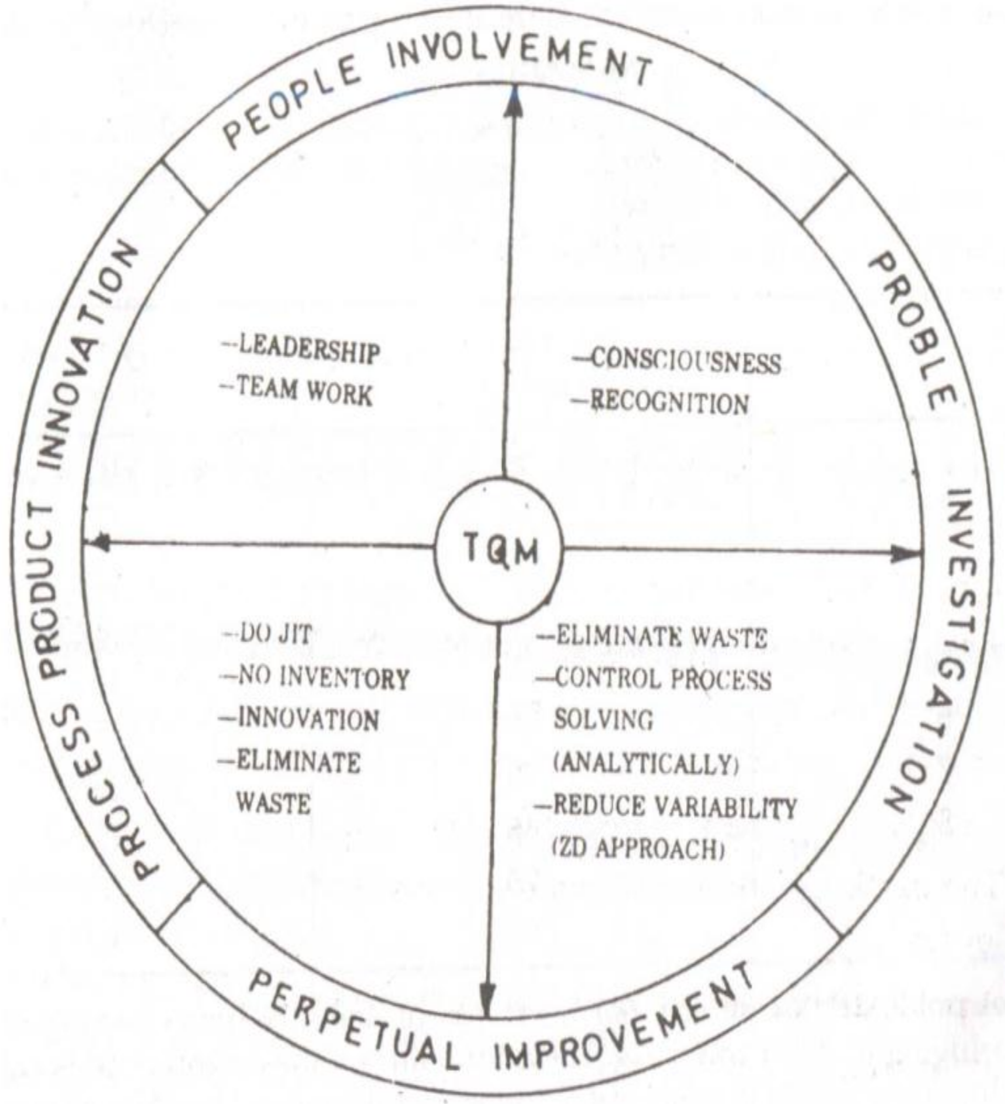
The TQM has the following three dimensions as:

(i) Excellence: The objective should be nearer to perfection.
(ii) Universality: Factors such as types of products, process, customers and employees pay very important role to achieve maintain and improve the quality.
(iii) Perpetuality: TQM has aspects of steadiness of progressive steps which direct us to attain perfect quality through continuous and innovative approach for improvement of process, using structural, systematic and analytical approach to problem solving.

Operations and Implementations of **TQM**:-

Operation & implementation of TQM contains four processes listed as under and shown in figure.

(i) People involvement
(ii) Product innovation
(iii) Problem investigation
(iv) Perpetual improvement.



Where JIT (just in time) aims at

PDCA (Plan, Do, Check and Act)

- Plan (Design innovate)
- Do (Manufacture)
- Check (Inspection & check)
- Act (Counter measure, modification)
- ZD (Aero defect)

CHAPTER-4: STANDARDS AND CODES

A standard is defined as a model or general agreement of a rule established by authority, conserves or custom, created and used by various levels of interest.

NATIONAL STANDARDS CODES:-

The national standards are provided by the ISI(Indian Standard Institute), which was set up in 1947. ISI was setup with an aim to promote standardisation, quality control for competing in international market and also to provide security in purchasing and safety for the consumer.

The different jobs performed by ISI are as under

(i) Providing standards in documented form for products, materials & the processes.
(ii) To issue the ISI certification for industrial products under ISI certification marks scheme under act 1952.
(iii) Circulation of latest information through their journals regarding standardisation.
(iv) Promoting international standards in India, in collaboration with ISO (International Organisation for Standardisation) & IEC (International Electro technical Commission) in Europe.

Working of ISI:-

The ISI works through ten Division Councils, which appoint a number of Technical Committees for making new standards, revise, withdraw and supersede the old standards. The technical committee consists of a few groups of expert people along with a representative of National Physical Laboratory. Instead of including manufacturer's representatives, the committee writes to as many as possible of the manufacturers known to be producers of equipment in question and ask for all the related information.

A preliminary draft is prepared and sent for comments to all the manufactures. Special care is taken not to include the things which are not 'essential' unless it affects the performance of the instrument. After that it formulates a standard, which is acceptable to all the manufacturers.

Licensing/Certification by ISI:-

The ISI certification scheme, started in 1955-56 under which the manufacturer, who has applied for getting on ISI mark for his product, is given a license after thorough testing of samples of his product. The license, also describes the procedures to be adopted for the quality control and testing and is given for the period of one year.

After the certification, a constant check on the quality of product is kept, by taking samples from the market by the inspectors appointed by ISI. The samples can be sent to one of the 17 laboratories for testing purpose at:

- Mumbai
- Bangalore
- Chennai
- Kolkata
- Kanpur
- Sahibabad(Ghaziabad)
- Cochin
- Patna
- Trivandrum
- Rajkot
- Guntur
- Jamnagar
- Mangalore
- Alleppy
- Tuticorin
- Virudhnagar
- Kozhikode

  The manufacturers may be punished and even their license may be cancelled if there are serious complaints made by consumers against the quality of ISI marked products. The license covers 1000 types of products ranging from biscuits to steel products and 6000 licenses have been issued so far.

Importance of ISI Codes:-

The Indian standards are available from Indian Institute Bahadur Shah Zafar Marg, New Delhi. Some of the important Indian standards are as follows:

- SP: 5-1969 Guide to the use of SI units.
- IS: 210-1970 Grey iron castings (amended in 1978).
- IS: 318-1962 leaded tin bronze ingots and casting.
- IS: 325-1970 Three phase induction motors (revised 1978).
- IS: 554-1975 Dimensions for pipe threads where pressure tight joints are required on the threads.
- IS: 696-1972 Code of practice for general engineering drawings (revised 1979, 1983).
- IS: 919-1963 Recommendations for limits and fits for engineering (revised 1978, 1980)
- IS: 1356-1972 Electrical equipment of machines for general use.
- IS: 1363-1967 Black hexagonal bolts, nuts and lock nuts (dia 6 to 39mm) and black hexagonal screws (dia 6 to 24mm).
- IS: 1367-1967 Technical supply conditions for threaded fasteners.
- IS: 2016-1967 Plain washers
- IS: 2102-1969 Allowable deviations for dimensions (amended 1978).
-
- IS: 2218-1962 Speeds for machine tools.
- IS: 2219-1962 Feeds for machine tools.
- IS: 2243-1971 Drill chucks.
- IS: 2473-1975 Dimensions for centre holes.
- IS: 2494-1974 V-belts for industrial purposes (amended 1987).
- IS: 3230-1970 Recommendations for tapping drill sizes.
- IS: 3406-1975 Dimensions for countersinks and counter-bores. (Part-I & II)
- IS: 3457-1966 Radii and chamfers for general engineering purposes.
- IS: 4218 (Part-III)-1967 ISO Metric screw threads basic dimensions for design.
- IS: 5692-1970 Tolerance for radial roller bearings.
- IS: 7513-1974 Graphical symbols for fluid power systems.
-

INTERNATIONAL CODES:-

National standards and codes are no longer enough in themselves for a nation like India, interested in export ties. The international scene has changed and due to this, a new set of requirements for industry standards have arisen. The development of own national standards by major industrial countries for similar type of products bear little resemblance to another. Thus, standards (national) have become a hindrance to easy flow of goods from country to country.

Due to this reason, by late 1920s eighteen countries sent their representatives to set up International Standard Organisation(ISO), in Europe until it finally ceased to function on outbreak of war 1939.

Evolution of ISO-9000:-

The first major international setup was IEC (International Electro-technical Commission) established in 1906 in London. Thirty six countries, including United States, USSR and china, along with their 60 technical committees successfully developed nearly 300 publications to provide participating countries, with electrical equipment standards ranging from tungsten filament bulbs to turbines. IEC still exists and works with ISO as its electrical division with headquarter at Geneva.

Later on, during second world war a United Nations Standards co-ordinating committee was formed with offices at London at New York. In 1945, fourteen members of united nations committee decided to invite other countries to join and convert it into a permanent organisation. As a result, in 1946 at London ISO was born. Now ISO has 60 countries as its member and has over 450 publications regarding basic engineering practices (screw threads, limits and fits, drawings), engineering components (nuts and bolts, bearings), textiles, rubber, building, computers and material handling.

The ISO 9000 family of standards got universal recognition after the British Standards BS 5750 : 1979 was adopted by ISO as ISO 9000 in 1987 after amendments, under the chairmanship of Canada. They were also adopted by CEN, the European Committee for Standardisation. From 1993, EEC (European Economic Community) made it mandatory for its members to get goods only from countries having ISO 9000 certification. EEC work within international frame work of two world standard bodies ISO and IEC and follow their recommendations.

Concept of ISO-9000:-

The ISO-9000 series of systems got considerable important after European countries made it compulsory for standards unification. Britain’s decision to adopt metric system is an indication of the industries, going hand in hand with world trends. Besides the benefit of giving eligibility to complete in European market, adopting ISO 9000, enables implementation of quality management systems in the company.

The NACCB (National Accreditation Council for Certification Bodies) is the organisation for issuing a certificate of registration, indicating the organisation fulfilling the requirements of ISO standards.

Assessment of companies are carried out in accordance with documented procedures. The assessment includes following steps:

(i) Visit of certification body or issuing a questionnaire by it after getting the initial application by the company.
(ii) Agreement of terms and quotation by the company.
(iii) Certification body asks for documented system of quality control in order to carry out adequate audit.
(iv) Audit is performed by:
  - Opening meeting
  - Assessment
  - Closing meeting
(v) Auditor will judge whether the company should be recommended or not for certification. Minor non conformities recorded referred to as **Isolated failures** are corrected, only then the company is registered. Major non-conformities are **Hold points** which reject the company for certification. A fixed payment fee is given by the company in advance or as per policy of certification body.

Recently, Indian Registrar of Quality System (IRQS) has been named as certification body, for assessing and certifying quality management systems in Asia.

Implication of ISO-9000:-

The ISO 9000 (1994) is a quality management and quality assurance standard. It gives guidelines for selection and use of ISO series of standards and quality concepts. ISO 9000 and ISO 9004 give guidance to all organisations for quality, where as ISO 9001, ISO 9002 and ISO 9003 are used for externally quality assurance purposes.

- **ISO 9001** quality system standards are followed for quality assurance in production, installation and servicing of quality systems. It is applicable to industries who design, install product and provide after sales service such as for coolers, filters etc. It is for contractual situations.
- **ISO 9002** are also model for quality assurance as ISO 9001 except that the design control is omitted. These are applied for products where quality assurance is required only during production till they are delivered/ installed with the customer such as civil structures, bridges etc.
- **ISO 9003** is model for quality assurance in final inspection and test these are followed where quality assurance is required after the product is in final shape. Customer is least interested in the manufacturing process but the end product for example automobiles, domestic appliances, petroleum products.

- **ISO 9004** are simply guidelines which assure quality where there is no contract between the company and ISO. It gives different elements of a quality management system.

India, adopted ISO 9000 as IS : 14000 series in 1988. To promote ISO 9000 certification, Govt. of India has provided a monetary incentive for all small scale industries having ISO 9000 certification as 75000/-.

<u>Benefits of getting ISO-9000:-</u>

The following advantages having ISO 9000 certification:

(i) Reduction of multiple assessments by audit as ISO 9000 is sufficient for all assessments.
(ii) Management control is better if all the activities are properly documented.
(iii) If any industry is having ISO 9000, there is rise in its status like a graduate having honours.
(iv) The most important aspect is that for a market in Europe, the ISO 9000 certification is must for the company.
(v) It helps in motivating the employees and bring a ‘Quality culture’ into the company.

CHAPTER-5 INSTRUMENTATION

MEASUREMENTS AND THEIR TRANSDUCTION METHODS:-

Sr. No.	Quantity to be measured	Types of Transducers
1.	Displacement	• Resistive • Inductive • Capacitive • Piezoelectric • Magneto-electric • Radioactive • Electron-tube
2.	Velocity	• Resistive • Inductive • Capacitive • Piezoelectric • Photoelectric • Magneto-electric • Radioactive • Electron-tube
3.	Thickness	• Inductive • Capacitive • Piezoelectric • Photoelectric • Radioactive
4.	Mass	• Inductive • Piezoelectric • Magneto-electric • Radioactive
5.	Force	• Resistive • Inductive • Piezoelectric • Radioactive
6.	Acceleration	• Resistive • Inductive • Capacitive • Piezoelectric • Magneto-electric • Electron-tube
7.	Pressure	• Resistive • Inductive • Capacitive

		• Piezoelectric • Thermoelectric • Magneto-electric • Radioactive • Electron tube
8.	Flow	• Resistive • Inductive • Capacitive • Piezoelectric • Magneto-electric • Radioactive
9.	Level	• Resistive • Capacitive • Piezoelectric • Photoelectric • Radioactive
10.	Temperature	• Resistive • Photoelectric • Thermoelectric • Radioactive
11.	Humidity	• Resistive • Capacitive
12.	Viscosity	• Resistive • Capacitive • Piezoelectric

<u>MEASUREMENT OF TEMPERATURE</u>:-

Temperature can be defined as a thermal state which depends upon the internal or molecular energy of the body. The temperature of a substance or a medium is used to express the degree of hotness or coldness. It is related with reference to its power of communicating heat to the surroundings. It is a measure of the kinetic energy of the molecules of the substances and represents the potential of heat flow.

Temperature is most fundamental parameter. It is required in the routine control of industrial plant and in carrying out performance and acceptance trials. The instruments used for temperature may be classified as:

(1) <u>Mechanical temperature sensors:-</u>
  (a) Expansion thermometers
    (i) Liquid in glass thermometers
    (ii) Bimetallic thermometers
  (b) Pressure thermometers
    (i) liquid filled thermometers

(ii) Vapour pressure thermometers
(iii) Gas filled thermometers

The change in dimensions accompanying a temperature change forms the basis of operation of the expansion thermometers such as liquid in glass thermometers and bimetallic thermometers.

The change in pressure of a gas or a liquid accompanying a temperature change forms the basis of operation of pressure thermometers.

(2) Electrical temperature sensors:-
(i) Thermocouples
(ii) Resistance thermometers
(iii) Thermistors.

Electrical methods are most convenient and accurate methods of temperature measurement. They include methods based on change in resistance and generation of thermo emf.

(3) Optical sensors:-
(i) Radiation pyrometer
(ii) Optical pyrometers

The optical methods are based on measuring energy radiation from a hot body.

Liquid in glass thermometers:-

It consists of a glass bulb joined to a length of round glass tubing having a capillary bore of oval shaped section. Generally a high grade glass properly engaged and annealed is used for making the glass bulb. The bulb is fitted with mercury and with rise of temperature expansion of both mercury and glass takes place.

However, mercury expands eight times than glass and thus the change in temperature is determined in terms of the length of mercury column in the glass tube. The range of the thermometer depends on the capacity of the bulb and the bore tube. A large bulb has a smaller range. A typical example is the standard clinical thermometer as shown in figure.

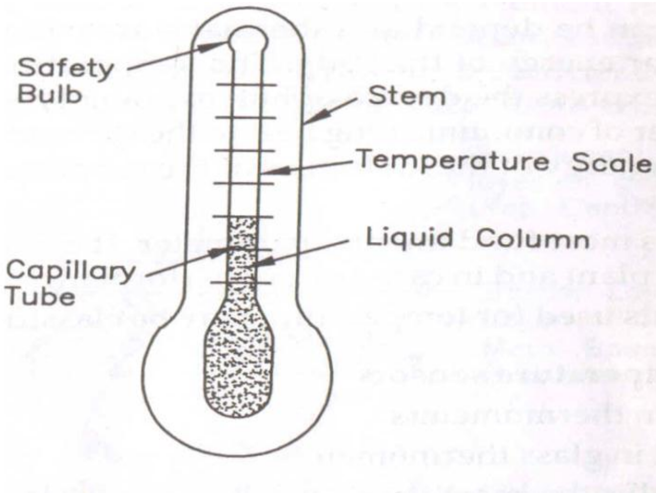


Fig. Liquid in glass thermometer.

Bimetallic thermometers:-

The following figure shows a Bimetallic thermometer. In this bimetallic thermometer differential expansion of bimetallic strip is used to indicate the temperature. In this type of thermometer two flat strips of different metals are placed side by side and are welded together. One of the strips is made of low expanding metal and other at high expanding metal. The bimetallic strip is coiled in the form of a spiral or helix. The curvature of the strip changes with the change in temperature. The differential expansion of the strip causes the pointer to move on the dial of the thermometer.

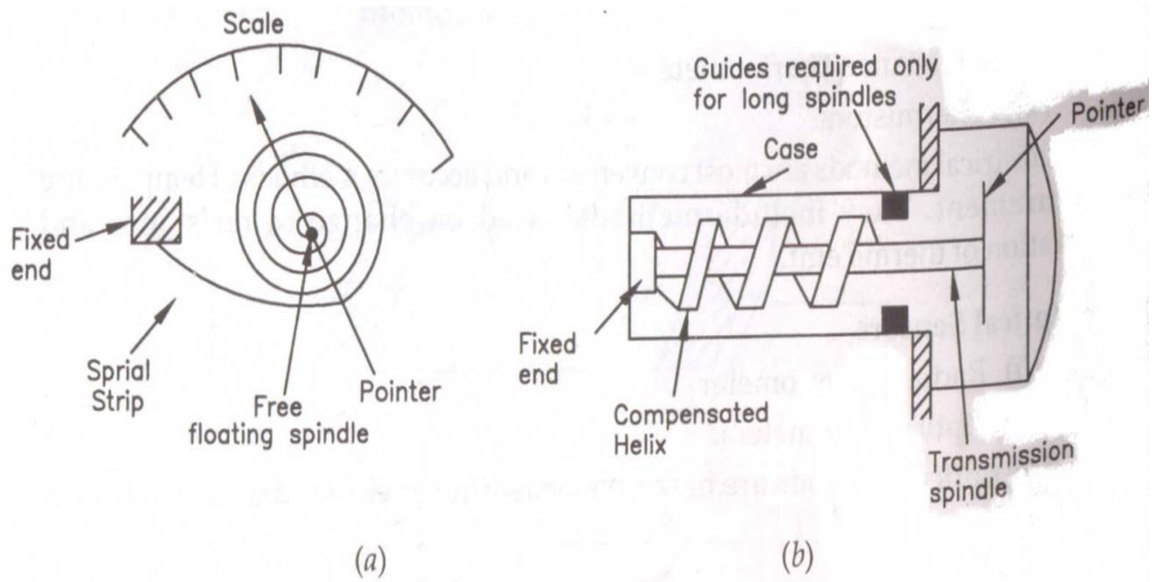


Fig. Bimetallic thermometer.

These are also used as compensators for ambient temperature change in the filled system (Thermometers, aneroid barometers etc.)

Liquid filled thermometers:-

A liquid filled thermometer is shown in figure. It consists of an immersible bulb, an elastic measuring element (tube or spiral spring) coupled to the bulb through a capillary tube and an indicating or recording attachment.

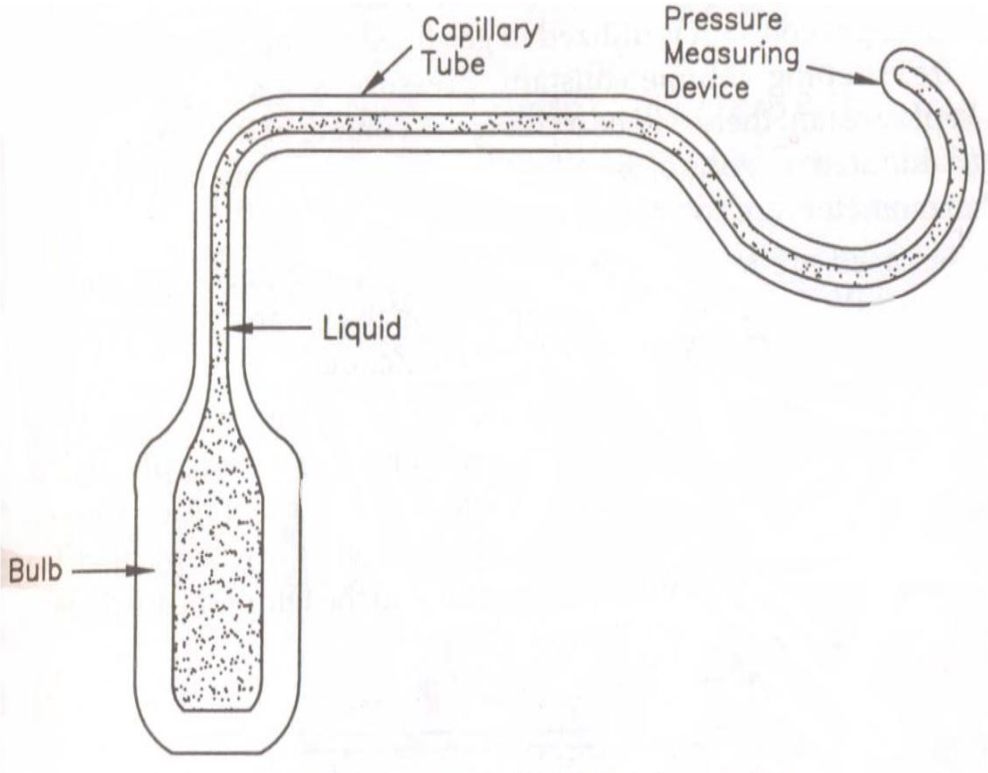


Fig. Liquid filled thermometer.

The liquid enclosed in the bulb expands, causes the change in volume and causes the pointer to move on the dial. Therefore, liquids having high co-efficient of expansion are used. In practice, many liquids e.g. mercury, alcohol and glycerine may be used. The operating pressure varies from about 3 to 100 bars. These types of thermometers could be used for a temperature up to 650˚C in which mercury could be used as the liquid.

Vapour pressure thermometers:-

Vapour pressure thermometers are very much similar in design and construction to the liquid filled thermometer. When the bulb containing the fluid is installed in the region whose temperature is required, some of the fluid vaporizes, and increases the vapour pressure. This change of pressure is indicated on the Bourdon tube.

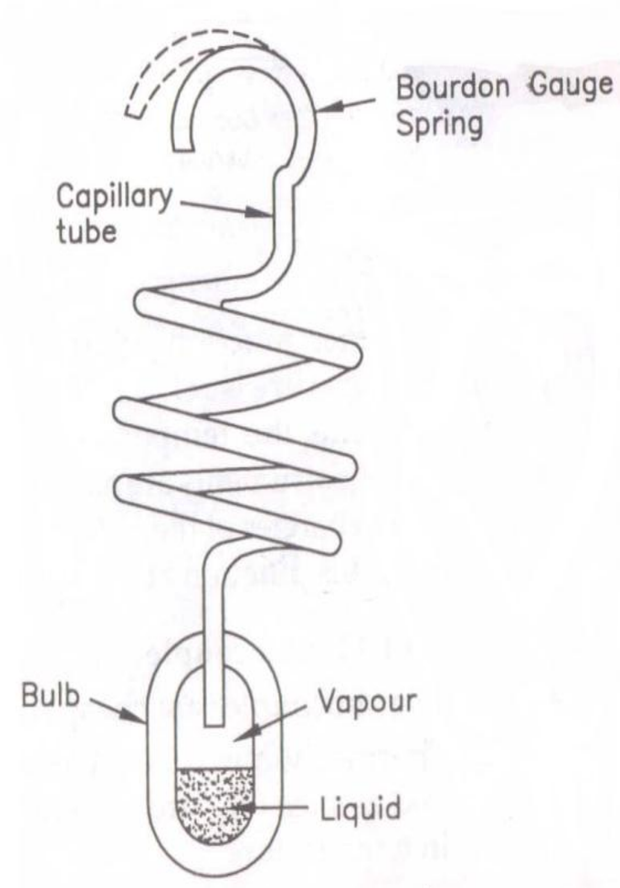


Fig. Vapour pressure thermometer.

The relation between temperature and vapour pressure of a volatile liquid is of the exponential form. Therefore, the scale of a vapour pressure thermometer will not be linear. Generally, ethylene, ethyl, ether and toluene are some of the liquids that can be used in vapour pressure thermometers.

Gas filled thermometers:-

The basic principle of gas law viz. PV=RT, where P is absolute pressure, V is volume and T is absolute temperature. and R is universal gas constant is utilized in gas filled thermometers, on increase of temperature, keeping volume constant, pressure will change, while if the pressure is constant. There will be a change, while if the pressure is constant there will be a change in volume of the gas. The changes are suitable calibrated in terms of temperature. Generally constant volume types gas filled thermometers are commercially used.

Thermocouples:-

Thermocouples are most commonly used electric device for temperature measurement. It is based upon the principle that e.m.f is developed in a closed circuit made up of two dissimilar metals or alloys if the reference and measuring junctions of the two metals are kept at different temperature, the e.m.f generated is proportional to the temperature difference.

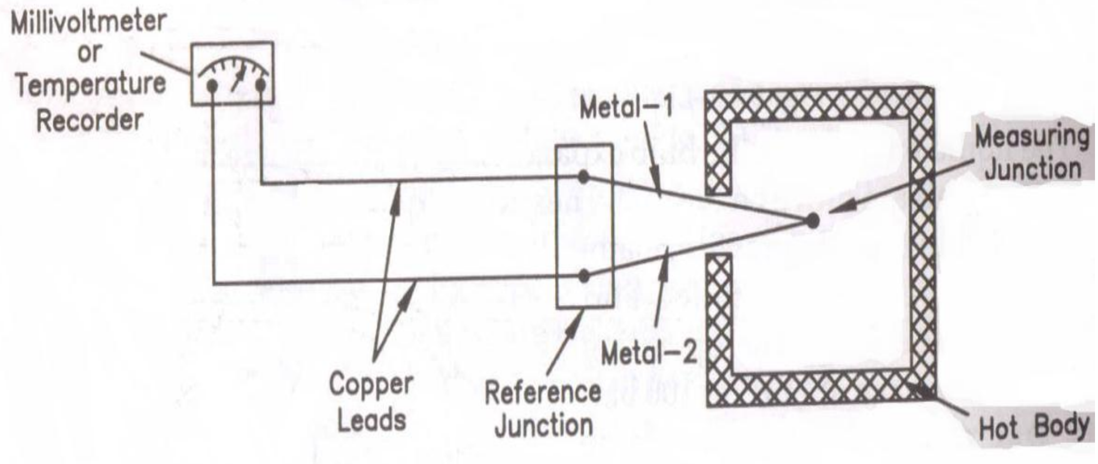


Fig. Thermocouple.

Advantages:-

- Thermocouples are cheaper than the resistance thermometer.
- Thermocouples follow the temp. changes with a small time lag as such they are suitable for reading comparatively rapid changes in temperatures.
- Thermocouples are very convenient for measuring the temperature at one particular point in a piece of apparatus.
- Thermocouples can be used to measures a wide range of temperature as high as 1400˚C can be measured.

Disadvantages:-

- Thermocouples cannot be used for precision work.
- Thermocouples are placed remote from measuring devices.
- To ensure long life of the thermocouples in their operating environment. They need protection in an open or closed end metals protecting tube.

Resistance thermometers:-

It is also known as resistance thermometer detector (RTD). A resistance thermometer is used for precision measurements below 150˚C. A simple resistance thermometer consists of a resistance element or bulb, electrical loads and a resistance of the metal changes with a change in temperature. This property is utilised for measurement of temp. in resistance thermometers.

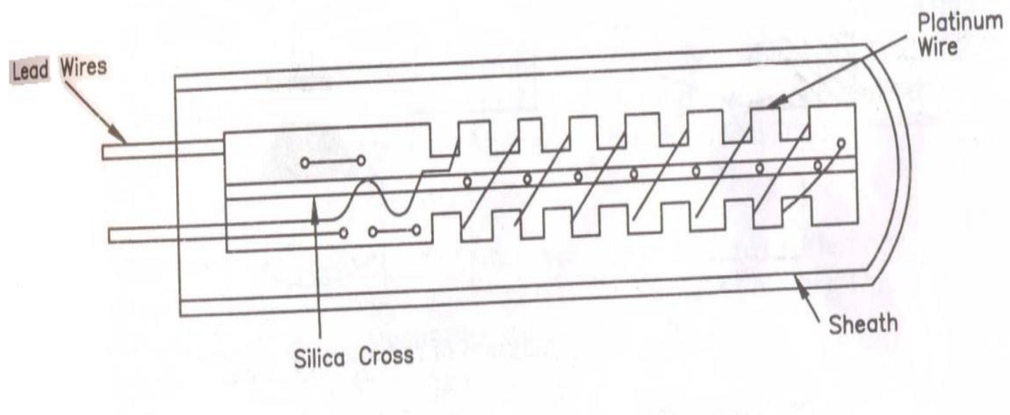


Fig. Platinum resistance thermometer.

Advantages:-

- It is very accurate for low ranges (below 150˚c).
- It requires no reference junction like thermocouple.
- It resists corrosion and is physically stable.
- It is more effective at room temperature.

Disadvantages:-

- It is very costly.
- They suffer from time lag.

Thermistors:-

Thermistor is a non-metallic resistor having a negative temperature co-efficient of resistance i.e. their resistance decreases with increases of temperature. The high sensitivity to temperature changes makes them extremely useful for precision temperature measurements. They are widely used for measurement in the range 60˚C to 15˚C. These are made by sintering mixture of metallic oxides.

Radiation pyrometers:-

A device which measures the totals intensity of radiation emitted from a body is called radiation pyrometer. It collects the radiation from an object whose temperature is required. A mirror is used to focus this radiation on a thermocouple. This energy which is concentrated on the thermocouple raises its temperature and generates e.m.f. Thus rise in temp. is a function of the amount of radiation emitted from the object.

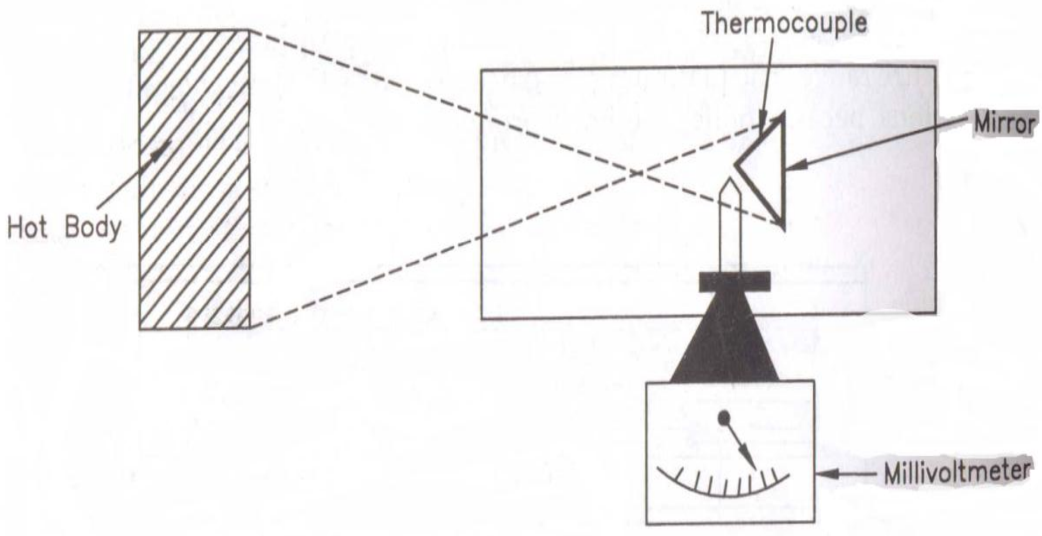


Fig. Schematic diagram of radiation pyrometer.

Advantages:-

- The average temp. of the extended surface can be measured.
- The temp. of moving objects can be measured.
- The temp. of the objects which are not easily accessible can be measured.
- A higher temp. measurement is possible.

Optical pyrometers:-

It works on the principle that matters glow above 480˚C and the column of visible radiated from the glowing matter (solid or liquid) is measured and employed to determine the temperature.

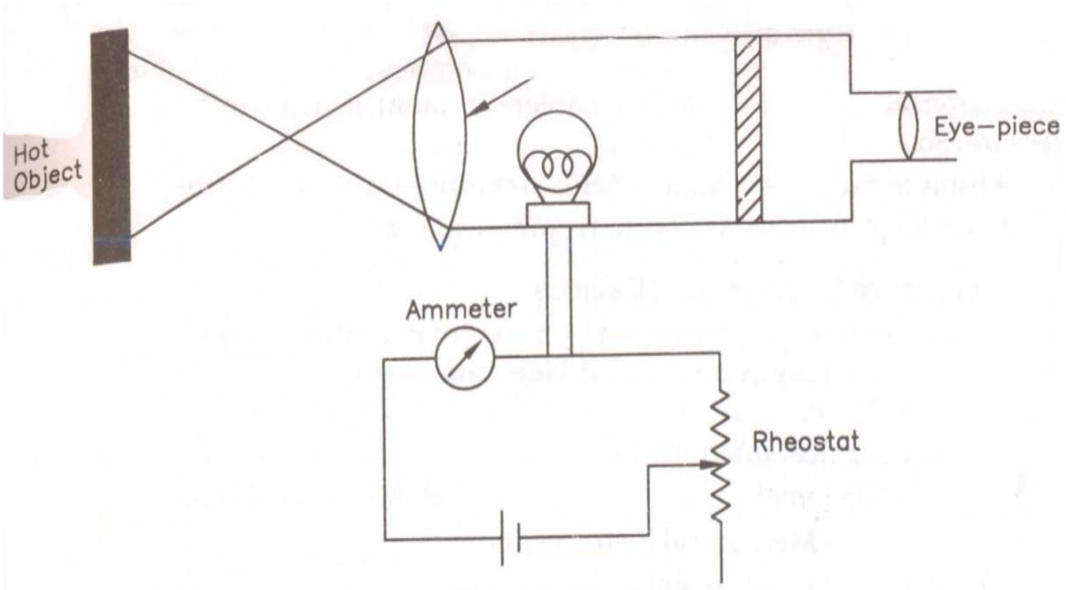


Fig. Optical pyrometer.

Working principle:-

The optical pyrometer is sighted at the hot body and focused. In the beginning filament will appear dark as compared to the background which is bright (being hot). By varying the resistance(R) in the filament circuit more and more current is feed into it, till the filament becomes equally bright as the background and hence disappears. The current flowing in the filament at this stage is measured with the help of an ammeter which is calibrated directly in terms of temperature. If the filament current is further increased, the filament appears brighter as compared to the background which then looks dark. An optical pyrometer can measure temperature ranging from 700˚ to 4000˚C.

Measurement of pressure:-

Pressure is defined as the force per unit area. Pressure is exerted by gases, vapours and liquids. The fundamentals SI unit of pressure is (N/m^2). This is also called as Pascal. In MKS it is usually expressed in kgf/cm^2.

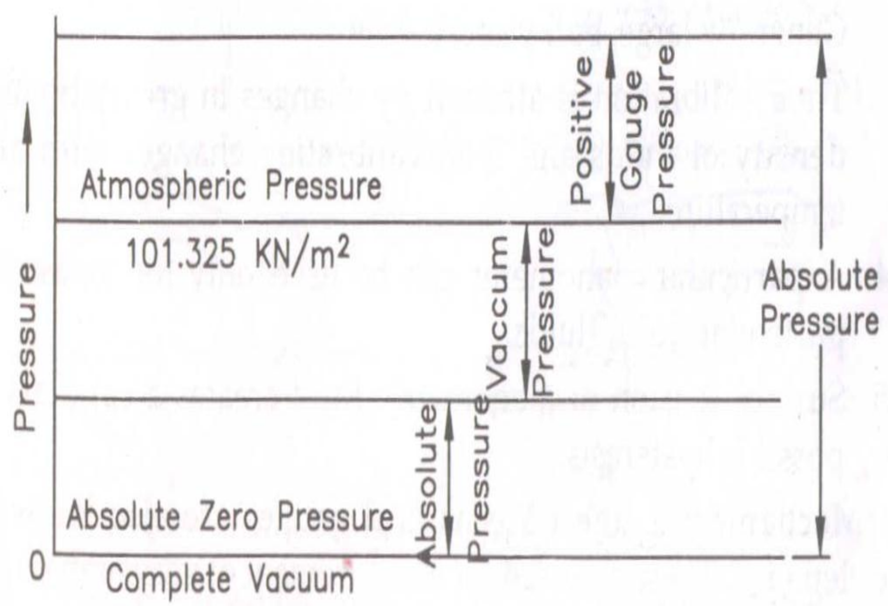


Fig. Schematic diagram showing gauge, vacuum and absolute pressure.

- If the pressure is measured above the atmospheric pressure as datum it is called as positive gauge pressure.

  However if the pressure is measured below atmospheric pressure as a datum, it is called as a negative gauge pressure or vacuum pressure. If the pressure is measured above the absolute, then it is called as absolute pressure. So,
  Absolute pressure = Atmospheric pressure + Gauge pressure
  Vacuum pressure = Atmospheric pressure – Absolute pressure

Classification of pressure gauge:-

Electrical pressure transducers can be classified as

1. Resistance type pressure transducer
2. Potentiometer devices
3. Capacitive type
4. Inductance type
5. Reluctance type
6. Piezoelectric type
7. Photoelectric type

- Resistance type pressure transducer:-

Resistance type devices used in pressure transducers includes

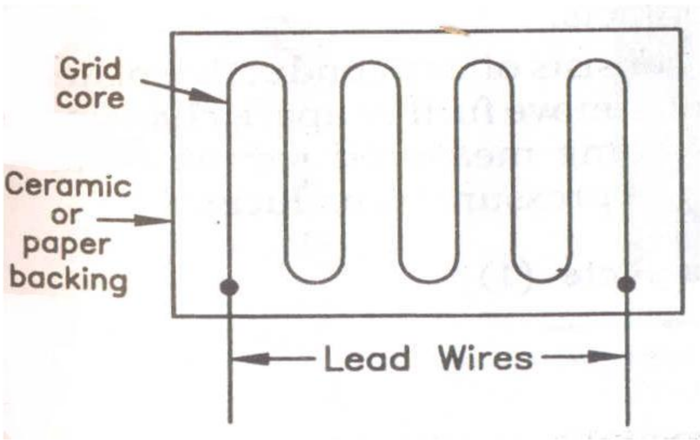
(a) Strain gauges:- A simple type of strain gauge is shown in fig. A strain gauge is simply a fine wire in the form a grid when the grid is distanced the resistance (R) of the wire change. According to formula

$$R = k\ (L/A)$$

Where K = a constant for the particular kind of wire.

L = length of wire

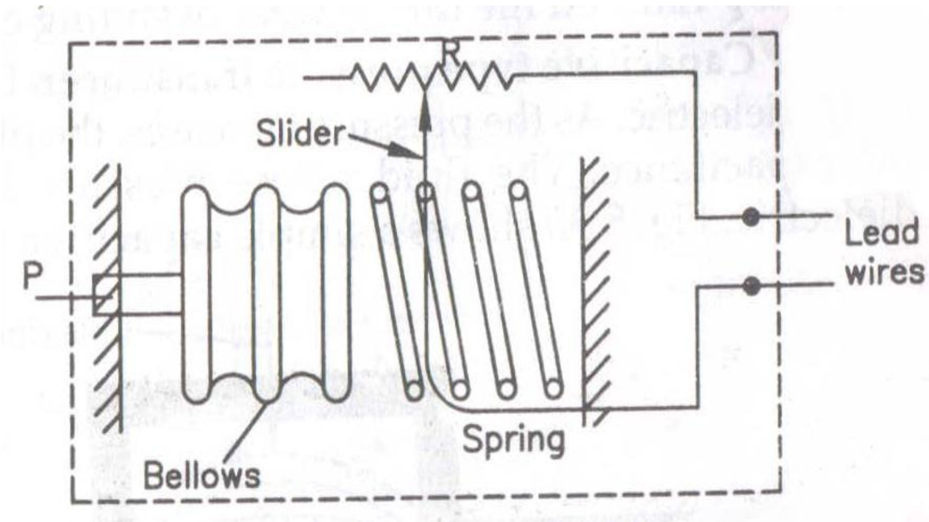
A = Cross-sectional area



As the strain gauges are distorted by the elastic deformation element, its length is increased and its cross section area is reduced. Both of these changes increase the resistances. This type of transducer can be used to detect very small movements.

(b) Moving contacts:-

This type of transducer is most often used with a bellow because of the force required. The following figure shows a typical circuit for such a transducer.



- Potentiometer devices:-

It is also known as pressure voltage transducer. It is used to convert a pressure signal into an electrical voltage. It shows a simple potentiometer device. It should have a little friction. Lever may be used to match the required movement of the potentiometer with that of the bellows; the signals applied to the potentiometer may be relatively larger of the order of several volts.

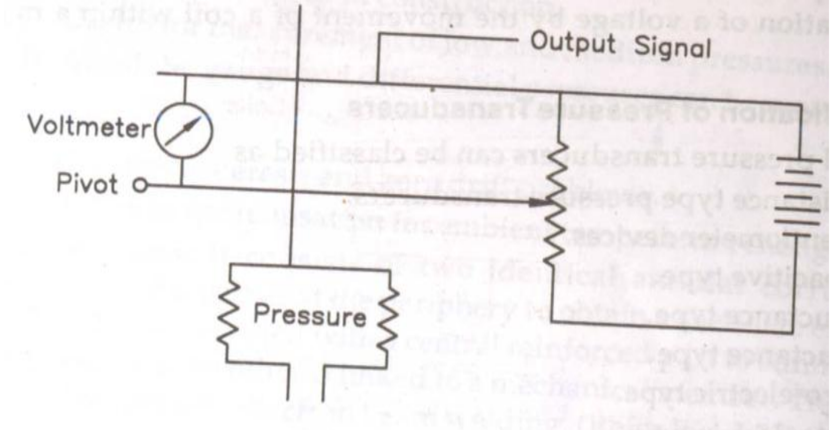


Fig. Potentiometer device.

Advantages:-

- They are less expensive.
- Very useful for Measurement of large amplitude
- Simple to operate
- Very high electrical efficiency

Disadvantages:-

- Poor dynamic response
- Poor resolution
- Pressure of noise in signal

- Capacitive type:-

It consists of two conductive plates and a dielectric. As the pressure increases, the plates moves further apart, changing the capacitance. The fluid whose pressure is being measured serves at the dielectric. Figure shows a capacitive type pressure transducer.

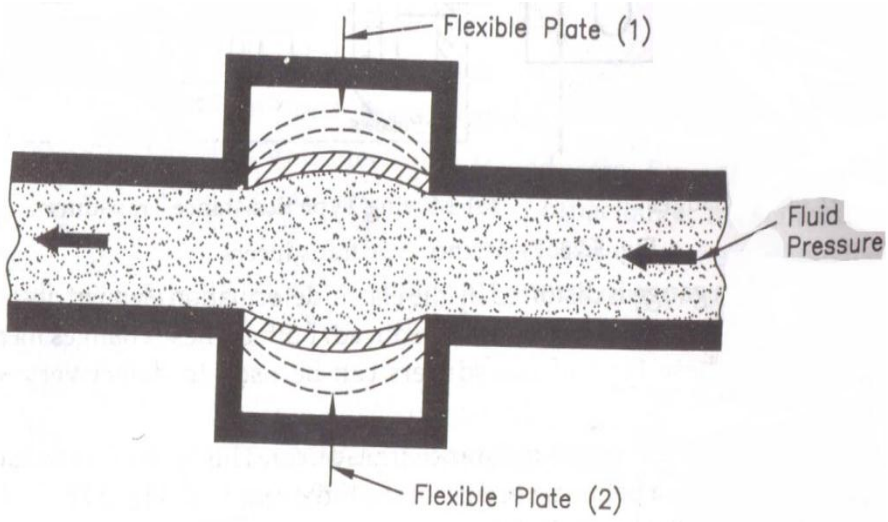


Fig. Capacitive type pressure transducer.

- <u>Inductance type:-</u>

It consists of following three parts.

- A coil
- A movable magnetic core
- A elastic deformation element

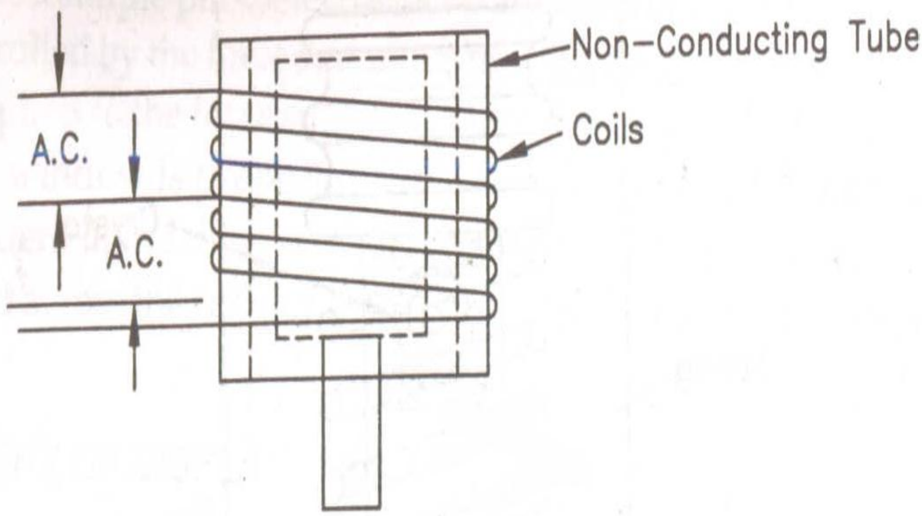


Fig Inductance type transducers.

The above figure shows an inductance type pressure transducer, the element is attached to the core. When the pressure varies, the element causes the core to move within the coil. An alternating current is passed through the coil, and as the core moves the inductance of the coil changes. The current passing through the coil increases as the inductance decreases. This type of transducer is used in a current sensitive coil. To get increased sensitivity, the coil may be divided into two parts, using a centre tap. This actually provided two coils. As the core moves inside the coils, the inductance of one coil decreases as the inductance of other increases.

MEASUREMENT OF DISPLACEMENT:-

Displacement is a vector representing a change in position of a body or a point with respect to a reference. It may be a linear or angular displacement expressed in absolute or relative terms. The magnitude of measurements ranges from a few microns to few centimetres in case of angular displacement & a few seconds to 360˚ in case of angular displacement. Many of the modern scientific and industrial observations need very accurate measurements of this parameter. They are following categories:-

(a) Measurement of linear displacement:-

Linear displacement may be measured by the following type transducers.

(i) Resistive potentiometers
(ii) Strain gauges
(iii) Linear Variables different transducers(LVDT)
(iv) Piezoelectric transducers
(v) Electronic transducers
(vi) Digital transducers
(vii) Variable inductance transducers
(viii) Capacitive transducers
(ix) Hall effect transducers
(x) Ionization Transducers

Mechanical displacement may be converted into an electrical variable by the simple expedient of adjusting resistance in an electrical circuit. A slide wire resistor, having a movable contact attached to the part whose displacement is to be measured, may be connected through a 2 conductor circuit to a steady voltage source in series with an ammeter calibrated in terms of the displacement. If the resistor is connected as a voltage divider, the need for a regulated supply is eliminated and with a 3 conductor circuit the display instrument may be a ratio meter or potentiometer. Such combinations are common & are available for both D.C & A.C operations. Where deflections are small (of the order of 0.25mm) measurement may be made by use of differential transformer.

(b) Measurement of angular displacement:-

Angular displacement can be measured by following transducers.

(i) Resistive potentiometer
(ii) Synchros
(iii) Rotary variable differential transformers.
(iv) Variable inductance transducer
(v) Capacitive transducers
(vi) Variable reluctance transducers.

Variable reluctance transducers:-

It consist of two identical coils, cam shaped iron core. (as shown in figure)

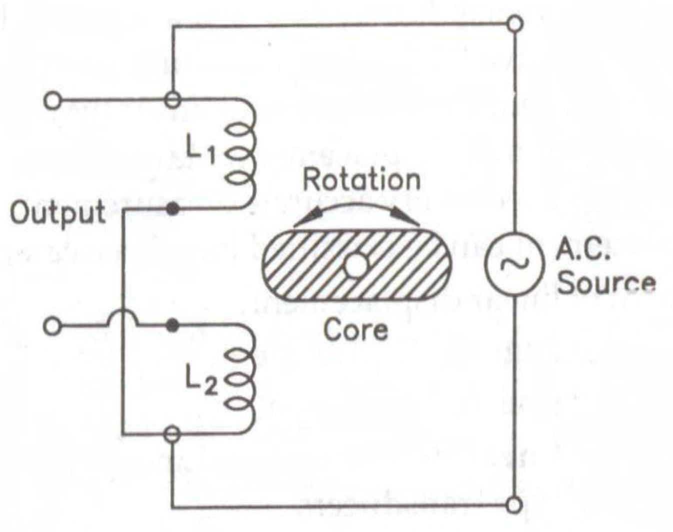


Fig. Variable reluctance transducer

L_1 & L_2 are the two identical coils connected in series opposition. These coils are so placed / positioned with respect to a cam shaped iron core that, when the core is the null position, the impedance of both the coils are the same, though they are 180˚ out of phase. Any angular displacement from the null position results in a differential voltage output proportional to the amount of displacement. The clockwise and anticlockwise angular displacement produce differential output which are opposite in phase. Thus it may be measured in magnitude and direction. In these transducers, angular phases from null position to $\pm$ 45˚ may be sensed.

(c) Measurement of small displacement:-

The linear of differential, transformer is the popular means for measuring small displacements of the order of 0.25. This device is generally produced with a single primary winding and two secondaries, all disposed along a common axis and having in the common magnetic circuit, a movable iron core longitudinally displaced with the motion to be measured. The secondaries may be connected additively or differentially and may be included in the circuit of a null type instrument based either by shifting the core of a similar transformer excited from the same source or by the use of a slide wire potentiometer.

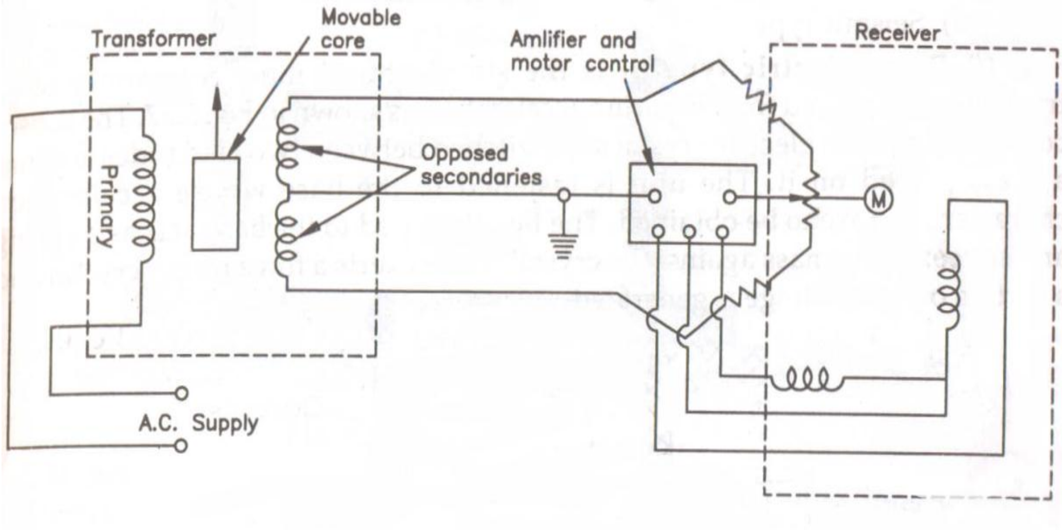


Fig. Differential transformer transducer.

Linear transformers are regularly supplied for operation at all frequencies upto 3000HZ. The sensitivity, of course increases with the frequency. These may be interconnected in a great variety of arrangement to perform computations or to be expressed desired mathematical functions of measured variations.

Measurement of vibrations and acceleration:-

(i) Vibration refers to the repeated cyclic oscillation of a system; the oscillatory motions may be simple harmonic or complex. The oscillations are caused when acceleration is applied to the m/c alternately in two directions. The need for making measurement of vibrations has arisen mainly because of growth of environmental testing.

(ii) Vibration measurements are frequently carried out on rotating and reciprocating machinery for analysis, design and troubleshooting purposes. Vibration monitoring is carried out on such important machines as power station turbines and generators to give an early warning of impending conditions which may develop and lead to complete failure and destruction of the equipment.

The excessive vibration level in a machine is an indication of the following troubles it can cause

1. Faulty production
2. Excessive wear
3. Incorrect operation of precision equipment and machinery.
4. Human discomfort leading to adverse effect such as motion sickness, breathing and speech disturbance.
5. Excessive noise.

There are two types of accelerometers generally used for measurement of acceleration.

(i) Piezoelectric type
(ii) Seismic type

<u>Piezoelectric type:-</u>

- It is the simplest and most commonly used transducer employed for measuring acceleration as shown in figure. The sensor consists of a piezoelectric crystal sandwiched between two electrodes and has a mass placed on it. The unit is fastened to the base whose acceleration characteristics are to be obtained. The box threaded to the base acts as a spring and squeezes the mass against the crystal. Mass exerts a force on the crystal and a certain output voltage is generated.

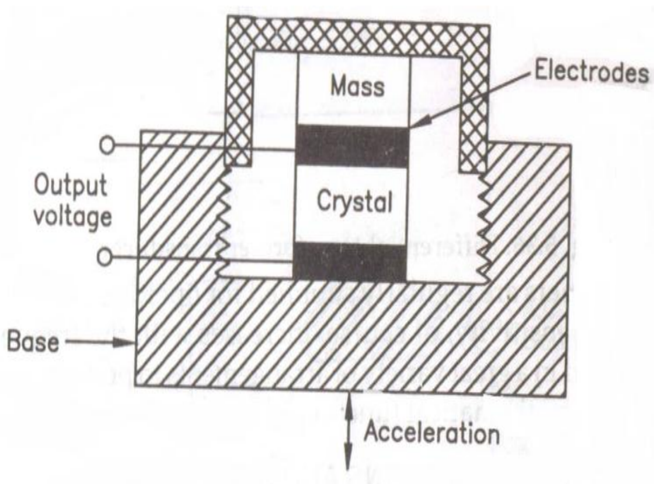


Fig. Piezo electric Accelerometer.

- If the base is now accelerated downwards, inertial reaction force on the base acts upwards against the top of the box. This relieves stress on the crystal. From Newton's 2nd law:-

  $$\boxed{\text{Force} = \text{mass} \times \text{acceleration}}$$

  Mass is fixed quantity, the decrease in force is in proportional to the acceleration. Likewise, an acceleration is upward direction would increase the force on the crystal in proportion to the acceleration. The resulting change in the O/P voltage is recorded & Corrected to the acceleration imposed on the base.

Advantages & Limitations:-

- Rugged and inexpensive device.
- High output impedance.
- High frequency responses from 10HZ to 50KHZ.
- High sensitivity varies from 10 to 100 mv/g

Where, $g = 9.807\ m/s^2$

- Capability to measure acceleration from a fraction of g to thousands of g.
- Somewhat sensitive to changes in temp.
- Subjected to hysteresis errors.

Seismic transducer or Displacement Sensing accelerometer:-

A schematic diagram of a seismic transducer is shown in figure. It is also called a seismic accelerometer. The mass is connected through a parallel spring and damper arrangement to a housing frame.

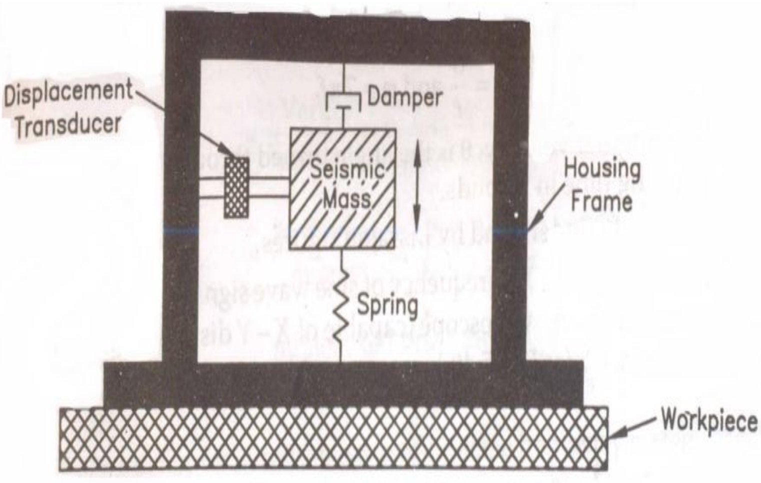


Fig. Seismic accelerometer.

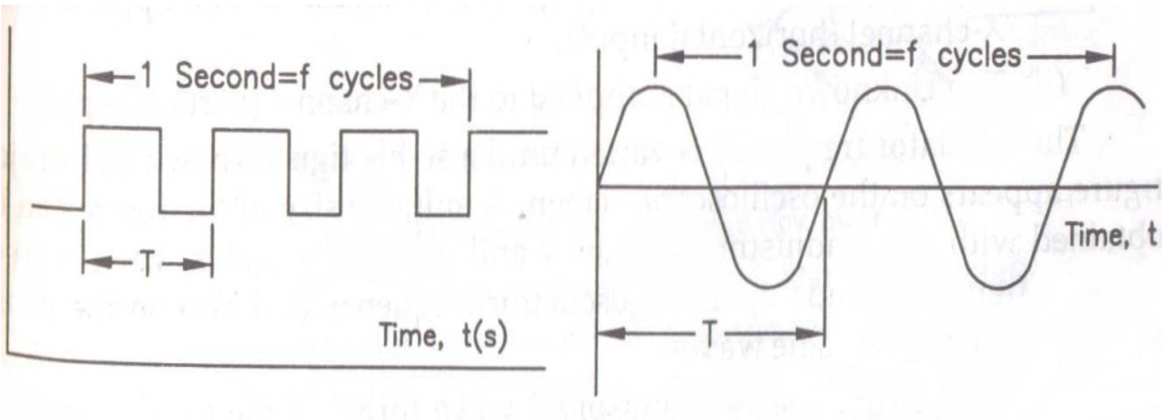
The housing frame is connected to the source of vibrations whose characteristics are to be measured. The mass has the tendency to remain fixed in its original position. So, that the vibration motion is registered as a relative displacement between mass and housing frame. This displacement is sensed and indicated by appropriate transducer. In this accelerometer, the displacement of a mass resulting from an applied force is measured and correlated to the acceleration. It also may be used as a vibration sensor.

<u>MEASUREMENT OF FREQUENCY:-</u>

Frequency is the no. of recurrences of a phenomenon on series of events during a given time interval. The unit of frequency is Hertz (HZ), which equals one cycle per second. The time taken for one cycle of events is known as periodic time (T-seconds)

$$F = 1/t \text{ Hz}$$

The concept of frequency & Periodic time



(a) Pulse wave form. (b) Sinusoidal wave form.

Fig. Pulse and sinusoidal wave form.

Many cyclic motions are rotational and the measured frequency of the motion has a linear relationship with the angular velocity which defines the rate of change of angular displacement about any axis.

$$w = \theta / t$$

&

$$w = 2\pi f$$

Where w = angular velocity

θ = Angle turned through in radiations

t = Corresponding time in seconds

Lissajou figures:-

The frequency of sine wave signals & the phase shift can be determined by an oscilloscope (capable of X-Y display) through the use of Lissajou fig.

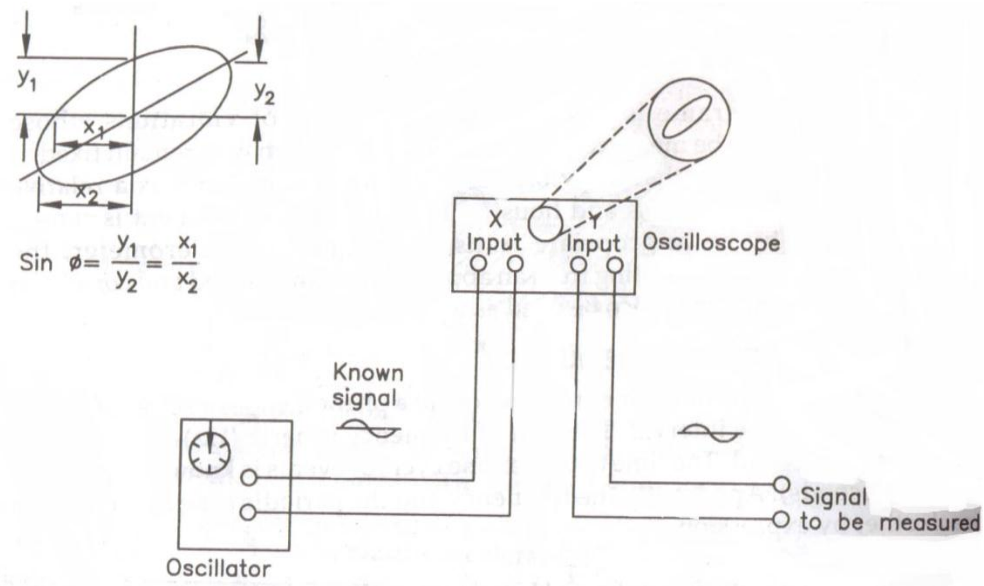


Fig. Schematic arrangement of an oscilloscope for frequency measurement (Lissajou Figure).

Two frequencies are impressed on the oscilloscope

(i) A known variable frequency signal from an oscillator is applied to be X- channel (horizontal input).

(ii) The unknown signal is applied to the Y- channel (Vertical input).

The oscillator frequency is varied until a stable figure is known as Lissajou fig. appears on the oscilloscope screen.

Phase shift ($\sin\theta = y^1 / y^2 = x^1 / x^2$)

Frequency = Vertical input frequency (f_y) / Horizontal input frequency (f_x)

MEASUREMENT OF HUMIDITY:-

Humidity:- It is known as the measure of water vapour present in a gas. It is usually measured as absolute humidity, relative humidity or dew point temperature. It is generally measured by hygrometers.

(a) Absolute humidity:- It is the mass of water vapour present per unit volume.

(b) Relative humidity:- It is the ratio of water vapour pressure actually present to water vapour pressure required for saturation at a given temperature. The ratio is expressed in percent. Relative humidity (RH) is always dependent upon temp.
(c) Dew point temperature:- It is the temperature at which saturation of water vapour pressure is equal to the partial pressure of water vapour in the atmosphere. The relative humidity at dew point is 100%. The dew point has also been defined as the temp. At which the quantity of water vapour in the atmosphere is sufficient to saturate this atmosphere with water vapour.

Hygrometers:-

A hygrometer measures the value of humidity directly. Generally, the output of a hygrometer is used to indicate relative humidity.

These are several types of hygrometers as

(i) Resistive hygrometer
(ii) Capacitive hygrometer
(iii) Microwave hygrometer
(iv) Aluminium oxide hygrometers
(v) Crystal hygrometers

Resistive hygrometer:-

A few hygroscopic salts exhibit a change in resistivity with humidity. The most common is lithium chloride. This, with a binder, may be coated on a wire or on electrodes. Resulting resistances changes cover a wide range i.e. 10^4 to 10^9 as the humidity changes from 100 to 0 percent. This makes it impractical to design a single element either with a Wheatstone bridge or by a combination of current & voltage measurements.

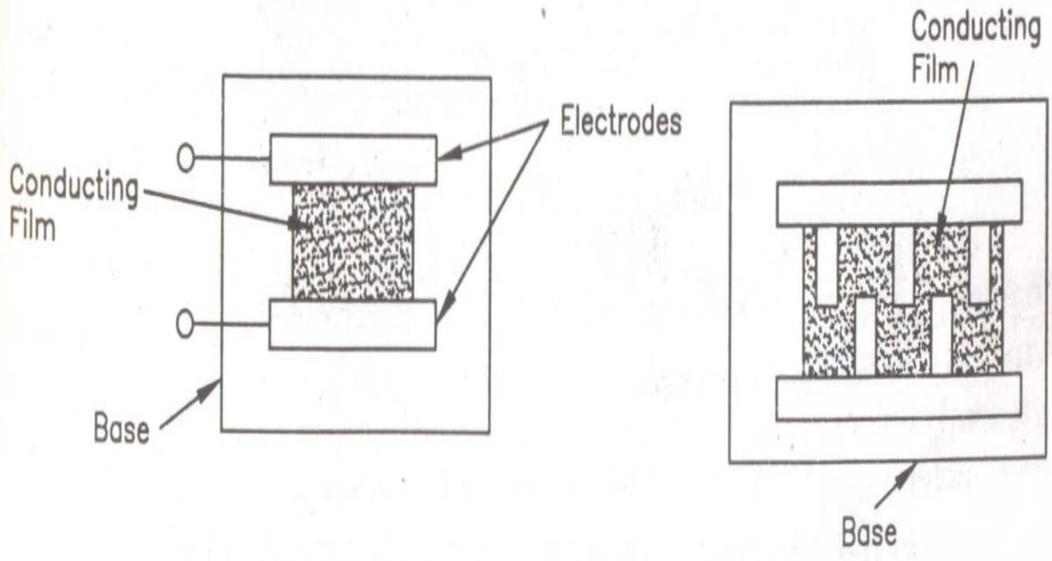


Fig. Resistive hygrometer.

It shows a mixture of lithium chloride and carbon which acts as a conducting film. This is put on an insulating substance between metal electrodes. The resistance of the element changes when it exposed to variations in humidity. The higher the relative humidity, the more moisture the lithium chloride will absorb, and the lower will be its resistance. The resistance should be measured by applying a.c. to the Wheatstone bridge. D.C voltage is not applied because it tends to breakdown the lithium chloride to its lithium & chlorine atoms.