AMIRAJ
COLLEGE OF ENGINEERING & TECHNOLOGY

LABORATORY MANUAL

MECHANICAL MEASUREMENT & METROLOGY

SUBJECT CODE: 3141901

MECHANICAL ENGINEERING DEPARTMENT

B.E. 4th SEMESTER

NAME:______________________________

ENROLLMENT NO: ______________________________

BATCH NO: ______________________________

YEAR: ______________________________

Amiraj College of Engineering and Technology,
Nr.Tata Nano Plant, Khoraj, Sanand, Ahmedabad.

COLLEGE OF ENGINEERING & TECHNOLOGY

Amiraj College of Engineering and Technology,
Nr.Tata Nano Plant, Khoraj, Sanand, Ahmedabad.

CERTIFICATE

This is to certify that Mr. / Ms. ____ Of class____________________ Enrolment No ___________________________has Satisfactorily completed the course in ____________________________________as by the Gujarat Technological University for ____ Year (B.E.) semester___ of Mechanical Engineering in the Academic year_______.

Date of Submission:-

Faculty Name and Signature
(Subject Teacher)

Head of Department
(Mechanical)

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List Of Experiments

Sr. No.	Title	Date of Performance	Date of submission	Sign	Remark
1.	Study of Instrument Characteristics				
2	Study of Linear Measurement Instruments				
3	Study of Angular Measurement Instruments				
4	Study of Different Types of Gauges				
5	Measurment of Gear Tooth Thickness				
6	Study of Pressure Measurement Instruments				
7	To Study Temprature Measurement Instruments				

PRACTICAL # 1 : STUDY OF INSTRUMENT CHARACTERISTICS

Objective : To Study about instrument characteristics

1. Range & Span

The region between the limits within which an instrument is designed to operate for measuring, indicating or recording a physical quantity is called as range of the instrument. The range is expressed by stating the lower and upper values of span. The span represents the algebraic difference between the upper and lower range values of the instrument.

Range : -10 to 80 Span : 90

Range : 5 kg/cm2 to 100 kg/cm2 Span : 95 kg/cm2

Range : 0 volt to 75 volt Span : 75 volt

2. Accuracy, Error & Correction

No instrument gives an exact value of what is being measured. There is always some uncertainty in the measured value. The uncertainty is expressed in terms of accuracy and error. Accuracy of an indicated value may be defined as conformity with or closeness to an accepted standard value. Accuracy of the measured signal depends upon the intrinsic accuracy of the instrument itself, variation of the signal being measured, accuracy of the observer and whether or not the quantity being truly impressed upon the instrument. For e.g. the accuracy of a micrometer depends upon factors like error in screw, anvil shape, temperature difference and the applied variation, etc.

In general the result of any measurement differs somewhat from the true value. The difference between the measured value (V_m) and true value (V_t) of the quantity represents the static error or absolute error of measurement (E_s), i.e., $E_s = V_m - V_t$

The error may be either positive or negative. For positive static errors, the instrument reads low.

From experimentalist's viewpoint, static correction or simply correction (C_s) is more important than the static error. The static correction is defined as the difference between the true value and the measured value of a quantity, i.e., $C_s = V_t - V_m$.

The correction of the instrument reading is of the same magnitude as the error but opposite in sign i.e. $C_s = - E_s$

3. Calibration

The magnitude of the error and consequently the correction to be applied is determined by making a periodic comparison of the instrument with a standard, which are known to be constant. The entire procedure laid down for making, adjusting or checking a scale so that reading of an instrument or measurement system confirm to an accepted standard is called calibration. The graphical re-presentation of the calibration record is called the calibration curve and this curve relates standard value of input or measurement to actual value of output throughout the operating range of the instrument. A comparison of the instrument reading may be made with :

1) A primary standard

2) A secondary standard of accuracy greater than the instrument to be calibrated

3) A known input source

For example, we may calibrate a flowmeter by computing it with an another flowmeter which has already been compared with a primary standard, or by direct comparison with a primary measurement such as weighing a certain amount of water in a tank and recoding the time elapsed for this quantity to flow through the meter.

The calibration standards along with their typical accuracies for certain physical parameters have been given in the table. The calibration standard should be atleast an order more accurate than the instrument being calibrated.

The following points and observation need consideration while calibrating an instrument.

1) Calibration of the instrument is carried out with the instrument in the same position and subjected to the same temperature and other environmental conditions under which it is to operate while in service.
2) The instrument is calibrated with values of the measured parameter both in the increasing and in the decreasing order. The result are then expressed graphically. Typically the output is plotted as the ordinate and the input is measured as the absicca.
3) Output reading for series of a impressed values going up the scale may not agree with the output reading for the same input values when going down.
4) Lines or curves plotted in the graph may or may not close to form a loop.

   In a typical calibration curve, ABC represent the reading obtained by ascending the scale. DEF represent the reading during descend. KLM represent the medium and is commonly accepted as the calibration curve. The terms medium refer to the means of series of up and down reading. Quite often, the indicated values are plotted as absicca and the ordinate represents the variation of the medium from the true values.

   A faired curve through the experimental points then represents the correction curve. This type of deviation presentation facilitates a rapid visual assessment of the accuracy of the instrument. The user looks along the absicca for the value indicated by the instrument. It then reads the correction to be applied. A properly prepared calibration curve gives information about absolute static errors of measuring device. The extents of the instrument linearity or conformity and the hysteresis and repeatability of the instrument.

4. Hysteresis & Dead Zone

From the instrument calibration curve, it would be noted that the magnitude of the output for a given input depends upon the direction of the change of input. This dependence upon previous input is called hysteresis. Hysteresis is the maximum difference for the same measured quantity between the upscale and down scale readings during the full range traversing each direction. Maximum difference is frequently specified as % of full scale.

Hysteresis results from the presence of irreversible phenomenon such as mechanical friction, slack motion in bearing and gears, elastic deformation magnitude and thermal effects. Hysteresis may also occur in electronic system due to heating and cooling effects, which occur differently under condition of rising and falling points.

Dead Zone is the largest range through which all input signal can be varied without initiating any response from the indicating instrument. Friction to play is the direct cause of dead zone.

5. Drift

It is an undesired gradual departure of the instrument output over a period of time that is unrelated to change in output, operating condition or load, wear and tear, high stress developing at some parts and contamination of primary sensing element. It may occur in obstruction flow meter because of wear and erosion of the orifice flange, nozzle or venture meter. Drift occur in thermocouples and resistance thermometer due to the contamination of the metal and change in atomic or metallurgical structure. Drift occurs very slowly and can be checked only when periodic inspection and maintenance of the instrument.

6. Sensitivity

Sensitivity of instrument or instrumentation system is the ratio of the magnitude of the response to the magnitude of the quantity being measured. (input signal)

Static Sensitivity, K = Change of output signal / Change of input signal

Sensitivity is represented by slope of the calibration curve if the ordinates are the expressed in actual units. With a linear calibration curve, sensitivity is constant, however, if the calibration curve is non-constant and must be specified in terms of input values as shown in figure.

Sensitivity has a wide range of units, and these depend upon the instrument or measurement system being investigated. For example, the operation of a resistance thermometer depends upon a change in temperature and as such its sensitivity will have unit of Ohm/^{O}C. Sensitivity system is usually required to be as high as possible because it becomes easier to take the measurement. Let the different elements comprising a measuring system have static sensitivities of k_1, k_2, k_3, etc. When these elements are connected in series or cascade then the overall sensitivity is worked out from the following relation.

$k_1 = \theta_1 / \theta_2$; $k_2 = \theta_2 / \theta_1$; $k_3 = \theta_0 / \theta_2$

Overall sensitivity $k = \theta_0 / \theta_1 = (\theta_1 / \theta_0) \times (\theta_2 / \theta_1) \times (\theta_0 / \theta_2) = k_1 \times k_2 \times k_3$

The above relation is based upon the assumption that no variation occurs in the value of individual sensitivities k_1, k_2, k_3, etc. due to loading effects.

When the input to the output from the measurement system used with electrical / electronic equipment have the same form. The term gain is used rather than sensitivity. Likewise an increase in displacement with the optical and mechanical instrument is described by the term amplification.

Apparently the terms sensitivity, gain and magnification all mean the same, and they describe the relationship between output and further when the input or output signal is changing with time, the term transfer or transfer operator is used than sensitivity gain or amplification.

7. Threshold and Resolution

The smallest increment of quantity being measured which can be detected with certainty by an instrument represents the threshold. When the input signal is gradually increased from zero, there will be some minimum value of input which is necessary to cause a detectable change from zero output. In a digital system, it is the input signal necessary to cause one least significant digit to cause one least significant digit of output reading to change. Thresh-hold may be caused by backlash or internal noise.

When the input signal is increased from non-zero value, one observes that the instrument output does not change until a certain input increment is exceeded. This increment is termed as resolution. It is determined by the ability of the observer to judge the position of a pointer on a scale e.g. the level of mercury in a glass tube. Resolution is usually reckoned to be no better than about +0.2 of the smallest scale division. With digital instruments, resolution is determined by the number of neon tubes taken to show the measured value. For e.g. if there are four neon tubes to represent voltage measurement on a 1 volt range, one tube will be taken by decimal point and the others by digits to show reading up to a maximum of 0.9 volts. Thus, the third digit shows or resolves the milli volts and consequently the resolution is 1 mV. Thresh-hold and resolutions may be expressed as an actual value or as a fraction or % of full scale value.

8. Stability

Stability refers to the reproducibility of the mean reading of an instrument repeated on different occasions separated by intervals of time which are long compared with the time of taking a reading. The condition of use of the instrument remains un-changed.

9. Linearity

The working range of most of the instrument provides a linear relationship between the output and input. This aspects tend to facilitate a more accurate data reduction. Linearity is defined as the ability to produce the input characteristics symmetrically and this can be expressed by straight line equation.

$Y = mv + c$; where

Y is the output

m is the slope of input vs. output curve / calibration curve v is the input

c is the intercept

Apparently the closeness of calibration curve to a specified straight line is the linearity of the instrument.

Any departure from the straight line relationship is due non-linear elements in the measurement device, mechanical Hysteresis, viscous flow or creep, and elastic after effects in the mechanical system. In a nominally linear measurement device, the non-linearity may take different forms as illustrated.

9.1 Theoretical slope linearity

Maximum departure as from the theoretical straight line between the theoretical endpoints, and it is drawn with respect to any experimentally determined values.

9.2 End point linearity

Maximum departure from the straight line or passing through the terminal reading.

9.3 Least square linearity

Maximum departure from the best fit straight line is determined by least square method.

In most of the instruments, the linearity is taken to be the maximum deviation from linear relationship between input and output i.e. from a constant sensitivity and is often expressed as a percentage of full scale.

The calculation of measurement error requires numerical value of accuracy, resolution and linearity, etc.

For the instrument being used, for majority of laboratory instruments, this data is given in a manufacture handbook. However for same instrument such as micro-meter, Vernier Callipers, thermometers and material testing equipments, the data is given in the standard maintained by the country.

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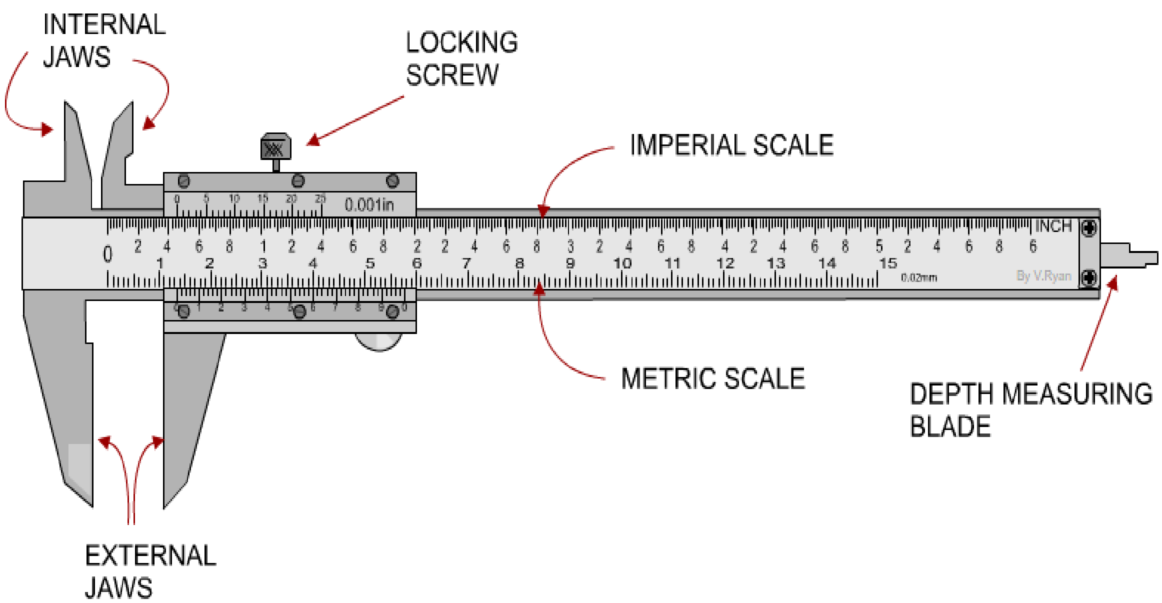
PRACTICAL # 2 : STUDY OF LINEAR MEASUREMENT INSTRUMENTS

Objective : To Study Vernier Callipers and Micrometer and measure the dimensions of given job.

1. VERNIER INSTRUMENT



1.1 Working principle

The principle of Vernier is that when two scale or divisions are slightly differing in size use. The difference between them is used to enhance the accuracy of the measurement. One of the scale i.e. main scales is engraved a solid shaped frame. On this scale cm graduations are divided into 20parts. So that one small division equals 0.05cm. One ends of frame contain a solid jaw, which is shaped into a contact tip at its extremity.

1.2 Construction

The free end of Vernier Callipers are beam, fixed jaw, sliding jaw permit substantial improvements in the commonly used measuring technique over direct measurement with line graduated rules. The datum of the measurement can be made to co inside precisely with one of the boundaries of the distance to be measured. The closely observable correspondence of the reference makes on the slide with a particular alignment along error.

A sliding jaw, which moves along the guiding surface provided by the main scale, is couple to Vernier scales. When two measuring tip surface are in contact with each other, scale shows zero reading. The nut B is tightened. Final adjustment depending upon the sense of correct feed is made by adjusting screw. The movement of adjusting screw makes the part containing locking nut A and sliding jaw to move, as the adjusting screw rotates on the screw which is in away fixed to the fixed to the movable jaw. After final tightened and the reading is noted down. The measuring tip is so designed that it can measure inside and outside diameter dimensions.

1.3 Reading the Vernier Scale

For understanding the working of Vernier scale let us assumes that each small division of the main scale is 0.025unit say the Vernier with division of main scale. So now one division of Vernier is 1/25 of 24scale division i.e. 1/25*24*0.025=0.024 unit.

Therefore, difference between one main scale small division and one Vernier division equal 0.025-0.024=0.001unit. It means if zero of main scale and zero of Vernier co-inside, then the first Vernier scale division will read 0.001 units less than the one small-scale division. Second Vernier division will read 0.002 units less than two small scale divisions and so on. Thus if zero Vernier scale lies in between two small division on main scale its exact value can be judged by seeing as of which Vernier division is co-inside with main scale division.

Thus to read a measurement from a Vernier Callipers, note the unit lengths and for tithe which the zero on the Vernier has moved from the zero on the main scale. Note down the Vernier division which co-inside with a scale division at to provide reading the number of thousand of unit indicated by the Vernier division ex. Reading in the scale is 3units to 0.1unit + 0.075unit + 0.008unit = 3.183units when the Vernier for internal measurement the width of measuring jaw must be taken into account.

LEAST COUNT: - $\dfrac{\text{Smallest division on main scale}}{\text{No. of division on Vernier scale}}$

MODEL CALCULATION:

Main Scale Reading =

Vernier Scale Coincides =

Measured Dimension= MSR + (VSC×LC)

1.4 Observation Table

COMPONENT	MAIN SCALE READING	VERNIER SCALE READING	MEASURED DIMENTION	AVERAGE(MM)
Inner Diameter				
Outer Diameter				
Thickness				
Depth				
Total Length				

1.5 Types of Vernier Calliperss

According to IS: 3651-1974 three types of Vernier Calliperss have been specified to meet the various needs of external and internal measurement up to 2000mm with Vernier accuracy of 0.002 to 0.05 &0.1mm. All the three types are made with only one scale on the front of the beam for direct reading. Type A has jaws on both sides for external & internal measurement and also has a blade for depth measurement. Type B is provided with jaw on one side for external and internal measurements. Type C has jaws on both sides for making the measurement and for making operations.

All parts of Vernier are made up of good quality steel and the measuring face hardened to 650HV minimum. The recommended measuring range of Vernier Calliperss as per IS: 365-1947 is 0-125, 0-200, 0-250, 0-300, 0-500, 0-1000, 750-1500 & 7500-2000mm.

On type A scale server for both external and internal measurements where as in case of type B & C, the main scale serves for external measurements and for making purpose also in type C but in types B & C internal measurements are made by adding with or the scale. For this reason, the combined width for internal jaw is marked on the jaws in case of types B & C Calliperss. The combined width should be 'V' form throughout its length width in 0.001mm.

Graduations on beam are at every 1/2mm and every alternate mm lines are extended 2number 2.4, 6.8

On Vernier scale there are 10 division within a distance of 9.5mm and 9.5mm=19division of main scale.

The beam for all the type is made flat throughout its length to within the tolerance of 0.05lmm for nominal length up to 2000mm, 0.08m from 9000 to 1000mm, 0.15 for 1500 and 2000mm sizes, and gauge surfaces of the beam are made straight to within 0.01mm measuring range of 200mm and 0.01mm over 2000mm and measuring range of large size. The measuring surfaces are given a fine ground finish. The fixed jaw is made integral part of the beam and the sliding fit along with the beam and made to have size are free movement along the bar. When sliding jaw is clamped to the beam at any position within measuring faces should remain square to the surface of the beam to within the measuring range.

The external measuring faces should remain square to the adjusting surface of the beam to within 0.003mm per 100mm. The external measuring faces are lopped flat to within 0.005mm. Each of internal measuring surfaces should be parallel to the corresponding external measuring surface to within 0.025mm in case of types B & C Calliperss. The internal measuring surfaces are formed cylindrically with radius not exceeds one half of their combined width.

1.6 Error in Measurements with Vernier Calliperss

Errors are usually made in measurements of Vernier Calliperss and its jaws on the work piece. For instance in measuring an outside Callipers bar and the plane of the Callipers jaws are truly perpendicular to the work piece is longitudinal centerline. I.e. one should be sure that the Callipers is not fitted. It happens because the relatively long extending main bar of the average Vernier Callipers so reading tips in one direction or the other.

The accuracy of the measurement with Vernier Calliperss to a great depends upon the conditions of the jaws of the Calliperss. The accuracy of the natural weans and warping of Vernier

Calliperss jaws should tested frequently by closing them together tightly or setting them the 0.0-point of the main and Vernier scales. In this position, the Callipers is held against a length source. If there is wear, spring or warp, a knock-kneed condition will be observed. If measurement error on this account is expected to the greater than 0.005mm the instrument should not be used and sent for repair.

When the sliding jaw frame has become worn or warped so that it doesn't slide squarely snugly on the main Callipers beam, then jaws would appear. Where a Vernier Callipers is used mostly for measuring inside diameter. The jaws may become bowlegged or its outside edges worn down .

1.7 Care In Case Of Vernier Calliperss

These should not be treated or used as a wrench or harmer because these are not rugged instruments. They must be wiped free from grit chip & oil. These should be brought to the work piece. The work piece should be clamped in the Callipers jaws and waved in air.

1.8 Precautions in the Use of Vernier Callipers

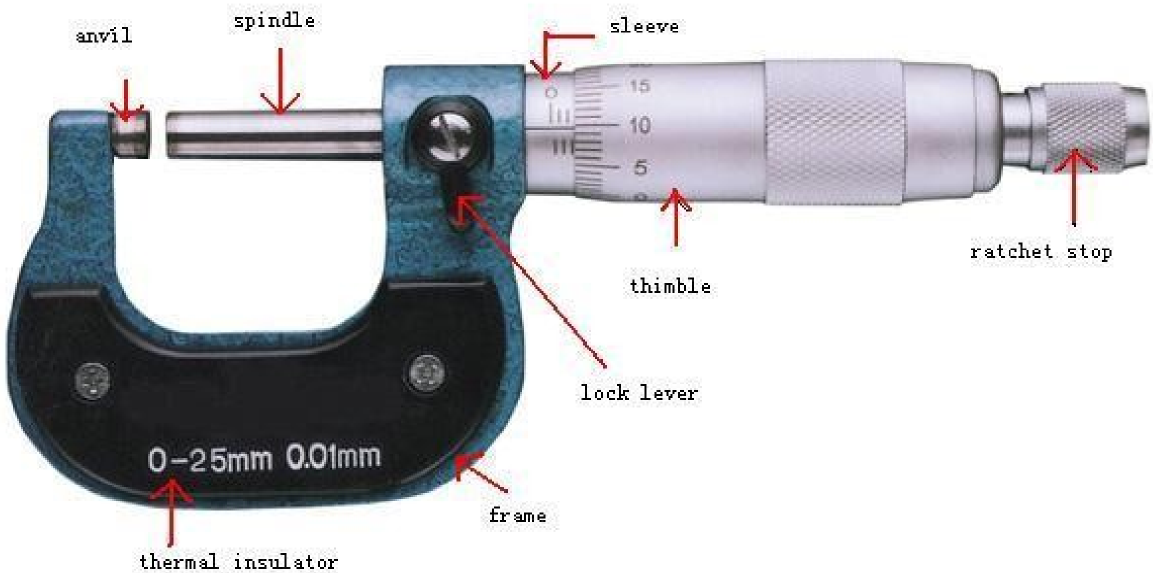
No play should be there between the sliding jaws on scale, otherwise the accuracy of the Vernier will be lost. If play exists then the job at the back of jaw assembly must be sent so that grid holds the jaw against the frame and play is removed. Usually the tip of measuring jaws are worth and that must be then into account. Most of the error usually from manipulations of the Vernier Calliperss and its jaws on the work piece.

In measuring an outside diameter, it should be insured that the Callipers bar and the plane of the Callipers jaws are truly perpendicular to the work piece's longitudinal centerline. It should be ensured that the Callipers is not fitted or twisted. The standard stationary Calliperss jaws of the Vernier should be used as the reference point and measured point and measured point is obtained by advancing or withdrawing the sliding jaw.

In general, the Vernier Callipers should be gripped near or opposite the jaws; one hand for the stationary opposite the jaw on hand for the stationary jaw and the other hand for the generally supporting the sliding jaw. The instrument should not be held by the overhanging "tail" formed by the projecting main bar of the Callipers.

The accuracy in measurement primarily depends on two sense of sight and sense of tooth. The shortcoming of imperfect vision can however be overcome by the use of corrective eyeglass and magnifying glass. But sense of touch is an important factor measurement sense of touch varies from person to person and can be developed with practice and proper handling of tools. Over one very important thing to note here is that sense of touch is most prominent in the fingertips therefore the measuring the instrument must always be properly balanced in hand and held tightly in such a way that only fingers handle held by force, then sense of feed is reduced. Vernier must always be held at short leaf of main scale and jaws never pulled.

2. MICROMETER



2.1 Reading a Micrometer

In order to make it possible to read up to 0.001 inch in micrometer screw gauge, a vernier scale is generally made on barrel. The vernier scale has 10 straight lines on barrel and this co- inside with exact division on thimble. Thus one small division on thimble is further subdivided into 10 parts and for taking the reading one has to see which of the vernier scale division is co-inside with a division of thimble accurately the reading for given arrangement in fig will be,

On main barrel : 0.120”
On thimble : 0.014”
On vernier scale : 0.001”
Total reading : 0.1342”

Before taking reading anvil and spindle must be brought to slitter carefully and the initial reading noted down. Its calibration must be checked by using standard gauge blocks.

In metric instrument the pitch of the screw thread is 0.5mm so that one resolution of the screw moves it axially by 0.5mm. Main scale on the barrel has least division of 0.5mm. The thimble has 50 divisions on its circumference.

So, one division on thimble scale = 0.5/50
= 0.001mm

If vernier scale is also incorporated then subdivision on thimble can be estimated up to an accuracy of 0.001mm. Reading of micrometer in fig is 3.5mm on barrel & y division on thimble
= 3.5+y (0.01)
= 3.5y mm

2.2 Cleaning the Micrometer

Micrometer screw gauge should be wiped free from oil, dust, and grit. When micrometer feels gummy and dust redder and the thimble fail to turn freely it should be bodily cleaned in kerosene or solvent because just soaking the micrometer fails to float the dirt away. Further it must be remembered that the apparent sticker of micrometer may not be due to grit and gum but it damage thread or to warped the spry frame or spindle.
Every time the micrometer is used, the measuring surface, anvil and spindle should be cleaned. Screw the spindle lightly but firmly down on to a clean piece of paper held between spindle and anvil. Pull the piece of paper out from between the measuring surface than unscrewed the spindle a few turns and blow our any fuzz particles of paper that may have damage to sharp edge of anvil and spindle.

2.3 Precaution in Using Micrometer

In order to set a good result out of the use of the micrometer screw gauge, the inspection of part must be made as follows. Micrometer should be cleaned of any dust and spindle should move freely.
The part whose dimension is to be measured must be held in left hand and micrometer in right hand. The way for holding the micrometer is place the small finger and adjoining figure in the U shape frame. The forefinger and thumb are placed near the thimble to rotate it and the middle finger supports the micrometer holding it firmly.
The micrometers are available in various sizes and ranges. The corresponding micrometer should be chosen depending upon the dimension. Error in reading may occurs due to lack of anvil, lack of parallelism of anvil, lack of flatness of anvil at parts of anvil parts of scale of through in accurate setting at zero reading etc. various tests to ensure these condition should be carried out from time to time.

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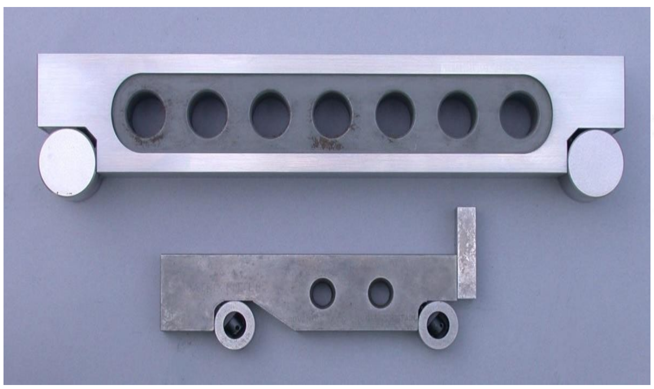
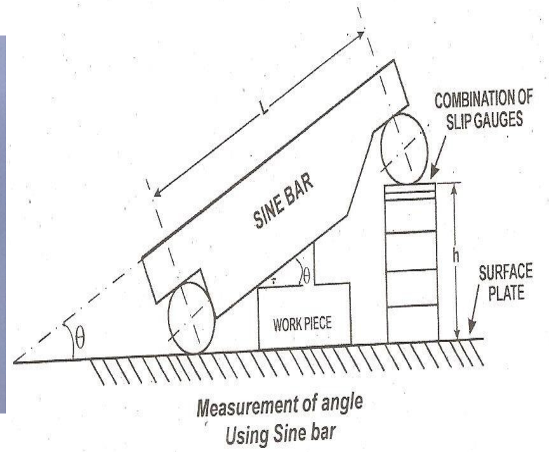
PRACTICAL # 3 : STUDY OF ANGULAR MEASURMENT INSTRUMENTS

Objective : To study angular measurement instruments like sine bar, bevel protector, angle gauge and measure the dimension of given job.

1. SINEBAR





1.1 Uses of Sine Bar

(1) Measuring Known Angle or Locating Any Work to A Given Angle
For this purpose the surface plate is assumed to be having a perfectly flat surface so that its surface could be treated as horizontal. One of the cylinders or roller of sine bar is placed on the surface plate and other roller is placed and the slip gauge of height h. Let the sine bar be set at an angle 900. Then sin =h/l, where l is the distance between the center of the rollers. Thus knowing h can be formed out and work could be at this angle as the top face of sine bar is inclined at angle to the surface plate. The use of angle plate and clamp could also be made in case of heavy components for better results both the rollers could also be placed on slip gauge of height h1 & h2 respectively. Then Sinθ = (h2-h1)/l

(2) Checking Of Unknown Angle
Many a times, angle of component to be checked is unknown. Un such a case it is necessary to first find the angle approximately with the help of a bevel protector. Let the angle be θ then the sine bar is set at an angle θ is placed on sine bar and clamped to an angle plate. Next the work is placed on sine bar as shown in figure. And dial indicator is set at one end of the work piece and move to the other and elevation is noted again slip gauges are so adjusted that dial indicator roads zero across work surface. It deviation noted down by the dial indicator to ever a length 'l' of work then height of slip gauge by which it should be adjusted is equal to h*/l'

In such case where component are heavy sine bar is mounted on the components as shown in fig. The height over the roller and then be measured by a vernier height gauge using a dial test gauge mounted on the anvil of height gauge as the fiducially indicator to ensure constant measuring pressure the anvil of height gauge is adjusted with prop of dial test gauge showing some reading for the top most position of rollers of sine bar fig shows the use of height gauge for obtaining two reading for height of the roller of sine bar. The difference of two readings of height gauge divided by the center distance of sine bar gives the sine of the angle of the component to be measured. There greater accuracy is required the position of dial test gauge probe can be sensed by adjusting a pipe of slip gauge till dial indicator indicates same reading over roller of sine bar and the slip gauges.

1.2 Precautions in Use of Sine Bars

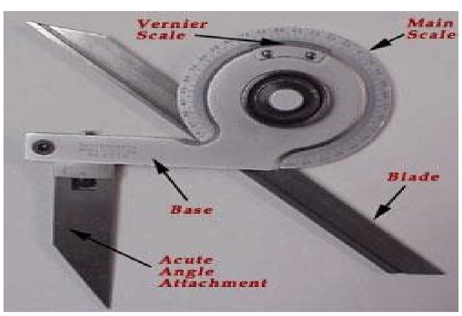
- The sine bar should not be used for angle greater than 60 because any possible error in construction is accentuated at this limit.
- A compound gauge should not be formed by this miss aligning of work piece with the sine bar. This can be avoided by attaching
- Accuracy of sine bar should be ensured
- As far a possible longer sine bar should be used since may errors are reduced by using longer sine bar.

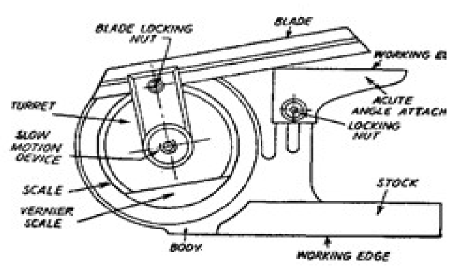
2. BEVEL PROTRACTOR

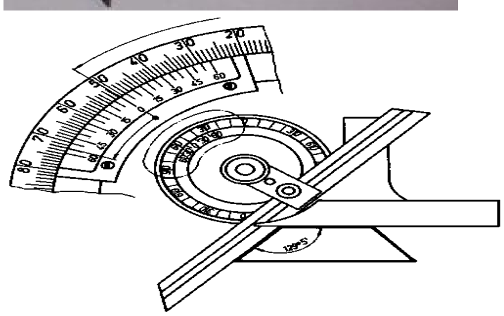
2.1 Bevel Protector as Per Indian Standard Practice

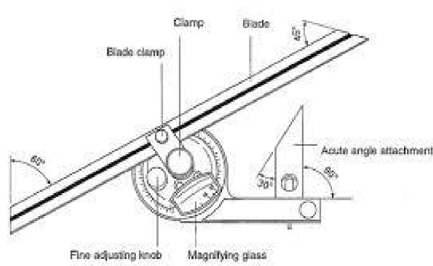
The bevel protectors are of two types

- Mechanical Bevel protector









- Optical Bevel protector

The mechanical bevel protectors are further classified into four types A, B, C & D. In types A & B the vernier is graduated to read to 5minutes of arc. Where as in case of type C the scale is graduated to read in degree and the bevel protector is without vernier or fine adjustment device or actual angle attachment. The difference between types A & B is that type A is provided with fine adjustment where as type B is not. The scales of all types are graduated either as a full-scale circle marked 0-90-0 with two vernier 180 apart. Type D is graduated in degree and is not provided with either vernier or fine adjustment device or actual angle attachment.
In the case of optical bevel protector it is possible to take readings up to approximately 2minutes of arc. The provision is made for internal circular scale, which is graduated in divisions of 10 minutes of arc. Reading is taken against a fixed index line or vernier by means of an optical magnifying system, which is hygral with the instrument.
The scale is graduated as a full circle marked 0-90-0-90. The zero positions correspond to the condition when the blade is parallel to the stock. Provision is also made for adjusting the focus of the system to accommodate normal variations in eyesight. The scale and vernier are so arranged that they are always in focus in the optical system. The principle of optical scale has already been discussed in details.

2.2 General Description of Various Components of Bevel Protectors

2.2.1 Body
It is designed in such a way, which is no projection beyond its back so that when the bevel protector is placed on its back on surface plate there shell is no perceptible rock. The flatness of the working edge of the stock and body is tested by checking the sequence of blade with respect to stock when blade is set at 900.

2.2.2 Stock
The working edge of stock is about 90mm in length and 7mm thick. It is very essential that the working edge of the stock is perfectly straight and if at all departure is there, it should be in the form of concavity and of the order of 0.01mm maximum over the whole span.

2.3.3 Blade
It can be moved along the turret throughout its length and can also be reversed. It is about 150 or 300mm long, 13mm wide, and 2mm thick and end beveled at an angle of 45 and 600 within the accuracy of 5 minute of arc. Its working edge should be straight up to 0.02mm and parallel up to 0.03mm over the entire length of 300mm. It can be clamped in any position.

2.4.4 Acute Angle Attachment
It can be readily fitted into body and clamped in any position. Its working edge should be flat to within 0.005mm and parallel to the working edge of the stack within 0.015mm over the entire length of attachment. The bevel protectors are tested for flatness, squreness, parallelism, straightness and angular intervals by suitable methods.

3. ANGLE GUAGES

3.1 Uses of Angle Gauges

3.1.1 Direct Use of Angle Gauges to Measure the Angle in the Die Insert

To test the accuracy of the angle in the die insert, the insert is placed against in illuminated glass surface plate of in front of an inspection light box. The combination of angle gauge is adjusted and the built up combination of angle gauge carefully inserted in position so that no while light can be seen between the gauge faces and die faces. It may be noted that when all the engraved Vs on the angle gauge are in the same line, all angles are added up. In case some engraves Vs on angle gauges are on other sides, those angles are subtracted.

3.1.2 Use of Angle Gauges with Square Plate

As already indicated, the use of square plate increases the versatility of the application of angle gauges. Generally the square plate has its 900 angle graduated within 2seconds of arc. Where very high degree of accuracy is required, the four corners of the square plate are numbered as A, B, C & D and at least certified measured angle of each corner. Fig shows a set up to test the angle of V-gauge whose included angle is 1020. The whole set up is placed against an illuminated glass surface plate. It may be noted that the use of slip gauge has to be made in order to facilitate the testing.
So far we have used angle gauge to obtain in a visual comparison of an angular dimension under test. It has also been realized that through it may be possible to obtain good result but it is difficult to give an estimate of the actual angular error. For very precise angular measurements, angle gauge are used in conjunction with angle Dekker described latter.

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PRACTICAL # 4 : STUDY OF DIFFERENT TYPES OF GAUGES

Objective : To Study different types of gauges

1. Plain Plug Gauge

Generally the gauge members of the plain plug gauges are made of suitable wear resistance steel and the handles can be made of any suitable steel e.g. handle may made of light metal alloys for heavy plain gauges or suitable non metallic handle may be provided for smaller plain plug gauges. The gauging surface of plain plug gauge is normally hardened if not less than 750HV and suitably stabilized and ground and lapped.

The plain plug gauges are normally of double-ended types for size up to 63mm. The usual way of designating the plug gauge is by 'Go' and 'No go' as applicable, the nominal size, number of the standards followed e.g. a double ended 'Go' or 'No go' plain plug gauge for gauging a bore of 10mm with tolerance H7 and it designated according to Indian standard shall be designed as:

'Go' and 'No go' plain plug gauge 10H7 I 3484. The various types of plain plug gauges in common use are as below :

1. 'Go' and 'No Go' plain plug gauges for size up to 10mm (solid type)
2. 'Go' and 'No Go' plain plug gauges for size over 10 and up to 30mm
3. 'Go' and 'No Go' plain plug gauges for size over 10 and up to 63mm
4. 'Go' and 'No Go' plain plug gauges for size over 63mm and up to 100mm.
5. 'Go' and 'No Go' plain plug gauges for size over 100mm and up to 250mm (flat type).

This is a shell from plug gauge. Each plug is caved to reduce weight. For still further bigger holes and to restrict weight use can be made segmental cylindrical indeed gauges spherically indeed rods are used for very large holes. It would be noted that with such types of gauges the full form of the gauge is lost and the errors of holes like ovality may not be detected. It is general practice not be use cylindrical plugs above 100mm diameters but to use cylindrical indeed bar or spherically indeed similarly 'Go' gauges between the sizes of 100 and 200mm diameter can take the forms of cylindrically indeed bar.

The plain gauges are marked with the following on their handles for their deification:

1. Nominal size
2. Class of tolerance
3. The word 'Go' on the 'Go' side

4. The word ‘No go’ on the ‘No go’
5. The actual value of tolerance
6. Manufacturer’s name or trade mark

The ‘No go’ side is always painted with a red band. It is usual practice to apply a anti corrosive coating to the plug gauges in order to protect them damage in handling and transmit these are packed in suitable case. It may be mentioned that gauges with the gauging portion integral with the handle are now becoming obsolete and gauges with renewable ends are going popularity because of the following advantages:

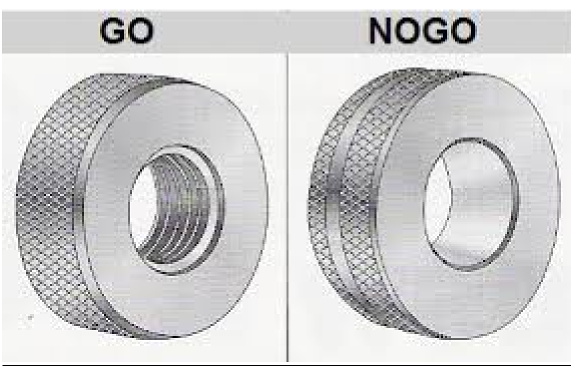
Worn or damage end can be replaced conveniently

In the event of scraping of gauge handle can be use for other gauges

To reduce the weight, handle can be made of plastic, which also facilitates in handling the gauges, reduces cost and minimizes risk of heat transfer.

For smaller through holes, and their useful renewable end plug gauge is the progressive type of gauge in which both the ‘Go’ and ‘No go’ gauging members are provided n same side, separated by a small distance. First ‘Go’ portion is inserted in hole, which would be further obstructed by ‘No go’ portion if hole is not tolerable size.

2. Plain Ring Gauge



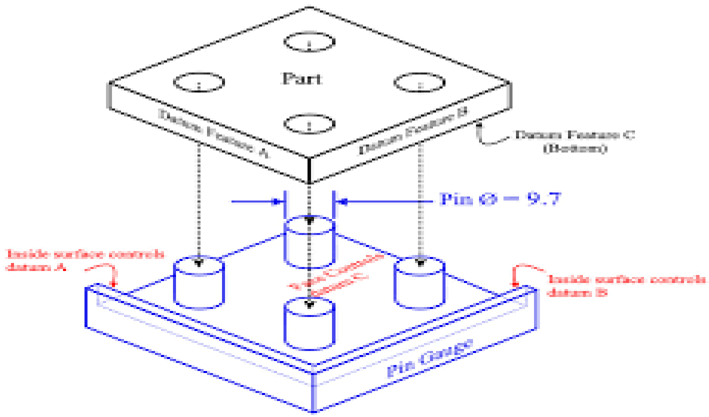
The plain ring gauges are made of suitable wear resisting tool and the gauging surface are hardened to a hardness of about 720HV. The gauging surfaces are first suitable stabilized using proper heat treatment process and then graduated and lopped and other surfaces are finished smooth. These are protected against climatic conditions by applying a suitably anticorrosive coating.

These are available into design ‘Go’ and ‘No go’ as may be applicable to be gauged another number of the standard followed.

The general shape of ‘Go’ and ‘No go’ gauge for range from 3to 70mm in 10 steps and from 70 to 250mm in 17steps Dimensions d2 varies from 22mm to 112mm correspondingly b varies from 5 to 22mm and c from 0.4to 16mm. For Dimensions d1=120 to 355 dimension d2 varies from 100mm to 230mm b from 12 to 28mm from 2.5 to 4mm d3 from 3 to 6mm, d4 from 3 to 8mm. For dimension d2 varies from 22mm for range d1=3.5mm to 112mm for ranged d1=60-70mm corresponding b, varies from 3 to 8mm [from .4 to 1.6mm].

For dimension d1 varies from 125 to 355mm d2 from 100to 280, d4 from 113to 335, b1 from 10 to 25, b2 from 7 to 16, l from 1.5 to 4, (from 1 to 3, and 6 from 3 to 6mm).

3. Position Gauge



There is a wide variety of position gauges in common use and their design is based upon the shape of the work. Thus practically different position gauges are employed for checking the position of some feature on the work in relation to another point or surface. Their design can be based either on the principle of sighting the gauge or on the method of fed.

A simple gauge for checking the location of a recess in relation to a flat surface. Another simple design in which the location of a surface parallel to the reference surface is to be located. It may be noted that no light will pass between the reference surface and gauge surface in contact with go side and light will pass with 'No go'.

5. Taylor's Principle

According to Taylor 'Go' and 'No go' gauges should be designed to check maximum and minimum material limits which are checked as below.

'Go' limit: This designating is applied to that limit of the two limits of sizes which corresponds to the maximum material limit considerations i.e. upper limit of a shaft and lower limit of hole. The form of the 'Go' gauge should be such that it can check one feature of the component in one pass.

'No go' Limit: This designation is applied to that limit of the two limits of sizes, which corresponds to the minimum material condition, i.e. the lower limit of a shaft and the upper limit of hole. 'No go' gauge should check only one part of feature the component at a time. So that specific discrepancies in shapes on size can be defected. Thus a separated 'No go' gauge is required for each different individual dimension.

The 'Go' plug gauge is the size of the minimum limit of the hole while 'No go' plug gauge corresponds to the maximum limits. Gauging faces of a normal shape on gap gauge must be parallel and square to each other and the gauging points of contact with the work should be in the same plane. The difference in size between the 'Go' and 'No go' shape gauge as well as the difference between the Go and No go plug gauges is approximately equal to the tolerance of the tested hole and shaft. In case of standard gauges, rigidity and robustness of shape gauge are important features so that gauges functions adequately and maintain size. Gauging diameter of component that are slightly longer than gap setting can produce highly welding action which may lead to gauges distortion and wrong interpretation of reading. Therefore larger gap gauge should preferably in the plain of gauge and sufficient rigidity in lateral direction.

Taylor's principle states that the 'go' gauge should check only one element of the diameter at a time.

To 'Go' plug gauge must be of corresponding section and preferably full length of hole so that straightness of hole can also be checked. Thus if not only controls diameters in any given section but also insures bore alienability. However if can't check the degree of ovality. To go plug gauge must be of co-responding section and preferably full length of hole so that straightness of hole can be checked. Thus if not only controls diameter in any given section but also insure bore aliqunability. However it can't check the degree of ovality.

The 'No go' gauge is relatively short and its function is dependent not only on the diameter but also on the circulatory of the hole. Thus to some extent, variation of the hole shape can be measured.

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PRACTICAL 5 :TO STUDY ABOUT MEASURMENT OF GEAR TOOTH THICKNESS BY GEAR TOOTH VERNIER

Objective : To study measure gear tooth thickness **by** ***gear tooth Vernier caliper***

1. Methods of measurement of gear tooth thickness

The permissible error or the tolerance on thickness of tooth is the variation of actual thickness. It is generally measured at pitch circle and is therefore, the pitch line thickness of tooth. It may be mentioned that the tooth thickness is defined as the length of an arc, which is difficult to measure directly. In most of the cases it is sufficient to measure the chordal thickness i.e. the chord joining the intersection of the tooth profile with the pitch circle. Also the difference between chordal tooth thickness and circular tooth thickness is very small for gear of small pitch. The checking of all other parameters, but thickness measurement is amount for all gears tooth thickness.

1. Measurement of tooth thickness by gear tooth Vernier caliper
2. Base tangent method
3. Constant chord method
4. Measurement of dimensions over pins

2. Measurement of gear tooth thickness by Gear tooth Vernier caliper

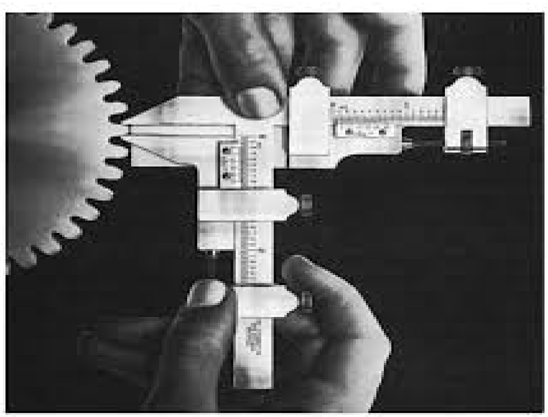

Figure 4-9 Correct use of the vernier gear-tooth caliper.
(Courtesy L.S. Starrett Co.)

It is used to measure the thickness of gear tooth at the pitch line or chordal thickness of teeth and the distance from the top of the tooth pitch line and an adjusting tongue on graduated base measures addendum. The effect of zero errors should be taken into consideration.

This method is simple and inexpensive. However it needs dissent setting for a variation in no of teeth for a given pitch and accuracy is limited by the least count of instrument since the wear during use is contracted on the two jaws. The caliper has to be calibrated at regular interval to maintain the accuracy of measurement.

The tooth thickness can be very conveniently measured by and gear tooth Vernier since the gear tooth thickness varies from tip to the base circle of the tooth. The instrument must be capable of measuring the tooth thickness at a specified position on the tooth. Further this is possible only when there is some arrangement to fix that position where the measurement is to be taken. The tooth thickness is generally measured at pitch circle and is therefore referred to as pitch line thickness of the tooth. The gear tooth Vernier has two Vernier scale and they are set for the width (w) of the tooth and depth (d) from the top at which width (w) occurs.

Considering one gear tooth, the theoretical values of w and d can be found out which may be verified by the instrument. In the fig it may be noted that w is a chord ADB, but tooth thickness is specified as an arc distance AEB. Also the distance d adjusted on instrument is slightly greater than addendum CE, w is therefore called chordal thickness and d is tooth thickness

AB=2AD

$$OD = RCOS\theta$$

$$= \frac{TM}{2} COS\theta \left\{ \frac{90}{T} \right\}$$

Therefore,

$$h = \frac{TM}{2} + m - \frac{TM}{2} \cos\left(\frac{90}{t}\right)$$ Now AOD= θ = 360/4T where T is no of teeth

$$h = \frac{TM}{2}\left(1 + \frac{2}{T} - \cos\left(\frac{90}{T}\right)\right)$$

$$h = m + \frac{TM}{2}\left(1 - \cos\left(\frac{90}{T}\right)\right)$$

w = 2AD = 2Asin θ =2Asin360/4T

Module, m = P.C.D. /no. Of teeth

= 2R/T

So, R= mT/2

W = 2mT/2 *sin360/4T

=mT sin 90/T ………………………… (1)

Also from fig d=OC-OD

But OC = OE+ addendum =R+m= (mT/2 +m)

& OD = Rcos

$$= \frac{TM}{2} COS\theta \left\{ \frac{90}{T} \right\}$$

Therefore,

$$h = \frac{TM}{2} + m - \frac{TM}{2} \cos\left(\frac{90}{t} \right)$$

$$h = \frac{TM}{2} \left(1 + \frac{2}{T} - \cos\left(\frac{90}{T} \right) \right)$$

$$h = m + \frac{TM}{2} \left(1 - \cos\left(\frac{90}{T} \right) \right)$$

<u>3. Drawbacks of the method</u>

The Vernier method is not very satisfactory because of the following reasons

1. Least count of Vernier itself is not the best.

2. The measurement depends upon two Vernier readings, which are function of each other.

3. Measuring is made with the edge of the measuring jaw, not its face, which again does not lead itself to an accurate measurement.

These can be overcome with measuring thickness of more then one number of teeth at a time with a Vernier caliper.

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PRACTICAL 6 : STUDY OF PRESSURE MEASUREMENT INSTRUMENTS

Objective : To study pressure measurement device and calibration of spiral type pressure gauge with dead weight piston gauge.

1. Introduction

Following terms are generally associated with pressure and its measurement:

1.1 Atmospheric pressure (Pat.)

This pressure exerted by the envelope of air surrounding the earth's surface. Atmospheric pressure is usually determined by mercury. The open and is stopped and the tab e is inserted into a mercury container. The stopper end kept well beneath the mercury surface. Atmospheric pressure acts at the mercury surface in the container and the mercury vapor pressure exists at the top of mercury column in the tube.

From hydrostatic equation,

$$P_{at} - P_{vp} = \rho gh$$

Mercury has low vapor pressure $1.6*10^{-2}$ kgf\cm^2 at 20 degree C. and thus for all intents and purposes it can be neglected in comparison to p_{at}, which is about 1.0 kgf\cm^2 at mean sea level. Then

$$P_{at} = \rho gh$$

Atmospheric pressure varies with altitude, because the air meager the earths surface is compressed by air above. At sea level, valve of atmospheric pressure is close to 1.01325 bars or 760 mm mercury column.

1.2 Absolute pressure (Pabs)

Pressure has been defined as the force per unit area due to interaction of fluid particles among themselves. Zero pressure intensity will occur when molecular momentum is zero.

Such a situation cans occur only when there is a perfect vacuum. Pressure intensity measured from this state of vacuum of zero pressure is called absolute pressure.

1.3 Gauge pressure (Pg) and Vacuum (Pac)

Instruments and gauges used to measure the fluid pressure generally measure the difference between the unknown pressures Pat at shown in fig. When the unknown pressure is more than atmospheric pressure recorded by the in strain is called gauge pressure. A pressure reading below the atmospheric pressure in known as the algebraic sum of the gauge indication and the atmospheric pressure. Relation between the pressure terms is in fig.

$$P_{abs} = P_{at} + P_g$$

$$P_{abs} = P_{at} - P_{vac}$$

1.4 Static pressure (Ps) and Total pressure (Pt)

Static pressure is defined as the force per unit area on the wall by the fluid at rest. Following parallel to the wall in a pipeline.

Static pressure of moving fluids is measured with an instrument which is at rest relative to the fluid care is taken to ensure that the tube does not protégé into pipe line and cause errors due to impact and eddy formation whine the tuber protrudes into the seam three would be local spending up of the flow due to its deflection around the tube, hence on erroneous reading of static pressure would be observed.

Total or stagnation pressure is defined as the pressure that would be obtained if the fluid steam there would be local where brought to rest in centrifugally. In the fig probe B senses the total pressure gives the pressure due to fluid density, referred to as the dynamic pressure. The dynamic pressure is due to flow speed and is also known as the velocity or impact pressure for an incompressible fluid of a gas flowing at low velocity the dynamic pressure equal $v^2\backslash 2g$ where v is the velocity of fluid flow.

1.5 Pressure units

Some of the commonly used pressure units are

1 bar = $10^5 N/m^2$ = 750.06 mm of Hg

1 micron = 10^{-3} mm of Hg

1 micro bar = 1 $dyne/cm^2$

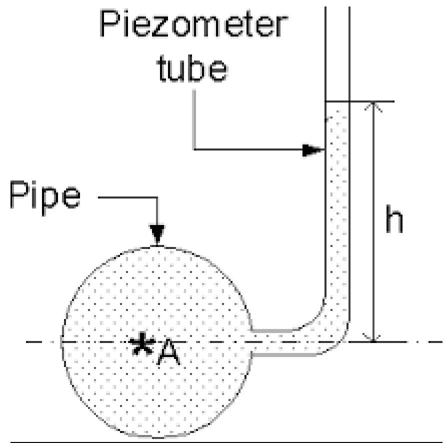
Quite often pressure is expressed in the unit atom. This unit simply uses the standard atom. Value of 1.01325 bar and defined as one atom. Two atmospheres would be 2.0664 kgf/cm^2. Sometimes we assume atmospheric pressure equivalent to rounded figure of 1 kgf per cm square.

Selection of one or another of the various units of pressure or head and pressure are related by the prostate equation $P = \rho gh$ where p is the pressure either absolute of gauge, h is the height of liquid column and ρ is the density of liquid. Conversions to standards conditions may also made by $h_s = h_m (\rho_m/\rho_s)$. where subscript s refers to conditions at the local measured temperature and subscript m refers to conditions at the desired standard temp.

2. Manometer

Manometer measures pressure by balancing a column of liquid against the pressure to be measured. Height of column so balance is noted and may be vertical inclined upon different or compound. Choice of and type depends on its sensitivity of measurement and measuring. Manometers can be used to measure gauge differential atom and absolute pressure.

2.1 Piezometer



It is a vertical transparent glass tube, the upper end of which is a pen to atom. And the lower end is I communications with the gauges point, a point in a communication with the gauge point a point in a fluid container at which pressure is to be measure at the pressure at that point.

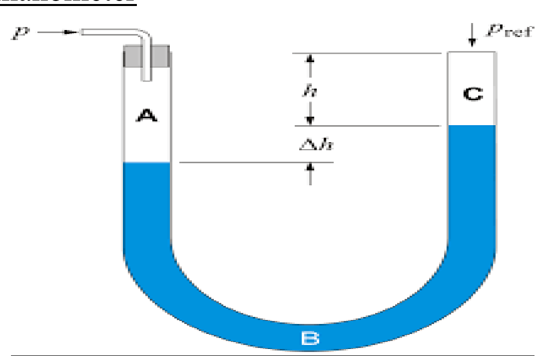
Fluid pressure at the gauge point = atmospheric pr.

Pressure at the free surface pressure due to a liquid column of height h : $P = Pa + \rho gh$

Where ρ is the density of the liquid pressure is are generally prescribed with atom. Pressure taken as zero of pressure scale evaluated is the gauge pressure.

When using a Piezometer to pressure the pressure of a moving fluid axis of the tube should be absolutely normal to the direction of flow and its bottom end must flats smoothly with the pipe surface. Further to reduce the tension and capillary effect, diameter of tube must be kept at least 6 mm. Piezometer cannot be used to measure pressure which are considerably excess of atom pressure use of very long glass tube would be unsafe if being both fragile and unmanageable further gas pressure can't be measured as gas con not form and free surface with atmosphere air. Their difficulties are overcome by modifying the Piezometer into a u tube manometer.

2.2 U-tube double column manometer



These simplest and useful measure devices consist of a transparent tube bent in the form of a letter U and partially filled with Manometric liquid whose density is known.

The choice of a particular Manometric liquid depends upon the pressure range and nature of fluid whose pressure is sought. For high pressure is the Manometric balancing liquid for low-pressure ranges, liquid like carbon tetrachloride or acetylene tetrachloride employed.

When both the limbs are open to atmosphere Manometric liquid fluid stands at even tight under application of pressure to one limb, Manometric fluid is forced downward on one side until a column of liquid between the two levels balances the difference between the unknown pressure Px and atom pressure Pa.

Due to greater pressure liquid is forced downwards in the lift limb of U-tube and there is a corresponding rise of Manometric equation is

$$Px + \rho_1 g_1 h_1 = Pa + \rho_2 g_2 h_2$$

Absolute pressure Px in container is

$$Px = Pa + \rho_1 g^1 h_1 + \rho_2 g_2 h_2$$

In term of heads:

$$Px\backslash \ \rho g = S_2 h_2 - S_1 h_1$$

Where ρthe density of water and symbol s is denotes the specific gravity of a liquid arrangement b measurement of pressure less than atm pressure.

Due to negative pressure Px in the container the Manometric liquid is containing fluid at pressure Pa Manometric liquid level in the reservoir will fall down and there will b e a corresponding level raise $h_2$in the narrow limb. By conservation of volume $A_o H = ah_2$, which give oh = (a\A) h2. Governing Manometric equation is

Pressure at point 1 in the left limb = pressure at point 2 in the right limb.

$$PX + \rho_1 g_1 h_1 + \rho_1 g\ \delta h = Pa + \rho_2 g_2 h_2 + \rho_2 g \delta x$$

Inserting the volume of δh we obtain the following expression for absolute pressure Px in the container,

$$Px = Pa + \rho_2 g_2 h_2 (1 + a\backslash A) - \rho_1 g[h_2 + h_2\ (a\backslash A)]$$

The underline term represent s the pressure due to liquid column in the reservoir and in the pipe connecting the reservoir to the source of pressure Px. If it is neglecting then,

$$Px = Pa + \rho_2 g_2 h_2$$

When the area ratio a\A is not negligible the scale may be calibrator in contracted units that is normal length units multiplied by A\a+A sucked upward in limb of the U- tube and there is a corresponding falls of Manometric liquid in right limb. The governing manometer equation is:

$$Px + \rho_1 g^1 h_1 + \rho_2 g_2 h_2 = Pa$$

Absoluter pressure in the container is

$$Px = Pa + \rho_1 g^1 h_1 - \rho_2 g_2 h_2$$

In terms of water column

$$Px\backslash \rho g = -\{s_1 h_1 + s_2 h_2\}$$

2.3 Single column manometer

In industrial well manometers one of the limb of a U-tube manometer is replaced by a large diameter will, the widened limb is made about 100times greater in cross-sectional area than the other limb. Pressure difference would then be inclined only by the height of liquid column in the narrow limb.

To start with lot both limbs of manometer be exposed to atom pressure. The liquid level in the wider limb and narrow limb will correspond to position 0-0. When the wider limb will correspond to a vessel.

Single column manometer is used as primary standard for calibrating other pressure gauge and is more sensitive than single U – tube manometer. However other manometers they are not portable and cost is more and unsuitable for reading.

2.4 Inclined manometer

To expand scale and thereby increase sensitivity, the narrow limb of the single column manometer is not set vertically but is kept inclined to the horizontal axis by an angle θ as shown in fig. Pressure Px is given by,

$$Px = Pa + \rho_2 gl(\sin\theta + a\backslash A)$$

Scale of the instrument is obviously expanded due to presence of sinθ. By making it quite small l can be increased such that l (sinθ remains constant. Any desired value of sensitivity may be obtained by incorporating a swivel mechanism for the inclined limb. Minimum value of angle is 5 degree with inclination angle less than this, exact position of the meniscus is difficult determine.

This tape of manometer is frequently called a raft gauge because it is so generally used for gauge because it is so generally settings and for measuring small pressure in low velocity gas flows.

2.5 U-Tube differential manometer

A typical arrangement where a U-tube has been used to measure the pressure differential across certain restriction in hydraulic main is shown in fig. Cobbering Manometric equation can be written by reaction that pressure in the two legs at level 1-2 must be equal.

$$Px + \rho_1 gh_1 = Py + \rho_2 gh_2 + \rho g(h_1 - h_2)$$

Thus in case of a mercury water differential manometer for which S = 13.6

$$Px - Py/\rho_2 g = 12.6(h_1 - h_2)$$

Pressure difference, easier as a head pf water cp, m so 12.6 limb the difference in height of mercury column.

Sensitivity of such gauge may be defined as the ratio of the observed difference in levels (h_1-h_2) to the difference of pressure head, Px – Py\$\rho_2$g of water being measured.

$$\text{Sensitivity} = (h_1 - h_2)\backslash\ Px - Py\backslash\rho_2 g$$

$$= 1\backslash s - 1$$

With mercury sensitivity is 1\12.6 and wraith paraffin the sensitivity is –1/. 15

2.6 U-Tube double reservoir manometer

Many different types of manometer have been made to obtain greater accuracy. The type shown in fig has two reservoirs and uses two Manometric fluids, which have different dementias further; liquids employed should be stable and should not diffuse with each other. Again to facilitate calculation, reservoirs shall be presumed tube equal cross sectional area.

Before any pressure is applied, let the liquid levels in the reservoirs and in the tubes corresponds to positions 0-0 and 0'-0 resp. enlarged ends of the manometer are next connected to two vessels containing a fluid density. Vessel connected to the left enlarged end is at pressure Px and flat connected to the right enlarged end is at pressure Py.

If Px>Py then level of liquid fall in the left limb by a distance h and there is a corresponding rise of liquid in the right limb. From volume conservation, a corresponding change (h/aA) occurs in the liquid levels of the reservoirs.

Under equilibrium conditions, pressure at point equals pressure at point 2 both bring at the same horizontal level. Governing Manometric equation is then.

$Px + (Z_1 + h_a/A)\ \rho g + (Z_{2\,-}\ h_a/A + h)\ \rho_2 g$

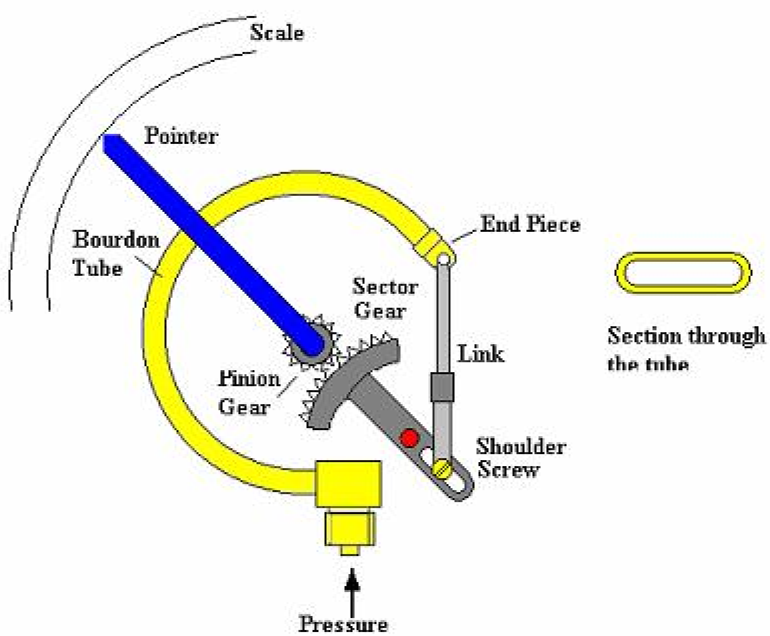
$= Py + (Z_1 - ha/A)\ \rho g + (Z_{2\,-}\ h_a/A - h)\ \rho_1 g + 2\rho_2 gh$

Manipulation and rearrangement would yield

$Px - Py = gh\ [\rho_{2\,-}\ \rho_1(a/A) - \rho(a/A)]$ __________________ 1

For greater sensitivity difficulty with this manometer is to find two liquids are stable and are of such characteristics that the contact surface remains cleans and clearly defined.

3. Bourdon Tube Pressure Gauge



The pressure responsible element of a burden gauge consists essentially of metal to be called bourdon. Oval in cross-section and bent to from a circular segment of approximately 200 to 300. The table is fixed but open at one end and it is fought this fixed end that the pressure to be measured is applied. When the pressure is applied to the inside of the tube its cross section tends to become circular.

This makes the tube straighten itself out with a consequent increase in its radius of curvature i.e. the free end moves away from the center.

The free end of the tube is connected to a spring-loaded linkage which amplifies the displacement and transmits it the angular rotation of pointer ever a calibrated scale to give a mechanical indication of pressure. Hairsprings sometimes use to fasten the spindle to the frame of the instrument to provide necessary tension for proper meshing of the gear teeth and they're by freeing the system from backlash. After prolonged use, the tooth gearing of the pinion and sector type linkage wears out and this impairs the accuracy of the gauge.

In a helicoids design, a cam and stainless steel roller replace the tooth sector and the pinion with a helical groove on it. The reference pressure in the casing containing the burden tube is usually atom and so the pointer indicates gauges pressure for absolute measurements. Either the gauge is completely evaded of the sensing bourdon tube is biased against the reference bourdon tube is evacuated and scaled.

Errors in Bourdon Gauge and their rectification

In general three of errors are found in Bourdon Gauge:

1) Zero error or constant error :

Which remains constant over the entire pressure range? This may be due to the pointers or hands having become loose on the spindle. Keeping the pointer in correct position prevents the error.

2) Multiple error

Multiplication error where in the gauge may tend to give progressively a higher or low reading. The error results from wrong setting in the multiplying between the bourdon tube and the spindle. To rectify the error, the multiplication screw is lessened and the connection link is moved either a little inward or little outwards.

3) Angularity error

Quite often it is sum that a one to one corresponds does not when approximately linear motion of the tip is converted to circular motion with the link lever and pinion attachment. Because of this distortion gauge may read correctly between max and minimum reading at the midpoint. But may give an accurate reading at the midpoint. To rectify this error angularity screw is adjusted and the pointer is set at some other point so that the gauge read correctly at the midpoint also. These errors are shown figure.

4.Diaphragm Gauge

In its elementary a diaphragm is a thin plate of circular shape clamped firmly around its edges. The dial gets deflection in accordance with the pressure differential across the slide being towards the low-pressure side. The deflection can be sensed by an approximate displaced transducer, i.e. it may convert into electrical signal may converted into mechanical amplification to permit display of the output on an indicator dial.

There are two basic type of diaphragm element design:

Metallic diaphragms, which depend up it, own resilience for its operation.

Non-metallic or slack diaphragm, which employs a soft material with no elastic characteristic. The movement of a diaphragm is opposed by a spring which deleing the deflection for a given pressure.

Fig illustrates the principle of operation of a diaphragm pressure gauge. The pressure deflection relation for a flat dia with edges clamped is given by:

$$P = \frac{16Et^4 * [y/t + .488(y/t)^3]}{3r^4(1-u^2)}$$

Where P is the pressure difference across the diaphragm.

E is the modulus of elasticity

t is the diaphragm thickness

u is the Poisson's ratio

r is the dia radius

y is the deflection to the center of the diaphragm.

For small deflection of a diaphragm must be less than 1/3 of the dia thickness to ensure a non-linearity of less than 5%. Further for the better performance, it is desirable that the diaphragm must not have a natural frequency which may be coin side with natural frequency of a circular diaphragm is

$$N =. 4775 * t/r^2 * [F/\rho(1-u^2)]^{1/2}$$

where ρ is the material density

<u>Diaphragm types</u>

The diaphragm can be in the form of flat, corrugated of depleted. The choice depends upon the strength and amount of deflection desired. Most common types of diaphragm are shown in figure. Corrugated diaphragm is normally used in larger diaphragm than the flat type. Larger size and increased deflection however reduce the dynamic response and this restricts their use mostly to static application.

Diaphragm material, pressure ranges and application metallic diameter are generally fabrication form a fall hard, cold rolled nickel chromium or iron alloy, which can have an elastic limit up to 5600 kgf/cm2. Typical pressure ranges are .50mm water gauge vacuum.

Non metallic slack diaphragm are made from a vertical material such as gold beater is skin, animal members, silk cloth synthetic material like Teflon neoprene poly styrene, etc.

5. Bellow Gauge

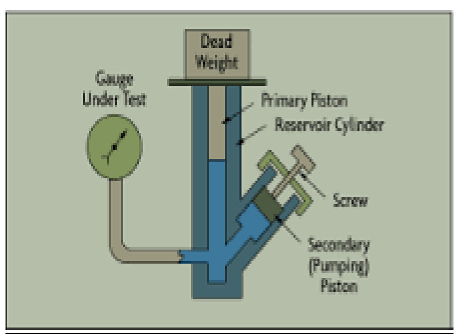
The bellow is a longitudinally expansive and collapsible member consisting of several convolution or folds. Generally acceptable methods of fabrication are:

1) Turning from a solid stock of metal.
2) Soldering or welding angular rings.
3) Roll in tubing.

Generally based on consideration like strength of the pressure range, hysterics and fatigue. Corrosiveness of bellow environment in case of fabrication is brass stainless steel phosphor bronze and beryllium cu

The unit is very sensitive changes of pressure on vacuum causing a proportional change in the effective length. Range of the order of about 125-mm. Water gauge to about 10.5 kgf/cm^2 with an accuracy of .5 to 1%. The arrangement shown in the figure shows how the bellow can installed to a gauge, for indicating the gauge pressure applied to one side of the bellows and the resulting deflection linkage, the bellow position is magnified and the gauge pressure is indicated by a pointer on the scale. The movement also called stroke corresponding to elastic deform ate can be increased by a pointer on the scale. Elastic deformation can be increased by increasing the number of convolutions the useful stroke is however normally limited to 5 to 10% of the maximum stroke. In the difference pressure arrangement two bellows they would extend by the same amount. The connecting lever would then rotate but no movement would result into movement sector, under a differential pressure, the deflection of the bellows would be unequal and the difference displacement of the connection levers would be indicated by the movement of the pointer on a scale. The pointer will indicate both the direction and the magnitude of the difference pressure.

6. Dead Weight Piston Gauge



The dead weight tester is a primary standard for pressure measurement and it upper a geed calibration facility once a wide ranges 10.0007 to 700 kgf/cm^2. Gauge is a step as small as .01-.05%of the reading.

A typical gauge is schematically shown in fig. It consists of an accurate machined bored and finished piston, which is inserted into a close finished piston into a closed cylinder both of known cross sectional areas. The chamber and the cylinder filled with cleaned oil, the oil being supplied from oil reservoir provided with a check vale at its bottom. The oil is withdrawn from a reservoir when the pump plunger exceeds an out ward motion of the pump plunger. When this occurs, the piston weight combination being float freely with in the cylinder. Under this equilibrium condition pressure force is balanced against the gravity force on the mass m of the calibrated masses plus the piston and plate form and a friction force. It is the equivalents area of the piston cylinder combination than

PA = mg + frictional drag

P = mg + frictional drag

The effective or equivalent area depends on such a factors as piston cylinder clearance pressure level temp. And is normally takes as the mean of the cylinder and piston areas.

The gauge under test is attached to the tester and the pressure P exerted on the fluid by the piston is transmitted to the gauge when the valve is open.

The accuracy of the gauge is limited by:

1) Uncertain increases of the loading and in area of the cylinder combination and
2) The friction between the cylinder and rotation.

Rotation of piston ensures that kinetic friction applies rather that static friction. Lubrication is provided by the fluid film formed due to leakage of oil form the clearance between the piston and cylinder. It is desirable 7to evaluate these effects and apply corrections these or so that magnitude of the overall measurement error is reduced to minimum.

6.1 Experimental procedure

1. Level the system with the help of leveling bolts.
2. Remove the oil filling cup cap and plunger.
3. Fill oil in oil filling cup and remove air by to and fro motion of screw pump.

   Keep pressure gauge side valve closed.
4. Keep initial weight over the plunger.
5. Close valve of oil filling cup tightly.
6. Required weight is kept over the initial weight.
7. Screw pump is then moved forward to develop pressure in the system. Slightly rotate the rotate the weights to eliminate initial friction.
8. The movement is continued till the plunger along with the weights is just lifted.
9. Note down the pressure shown by pressure gauge.
10. If any difference is found between the weight put and the pressure gauge reading, the pointer of the pressure gauge is adjusted with the help of pointer puller.

PRACTICAL 7 : STUDY OF TEMPERATURE MEASURING INSTRUMENTS

Objective : To study temperature measurement devices and calibration of thermocouple

1. Temperature Measurement Instruments

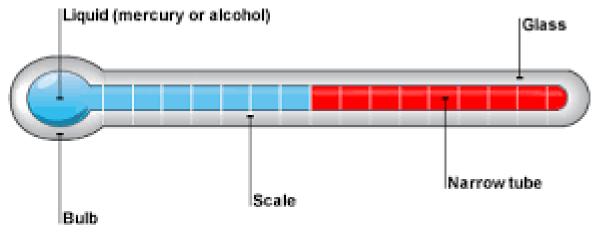
Temperature measuring instruments may be classified either according to range of temperature measurement or according to the nature of change produced in the temperature sensing element.

1. Glass thermometers with mercury alcohol, pentane and other organic liquids
2. Pressure gauge thermometer with vapour or liquids as the actuating fluids. There are two classes of these thermometers :

   a) The vapor pressure type, partially filled with liquid either sulphur dioxide, ethyl chloride, methyl chloride, etc.; and

   b) Those completely filled with a liquid or gas such as mercury, alcohol and nitrogen, etc. These are differential expansion thermometers in which the differential expansion of two solids is used as an indication of temperature.
3. Electrical resistance thermometer with temperature is determined by measuring the resistance of the calibrated wire.
4. The pyrometer in which the electromotive force setup the junction of two dissimilar metals used as an indication of temperature.
5. Optical pyrometer in which temperature is determined by matching the luminosity of the hot body with that of the calibrated source or by other means which utilizes the visible radiation emitted from a hot body.
6. Radiation pyrometer in which radiation of all wavelength upon a small body are absorbed to determine the temperature.
7. Fusion pyrometer which is determined by noting a series of metals with graduated fusion temperature. Melt or soften when exposed to the temperature under investigation.
8. Calorimetric pyrometer with which temperature is determined by noting the quantity of heat removed in bringing a body of known thermal capacity from temperature to b measured to some known lower temperature.
9. Color temperature chart with which temperature is estimated by comparing the colors of a luminous hot body with colors given on the charts.

2. Liquid in Glass Thermometer



The liquid in glass thermometer is one of the most common types of a temperature measuring devices. It consists of a glass envelope, a responsive liquid and an indicating scale. The two parts are used together and the top end of the capillary tube is scaled. The size of the capillary depends upon the size of sensing bulb, responsive liquid and the desired temperature range of instrument. Change in the temperature will cause the fluid to expand and rise up the stream. Since the area of stem is much less than the bulb, the relatively small change of fluid volume will result in significant rise in the stem.

The thermometer bulb is usually filled with mercury. It has the advantage of a board temperature span between its freezing and boiling point a really linear co-efficient of expansion relative case of obtaining it in a very pure state and its non wetting glass characteristics. This is prevented by filling the space above mercury with nitrogen or carbon dioxide under high pressure. This raises the boiling point and allows temperature up to 610˚ C to be measured.

However in many industrial applications the escape of mercury through breakage causes considerable damage to the products. This may necessitate the use of other liquids such as alcohol, pentane and toluene, etc. which do not cause contamination. These liquids have further advantage of suspension readability to mercury when colored with insert dyes of low cost.

3. Calibration of thermometer

These thermometers are generally designed and calibrated for one of the following three conditions shown in figure.

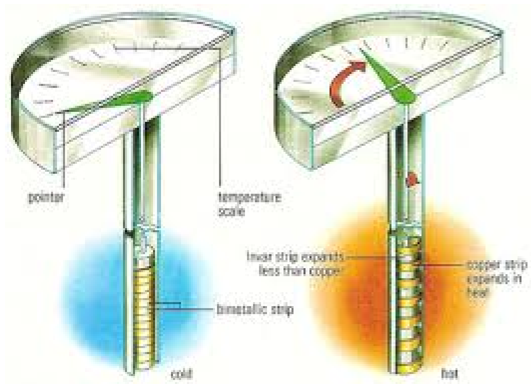
1. Total immersion : The bulb and liquid containing part of the capillary is exposed in the temperature being measured.
2. Complete immersion : The entire thermometer is exposed to the temperature being measured.
3. Partial immersion : The liquid in the stem emerging from the liquid bath is subjected to the ambient temperature, which may be radically different from the temperature of the liquid bath.

Generally, the glass stem thermometers are graduated for total immersion of bulk and indicated temperature is corrected for the stem emergence effect. The ASME power test codes recommend that a primary thermometer be attached to the stem of the primary thermometer and that a correction to the observed temperature be made in accordance with emergent stem error given by

$$C = 0.00016\ N\ (t_1 - t_2)\ ^\circ C$$

For the common construction of mercury thermometer.

4. Bimetallic thermometer:-



A bi-metallic strip consist of two pieces of different metals firmly bonded together by welding for a bimetal, in form of a straight cantilever beam. Temperature changes cause the free end to deflect because of the different expansion rate of the components. This deflection can be corrected quantitatively to the temperature change.

The radius of curvature of the bend of a straight bi- metal beam may be calculated as

$r = 2 / [3 (\alpha_1-\alpha_2) (T-To)]$; where

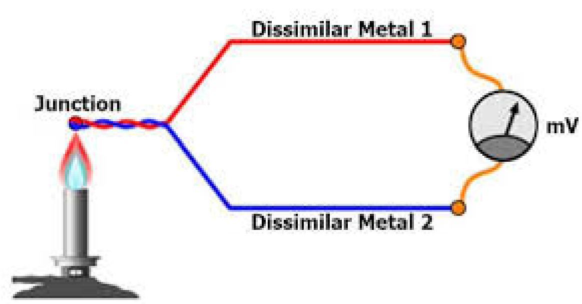
α_1 - lower co-efficient of expansion α_2 - higher co –efficient of expansion

T - Operating temperature T_o - Initial boiling temperature

Generally, r is very large and movable free tip is very small.

Bimetallic element can be arranged in the flat spiral, the single helix and multiple helixes. In response to the temperature change the bimetallic expand to helical bimetal rotates at its free end, thus turning the stem and pointer to a new position on the dial. The continuous strip wound into helical or spiral from has the advantage of compactness while providing a long length of string required for adequate indicator movement.

Thermocouple:-



If two wire of different material A and B are joints in a circuit as show in figure with a junction at temperature T1and other T2 then infinite resistant voltmeter defect an electromotive force of an ammeter is connected to current I is measured.

See back effect:-

The overall reaction between voltmeter E and temperature measurement T_1 & T_2 which is the basis of temperature measurement is called the see back effect.

Temperature T_1 & T_2 refer to the junction thermometer measurement measure the temperature of somebody in contact with the thermo junction.

Thomson's effect:-

Another reversible heat flow effect in Thomson effect influences the temperature of the conductor between the junction rather themselves. Thomson emf is proportional to the difference between the square root of junction temperature for the total voltage. The equation takes the form of

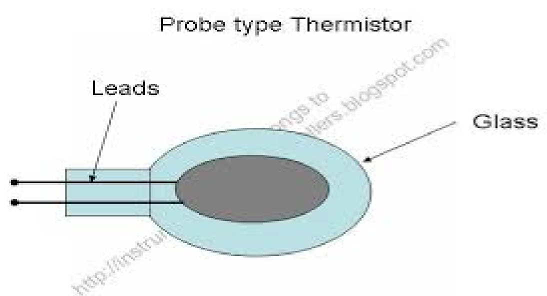
$E=C1 (T1-T2) + C2 (T1^2 – T2^2)$

Where, E-total voltage

T_1 & T_2 - absolute junction temperature

- temperature.

Thermistor:-



Thermistor differs from metal register in following aspect.

I. Resistant change in metal is +ve but thermistor having – ve thermal co-efficient of resistance.
II. Metal have an approximately linear temperature resistance relationship.
III. Practical operating range of thermistor lies between -100 to 300 the range for resistance thermistor is much great being from -160 to 600c

Thermistors have the advantage of high sensitivity availability in very small size fast thermal response fairly low cost and easy adoptability to electrical read ant device.