Chapter 1: STANDARDS OF MEASUREMENT

Definition of Metrology: Metrology (from Ancient Greek metron (measure) and logos (study of)) is the science of measurement. Metrology includes all theoretical and practical aspects of measurement.

Metrology is concerned with the establishment, reproduction, conservation and transfer of units of measurement & their standards.

For engineering purposes, metrology is restricted to measurements of length and angle & quantities which are expressed in linear or angular terms.
Measurement is a process of comparing quantitatively an unknown magnitude with a predefined standard**.**

Objectives of Metrology: The basic objectives of metrology are;

1. To provide accuracy at minimum cost.
2. Thorough evaluation of newly developed products, and to ensure that components are within the specified dimensions.
3. To determine the process capabilities.
4. To assess the measuring instrument capabilities and ensure that they are adequate for their specific measurements.
5. To reduce the cost of inspection & rejections and rework.
6. To standardize measuring methods.
7. To maintain the accuracy of measurements through periodical calibration of the instruments.
8. To prepare designs for gauges and special inspection fixtures.

Definition of Standards:

A standard is defined as "something that is set up and established by an authority as rule of the measure of quantity, weight, extent, value or quality".

For example, a meter is a standard established by an international organization for measurement of length. Industry, commerce, international trade in modern civilization would be impossible without a good system of standards.

Role of Standards: The role of standards is to achieve uniform, consistent and repeatable measurements throughout the world. Today our entire industrial economy is based on the interchangeability of parts the method of manufacture. To achieve this, a measuring system adequate to define the features to the accuracy required & the standards of sufficient accuracy to support the measuring system are necessary.

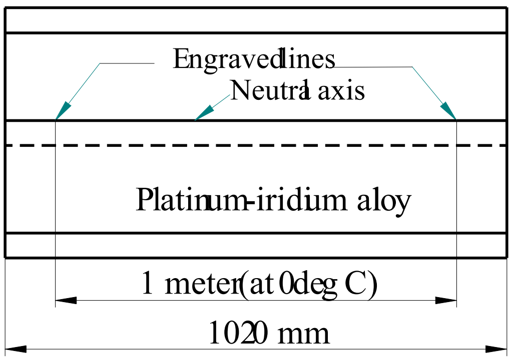
STANDARDS OF LENGTH

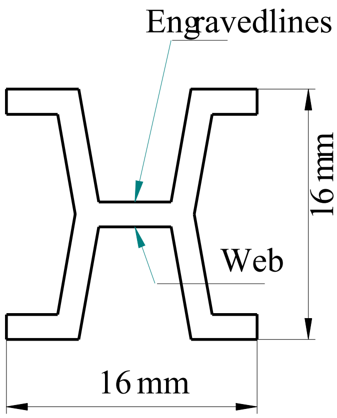
In practice, the accurate measurement must be made by comparison with a standard of known dimension and such a standard is called "Primary Standard"

The first accurate standard was made in England and was known as "Imperial Standard yard" which was followed by International Prototype meter" made in France. Since these two standards of length were made of metal alloys they are called 'material length standards'.

International Prototype meter:

It is defined as the straight line distance, at 0°C, between the engraved lines of pure platinum-iridium alloy (90% platinum & 10% iridium) of 1020 mm total length and having a 'tresca' cross section as shown in fig. The graduations are on the upper surface of the web which coincides with the neutral axis of the section.





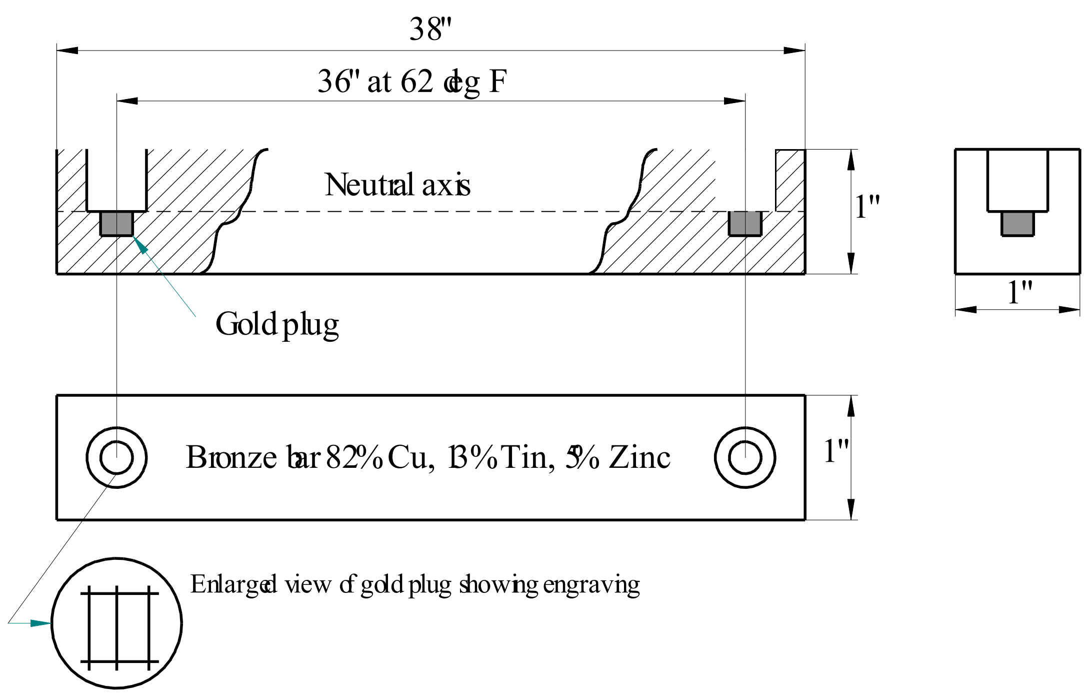
Historical International Prototype Meter bar, made of an alloy of platinum and iridium, that was the standard from 1889 to 1960.

The tresca cross section gives greater rigidity for the amount of material involved and is therefore economic in the use of an expensive metal. The platinum-iridium alloy is used because it is non oxidizable and retains good polished surface required for engraving good quality lines.

Imperial Standard yard:

An imperial standard yard, shown in fig, is a bronze (82% Cu, 13% tin, 5% Zinc) bar of 1 inch square section and 38 inches long. A round recess, 1 inch away from the two ends is cut at both ends upto the central or 'neutral plane' of the bar.

Further, a small round recess of (1/10) inch in diameter is made below the center. Two gold plugs of (1/10) inch diameter having engravings are inserted into these holes so that the lines (engravings) are in neutral plane.



Yard is defined as the distance between the two central transverse lines of the gold plug at 62^0F.

The purpose of keeping the gold plugs in line with the neutral axis is to ensure that the neutral axis remains unaffected due to bending, and to protect the gold plugs from accidental damage.

Bronze Yard was the official standard of length for the United States between 1855 and 1892, when the US went to metric standards. ***1 yard = 0.9144 meter****. The yard is used as the standard unit of field-length measurement in American, Canadian and Association football, cricket pitch dimensions, swimming pools, and in some countries, golf fairway measurements.*

Disadvantages of Material length standards:

1. Material length standards vary in length over the years owing to molecular changes in the alloy.
2. The exact replicas of material length standards were not available for use somewhere else.
3. If these standards are accidentally damaged or destroyed then exact copies could not be made.
4. Conversion factors have to be used for changing over to metric system.

Light (Optical) wave Length Standard:

Because of the problems of variation in length of material length standards, the possibility of using light as a basic unit to define primary standard has been considered. The wavelength of a selected radiation of light and is used as the basic unit of length. Since the wavelength is not a physical one, it need not be preserved & can be easily reproducible without considerable error.

A krypton-filled discharge tube in the shape of the element's atomic symbol. A colorless, odorless, tasteless noble gas, krypton occurs in trace amounts in the atmosphere, is isolated by fractionally distilling liquefied air. The high power and relative ease of operation of krypton discharge tubes caused (from 1960 to 1983) the official meter to be defined in terms of one orange-red spectral line of krypton-86.

Meter as on Today: In 1983, the 17th general conference on weights & measures proposed the use of speed of light as a technically feasible & practicable definition of meter.

Meter is now defined as the length of path of travelled by light in vacuum in (1/ 299792458) second. The light used is iodine stabilized helium-neon laser.

Advantages of using wave length standards:

1. Length does not change.
2. It can be easily reproduced easily if destroyed.
3. This primary unit is easily accessible to any physical laboratories.
4. It can be used for making measurements with much higher accuracy than material standards.
5. Wavelength standard can be reproduced consistently at any time and at any place.

Subdivision of standards:

The imperial standard yard and the international prototype meter are master standards & cannot be used for ordinary purposes. Thus based upon the accuracy required, the standards are subdivided into four grades namely;

1. Primary Standards
2. Secondary standards
3. Teritiary standards
4. Working standards

Primary standards:

They are material standard preserved under most careful conditions.

These are not used for directly for measurements but are used once in 10 or 20 years for calibrating secondary standards.

Ex: International Prototype meter, Imperial Standard yard.

Secondary standards:

These are close copies of primary standards w.r.t design, material & length. Any error existing in these standards is recorded by comparison with primary standards after long intervals. They are kept at a number of places under great supervision and serve as reference for tertiary standards. This also acts as safeguard against the loss or destruction of primary standards.

Teritiary standards:

The primary or secondary standards exist as the ultimate controls for reference at rare intervals.

Tertiary standards are the reference standards employed by National Physical laboratory (N.P.L) and are the first standards to be used for reference in laboratories & workshops. They are made as close copies of secondary standards & are kept as reference for comparison with working standards.

Working standards:

These standards are similar in design to primary, secondary & tertiary standards. But being less in cost and are made of low grade materials, they are used for general applications in metrology laboratories.

Sometimes, standards are also classified as;

- Reference standards (used as reference purposes)
- Calibration standards (used for calibration of inspection & working standards)
- Inspection standards (used by inspectors)
- Working standards (used by operators)

LINE STANDARDS

When the length being measured is expressed as the distance between two lines, then it is called "Line Standard".

Examples: Measuring scales, Imperial standard yard, International prototype meter, etc.

Characteristics of Line Standards:

1. Scales can be accurately engraved but it is difficult to take the full advantage of this accuracy. ***Ex:*** A steel rule can be read to about ± 0.2 mm of true dimension.
2. A scale is quick and easy to use over a wide range of measurements.
3. The wear on the leading ends results in ***'under sizing'***
4. A scale does not possess a 'built in' datum which would allow easy scale alignment with the axis of measurement, this again results in 'under sizing'.
5. Scales are subjected to parallax effect, which is a source of both positive & negative reading errors'
6. Scales are not convenient for close tolerance length measurements except in conjunction with microscopes.

END STANDARDS

When the length being measured is expressed as the distance between two parallel faces, then it is called ***'End standard'.***

End standards can be made to a very high degree of accuracy.

Ex: Slip gauges, Gap gauges, Ends of micrometer anvils, etc.

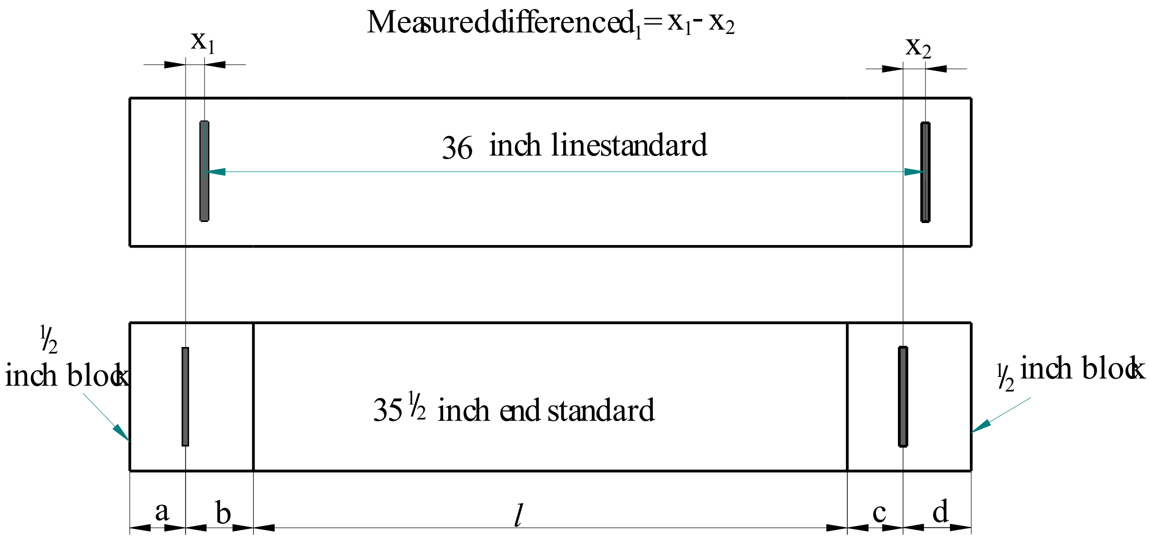
Characteristics of End Standards:

1. End standards are highly accurate and are well suited for measurements of close tolerances as small as 0.0005 mm.
2. They are time consuming in use and prove only one dimension at a time.
3. End standards are subjected to wear on their measuring faces.
4. End standards have a 'built in' datum, because their measuring faces are flat & parallel and can be positively located on a datum surface.
5. They are not subjected to the parallax effect since their use depends on ***"feel".***
6. Groups of blocks may be ***"wrung"*** together to build up any length. But faulty wringing leads to damage.
7. The accuracy of both end & line standards are affected by temperature change.

TRANSFER FROM LINE STANDARD TO END STANDARD

(NPL method of deriving End standard from line standard)

Line Standard Comparator:



A line standard comparator is used to transfer the line standard correctly to the ends of a bar.

It consists of two microscopes mounted about a yard apart over a table. An end standard about 351/2 inch in length is produced with flat & parallel faces. Two 1/2 inch blocks with centrally engraved lines are 'wrung' to the ends of this end standard, such that the distance between the center lines is approximately 36 inches.

The difference of readings between the lines on the line standard & the lines on the end standard are noted every time, by arranging the end blocks in different ways to eliminate errors in wringing & of marking of center lines.

If the actual length of the end standard is ***l***, then for the four different ways of wringing the end blocks, we can write;

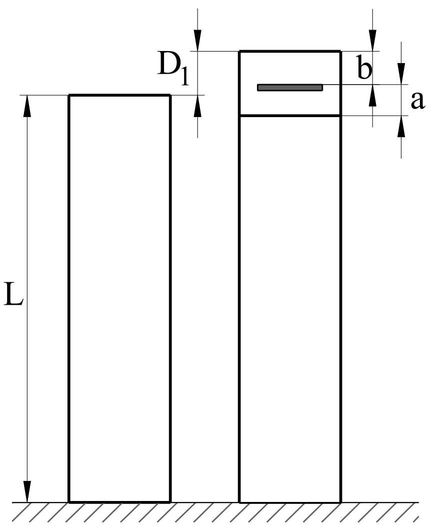
$$l + b + c = 36 + d_1 \qquad l + b + d = 36 + d_2$$

$$l + a + c = 36 + d_3 \qquad l + a + d = 36 + d_4$$

Where d_1, d_2, d_3 & d_4 are the differences noted for the successive positions of the 1/2 inch blocks respectively.

Taking mean,

Next the $35^1/_2$ inch end standard wrung with one of the 1/2 inch blocks is compared with 36 inch end bar (to be calibrated) on a Brooke's level comparator & the deviation D_1 may be noted.



Then the other 1/2 inch block is wrung with it & again is compared with the end bar (to be calibrated) & the deviation D_2 is noted. If L is the actual length of the 36 inch end bar, then;

$$l + a + b = L + D_1, \qquad l + c + d = L + D_2$$

Combining the above equations,

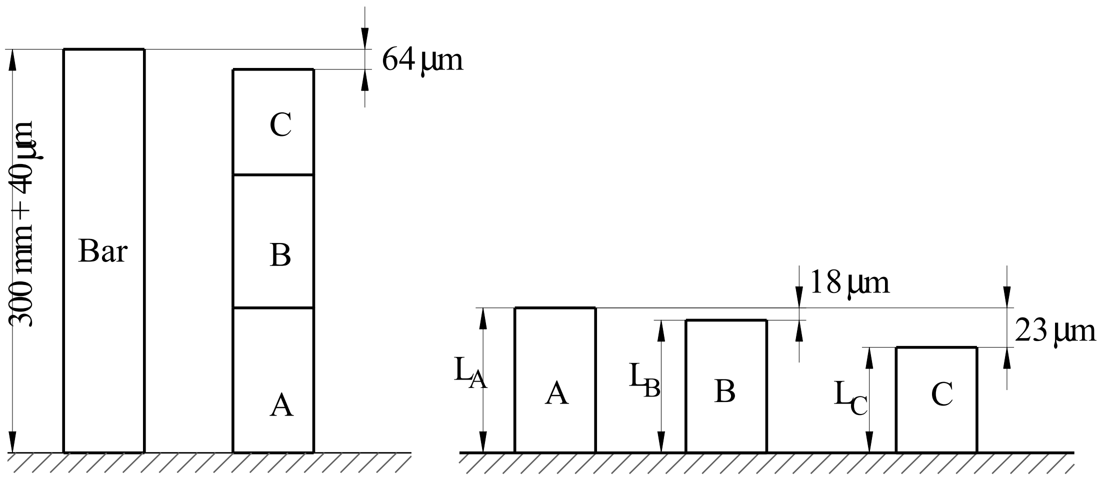
CALIBRATION OF END BARS

The actual lengths of end bars can be found by wringing them together and comparing them with a calibrated standard using a level comparator and also individually comparing among themselves. This helps to set up a system of linear equations which can be solved to find the actual lengths of individual bars.

The procedure is clearly explained in the forthcoming numerical problems.

Numerical problem-1:

Three 100 mm end bars are measured on a level comparator by first wringing them together and comparing with a calibrated 300 mm bar which has a known error of +40µm. The three end bars together measure 64 µm less than the 300 µm bar. Bar A is 18 µm longer than bar B and 23 µm longer than bar C. Find the actual length of each bar.



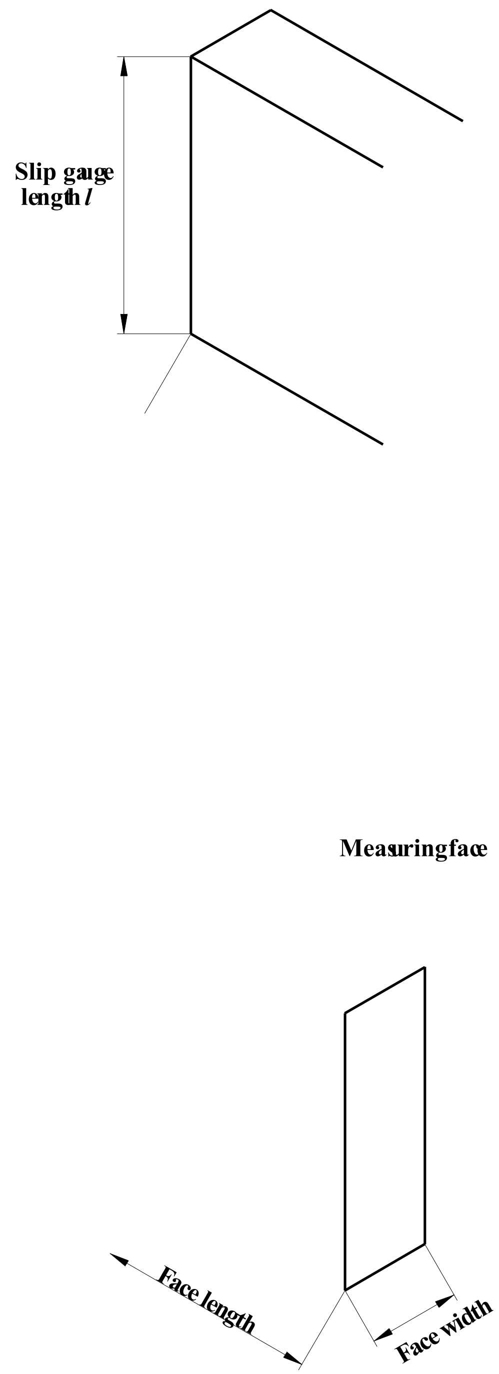
Numerical problem-2:

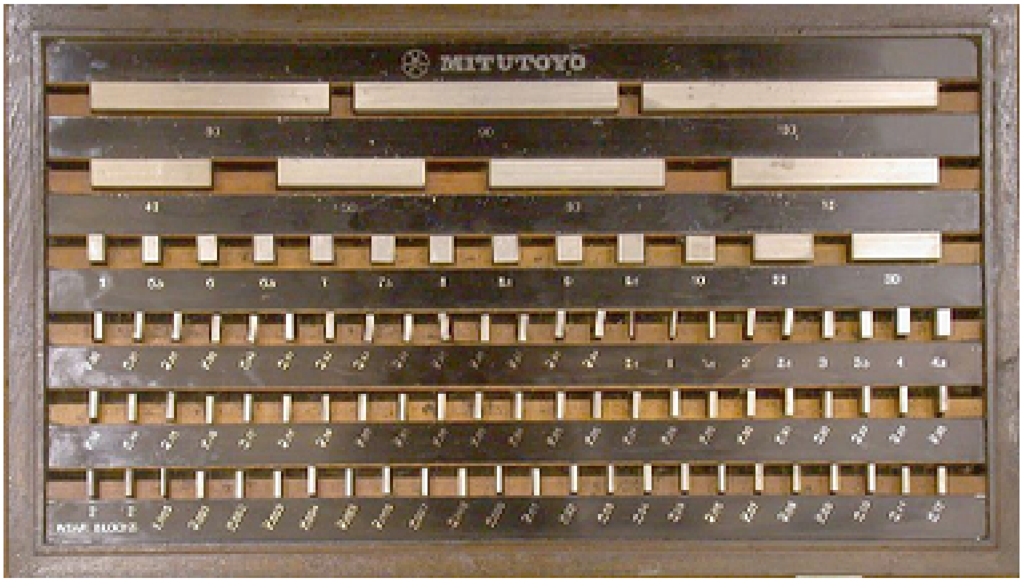
Four end bars of basic length 100 mm are to be calibrated using a standard bar of 400 mm whose actual length is 399.9992 mm. It was also found that lengths of bars B,C & D in comparison with A are +0.0002 mm, +0.0004 mm and -0.0001 mm respectively and the length of all the four bars put together in comparison with the standard bar is +0.0003 mm longer. Determine the actual lengths of each end bars.

SLIP GAUGES OR GAUGE BLOCKS

(JOHANSSON GAUGES)

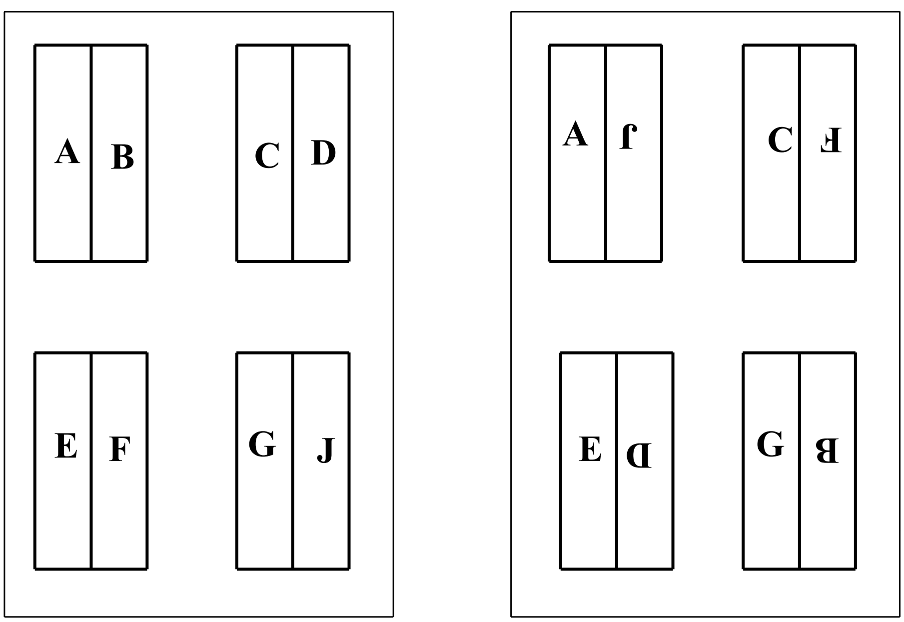
Slip gauges are rectangular blocks of steel having cross section of 30 mm face length & 10 mm face width as shown in fig.





Slip gauges are blocks of steel that have been hardened and stabilized by heat treatment. They are ground and lapped to size to very high standards of accuracy and surface finish. A gauge block (also known Johansson gauge, slip gauge, or Jo block) is a precision length measuring standard consisting of a ground and lapped metal or ceramic block. Slip gauges were invented in 1896 by Swedish machinist Carl Edward Johansson.

Manufacture of Slip Gauges:



When correctly cleaned and wrung together, the individual slip gauges adhere to each other by molecular attraction and, if left like this for too long, a partial cold weld will take place.

If this is allowed to occur, the gauging surface will be irreparable after use, hence the gauges should be separated carefully by sliding them apart. They should then be cleaned, smeared with petroleum jelly (Vaseline) and returned to their case.

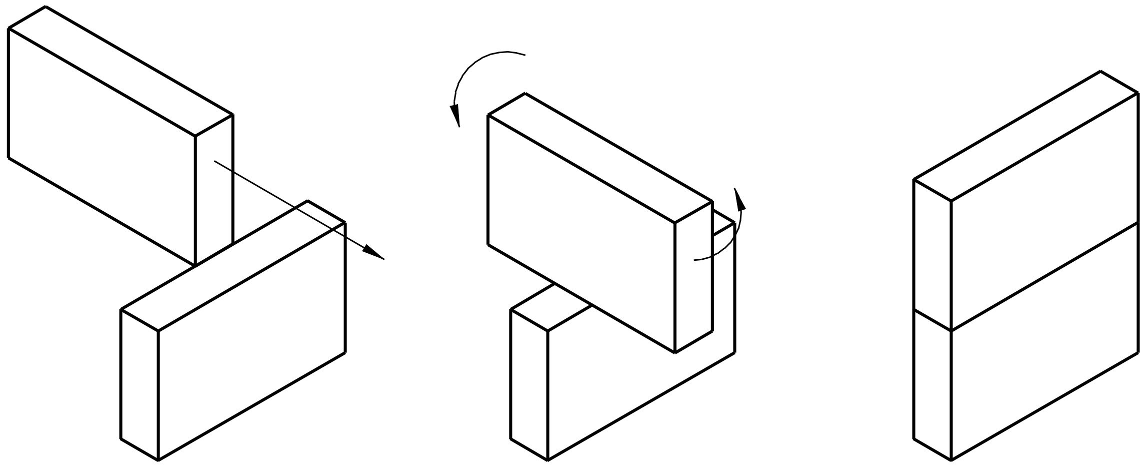
Protector Slips:

In addition, some sets also contain protector slips that are 2.50mm thick and are made from a hard, wear resistant material such as tungsten carbide. These are added to the ends of the slip gauge stack to protect the other gauge blocks from wear. Allowance must be made of the thickness of the protector slips when they are used.

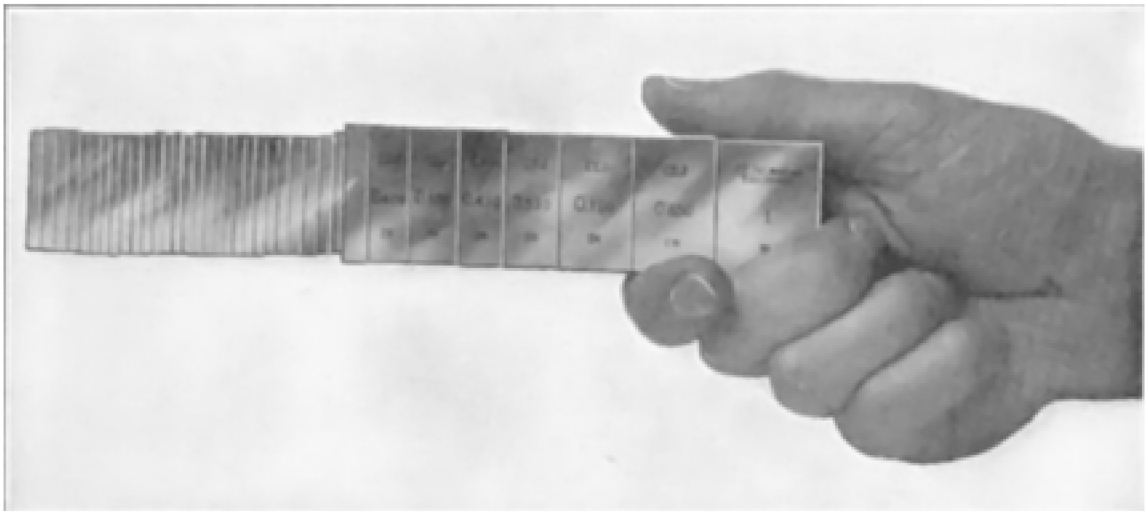
Wringing of Slip Gauges:

Slip gauges are wrung together to give a stack of the required dimension. In order to achieve the maximum accuracy the following precautions must be taken.

- Use the minimum number of blocks.
- Wipe the measuring faces clean using soft clean chamois leather.
- Wring the individual blocks together by first pressing at right angles, sliding & then twisting.



Wringing of Slip Gauges



36 Johansson gauge blocks wrung together easily support their own weight

INDIAN STANDARD ON SLIP GAUGES (IS 2984-1966)

Slip gauges are graded according to their accuracy as Grade 0, Grade I & Grade II.

Grade II is intended for use in workshops during actual production of components, tools & gauges.

Grade I is of higher accuracy for use in inspection departments.

Grade 0 is used in laboratories and standard rooms for periodic calibration of Grade I & Grade II gauges.

M-87 set of slip gauges:

Range (mm)	Steps (mm)	No. of pieces
1.001 to 1.009	0.001	9
1.01 to 1.49	0.01	49
0.5 to 9.5	0.5	19
10 to 90	10	9
1.0005	---	1
	Total	87

M-112 set of slip gauges:

Range (mm)	Steps (mm)	No. of pieces
1.001 to 1.009	0.001	9
1.01 to 1.49	0.01	49
0.5 to 24.5	0.5	49
25,50,75,100	25	4
1.0005	---	1
	Total	112

Important notes on building of Slip Gauges:

- Always start with the last decimal place.
- Then take the subsequent decimal places.
- Minimum number of slip gauges should be used by selecting the largest possible block in each step.
- If in case protector slips are used, first deduct their thickness from the required dimension then proceed as per above order.

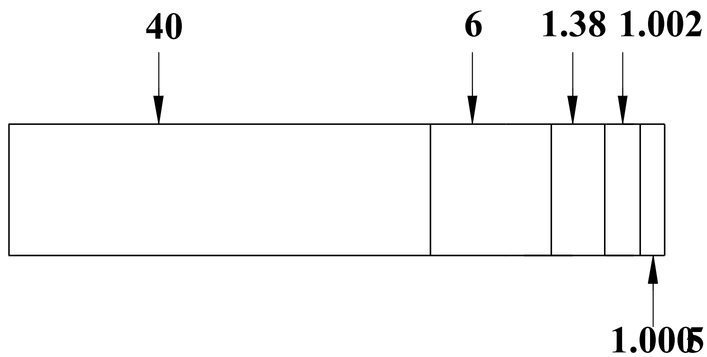
Numerical problem-1

Build the following dimensions using M-87 set. (i) 49.3825 mm (ii) 87.3215 mm

Solution:

(i) To build 49.3825 mm:

Combination of slips; 40+6+1.38+1.002+1.0005 = 49.3825 mm



(ii) To build 87.3215 mm:

Combination of slips; 80+4+1.32+1.001+1.0005 = 87.3215 mm