1.6 Standards of Measurement

Two standard systems for linear measurement that have been accepted and adopted worldwide are English and metric (yard and metre) systems. Most countries have realized the importance and advantages of the metric system and accepted metre as the fundamental unit of linear measurement.

Yard or metre is defined as the distance between two scribed lines on a bar of metal maintained under certain conditions of temperature and support.

1.6.1 Yard

The imperial standard yard is a bronze bar 1 sq. inch in cross-section and 38 inches in length, having a composition of 82% Cu, 13% tin, and 5% Zn. The bar contains holes of ½-inch diameter × ½-inch depth. It has two round recesses, each located one inch away from either end and extends up to the central plane of the bar. A highly polished gold plug having a diameter of 1/10 of an inch comprises three transversely engraved lines and two longitudinal lines that are inserted into each of these holes such that the lines lie in the neutral plane. The top surface of the plug lies on the neutral axis.

Yard is then defined as the distance between the two central transverse lines of the plug maintained at a temperature of 62 °F. Yard, which was legalized in 1853, remained a legal standard until it was replaced by the wavelength standard in 1960. One of the advantages of maintaining the gold plug lines at neutral axis is that this axis remains unaffected due to bending of the beam. Another advantage is that the gold plug is protected from getting accidentally damaged.

Three orthographic views of the imperial standard yard are shown in Fig. 1.6. It is important to note that an error occurs in the neutral axis because of the support provided at the ends. This error can be minimized by placing the supports in such a way that the slope at the ends is zero and the flat end faces of the bar are mutually parallel to each other.

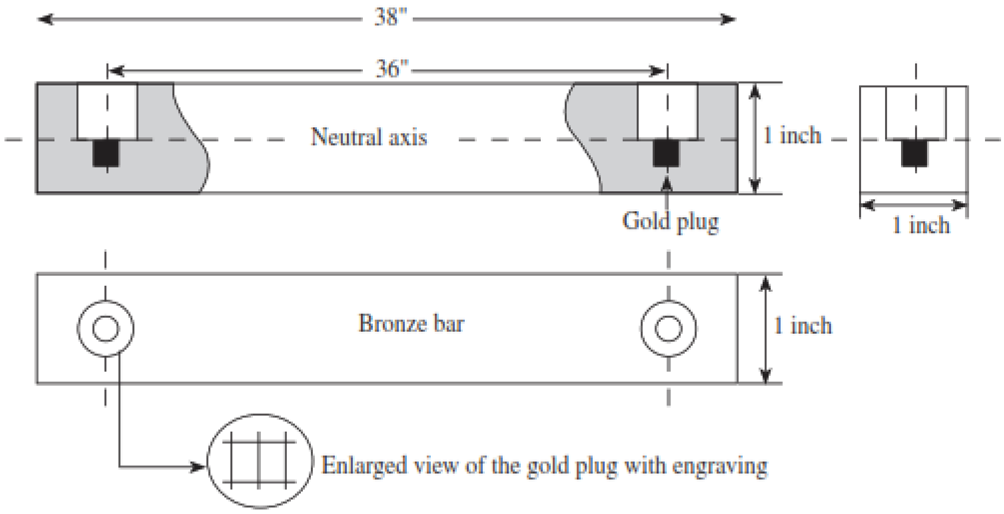

Fig.1.5 Imperial standard yard

[source: "Engineering Metrology & Measurements", N.V. Raghavendra., page-24]

1.6.2 Metre

This standard is also known as international prototype metre, which was established in 1875. It is defined as the distance between the centre positions of the two lines engraved on the highly polished surface of a 102 cm bar of pure platinum–iridium alloy (90% platinum and 10% iridium) maintained at 0 °C under normal atmospheric pressure and having the cross-section of a web, as shown in Fig. 1.6. The top surface of the web contains graduations coinciding with the neutral axis of the section. The web-shaped section offers two major advantages. Since the section is uniform and has graduations on the neutral axis, it allows the whole surface to be graduated. This type of cross-section provides greater rigidity for the amount of metal involved and is economical even though an expensive metal is used for its construction. The bar is in oxidizable and can have a good polish, which is required for obtaining good-quality lines. It is supported by two rollers having at least 1 cm diameter, which are symmetrically located in the same horizontal plane at a distance of 751 mm from each other such that there is minimum deflection.

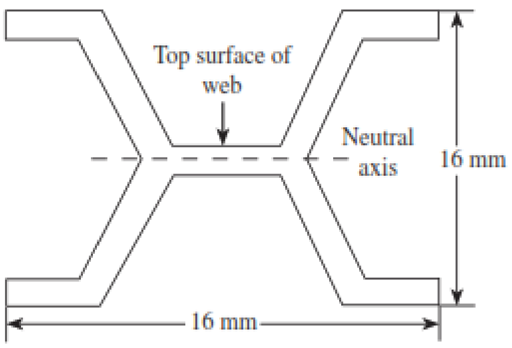

Fig.1.6 International prototype metre

[source: "Engineering Metrology & Measurements", N.V. Raghavendra., page-25]

1.6.3 WAVELENGTH STANDARD

It is very clear from the methods discussed earlier that comparison and verification of the sizes of the gauges pose considerable difficulty. This difficulty arises because the working standard used as a reference is derived from a physical standard and successive comparisons are required to establish the size of a working standard using the process discussed earlier, leading to errors that are unacceptable. By using wavelengths of a monochromatic light as a natural and invariable unit of length, the dependency of the working standard on the physical standard can be eliminated. The definition of a standard of length relative to the metre can easily be expressed in terms of the wavelengths of light.

1.6.4 SUBDIVISIONS OF STANDARDS

In order to facilitate measurement at different locations depending upon the relative importance of standard, they are subdivided into the following four groups:

1.6.4.1 Primary standards

For defining the unit precisely, there shall be one and only one material standard. Primary standards are preserved carefully and maintained under standard atmospheric conditions so that they do not change their values. This has no direct application to a measuring problem encountered in engineering. These are used only for comparing with secondary standards. International yard and international metre are examples of standard units of length.

1.6.4.2 Secondary standards

These are derived from primary standards and resemble them very closely with respect to design, material, and length. Any error existing in these bars is recorded by comparison with primary standards after long intervals. These are kept at different locations under strict supervision and are used for comparison with tertiary standards (only when it is absolutely essential). These safeguard against the loss or destruction of primary standards.

1.6.4.3 Tertiary standards

Primary and secondary standards are the ultimate controls for standards; these are used only for reference purposes and that too at rare intervals. Tertiary standards are reference standards employed by NPL and are used as the first standards for reference in laboratories and workshops. These standards are replicas of secondary standards and are usually used as references for working standards.

1.6.4.4 Working standards

These are used more frequently in workshops and laboratories. When compared to the other three standards, the materials used to make these standards are of a lower grade and cost. These are derived from fundamental standards and suffer from loss of instrumental accuracy due to subsequent comparison at each level in the hierarchical chain. Working standards include both line and end standards.

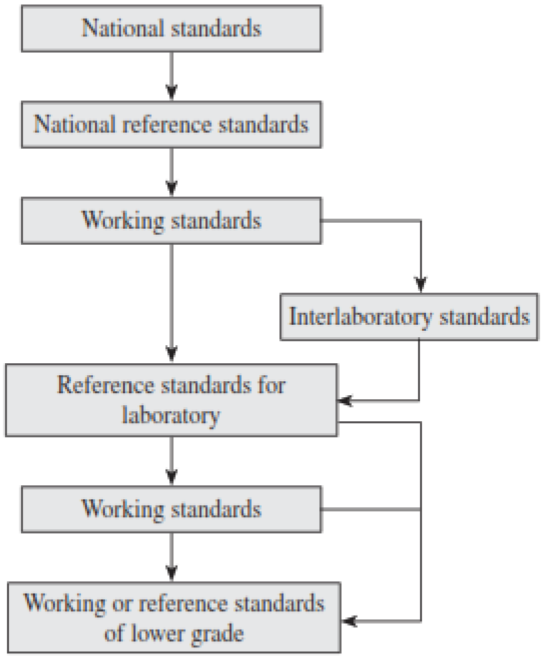

Fig 1.7 Hierarchical classification of standards

[source: "Engineering Metrology & Measurements", N.V. Raghavendra., page-27]

Accuracy is one of the most important factors to be maintained and should always be traceable to a single source, usually the national standards of the country. National laboratories of most of the developed countries are in close contact with the BIPM. This is essential because ultimately all these measurements are compared with the standards developed and maintained by the bureaus of standards throughout the world.

Table 1.2 Classification of standards based on purpose

Standard	**Purpose**
Reference	Reference
Calibration	Calibration of inspection and working standards
Inspection	Used by inspectors
Working standards	Used by operators

1.6.5 Line Standards

When the distance between two engraved lines is used to measure the length, it is called line standard or line measurement. The most common examples are yard and metre. The rule with divisions marked with lines is widely used.

1.6.5.1 Characteristics of Line Standards

The following are the characteristics of line standards:

1. Measurements carried out using a scale are quick and easy and can be used over a wide range.
2. Even though scales can be engraved accurately, it is not possible to take full advantage of this accuracy. The engraved lines themselves possess thickness, making it difficult to perform measurements with high accuracy.
3. The markings on the scale are not subjected to wear. Under sizing occurs as the leading ends are subjected to wear.
4. A scale does not have a built-in datum, which makes the alignment of the scale with the axis of measurement difficult. This leads to under sizing.
5. Scales are subjected to parallax effect, thereby contributing to both positive and negative reading errors.
6. A magnifying lens or microscope is required for close tolerance length measurement.

1.6.6 End Standards

When the distance between two flat parallel surfaces is considered a measure of length, it is known as end standard or end measurement. The end faces of the end standards are hardened to reduce wear and lapped flat and parallel to a very high degree of accuracy. The end standards are extensively used for precision measurement in workshops and laboratories. The most common examples are measurements using slip gauges, end bars, ends of micrometer anvils, vernier callipers, etc.

1.6.6.1 Characteristics of End Standards

End standards comprise a set of standard blocks or bars using which the required length is created. The characteristics of these standards are as follows:

1. These standards are highly accurate and ideal for making close tolerance measurement.
2. They measure only one dimension at a time, thereby consuming more time.
3. The measuring faces of end standards are subjected to wear.
4. They possess a built-in datum because their measuring faces are flat and parallel and can be positively located on a datum surface.
5. Groups of blocks/slip gauges are wrung together to create the required size; faulty wringing leads to inaccurate results.
6. End standards are not subjected to parallax errors, as their use depends on the feel of the operator.
7. Dimensional tolerance as close as 0.0005 mm can be obtained.

The end and line standards are initially calibrated at 20 ± ½ ºC. Temperature changes influence the accuracy of these standards. Care should be taken in the manufacturing of end and line standards to ensure that change of shape with time is minimum or negligible.

Table 1.3 Comparison of line and end standards

Characteristics	Line standard	End standard
Principle of measurement	Distance between two engraved lines is used as a measure of length	Distance between two flat and parallel surfaces is used as a measure of length
Accuracy of measurement	Limited accuracy of ±0.2 mm; magnifying lens or microscope is required for high accuracy	High accuracy of measurement; close tolerances up to ±0.0005 mm can be obtained
Ease and time of measurement	Measurements made using a scale are quick and easy	Measurements made depend on the skill of the operator and are time consuming
Wear	Markings on the scale are not subjected to wear. Wear	Measuring surfaces are subjected to wear

	may occur on leading ends, which results in under sizing	
Alignment	Alignment with the axis of measurement is not easy, as they do not contain a built-in datum	Alignment with the axis of measurement is easy, as they possess a built-in datum
Manufacture	Manufacturing process is simple	Manufacturing process is complex
Cost	Cost is low	Cost is high
Parallax effect	Subjected to parallax effect	No parallax error; their use depends on the feel of the operator
Wringing	Does not exist	Slip gauges are wrung together to build the required size
Examples	Scale (yard and metre)	Slip gauges, end bars, ends of micrometer anvils, and vernier callipers