1.5 Errors in Measurement

- It is never possible to measure the true value of a dimension, there is always some error. The error in measurement is the difference between the measured value and the true value of the measured dimension.

- Error in measurement =Measured value - True value. The error in measurement may be expressed or evaluated either as an absolute error or as a relative error.

Absolute Error

- True absolute error. It is the algebraic difference between the result of measurement and the conventional true value of the quantity measured.
- Apparent absolute error. If the series of measurement are made then the algebraic difference between one of the results of measurement and the arithmetical mean is known as apparent absolute error.

Relative Error

- It is the quotient of the absolute error and the value of comparison used for calculation of that absolute error. This value of comparison may be the true value, the conventional true value or the arithmetic mean for series of measurement.

The accuracy of measurement, and hence the error depends upon so many factors, such as:

- Calibration standard
- Work piece
- Instrument
- Person
- Environment etc. as already described.

No matter, how modern is the measuring instrument, how skillful is the operator, how accurate the measurement process, there would always be some error. It is therefore attempted to minimize the error. To minimize the error, usually a number of observations are made and their average is taken as the value of that measurement.

- If these observations are made under identical conditions i.e., same observer, same instrument and similar working conditions excepting for time, then, it is called as Single Sample Test'.

- If however, repeated measurements of a given property using alternate test conditions, such as different observer and/or different instrument are made, the procedure is called as 'Multi-Sample Test'. The multi-sample test avoids many controllable errors e.g., personal error, instrument zero error etc. The multi-sample test is costlier than the single sample test and hence the later is in wide use.

- In practice good numbers of observations are made under single sample test and statistical techniques are applied to get results which could be approximate to those obtainable from multi-sample test.

Types of Error

During measurement several types of error may arise, these are

1. Static errors which includes
   - Reading errors
   - Characteristic errors
   - Environmental errors.
2. Instrument loading errors.
3. Dynamic errors.

Static errors

These errors result from the physical nature of the various components of measuring system. There are three basic sources of static errors. The static error divided by the measurement range (difference between the upper and lower limits of measurement) gives the measurement precision.

Reading errors

Reading errors apply exclusively to the read-out device. These do not have any direct relationship with other types of errors within the measuring system.

Reading errors include: Parallax error, Interpolation error.

Attempts have been made to reduce or eliminate reading errors by relatively simple techniques. For example, the use of mirror behind the readout pointer or indicator virtually eliminates occurrence of parallax error.

Interpolation error.

It is the reading error resulting from the inexact evaluation of the position of index with regards to two adjacent graduation marks between which the index is located. How accurately can a scale be readthis depends upon the thickness of the graduation marks, the spacing of the scale division and the thickness of the pointer used to give the reading Interpolation error can be tackled by increasing; using magnifier over the scale in the viscinity of pointer or by using a digital read out system.

Characteristic Errors

It is defined as the deviation of the output of the measuring system from the theoretical predicted performance or from nominal performance specifications.

Linearity errors, repeatability, hysteresis and resolution errors are part of characteristic errors if the theoretical output is a straight line. Calibration error is also included in characteristic error.

Loading Errors

Loading errors results from the change in measurand itself when it is being measured, (i.e., after the measuring system or instrument is connected for measurement). Instrument loading error is the difference between the value of the measurand before and after the measuring system is connected/contacted for measurement. For example, soft or delicate components are subjected to deformation during measurement due to the contact pressure of the instrument and cause a loading error. The effect of instrument loading errors is unavoidable. Therefore, measuring system or instrument should be selected such that this sensing element will minimize instrument loading error in a particular measurement involved.

Environmental Errors

These errors result from the effect of surrounding such as temperature, pressure, humidity etc. on measuring system.

External influences like magnetic or electric fields, nuclear radiations, vibrations or shocks etc. also lead to environmental errors.

Environmental errors of each component of the measuring system make a separate contribution to the static error. It can be reduced by controlling the atmosphere according to the specific requirements.

Dynamic Errors

Dynamic error is the error caused by time variations in the measurand. It results from the inability of the system to respond faithfully to a time varying measurement. It is caused by inertia, damping, friction or other physical constraints in the sensing or readout or display system.

For statistical study and the study of accumulation of errors, these errors can be broadly classified into two categories

1. Systematic or controllable errors, and
2. Random errors.

Systematic Errors

Systematic errors are regularly repetitive in nature. They are of constant and similar form. They result from improper conditions or procedures that are consistent in action. Out of the systematic errors all except the personal error varies from individual to individual depending on the personality of observer. Other systematic errors can be controlled in magnitude as well as in sense. If properly analyzed they can be determined and reduced. Hence, these are also called as controllable errors.

Systematic errors include:

1. Calibration Errors. These are caused due to the variation in the calibrated scale from its normal value. The actual length of standards such as slip gauge and engraved scales will vary from the nominal value by a small amount. This will cause an error in measurement of constant magnitude. Sometimes the instrument inertia and hysteresis effect do not allow the instrument to transit the measurement accurately. Drop in voltage along the wires of an electric meter may include an error (called single transmission error) in measurement.

2. Ambient or Atmospheric conditions (Environmental Errors). Variation in atmospheric condition (i.e., temperature, pressure, and moisture content) at the place of measurement from that of internationally agreed standard values (20° temp. and 760 mm of Hg pressure) can give rise to error in the measured size of the component. Instruments are calibrated at these standard conditions; therefore error may creep into the given result if the atmosphere conditions are different at the place of measurement. Out of these temperatures is the most significant factor which causes error in, measurement due to expansion or contraction of component being measured or of the instrument used for measurement.

3. Stylus Pressure. Another common source of error is the pressure with which the work piece is pressed while measuring. Though the pressure involved is generally small but this is sufficient enough to cause appreciable deformation of both the stylus and the work piece.

In ideal case, the stylus should have simply touched the work piece. Besides the deformation effect the stylus pressure can bring deflection in the work piece also.

Variations in force applied by the anvils of micrometer on the work to be measured results in the difference in its readings. In this case error is caused by the distortion of both micrometer frame and work-piece.

4. Avoidable Errors. These errors may occur due to parallax, non-alignment of work piece centers, improper location of measuring instruments such as placing a thermometer in

sunlight while measuring temperature. The error due to misalignment is caused when the centre line of work piece is not normal to the centre line of the measuring instrument.

5. Random Errors. Random errors are non-consistent. They occur randomly and are accidental in nature. Such errors are inherent in the measuring system. It is difficult to eliminate such errors. Their specific cause, magnitudes and source cannot be determined from the knowledge of measuring system or conditions of measurement.

The possible sources of such errors are:

1. Small variations in the position of setting standard and work piece.
2. Slight displacement of lever joints of measuring instruments.
3. Operator error in scale reading.
4. Fluctuations in the friction of measuring instrument etc.

Comparison between Systematic Errors and Random Errors

Systematic Errors	Random Errors
These errors are repetitive in nature and are of constant and similar form	These are non-consistent. The sources giving rise to such errors are random.
These errors result from improper conditions or procedures that are consistent in action.	Such errors are inherent in the measuring system or measuring instruments.
Except personal errors, all other systematic errors can be controlled in magnitude and sense.	Specific causes, magnitudes and sense of these errors cannot be determined from the knowledge of measuring system or condition.
If properly analyzed these can be determined and reduced or eliminated.	These errors cannot be eliminated, but the results obtained can be corrected.
These include calibration errors, variation in contact pressure, variation in atmospheric conditions, parallax errors, misalignment errors etc.	These include errors caused due to variation in position of setting standard and work-piece, errors due to displacement of lever joints of instruments, errors resulting from backlash, friction etc.