SEE1123 INSTRUMENTATION & ELECTRICAL MEASUREMENT

Metrology

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Introduction

- Metrology is the field of measurement.
- Metrology is vital in man's daily life.
- As such it is vital for the prosperity of mankind.
- Metrology is concerned with accuracy and precision as well as other related measurement parameters.
- Metrology has evolved from time to time and has seen rapid advancement with the introduction of new technologies and new techniques.

1.0 Introduction

The measurement of a given quantity involved the comparison between the quantity with an unknown magnitude) and a predefined standard. As two quantities are compared the result is expressed numerically. Advancement in instrumentation and measurement techniques are signs of progress in science and technology A method of evaluating a nation's progress in science and technology is to observe the type of measurements which are being performed and the way in which data is obtained by measurements and is processed.

1.0 Introduction (cont)

We can comprehend this because as science and technology progresses, new concepts and inventions are discovered and these advances make new types of measurements vital. New concepts, theories or innovations are not of any practical use unless they are backed by practical measurements. Measurements verify the validity of a theory and also strengthen to its understanding. Today we observe wide mass production, processed products, rapid progress in communications and travel, and plenty of other gigantic leap in scientific and technological progress all of which would not have exist without adequate measurement techniques.

1.1 Metrology Terms

There are various terminologies used in metrology. It is important to be precise in defining various terminologies. Some of them are given below:

Accuracy: The agreement of the result of measurement with the true value of the measured quantity.
Bias: The difference between the average test results and the true value of that quantity.

1.1 Metrology Terms (cont)

Calibration: A set of operations which under specified and controlled conditions such as establish the relationship between values of quantities displayed by a measuring instrument and the corresponding values given by standards of higher accuracy.

Deadband: The change in input needed to produce a change in output when the direction of the input is reversed.

Distortion: It specifies the fluctuation of a signal from its true form. It may be due to poor frequency response or poor phase shift response.

1.1 Metrology Terms (cont.)

Drift: The undesirable characteristic which occurs over a period of time when the output of a measuring system for a fixed measurand may change although all environmental factors remain constant.

Hysterisis: The error produced by approaching the same value when increasing and decreasing directions.

Instrument: A device which indicates or measure physical quantities or conditions, performance, position, direction, etc.

Linearity: A measure of the proportionality between the actual value of a measured variable and the output of the instrument.

1.1 Metrology Terms (cont.)

Precision: A measure of the reproducibility of the measurements, i.e. given a fixed value of quantity, precision is a measure of the degree of agreement within a group of measurements.

Repeatability: The ability of a device to produce the same output reading when the same measurand is applied using the same procedure.

Reproducibility: The closeness with which an instrument repeats indications when measuring the same values of the measured variable under the same conditions.

1.1 Metrology Terms (cont.)

Resolution: The smallest increment in input (the quantity being measured) that can be detected with certainty by an instrument is its resolution.

Sensitivity: A measure of the change in the output of an instrument for a change in the measured variable.

Traceability: The documentation process which validates the lineage of a measurement by relating a measured result to stated references through an unbroken chain of standards to national standard laboratory.

Uncertainty: The range within which the true value of the quantity measured is most likely to exist at a given level of probability. Uncertainty is not error although it is a characteristic of measurement and is not applicable to a measuring instrument. It comprises of a number of measurement results each of which has an error.

1.2 Dimension

Analysis of dimensions are vital in comprehending physical phenomenon which involved a mixture of various parameters.

Table 1 Dimensions of selected parameters

Quantity	Dimension
Area	L2
Volume	L3
Velocity	LT-1
Acceleration	LT-2
Angular velocity	T-1
Mass density	ML-3
Force	MLT-2
Weight	MLT-2
Pressure	ML-1T-2
Modulus of elasticity Absolute	ML-1T-2
viscosity	ML-1T-1
Power	ML2T-3
Torque	ML2T-2
Surface tension	MT-2
Work	ML2T-2
Stiffness	ML2T-2
Momentum	MLT-1

1.4 Practical Units

Practical units represent units which are commonly used to represent various parameters such as charge, current and voltage.

1.5 Dimension Equation

In the dimensional system, the dimensional equation is used in order to show that there is a balance of dimension in the left-hand side and right-hand side of the equation.

Example:
Verify that the following displacement equation is dimensionally balanced,
s = ut + at2/2
where u = initial velocity, t =time, and a = acceleration.
Solution
The equation dimensionally becomes
[L] = [LT-1] [T] + [LT-2] [T]2
The indices are simplified as
[L] = LT-1+1 + LT-2+2
Hence,
[L] = [L] + [L]
The equation is dimensionally correct since it has the same dimension at the left hand side and the right hand side of the equation.

1.6 International System of Units

The international system of units represents units that are widely accepted as units of measurement.

The dominant units used worldwide today in measurement are those adopted in the International System of Units (SI). It also called the modern metric system. In **SI, there are 29 units (7 base, and 22 derived units).**

- The seven SI base units are:
- the meter for distance,
- the kilogram for mass,
- the second for time,
- the ampere for electric current,
- the kelvin for temperature,
- the mole for amount of substance, and
- the candela for intensity of light.

1.6 International System of Units (cont)

The SI derived units, are defined algebraically in terms of these fundamental units. As an example, the SI unit of force, the newton, is defined to be the force that accelerates a mass of one kilogram at the rate of one meter per second per second. Hence the algebraic relationship is N = kg•m•s-2. Currently there are 22 SI derived units. They include:

- the radian and steradian for plane and solid angles, respectively;
- the newton for force and the pascal for pressure;
- the joule for energy or work and the watt for power;
- the degree Celsius for temperature;
- units for measurement of electricity: the coulomb (charge), volt (potential), farad (capacitance), ohm(resistance), and siemens (conductance);
- units for measurement of magnetism: the weber (flux), tesla (flux density), and henry (inductance);
- the lumen for flux of light and the lux for illuminance;
- the hertz for frequency of regular events and the becquerel for rates of radioactivity and other random events;
- the gray and sievert for radiation dose; and
- the katal (added in 1999), a unit of catalytic activity used in biochemistry.

1.7 Traceability

Traceability is important in order to prove that lower standards can be traced to the upper standards via a chain of comparison.

In order to preserve the integrity of measurement, it is important to ensure that a measurement result is related to references at the higher levels. This is where the concept of traceability is important. Traceability means an unbroken chain of comparison, all of which have stated uncertainties which ensure that a measurement result or the value of a standard is related to references at the higher levels, ending at the appropriate national primary standard or international standard having the highest accuracy. Figure 1.1 shows a traceability chain which shows an unbroken chain of comparison between different levels of standards.

1.8 Calibration

To ensure that the performance of instruments is always consistent and accurate, instruments have to be regularly calibrated.

Calibration consists of a set of operations that relates values of quantities indicated by a measuring instrument and the corresponding values realized by standards. Calibration removes one or more of the systematic errors using an equation called an error model. Measurement of high quality standards allows the analyzer to solve for the error terms in the error model. Calibration improved measurement accuracy.

Basically the reasons for calibrating instruments are:

1. To make sure that the instrument readings are consistent with other measurements.
2. To obtain the accuracy of the readings from the instrument.
3. To determine the reliability of the instrument.

1.8 Calibration (cont)

Calibration should be done under the following circumstances:

- Obtain the best accuracy possible.
- Adapt to a different connector type or impedance.
- Connect a cable between the test device and an analyzer test port.
- Measure across a wide frequency span or an electrically long device.
- Connect an attenuator or other such device on the input or output of the test device.

1.8 Calibration (cont)

A calibration laboratory should implement strict procedures when carrying out calibration including the following:

1. Each measurement must be documented specifying details of the standards and method used to perform the calibration.
2. The documents must be ready at all times to enable indepedent arbitration in case of disagreement with client.
3. It is important to keep documents which provide a history of the equipment and standards which are calibrated at regular intervals.
4. The uncertainty of measurement must be assessed and must be quoted on a certificate for each size of quantity given.

1.8 Calibration (cont)

All instruments such as voltmeters, ammeters and wattmeters should be calibrated periodically to check that they are within their prescribed accuracy. The simplest method to do this is to compare the instrument reading with that of a more accurate instrument when they are both measuring the same quantity. Bench-type digital meters are usually sufficient to calibrate other digital and analog instruments. Highly accurate voltage and current sources, known as calibrators are designed to calibrate instruments. The potentiometer can be combined with precision resistors and potential dividers for ammeter and voltmeter calibration.

1.8 Calibration (cont)

Calibration should only be carried out by qualified personnel. When a calibration has been carried out, a calibration certificate should be issued by the organization which carried out the calibration process. The certificate should contain the following details:

1. the calibration date,
2. the identification of the instrument calibrated,
3. the results of the calibration,
4. the uncertainty obtained as a result of the calibration,
5. the authority which issued the certificate.

Exercise

Why is calibration important?