SEE1123 INSTRUMENTATION & ELECTRICAL MEASUREMENT

Standards

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2.0 Classification of Standards

Standards can be classified into four categories namely international standards, primary standard, secondary standard and working standard.

a) **International Standards**

International standards are devices which are defined, designed and built according to specifications agreed at the international level. They represent various units of measurement of various physical quantities such as mass, time and length. They are designed to the highest possible accuracy using the most sophisticated technological and scientific methods. They are checked and assessed regularly against absolute measurements in terms of the fundamental units. In order to protect their integrity, they cannot be used by the ordinary user for the aim of calibration or comparison. The International Bureau of Weights and Measures (BIPM) at Sevres, France, preserved various international standards.

2.0 Classification of Standards (cont)

b) **Primary Standards**

Primary standards are instruments preserved by national standards laboratories in various parts of the world. In Malaysia, SIRIM plays the role of preserving the Malaysian national standards. Normally national standards have been kept for years and years in the laboratory and as such their stability and uncertainty are known and accepted. They either represent the fundamental or derived quantities. From time to time they are independently calibrated by absolute measurements. They are used to calibrate secondary standards. As with international standards, they cannot be used by ordinary user of instruments or brought out of the laboratory in order to protect the integrity of the instruments.

2.0 Classification of Standards (cont)

c) **Secondary Standards**
Secondary standards are used in industrial measurement laboratories as the basic reference standards. They disseminate the SI units from the primary standards. Normally they are utilized to calibrate calibrators or strengthen the performance of calibrators when making very accurate measurements. Each laboratory sends its secondary standards to be calibrated against the national standards which have higher accuracy.

2.0 Classification of Standards (cont)

d) **Working Standards**

Working standards are the main instruments used in a measurement laboratory. They are utilized to verify and calibrate the devices used in the laboratory, or to perform comparison measurements in industrial applications. They are commercially available and from time to time are calibrated against either the primary or secondary standards. They are less accurate and cheaper than other types of standards.

2.1 Mass Standard

The international mass standard is represented by the international prototype kilogram. This prototype is in the form of a platinum-iridium cylinder maintained at specially-built laboratory maintained by the International Bureau of Weights and Measures in France.

2.2 Length Standard

The internationally-accepted standard for length is defined as the length of the path traveled by light in a vacuum during a time of 1/299,792,458 of a second.

The international prototype meter was represented by a standard bar made of platinum-iridium kept at Sevres, France. The international prototype of the kilogram is always 1 kilogram exactly. However, due to the inevitable accumulation of contaminants on surfaces, the international prototype is subject to reversible surface contamination that approaches 1 μg per year in mass. To protect the integrity of the prototype, the reference mass of the international prototype is that immediately after cleaning and washing by a specified method. The reference mass is used to calibrate national standards of platinum-iridium alloy.

2.2 Length Standard (cont)

The 1889 definition of the metre, based on the international prototype of platinum-iridium, was replaced in 1960 when the meter was redefined in terms of the wavelength of a krypton-86 lamp as the length equal to 1,650,763.73 wavelengths in vacuum corresponding to the transition between two energy levels of the atom krypton 86. The krypton-86 standard was reproducible to approximately 2 parts in 108. The current definition based on the speed of light in a vacuum was used since 1983. For the measurement, light from a helium-neon laser illuminates iodine which fluoresces at a highly stable frequency.

2.2 Length Standard (cont)

The standard of length cannot be used for routine calibration in order to protect it from deterioration. Normally in each country, interlaboratory standards are created. These interlaboratory standards are standards sent in to the national standards laboratory for calibration by factories and laboratories throughout a country and they are readily available to the working engineers in order to calibrate motion transducers.

2.2 Length Standard (cont)

The BIPM states that the meter can be realized using the following three methods. **c** is the speed of light. The meter can be realized by:

1. By directly measuring distance L that light travels in vacuum in the time interval **t**, using the formula **L = c x t;**
2. By directly measuring the frequency **f** of radiation and calculating the wavelength **L** in vacuum **λ** using the formula **λ = c/f;**
3. By using one of the radiations from a list provided by the BIPM whose frequency and vacuum wavelength can be utilized with a stated uncertainty.

2.3 Absolute Ampere

The ampere is defined as that constant current which would yield a force of 2x10-7 N/m between two conductors if the current is maintained in two separate parallel conductors having an extremely large length.

As the standard ampere is quite difficult to realize, its uncertainty is large which is about 15 parts per million. It is also difficult to maintain the standard ampere for more than a few minutes. The ampere is realized using an ampere balance. In the ampere balance, the magnetic fields of the coil on the left side of the balance arm produce an attractive force proportional to the current flowing and the number of turns in each coil. The force is balanced by the weight on the right side of the balance arm. The force is produced by the electromagnetic field related to the moving electrons. As such 1A is equal to the flow of 1 Coulomb of electrons per second past a given point in an electrical circuit. Although the SI made use of ampere as the base unit for electricity, it is difficult to realize and as such there is no standard representation of the ampere.

2.3 Absolute Ampere (cont)

Practically the ampere is maintained through the Ohm's law from the units of voltage and resistance, the volt and the ohm, as the volt and the ohm can be tied to physical phenomenon which can be easily reproduced. The volt can be realized using the Josephson junction and the resistance can be realized using the Quantum Hall effect.

2.4 Temperature Standard

The temperature standard which is used internationally is based on the International Temperature Scale of 1990 or also known as ITS-90.

The 10th CGPM held in 1954 selected the triple point of water as the fundamental fixed point of temperature and assigned to it the temperature 273.16 K, so defining the unit. The 13th CGPM (1967/68) adopted the name kelvin, symbol K, and defined the unit of thermodynamic temperature as follows:

The kelvin, unit of thermodynamic temperature, is the fraction 1/273.16 of the thermodynamic temperature of the triple point of water.
The thermodynamic temperature of the triple point of water is exactly 273.16 kelvins, Ttpw = 273.16 K.

2.4 Temperature Standard (cont)

The CIPM in 2005 stated that:

This definition refers to water having the isotopic composition defined exactly by the following amount of substance ratios: 0.000 155 76 mole of 2H per mole of 1H, 0.000 379 9 mole of 17O per mole of 16O, and 0.002 005 2 mole of 18O per mole of 16O.

It is a common practice to express a thermodynamic temperature, symbol T, in terms of its difference from the reference temperature T0 = 273.15 K, the ice point. This difference is called the Celsius temperature, symbol t, which is defined by:

t = T – T0.

2.4 Temperature Standard (cont)

The unit of Celsius temperature is °C. The numerical value of a Celsius temperature expressed in degrees Celsius is related to the numerical value of the thermodynamic temperature expressed in kelvins by the formula
t/°C = T/K – 273.15.

The kelvin and the degree Celsius are also units of the International Temperature Scale of 1990 (ITS-90). The International Temperature Scale 1990 ITS-90, replaced several previous attempts to regulate the measurements of temperature on an international level among different laboratories.

2.5 Voltage Standard

The voltage standard is based on the quantum standard i.e. the Josephson junction. It was based on the discovery by Brian Josephson in 1962. It was only in 1990 that the standard for voltage made use of the Josephson effect. The Josephson junction is based on the concept of cooling semiconductors in liquid helium which enabled the semiconductors to become superconductors and have zero resistance. The junction is biased with dc current. A high frequency microwave source irradiates the Josephson junctions in a Josephson array. A dc voltage is produced across the junction voltage. The voltage is directly proportional to frequency. Increasing the bias current resulted in the increase of voltage in a number of equal steps of constant voltage.

2.5 Voltage Standard (cont)

At a particular step, the voltage is

Vn = fnh/2e

Where

f = the microwave frequency (Hz),

n = number of particular step,

e = the fundamental charge on an electron, and

h = Planck's constant.

Furthermore,

Vn = fn/Kj

Where **Kj** = the Josephson constant = 483 597.9 GHz/V.

2.6 Resistance Standard

The resistance standard is based on the Quantum Hall Effect. Since 1st January 1990, the definition of the ohm has been related to the Quantum Hall Effect (QHE) using the von Klitzing constant. In QHE, the von Klitzing constant, Rk, is a function of the ratio of the fundamental constants h and e, as in the formula:

Rk = h/e2
where
e = elementary charge
h = Planck's constant

2.6 Resistance Standard (cont)

The QHE was discovered in 1980 where cooling a thin semiconductor bar (carrying a dc current) in liquid helium, resulted in the semiconductor becoming a semiconductor. By greatly increasing the magnetic field, the Hall resistance increased in discrete steps. At each step the resistance remained extremely constant. This phenomenon is termed the QHE which can be depicted using the graph of Hall resistance versus the magnetic field.