

Section D

Temperature Measurement

Definition of temperature

- Temperature is the degree of hotness or coldness of a body or an environment measured on a definite scale.
- Temperature is a condition of a body by virtue of which heat is transferred to or from other body.
- The zeroth law of thermodynamics states that if a system C is in equilibrium separately with two thermodynamic systems A and B then A and B are also in equilibrium with each other. At once we may conclude that systems A and B are at the same temperature. Thermometry thus consists of using a thermometer (system C) to determine whether or not two systems (A and B in the above) are at the same temperature

Temperature Scale

$$K = {}^{\circ}\text{C} + 273.15$$

$$R = {}^{\circ}\text{F} + 459.69$$

$${}^{\circ}\text{F} = 32 + 9/5 {}^{\circ}\text{C}$$

$$R = 9/5 K$$

K is absolute temperature on Kelvin scale

R is absolute temperature on Rankine

scale ${}^{\circ}\text{C}$ is temperature on Celsius scale

${}^{\circ}\text{F}$ is temperature on Fahrenheit scale

Types of Thermometers

Non Electrical Methods (Thermal expansion)

- Bimetallic Thermometer,
- Liquid-in-Glass thermometer,
- Pressure Thermometer
- Solid Rod Thermometer,

Electrical Methods

- Electrical Resistance Thermometers using metallic materials like Platinum, Copper, Nickel etc.
- Semiconductor Resistance Sensors (Thermistors consisting of semiconductor materials like Manganese-Nickel-cobalt oxide mixed with proper binders)

Thermo–Electric method

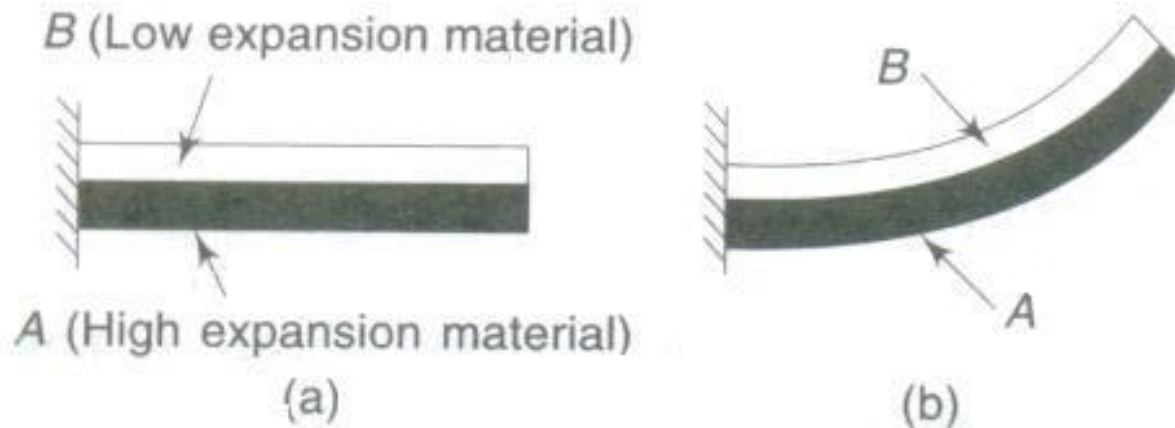
- Thermocouple thermometers using two wires of different materials

Pyrometry and spectroscopic methods

- Radiation thermometry using a pyrometer (Total Radiation Pyrometer, Selective Radiation Pyrometer.)
- Special methods like spectroscopic methods, laser based methods, interferometry etc.

Bimetallic Thermometer

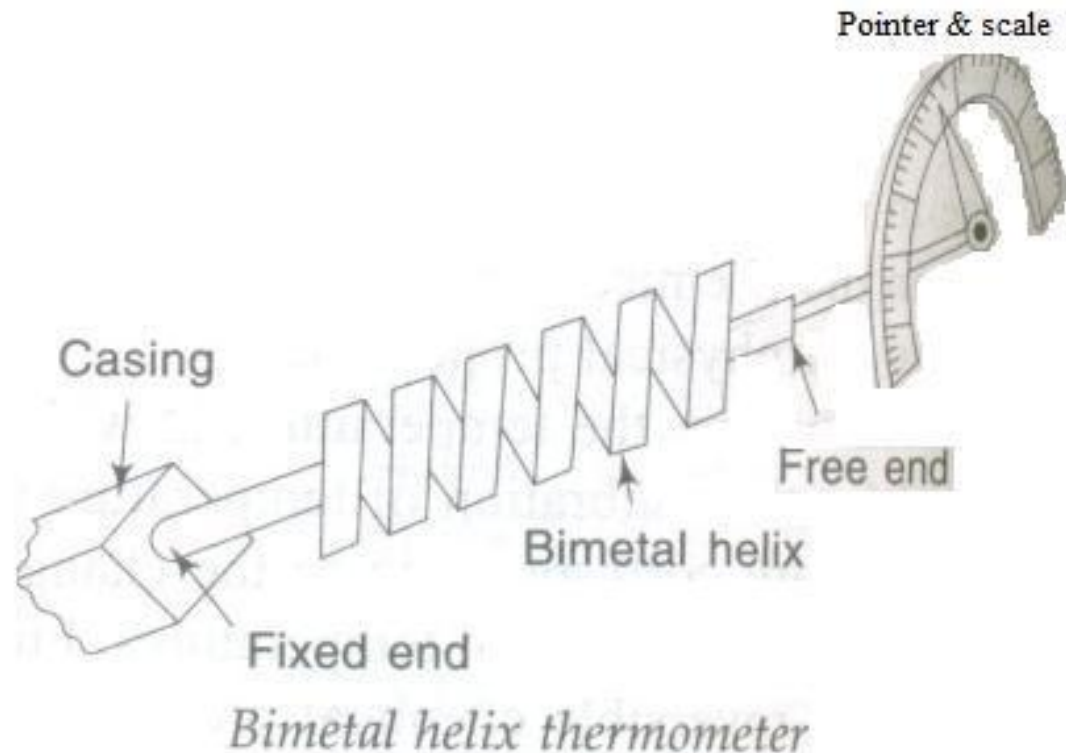
- Two metal strips brazed together with one having property of high coefficient of linear expansion and other low.
- Advantages – self generating type, low cost, low maintenance expenses, stable operation over extended period of time.
- Disadvantages – inability to measure rapidly changing temperatures due to its relatively higher thermal inertia.



Bimetallic thermometer

Helical Bimetallic Thermometer –

- Sensing strip is in helical form.
- As temperature changes, free end of helix rotates (the diameter of helix either increasing or decreasing due to differential action.)
- The rotational motion is directly indicated by movement of a pointer over a circular scale.



Liquid-in-Glass thermometer

- Most commonly used.
- Both liquid and glass expands on heating and their differential expansion is used to indicate temperature.
- Lower temp. limit is -37.8°C for mercury & -130°C for pentane.
- Higher temp. limit is 340°C (B.P. of mercury is 357°C)
- HTL may be extended to 560°C by filling space above mercury with CO_2 or N_2 at high pressure.
- Precision of thermometer depend on care used in calibration.
- A typical instrument is checked & marked from two to five reference temperatures. Intermediate points are marked by interpolation.
- Accuracy is limited to 0.1°C .

- For increased accuracy, a Beckmann range thermometer can be used.
- Contains a big bulb attached to a very fine capillary.
- Range is 5-6 °C with accuracy of 0.005 °C.
- Liquid in glass thermometers have properties like- low cost, simplicity in use, portability and convenient visual indication without the use of any external power.
- Use is limited to certain laboratory applications.
- Not proffered in industrial application because of its fragility and lack of adaptability to remote indication.
- Introduces time lag in measurement of dynamic signals because of relatively high heat capacity of the bulb.

Pressure Thermometers

- Based on principle of fluid expansion due to an increase in the pressure in a given volume of temp. measuring system.
- Most economical, versatile, robust, easy-to-read & widely used in industries.
- Easy to read remotely by connecting the bulb to a bourdon pressure gauge or any other pressure measuring device by means of a capillary tube.
- Relatively large metal bulb (stainless steel) instead of glass.
- Bulb is filled with liquid (mercury) or gas or a liquid-vapour mixture and depending upon type of fluid, thermometer is termed as mercury-in-steel thermometer or constant volume gas thermometer or vapour pressure thermometer resp.

- Low in cost, self-operated type, rugged in construction, no maintenance cost, stable in operation and accurate to $\pm .1^{\circ}\text{C}$
- Response can be increased by using a small bulb connected to an electrical type of pressure sensor connected through a short length of capillary tube.

