[Temperature Measurement]

Temperature of a body can be defined as degree of hotness or coldness of the body measured on a definite scale. The principle of temp. measurement is based on zeroth Law of thermodynamics.

To measure the temperature quantitatively, we use some property of matter that changes with temperature. The device which utilizes the property of matter to measure temperature is known as thermometer.

Temperature Measuring Instruments :

Temp. Measurement

Mechanical Thermometers

1. Metallic Expansion Thermometers
   (a) Expansion Rod thermometers
   (b) Bimetallic Thermometers
2. Filled System Thermometers
   (a) Liquid Filled Thermometer
   (b) Mercury Filled Thermometer
   (c) Constant Volume Gas thermometer
   (d) Vapour pressure thermometer

Electrical Thermometers

1. Metallic Resistance Thermometer
2. Thermistor
3. Thermo couple

Radiation Pyrometers

1. Total Radiation Pyrometer
2. Optical Pyrometer

Radiation Pyrometers :

The devices used to measure temp. using radiation method are called radiation pyrometers. Two common type of pyrometers are-total radiation pyrometer and selective radiation pyrometer.

Total Radiation Pyrometer :

It can be used to measure temperature in the range 700°C to 2000°C.

The principle of this pyrometer is based on Stefan Boltzmann law which states that the total energy emitted by a unit area of a perfect radiator per second is proportional to the forth power of its absolute temperature.

In other words, if a body 'A' at temp 'T_A' is surrounded by another body 'B' at lower temp T_B, then rate of radiations from body 'A' to body 'B' is given by

$$Q_{A \to B} = \sigma (T_A^4 - T_B^4)$$

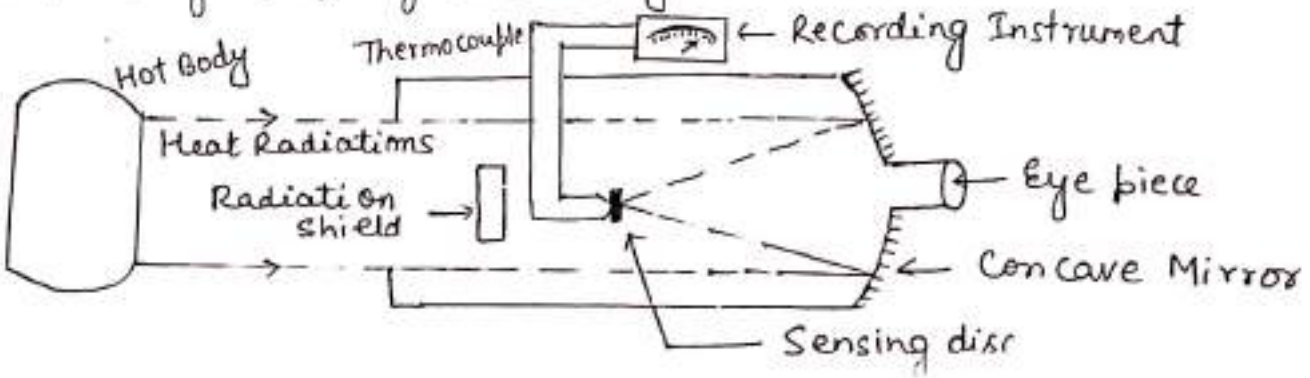
where σ is known as Stefan-Boltzmann constant.

A total radiation pyrometer is basically a thermocouple instrument placed in a black tube. One junction of the thermocouple has the sensing disc. The sensing disc is a platinum foil painted black in colour.

Radiations coming from the hot body are made to focus on the sensing disc by means of concave mirror which can be adjusted by a rack and pinion arrangement.

As the sensing disc absorbs radiation heat, the temp of the corresponding junction of thermocouple rises and an emf is induced which can be read by recording element.

The recording instrument can also be directly calibrated in terms of temp of hot body.



Metallic Expansion Thermometers :

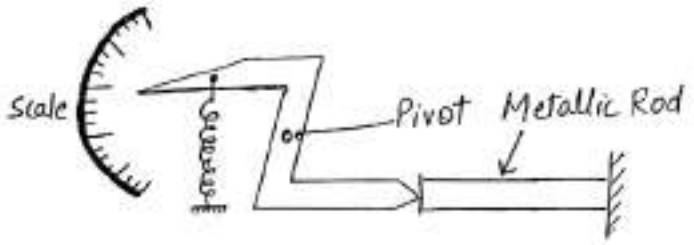
These comprise of expansion rod thermometers and bimetallic thermometers.

Expansion Rod Thermometer :

It is based on linear expansion of metals with rise in temperature. The change (Δl) in the length of rod is directly proportional to original length (l) and rise in temp (Δt).

$$\Delta l = \alpha l \Delta t$$

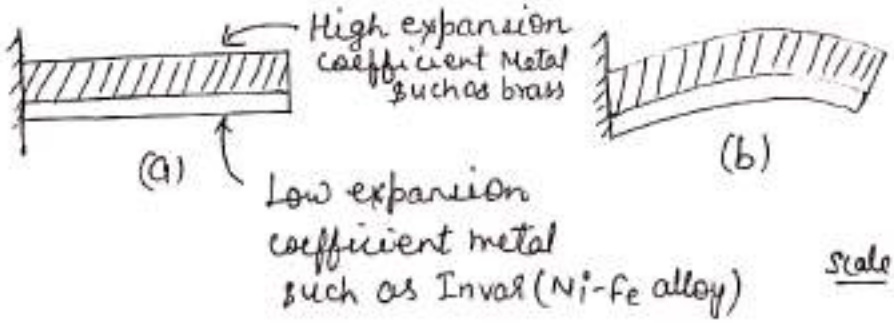
where 'α' is called coefficient of linear expansion of metal.



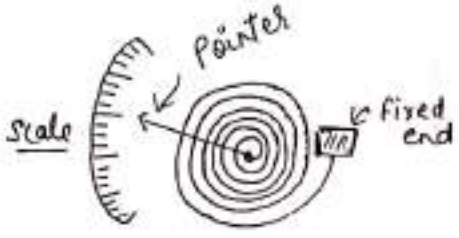
(Metallic Expansion Thermometer)

Bimetallic Thermometer :

It consists of bimetallic strip in form of cantilever, a spring or helix. Two two metals are welded or rivetted together to prevent relative motion between them. Consider a bimetallic strip which is straight initially. With rise in temp, the strip bends as shown in figure given below.



When strip is bend in the form of helix, a pointer is connected at the free end. As temp increases the strip expands, thus causing pointer to move on



Bimetallic strip

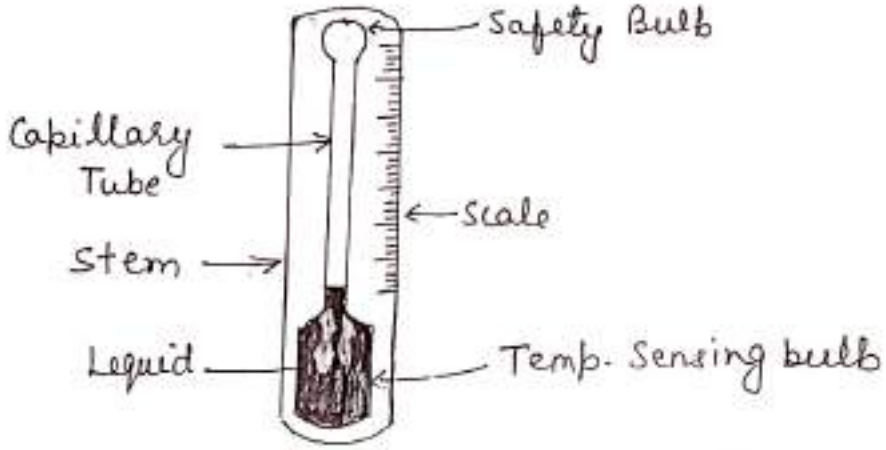
(C)

Filled System Thermometer :

Liquid Filled Thermometer :

It is oldest and most commonly used temp. measuring instrument.

It consists of a capillary tube having a relatively large temp. sensing bulb at one end and a small safety bulb at the other end. As the capillary tube is very delicate, it is enclosed in a glass stem. The liquid lies in the temp. sensing bulb and a small part of capillary tube. When the bulb is placed in the medium whose temp is to be measured, the liquid absorbs heat, expands and its level starts rising in the capillary. When liquid level stabilizes, the height of the liquid column indicates the temp.



(Liquid filled thermometer)

Constant Volume Gas Thermometer :

It works on the principle that pressure of a gas enclosed in a constant volume increases with rise in temp. Inert gas nitrogen is used in this type of thermometer. Construction of this thermometer is just like liquid filled thermometer but the sensing bulb in this case is much larger than a liquid filled thermometer. The change in pressure is detected by elastic elements like bourdon tube, bellows etc.

Electrical Thermometers :

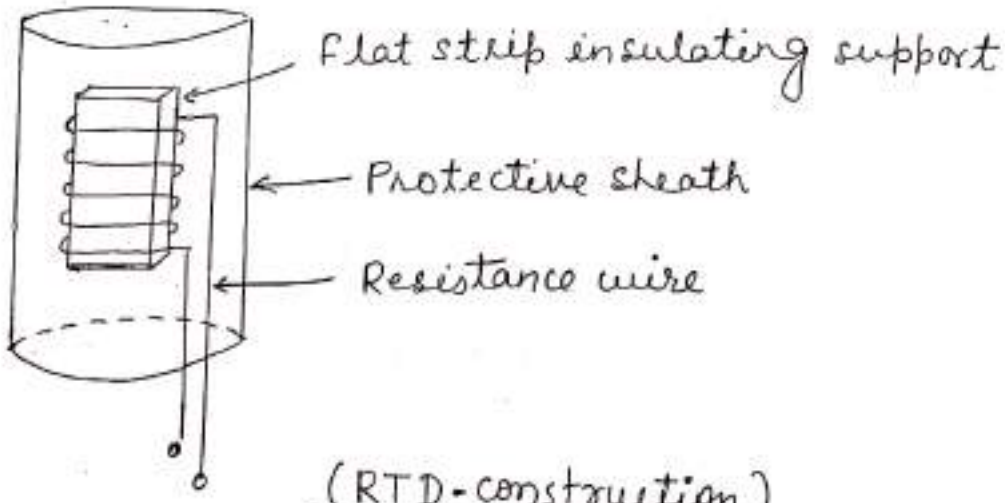
1) Metallic Resistance Thermometer :

It is commonly called as resistance temperature detector (RTD). It can make use of metals like copper, Nickel and platinum etc. Resistance of these metals rise with increase in temp. The relationship between temp and resistance is,

$$R_t = R_0(1 + at + bt^2)$$

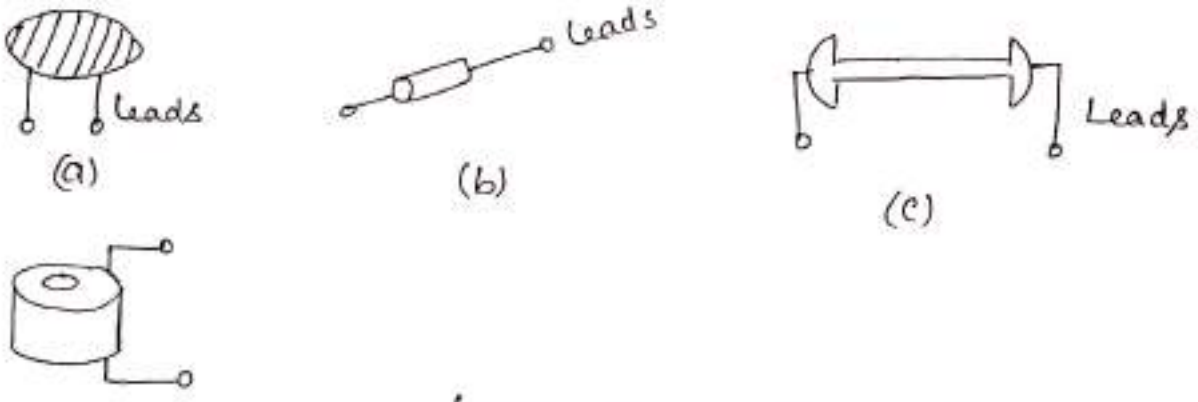
where R_t is resistance at absolute temp 't' and R_0 is resistance at 0°C (273°K).
Here 'a' and 'b' are constants.

In RTD a metal wire is wound over a support made of insulating material such as glass, mica or ceramic. The ends of the ristance wire are welded to copper leads that are connected in one of the arms of wheat stone bridge circuit. Generally a protective metal sheath is provided to improve strength and rigidity of the enstrument.
The main advantages of RTD, which have made them popular in industry, are high accuracy and precision. The limitations of RTD are high cost, larger size as compared to thermo-couples and possibility of current leakage.

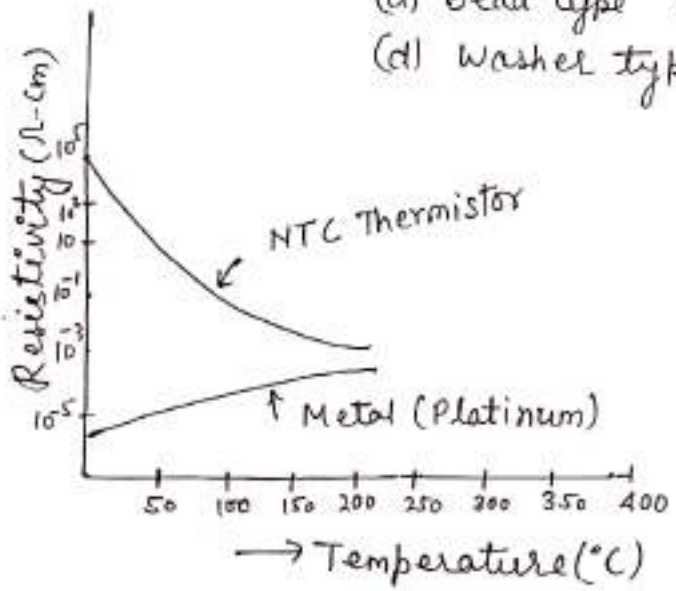


(RTD - construction)

(b) **Thermistor**: Resistor with negative temp. coefficient is known as thermistor. Thermistors are made of semiconductor materials. The resistance of thermistors ranges from 0.5 Ω to 0.75 MΩ. Thermistors are available in variety of shapes – thin chip, thin rods, washer etc. Thermistors are made of sintered mixture of metallic oxides such as maganese, chromium, copper, iron, nickel, cobalt etc.



(Various forms of thermistors available)
(a) Bead type (b) disc type (c) Rod type
(d) Washer type.



Thermosensitive resisters having negative temp. coefficient are commonly known as NTC thermistors. From the graph it is clear that with rise in temp, the resistance of thermistor decreases while that of a metal increases.

Resistance R_t of thermistor measured at temp T (Kelvin) is given by equation, $R_t = R_0 e^{\beta\left[\frac{1}{T} - \frac{1}{T_0}\right]}$

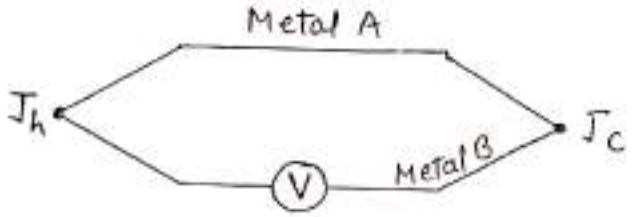
where R_0 is resistance at reference temp T_0 (Kelvin) & 'β' is a constant.

(c) Thermo couple :

It is the most popular method for temperature measurement in industrial applications.

A thermo couple basically consists of two wires of different metals which are joined together at the ends (by welding or brazing) to form measuring junctions. The wires are insulated by magnesium oxide for normal duty and by ceramic for heavy duty.

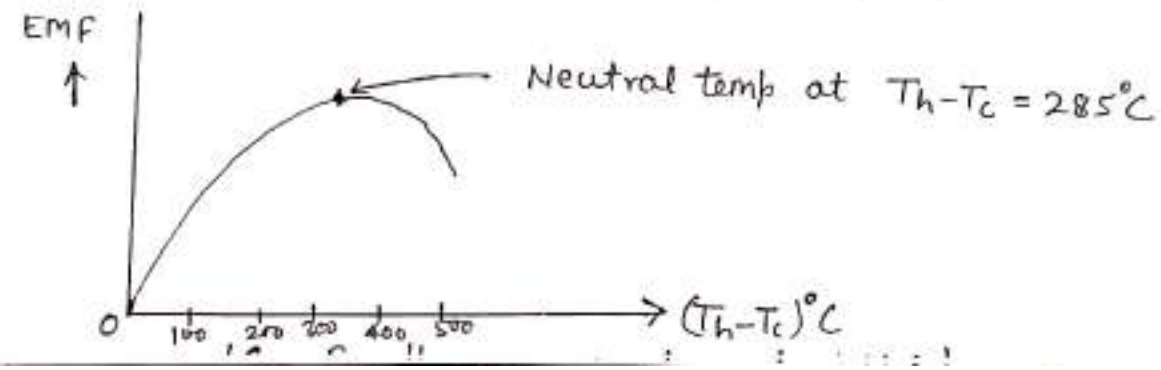
The working of a thermo couple is based on 'Seeback Effect'.



When two dissimilar metals are joined together to form junctions J_h and J_c ($J_h \rightarrow$ hot junction and $J_c \rightarrow$ cold junction), a sensitive voltmeter connected to the circuit will indicate a voltage (emf) which is approximately, directly proportional to the difference in temp between hot junction and cold junction. This phenomeno is known as Seeback Effect. The cold junction J_c is usually maintained at some known reference temp (such as ice point).

The emf - temp characteristics of copper - iron thermocouple is shown below.

$$EMF = a(T_h - T_c) + b(T_h - T_c)^2$$

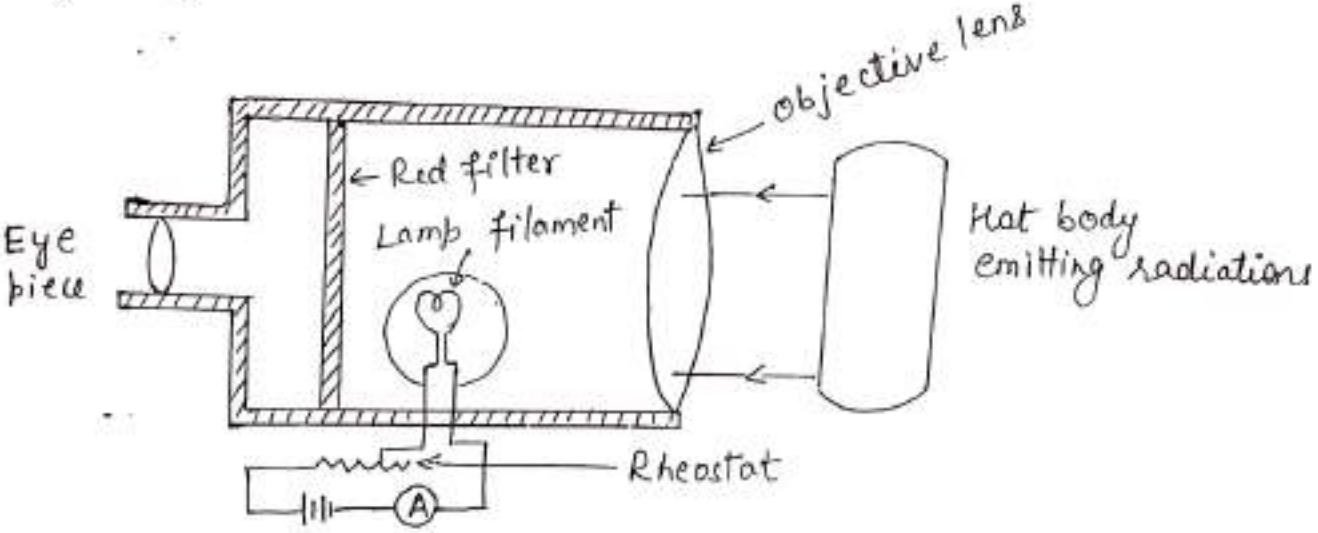


Optical Pyrometers :

These are used to measure temp in the range of 850°C. to 1200°C.

According to Plank's Law, energy levels in the radiation emitted by a hot body are distributed in different wavelengths. As the temp of hot body rises, the emissive power shifts towards shorter wavelengths. If we can measure brightness of the light of a given colour emitted by a hot source, we can estimate its temp. This is principle of optical pyrometers.

The disappearing filament type optical pyrometer is shown in figure given below.



Using the rheostat, current can be varied in the tungsten lamp so as to vary the brightness of the light. The image of the radiating source (hot body), produced by the objective lens system is made to superimpose on filament of electric lamp. The electric current is varied while being viewed through a filter and eye piece.

When brightness of filament is same as that of hot body, the filament disappears as shown in figure below. At this time temp of filament is equal to temp of hot body.