Mercury-in-steel Thermometer

- It has a nearly linear scale.
- The system is subject to ambient temperature errors.
- Change in pressure head also can create error . (change in relative levels of the bulb & display)
- The volumes of capillary & Bourdon tube are made as small as possible.
- Long capillary tubes can be used for remote measurements (upto 100 m.)
- When mercury is filled under pressure in steel bulb, temperature range is -25 ^{o}C to 550 ^{o}C.

Constant Volume Thermometer

- Uses an inert gas (usually nitrogen)
- Operate over a range -130 ^{o}C to 540 ^{o}C with linear range.
- Accuracy is of the order of $\pm$ 1% at lower ranges upto 300 ^{o}C and $\pm$ 2% above this range.
- Disadvantage- pressure developed for a given temperature change is small and also temperature compensation is more difficult.

Vapour Pressure Thermometer

- Thermometer is filled partly with liquid and partly with vapour of the same liquid so that there is a liquid-vapour interface in the bulb.
- Fluids used are hydrocarbon type of fluids like ethane , ethyl alcohol, ethyl chloride, methyl chloride, chlorobenzene, toluene, pentane, ether, acetone, etc.
- Scale range is of the order of 100 ^{o}C and accuracy is upto $\pm$ 1%.
- The temperature is roughly a logarithmic function of pressure ($log\ p = a - b/T$) so scale of this thermometer is non-linear.

Electrical Methods

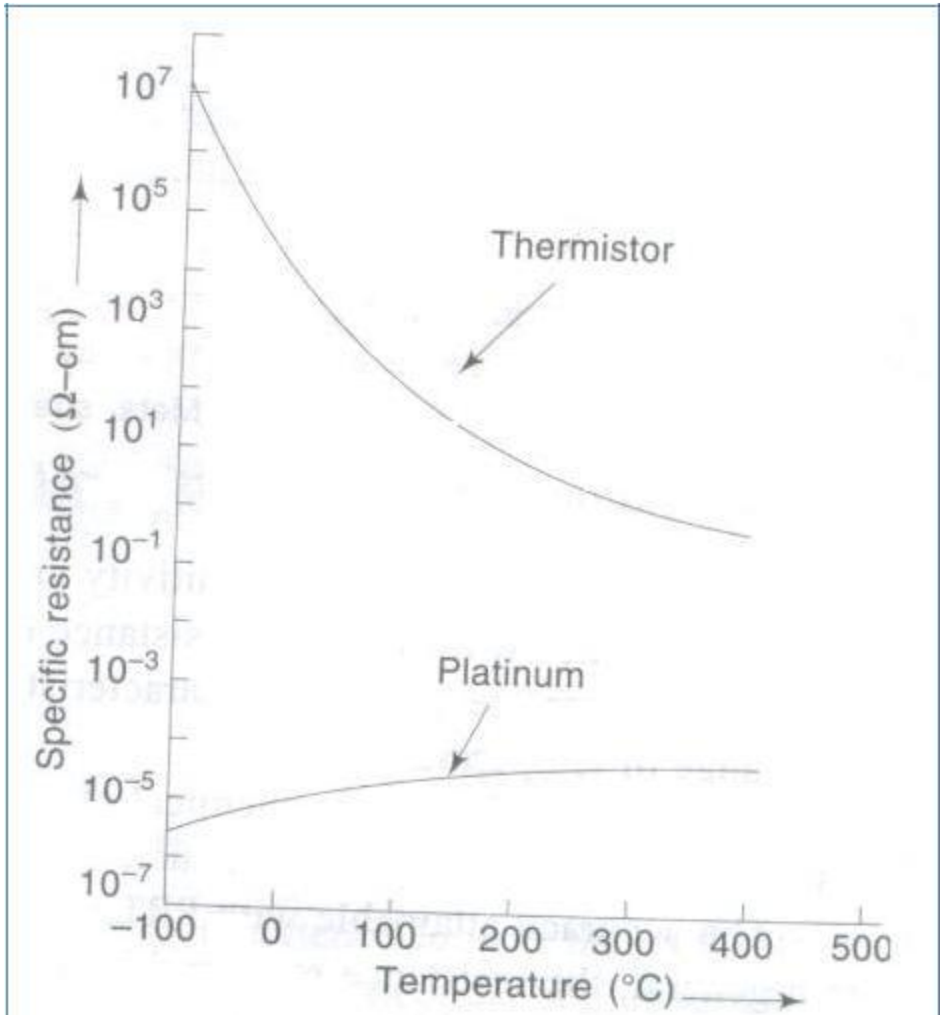
- Preferred as they furnish a signal which can be easily detected, amplified or used for control purposes.

  Two types –

1. Thermo-resistive type i.e. variable resistance transducers
2. Thermo-electric type i.e. emf generating transducers.

Electrical Resistance Thermometers

- Acts on principle of change in resistance of various materials due to change in temperature.
- Materials may be conductors(metals) and semiconductors.
- In general resistance of highly conducting materials increases with increase in temperature.
- Resistance of semiconductor materials generally (not always) decreases with increase in temperature.
- Thermo-sensitive resistors having negative temperature characteristics are known as NTC thermisters.

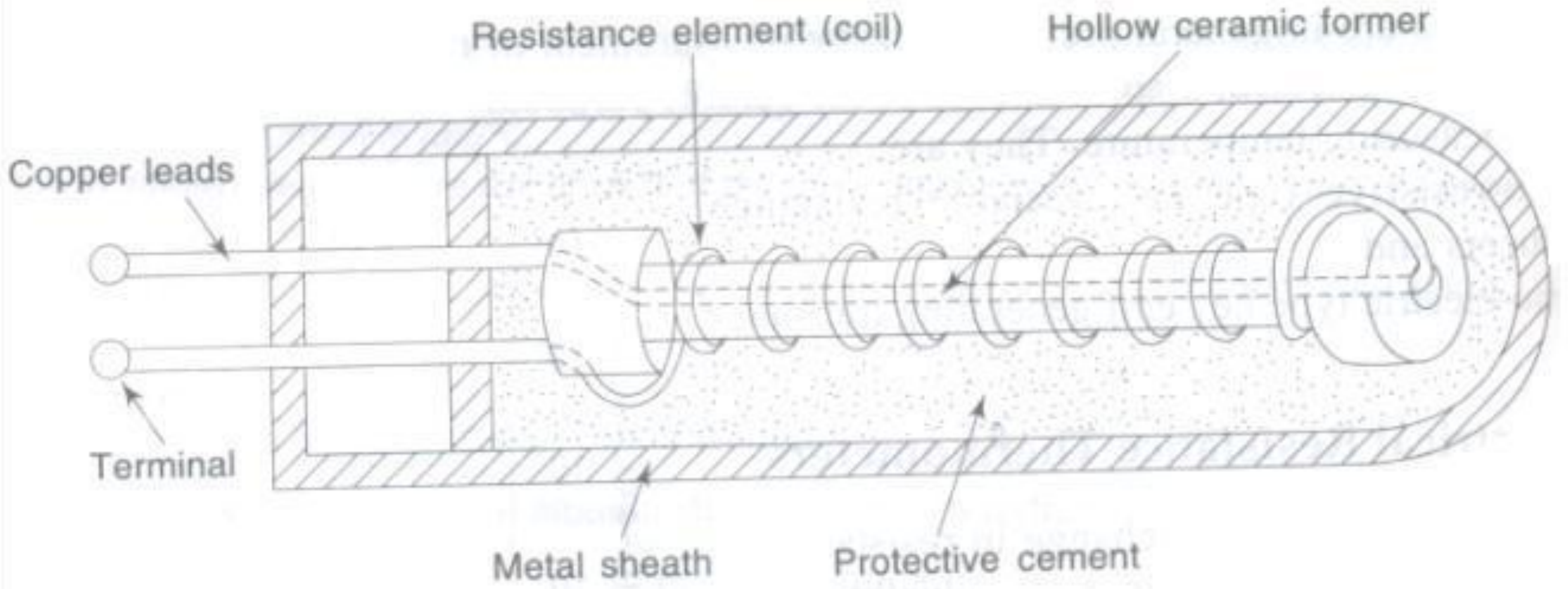


Resistance–temperature characteristics of platinum and a typical NTC thermistor

Metallic resistance thermometers or Resistance-Temperature Detectors (RTDs)

- Metals such as platinum copper, tungsten and nickel exhibit small increase in resistance as temperature rises.
- Platinum is very widely used sensor having range 4K to 1064 ^{o}C.
- platinum provides extremely reproducible output, so used in establishing International Practical Temperature Scale from 13.81K to 961.93 ^{o}C .
- For lower temperatures up to 600 ^{o}C , RTD sensor is made of nickel.
- For temp. up to 300 ^{o}C , RTD sensor is made of pure copper wire.
- RTD is useful for both lab. & industrial applications.
- High degree of accuracy & long-term stability.
- Wide operating range & linear characteristics.
- Limitations- low sensitivity, higher cost, and produce errors caused due to contact resistance, shock & accelerations.

Metallic resistance thermometers or Resistance-Temperature Detectors (RTDs)



Construction of a platinum resistance thermometer (PRT)

Metallic resistance thermometers or Resistance-Temperature Detectors (RTDs)

Construction of platinum resistance thermometer –

- A coil of fine metal wire is wound on grooved hollow insulating ceramic former & covered with protective cement.
- Ends of coils are welded to stiff copper leads that are taken out to be connected in one of the arms of Wheatstone bridge circuit.
- A protective metal sheath is used to provide rigidity and mechanical strength.
- Alternatively, RTD may be fabricated by depositing thin films of platinum, nickel or copper on a ceramic substrate.
- These thin film sensors have advantage of extremely low mass and more rapid thermal response.
- Accuracy for PRT is $\pm$ 0.01 ^{o}C up to 500 ^{o}C and $\pm$ 0.1 ^{o}C up to 1200^{o}C.

Resistance – temperature relationship of most metals

$$\mathbf{R = R_0 [1 + aT + bT^2]}$$

Where, R = resistance at absolute temperature T

R_0 = resistance at 0 ^oC

a & b = constants

For limited temp. range around 0^oC (273 K)

$$\mathbf{R_t = R_0 (1 + \alpha t)}$$

α = temp. coefficient of resistance of material in $^oC^{-1}$

t = temperature relative to 0 ^oC

Values of α for copper = 0.0043 $^oC^{-1}$

nickel = 0.0068 $^oC^{-1}$

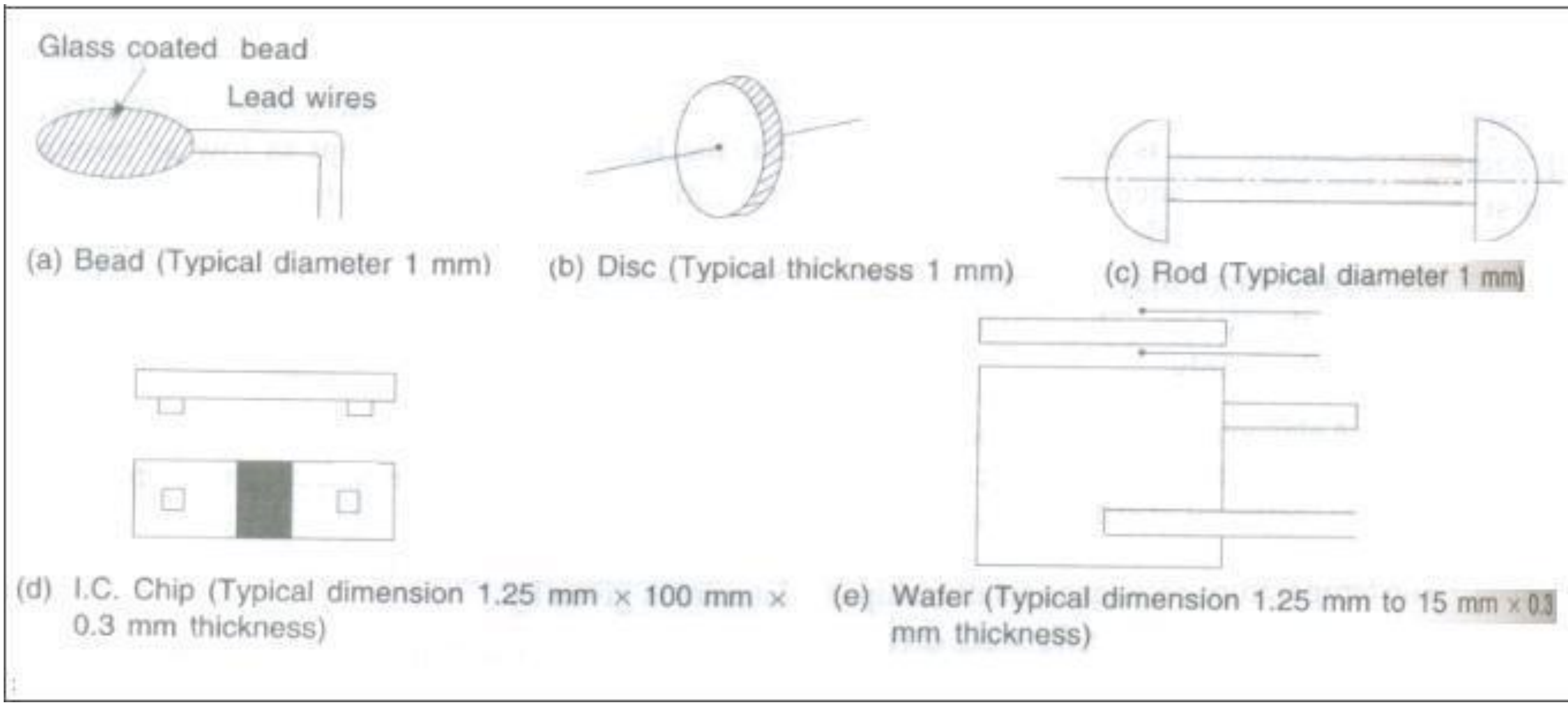
platinum = 0.0039 $^oC^{-1}$

If a change in temperature from t_1 to t_2 is considered,

$$\mathbf{R_2 = R_1 + R_0 \alpha (t_2 - t_1)}$$

Semiconductor Resistance Sensors (Thermistors)

- Thermistor (thermal resistor) is a thermally sensitive variable resistor made of ceramic-like semiconducting materials.
- Available in greater variety of shapes and sizes having cold resistance ranging from few ohms to mega ohms.
- Shapes may be extremely small bead, thin disc, thin chip or wafer to a large sized rod.



Thermistors

- Made up of semiconducting materials as oxides of copper, manganese, nickel, cobalt, lithium & titanium.
- Oxides are blended in suitable proportion & compressed into desired shapes from powders and heat treated to recrystallise them, resulting in a dense ceramic body with required resistance-temperature characteristics.

Thermistors have the following advantages for temperature measurements:

1. a large temperature coefficient which makes the thermistor an extremely sensitive device, thus enabling accuracy of measurement up ± 0.01°C with proper calibration,
2. ability to withstand electrical and mechanical stresses,
3. fairly good operating range which lies between –100 and 300°C,
4. fairly low cost and easy adaptability to the available resistance bridge circuits, and
5. the high sensitivity and the availability in extremely small sizes (of the size of a pin head) enable a fast speed of thermal response.

Thus, these devices are extremely useful for dynamic temperature measurements.

However, the *disadvantages* are a highly non-linear resistance–temperature characteristics and problems of self-heating effects which necessitate the use of much lower current levels than those with metallic sensors.

The temperature-resistance characteristics of a thermistor is of exponential type and is given by:

$$R = R_0 \exp\left[\beta\left(\frac{1}{T} - \frac{1}{T_0}\right)\right] \tag{12.9}$$

where R_0 is the resistance at the reference temperature T_0 (kelvin)
R is the resistance at the measured temperature T (kelvin)
β is the experimentally determined constant for the given thermistor material.

The values of β usually lie between 3000 and 4400 K depending on the formulation or grade.

Using Eq. (12.9) we can obtain the temperature coefficient of resistance as:

$$\frac{dR/dT}{R} = -\frac{\beta}{T^2} \tag{12.10}$$

Assuming $\beta = 4000$ K and $T = 298$ K

we get, $$\frac{dR/dT}{R} = -0.045\ \mathrm{K}^{-1}$$

The value of $\frac{dR/dT}{R}$ for platinum is 0.0039 K^{-1}, indicating that the thermistor is at least 10 times more sensitive than the platinum resistance element.