Unit– III

Temperature Measurement

3.1 Definition and units
3.2 First law of thermodynamics
3.3 Different temperature scales & their conversions
3.4 · Classification of temperature measuring transducers :
3.4.1 Filled system type thermometer.
3.4.2 Bimetallic thermometer
3.4.3 Electrical Temperature transducer

- Thermistors
- RTD – (PT-100) , 2 /3/4 wire systems (circuit diagram only)
- Thermocouple – working principle -Seeback & Peltier effect , Types J, K, R , S, T etc. (Based on material, temperature ranges)
- Pyrometer - Optical, Radiation

3.5 Specifications of thermistor, RTD and Thermocouple.

Temperature:-

"Degree of hotness or coldness of a body "

OR "An environment measured on a definite standard scale"

List different temperature scales.

Different temperature scales are as follows

i) Degree Fahrenheit (^{0}F)

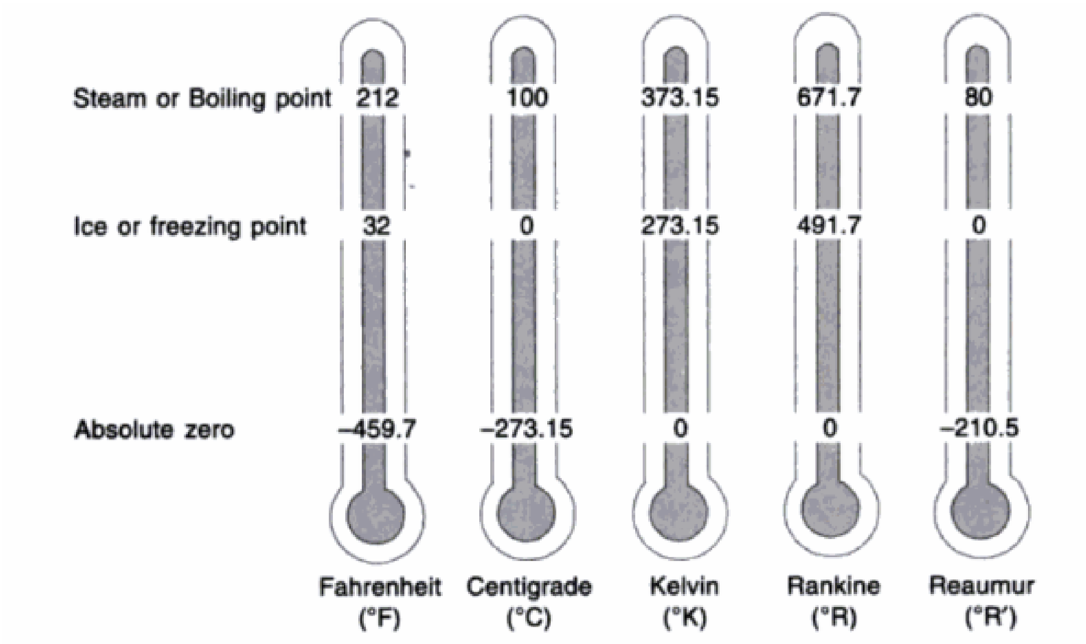
ii) Degree Celsius or centigrade (^{0}C)

iii) Kelvin (^{0}K)

iv) Degree Rankine (^{0}R)

v) Degree Reaumur (^{0}R')

^{0}C	^{0}K	^{0}F	^{0}R	^{0}R'	
100	373.15	212	671.7	80	Steam or boiling point
0	273.15	32	491.7	0	Ice point or freezing point
-273.15	0	-459.7	0	-210.5	Absolute zero



Ranges of Different Temperature Scales.

CONVERSIONS

Formulae

1	Fahrenheit to Celsius or centigrade	$^0C = \frac{5}{9}(^0F - 32)$
2	Celsius or centigrade to Fahrenheit	$^0F = \frac{9}{5}(^0C) + 32$
3	Fahrenheit to Rankine	$^0R = {}^0F + 459.7$
4	Celsius or centigrade to Kelvin	$^0K = {}^0C + 273.15$
5	Kelvin to Celsius or centigrade	$^0C = {}^0K - 273.15$
6	Kelvin to Rankine	$^0R = 1.802\ K$
7	Rankine to Kelvin	$^0K = 0.555\ ^0R$
8	Fahrenheit to Reaumur	$^0R' = (^0F - 32)/2.25$
9	Kelvin to Fahrenheit	$°F = 9/5\,(K - 273) + 32$
10	Fahrenheit to Kelvin	$K = 5/9\,(°F - 32) + 273$

Both the Rankin & Kelvin scales are called absolute scales because they use absolute zero as one of their reference points.

NUMERICALS

1) Convert 200^0F (Fahrenheit) into Celsius(^0C) ,Kelvin (^0K) , Reaumur ($^0R'$), Rankine (^0R) scale

Solution:
Given Temperature = 200^0F

i) $^0C = \frac{5}{9}\,(^0F - 32)$

$^0C = \frac{5}{9}\,(200 - 32)$

$\therefore$ $\underline{200^0F = 93.33\ ^0C}$

ii) $^0\,K = {}^0C + 273.15$

$^0\,K = 93.33 + 273.15$

$\therefore$ $\underline{200^0F = 366.48\ ^0K}$

iii) $^0\,R' = (\ ^0F\text{-}32)/2.25$

$^0\,R' = (\ 200\text{-}32)/2.25$

$\therefore$ $\underline{200^0F = 74.667\ ^0R'}$

iv) $^0R = {}^0F + 459.7$

$^0R = 200 + 459.7$

$\therefore$ $\underline{200^0F = 659.7^0R}$

2) Convert 50 ^0C into any two different scales of temperature.

Solution:

Given Temperature = 50 ^0C

i) Temperature = ^{o} K = ?

$^o\,K = {}^o\,C + 273.15$

= 50 + 273.15 = $\underline{323.15\ ^o\ K}$

Therefore, Temperature = $\underline{\mathbf{323.15\ ^o\ K}}$

ii) Temperature = ^{o} F = ?

$^o\,F = {}^o\,C * 1.8 + 32$

= 50 * 1.8 + 32 = 122 ^{o} F

Therefore, Temperature = $\underline{\mathbf{122\ ^o\ F}}$

(EXTRA INFORMATION

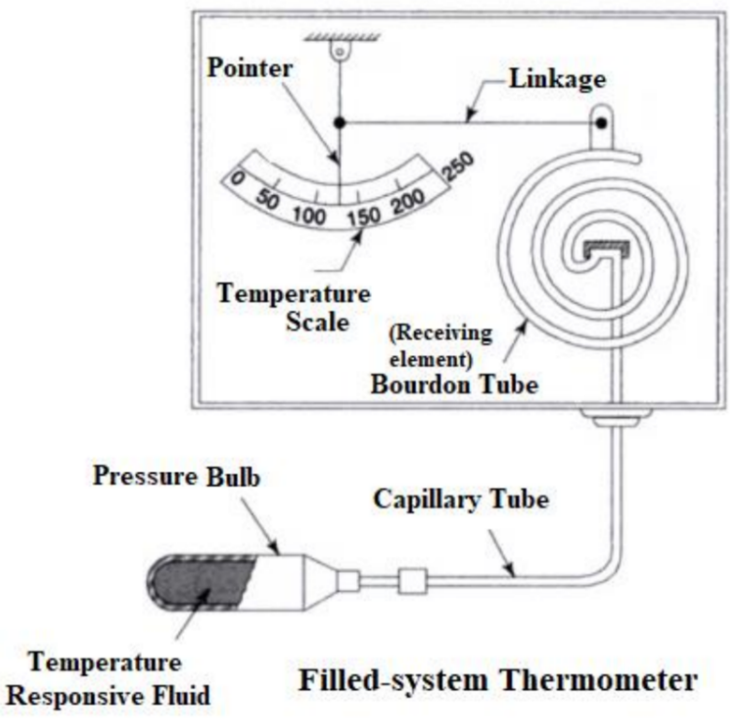
$$\frac{C}{5} = \frac{F-32}{9} = \frac{R'}{4} = \frac{K-273}{5}$$

Where C = Celsius ; F = Fahrenheit ; R’ = Reaumur ; K = Kelvin)

First Law of Thermodynamics

The First Law of Thermodynamics states that heat is a form of energy, and thermodynamic processes are therefore subject to the principle of conservation of energy. This means that heat energy cannot be created or destroyed. It can, however, be transferred from one location to another and converted to and from other forms of energy.

1. **Filled system type thermometer.**



Filled-system Thermometer

- It consists of a bourdon tube, capillary tube and thermometer bulb interconnected together.
- The entire system is sealed after filling with an appropriate liquid at a pressure at the normal ambient temperature.
- The common liquids are mercury, ethyl alcohol or xylene.
- The thermometer bulb is installed inside the substance whose temperature is to be measured.
- The filling liquid inside the bulb gets the temperature of the substance.
- This causes the filling liquid to expand or contract

• The Bourdon tube moves due to this.
• With increase in temperature, the liquid expands and due to this expansion Bourdon tube uncoils.
• With decrease in temperature, the liquid contracts and this forces the Bourdon tube to coil more tightly.
• The movement of the Bourdon tube is used to drive the pointer for indicating the temperature.
• Basically there are four types of filled system thermometer :

a) Gas- filled Thermometer
b) Liquid-filled Thermometer
c) Mercury-filled Thermometer
d) Vapour pressure thermometer.

- **Advantages of Filled system thermometer:**

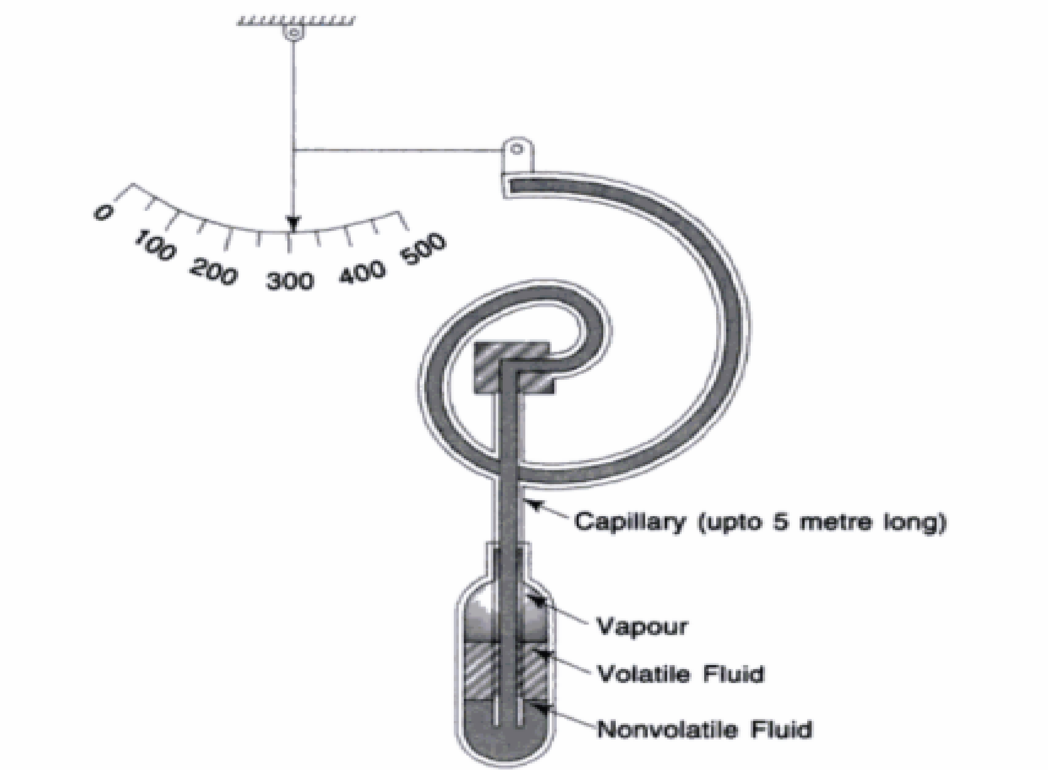
i) Rugged construction
ii) Low maintenance
iii) No need for electric power
iv) Point of display can be kept away from the point of measurement
v) Low cost
vi) Good accuracy and time response sensitivity
vii) Deliver enough power to drive the pointer and controller mechanism

- **Disadvantages of Filled system thermometer:**

i) Requires large bulb for accuracy
ii) Entire system has to be replaced in case of failure
iii) Less accuracy, sensitivity and span than electrical temperature transducers
iv) Limited maximum temperature than electrical temperature transducers
v) Separation of measuring element and Bourdon tube of more than 75m is not recommended here.

• Commonly used filled system thermometer is the Vapour pressure thermometer.

VAPOUR PRESSURE THERMOMETER

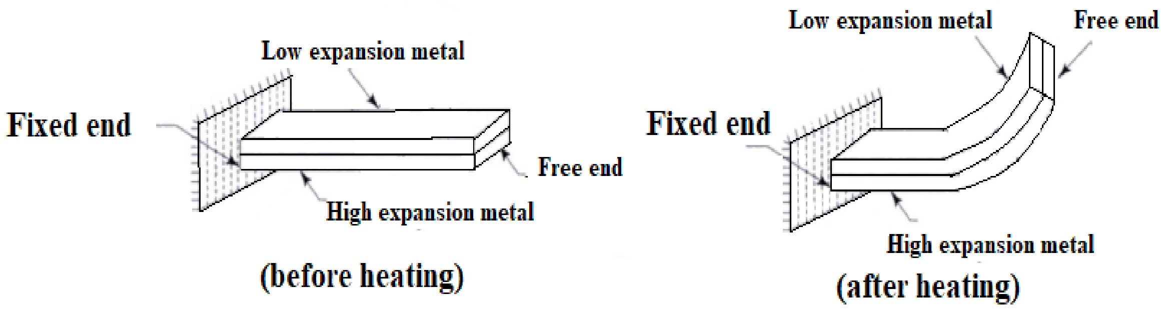


- Here, the bulb is partially filled with liquid and the capillary and Bourdon tube are filled with vapour.
- The liquid boils and vaporizes during operation which creates a gas or vapor inside the capillary and Bourdon tube. Thus, the capillary and Bourdon tube are filled with vapor.
- The liquid inside the bulb continues to boil until the pressure in the system equals the vapor pressure of the boiling liquid. At this point the liquid stops boiling unless its temperature increases.
- When the temperature of the substance surrounding the bulb drops, the liquid and the vapour inside the bulb is also cool. This causes some of the vapour to condense.
- As the vapor condenses, the pressure inside the system decreases.
- This action continues till the pressure drops to the vapor pressure of the boiling liquid.
- Due to this change in pressure, the Bourdon tube uncoils as the pressure increases.
- It coils tightly when it decreases.
- This movement of Bourdon tube is connected to a pointer to indicate the temperature

• The various liquids used in this system are shown below:

Liquid	Range of temperature
Argon	Down to -253°C
Methyl chloride	0° to 50°C
Sulphur dioxide	30° to 120°C
Ethyl chloride	30° to 100°C
Water	120° to 220°C
Ethyl alcohol	200° to 350°F

2. EXPANSION THERMOMETER –BIMETALLIC THERMOMETER



Bimetallic Strips

Construction and working :

Figure shows construction of a bimetallic thermometer; it consists of a bimetallic strip usually in the form of a cantilever beam, which is prepared from two thin strips of different metals having different coefficients of thermal expansion.

The bonding of two strips is done by welding such that they cannot move relative to each other.

Brass is used as a high expansion metal and Invar (alloy of iron-nickel) is used as low expansion metal.

1) All metals expand or contract with change in temperature.
2) The temperature co- efficient of expansion is not same for all metals therefore their rate of expansion or contraction is not the same. The difference in thermal expansion rate produces deflections proportional to the change in temperature.
3) As the temperature applied to the strip increases, there is deflection of the free end of the strip as shown in figure. The length of metal will change according to the individual expansion rate.
4) As one end of the bimetallic strip is fixed, the strip will bend at free end towards the side of the low coefficient of thermal expansion metal.
5) The deflection of the free end is directly proportional to the square of the length of the metal strip, as well as to the total change in temperature, and is inversely proportional to the thickness of the metal.
6) Pointer is attached to the free end to indicate the temperature.

Advantages:

1) Simple , Robust, inexpensive
2) Easily installed and Maintained
3) Wide temperature range (-40 ^{0}C to 550^{0}C)
4) Stable operation over extended periods of time

Disadvantages:

1) Limited to local mounting
2) There is always possibility of calibration change due to rough handling
3) Not recommended for use at temperatures above 400^{0}C for continuous measurements above 550 ^{0}C for intermittent measurements

Applications:

Used in Process industries for local temperature measurements

1) Refineries
2) Oil burners
3) Hot solder tanks
4) Hot wire heaters
5) Frequently used in simple on- off temperature control devices (Thermostat)

Materials Used for Bimetallic Thermometer

Sr. No.	**Material**	**Thermal coefficient of expansion(per ^{0}C)**
1	Invar	1.7 X 10 $^{-6}$
2	Brass	20.2 X 10 $^{-6}$
3	Monel 400	13.5 X 10 $^{-6}$
4	Inconel 702	12.5 X 10 $^{-6}$
5	Stainless steel Type -316	16.0 X 10 $^{-6}$

3) ELECTRICAL METHODS

a) THERMISTORS (Thermally Sensitive Resistors)

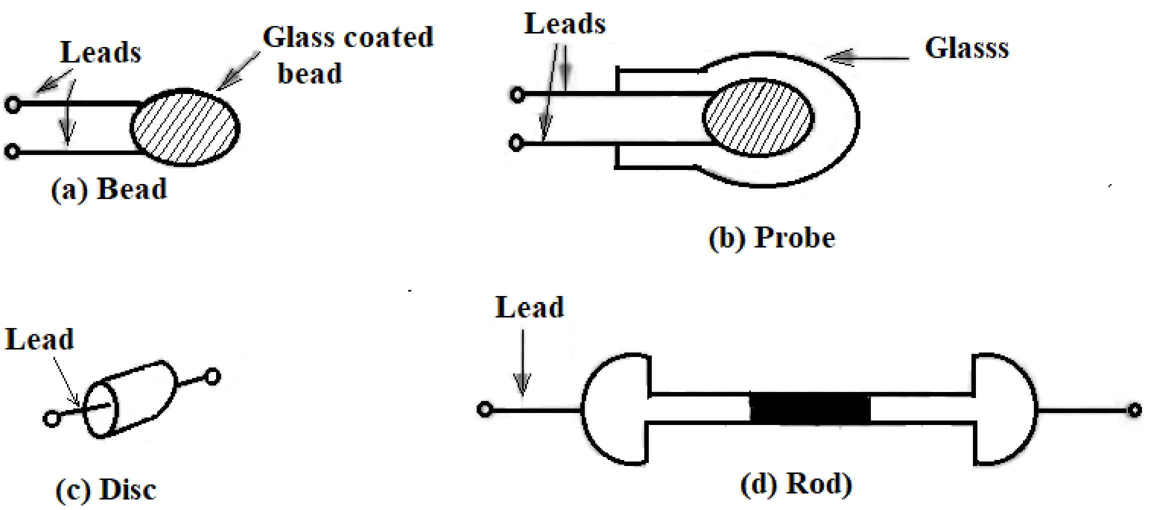
Thermistors are generally composed of semiconductor materials. Although +ve temperature coefficient of units are available, most thermistors have –ve coefficient of temperature resistance i.e. their resistance decreases with increase of temperature.

Construction:

Thermistors are generally composed of semiconductor materials. They are generally composed of a sintered mixture of metallic oxides such as manganese, nickel, cobalt, copper, iron, tin & zinc.

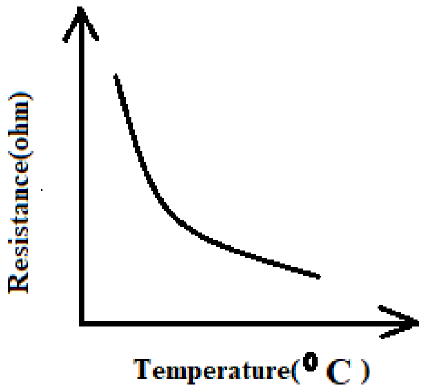
They are available in a variety of sizes and shapes. The thermistors may be in the form of beads, rods, disks. They can be encapsulated in plastic, cemented or glass coated to protect against damage to provide support.

TYPES OF THERMISTORS



The negative temp. the coefficient of resistance can be as large as several % per degree celsius. This allows the thermistor circuits to detect very small changes in temperature which could not be observed with an RTD or a thermocouple .

The thermistor exhibits highly nonlinear characteristics of resistance versus temperature.



Measurement range is -60 ^{0}C to 15 ^{0}C

The resistance of thermistor ranges from 0.5 Ω yo 0.75 MΩ

Thermistor is a highly sensitive device.

Advantages:

1) Compact & Inexpensive
2) Highly sensitive
3) Fast speed of response
4) The measuring current should be maintained to as low a value as possible to avoid self-heating of the thermistor.
5) Lead wire error is absent due to the large value of thermistor resistance.

Disadvantages:

1) Nonlinear characteristics of resistance versus temperature.
2) Small temperature range of operation.
3) Restricted to some process applications.

List applications of thermistor

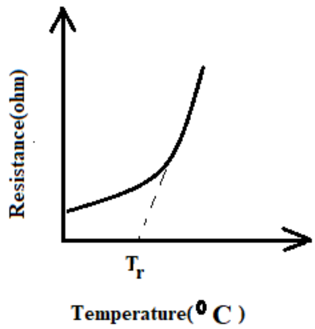
Applications of Thermistor

1) Major applications of thermistors are measurement and control of temperature
2) Used in temperature compensation circuit
3) Measurement of power at high frequencies
4) Measurement of thermal conductivity
5) Climate Control Systems Such As Air Conditioners, Freezers, Heaters, Refrigerators, Water Heaters.
6) Measurement of level , flow & pressure of liquids.
7) Vacuum measurements.
8) Providing time delay.

PTC Thermistors

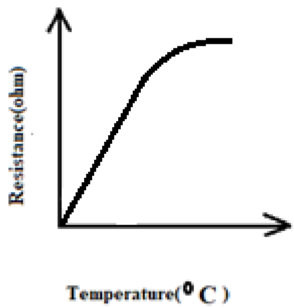
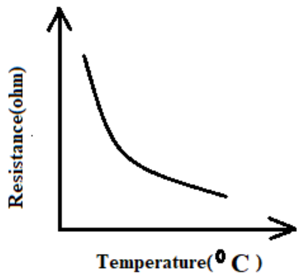
Manufactured from compounds of barium lead & strontium Titanate.

These are designed for protection of wound equipment such as transformers & motors.

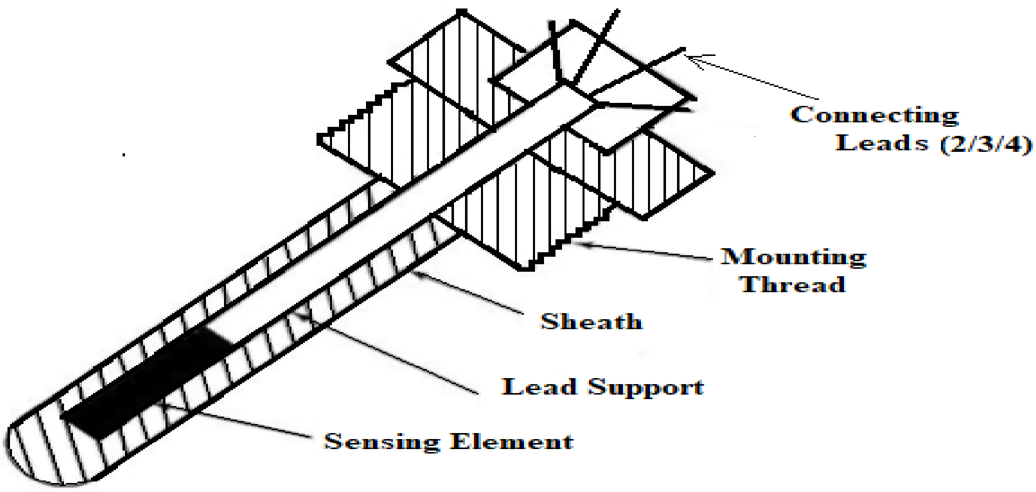


They are connected in series with the coil of the equipment contactor or protection relay. If the temperature of the winding exceeds temperature T_r the current becomes so small that power is effectively disconnected from the equipment.

Compare NTC and PTC

Sr. No.	PTC	NTC
1	It is positive temperature coefficient	It is negative temperature coefficient
2	As temperature increases resistance also increases Rα T	As temperature increases resistance also decreases Rα 1/T
3	PTC manufactured from barium titanate, titanium oxide, and powdered Barium carbonate	NTC composed of metal oxides such as manganese, nickel, cobalt, copper, iron and uranium.
4		

RTD-(PT-100, 2/3 WIRE)
(Resistance Temperature Detectors) Resistance Thermometer



Working:

An RTD (resistance temperature detector) is a temperature sensor that operates on the Measurement principle that a material's electrical resistance changes with temperature. Temperature sensitive materials used in the construction of RTDs include platinum ,nickel, and copper; platinum being the most commonly used.

RTD operates on the principle that the electrical resistance of a metal changes predictably in an essentially linear and repeatable manner with changes in temperature.

RTD has positive temperature coefficient (resistance increases with temperature). The resistance of the element at a base temperature is proportional to the length of the element and the inverse of cross sectional area.

A typical electrical circuit designed to measure temperature with RTD's actually measures a change in resistance of the RTD, which is then used to calculate change in temperature.

What is Pt-100?

Ans: The Resistance Temperature Detector (RTD) made of Platinum which has 100Ω resistance measured at 0^0C is called Pt-100.

Numericals

1) **Calculate the o/p resistance of PT 100 RTD for temperature values 35^0C, 85^0C.**

a) **For 35^0 C temperature:**

For PT 100:

$R_0 = 100\Omega$ at $t_0 = 0^0C$

R_t = ? , at t= 35 ^{0}C

Relation between resistance & temperature for resistance thermometer is

$R_t = R_0 (1+ \alpha \Delta t)$

Assume $\alpha = 0.00392/^0 C$

Resistance at t=35^0C ,

R_t =100[1+0.00392*(35-0)]

R_t =113.72 Ω

b) **For 85^0 C temperature:**

For PT 100:

$R_0 = 100\Omega$ at $t_0 = 0^0C$

R_t = ? , at t= 85 ^{0}C

Relation between resistance & temperature for resistance thermometer is

$R_t = R_0 (1+ \alpha \Delta t)$

Assume $\alpha = 0.00392/^0 C$

Resistance at t=85^0C ,

R_t =100[1+0.00392*(85-0)]

R_t =133.32 Ω

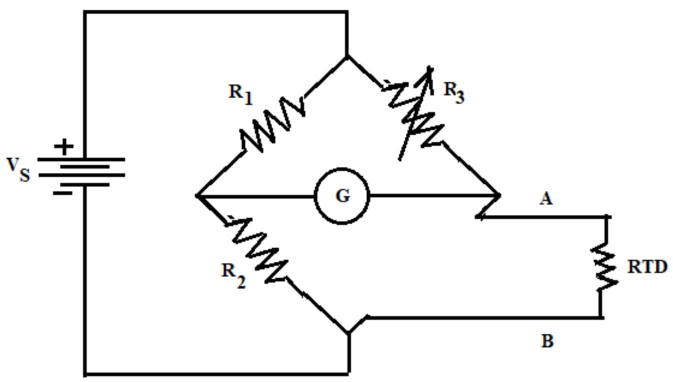
Materials used to construct RTD's are

Sr.No.	Material	Resistance Temperature coefficient ($/^0C$)	Temperature range
1	Platinum	0.00392	$-260\ ^0C$ to $111^0\ C$
2	Copper	0.00393	$0\ ^0C$ to $180^0\ C$
3	Nickel	0.0062	$-220\ ^0C$ to $300^0\ C$
4	Tungsten	0.0045	$-200\ ^0C$ to $1000^0\ C$

Measurement using RTD

The change in resistance due to change in temperature is measured using Wheatstone bridge with RTD connected as one of its arm.

1) TWO WIRE RTD



When bridge is Balanced (Galvanometer I=0)

$R_1+R_3 = R_2 + A+B+RTD$

$\underline{\mathbf{R_3 = A+B+RTD}}$ (since $R1 = R_2$)

In actual installations, the RTD element is connected by lead wires to the readout or transmitting instrument.

The temperature coefficients of resistors R_1, R_2, R_3 are nearly zero & the value of R_3 is adjusted until the current flow of G is zero.

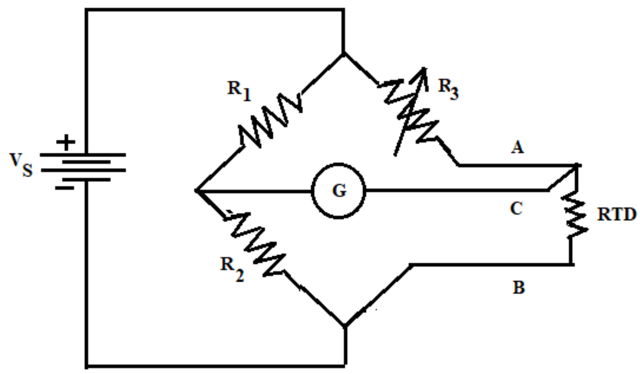
Under these conditions the value of R_3 equals the unknown resistance of measuring leg

$\therefore R_3 = A+B+RTD$

Thus A+B will contribute a measurement error.

Thus to minimize lead wire error three wire & four wire configurations are used.

2) THREE WIRE RTD



When bridge is Balanced (Galvanometer I=0)

$R_1+R_3 + A + C = R_2 + B + RTD + C$

$\underline{R_3 = RTD + B - A}$ (since $R_1 = R_2$)

$\underline{\mathbf{R_3 \approx RTD}}$ (since $A = B$)

C acts as sense lead & is part of both halves of the bridge & therefore cancels out at balance condition . The lead wire A & B are in different halves of the bridge & therefore at null balance

$R_3 = RTD + B - A$

Therefore now lead wire error is no longer

We can use this type when lead wire lengths are short however it is not a complete solution (A & B are not exactly same)

Advantages:

1) Most stable
2) Most accurate
3) More linear than thermocouple
4) Fast response

Disadvantages:

1) High cost
2) Large size
3) Need of bridge circuit
4) Current flowing through the bridge circuit may heat up the resistance element.

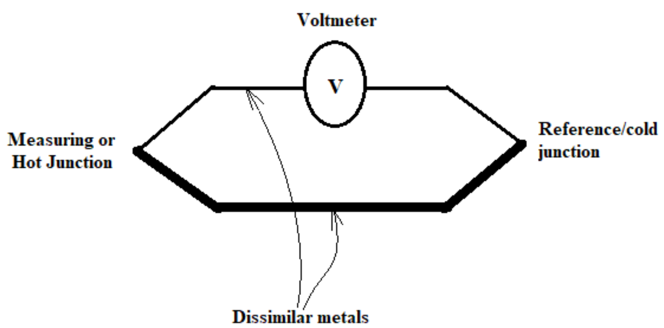
Applications:

RTDs can be used in:
1) Air conditioning and refrigeration servicing
2) Food Processing
3) Stoves and grills
4) Textile production
5) Plastics processing
6) Petrochemical processing
7) Microelectronics
8) Air, gas and liquid temperature measurement
9) Exhaust gas temperature measurement

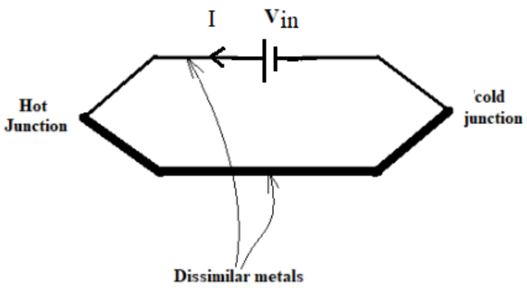
c. THERMOCOUPLE- LAW OF INTERMEDIATE TEMPERATURE AND INTERMEDIATE METALS, SEEBACK AND PELTIER EFFECT, TYPES J,K,R,S,T

State Seeback and Peltier effect.

Seeback effect: Seeback effect states that whenever two dissimilar metals are connected together to form two junctions out of which, one junction is subjected to high temperature and another is subjected to low temperature then e.m.f is induced proportional to the temperature difference between two junctions.

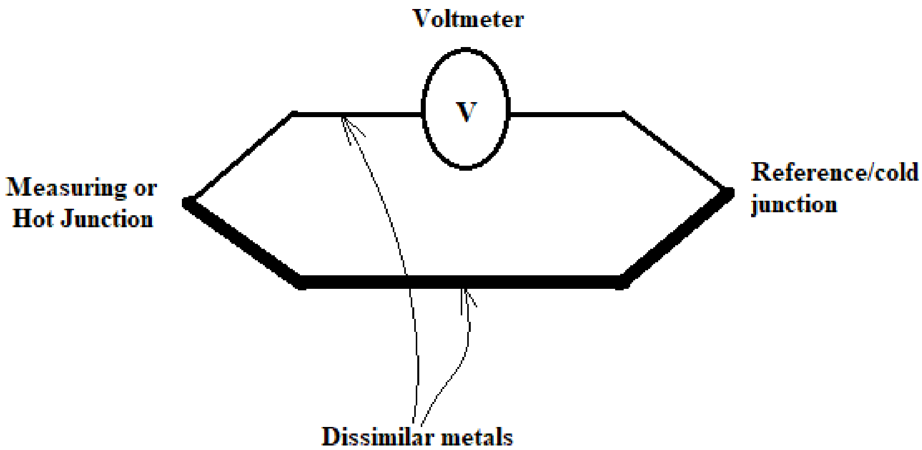


Peltier effect: Peltier effect states that for two dissimilar metals closed loop, if current is forced to flow through the closed loop then one junction will be heated and other will become cool.



State the working principle of thermocouple.

Thermocouple is a temperature transducer that develops an emf which is a function of temperature between hot junction and cold junction.



THERMOCOUPLE

the thermocouple has two metals connected to form two junctions. One junction is kept at a constant temperature (cold junction) and the other in the medium whose temperature is to be measured (hot junction). When a temperature difference exist between both the junctions a very low emf is produced which causes a current in the circuit.

Write the materials used for thermocouple along with their temperature range and its sensitivity.

Type	Temperature Range	Material Used		Sensitivity $\mu V/^0C$
		+ve wire	-ve wire	
J	-196 to 760	Iron	Constantan	50.4
K	-190 to 1371	Chromel	Alumel	39.4
R	-18 to 1704	Pt 87%-Rh 13%	Platinum	5.8
S	-18 to 1760	Pt 90%-Rh 10%	Platinum	5.9
T	-190 to 399	Copper	constantan	38.7

Advantages:

1) Rugged construction
2) Less cost
3) Simple to use
4) No need of bridge circuit
5) Extremely wide temperature range (-270 ^{0} C to 2800 ^{0} C)
6) Good accuracy
7) Good reproducibility

Disadvantages:

1) Temperature – voltage relationship is nonlinear
2) Reference required
3) Less stable

Applications:

Thermocouples are widely used in science and industry.
They can be used for

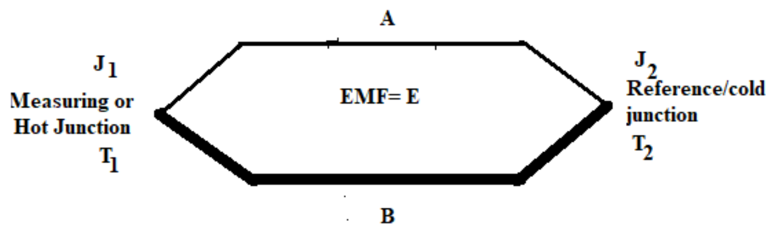
1) gas turbine exhaust,
2) kilns,
3) diesel engines,
4) And other industrial processes.
5) They can also be used in offices, homes, and businesses as the temperature sensors in thermostats.

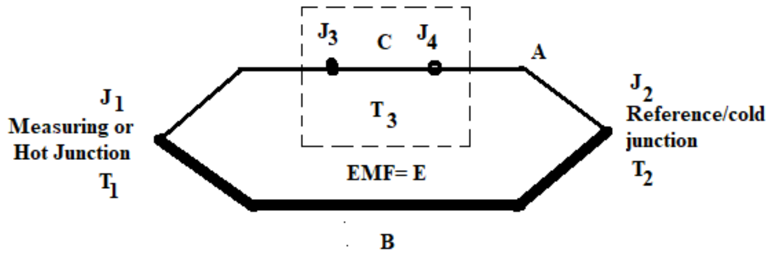
Reason why cold junction compensation is required:

- Temperature should be measured with the cold junction at 0°C or 32°F, when a thermocouple or its extension wires are connected to the terminals of a device like a thermocouple transmitter the cold junction is at the room temperature T1°C.
- If both temperatures of the hot and the cold junctions are above 0°C, the device receives a lower e.m.f than when the cold junction temperature is 0°C.
- In order to measure the temperature accurately, we need to add the e.m.f value which corresponds to T1 to the measured e.m.f. It is called cold junction compensation.

Law of intermediate metals

In a circuit consisting of two dissimilar homogeneous metals having the junctions at different temperatures, the e.m.f developed will not be affected when a third homogeneous metal is made a part of the circuit, provided the temperatures of its two junctions are the same This is called law of intermediate metals



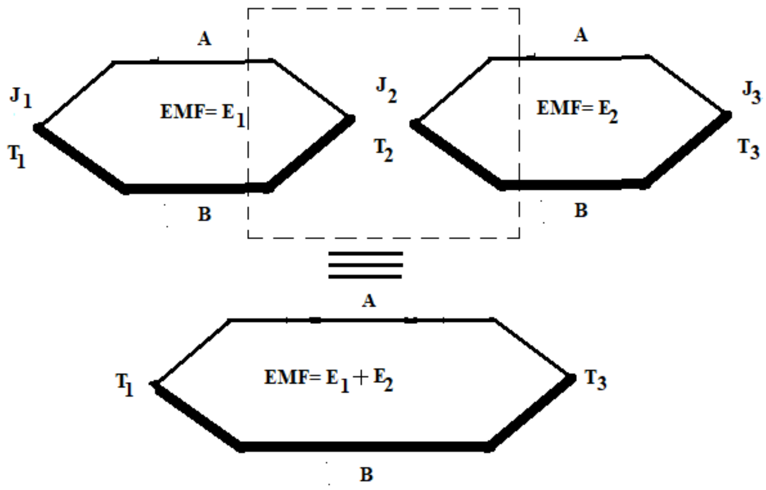


Application of this law

1) The law makes it possible to use extension wires of a metal different from the metals used for thermocouple.
   For example ,the extension wires used for platinum/platinum rhodium thermocouple may be made up of copper which is an inexpensive material.
2) The law enables a measuring instrument to be introduced into the circuit without affecting the e.m.f generated by the thermocouple.

Law of intermediate temperatures

The thermal e.m.f produced when a circuit of two homogeneous metals exits between a first temperature & a second and thermal e.m.f produced when the same circuit exists e.m.f produced when the same circuit exists between the second temperature & a third are algebraically equal to the thermal e.m.f produced when the circuit exists between first & third temperatures This is called law of intermediate temperatures.



As shown in figure , the e.m.f generated with junction temperatures T_1 & T_3 is equal to the sum of e.m.f produced by two similar thermocouples, one operating with junction temperature T_1 & T_2 & the other with T_2 & T_3 where T_2 lies between T_1 & T_3.

Application of this law

This law is used while making corrections to the thermocouple readings in case reference (cold) junction temperature is different from one for which the thermocouple was calibrated.

Compare RTD and thermistor

Sr.No	Parameters	RTD (Resistance Thermometer)	Thermistors
1	Temperature coefficient	It has positive temperature Coefficient (PTC) of Resistance.	It has both positive and negative temperature Coefficient (PTC and NTC) of Resistance.
2	linearity	It shows Linear characteristics	It shows highly non Linear characteristics
3	Temperature range	$-270^{o}C$ to $2800^{o}C$	$-150^{o}C$ to $300^{o}C$
4	Cost	High cost	Low cost
5	materials	Platinum, Copper, Nickel, Tungsten Etc.	Sintered mixture of metallic oxides such as manganese, nickel, cobalt, copper, iron, tin & zinc.
6	Size	Large	Small

Compare thermocouple and thermistor.

Sr.No	Parameter.	Thermocouple	Thermistor
1	Materials	Two dissimilar metals Iron-constantan , Chromel – Alumel , Pt 87%-Rh 13%-platinum, Pt 90%-Rh 10%-platinum, Copper- constantan	Metal oxides (sintered mixture of metallic oxides such as manganese, nickel, cobalt, copper, iron, tin & zinc.)
2	Response	Linear	Nonlinear
3	Range of temperature	$-200\ ^{0}C$ to $2000\ ^{0}C$	$-150^{0}C$ to $300^{0}C$
4	Size	Large as compared to thermistor	Small in size
5	Whether active or passive	Active Transducer	Passive Transducer
6	Transduction principle	Thermo- electric effect	Resistive transducer

PYROMETER –OPTICAL METHOD, RADIATION METHOD

Pyrometer: -

When physical contact with the medium to be measured is not possible or impractical due to very high temperature (above 1400°C) (at high temperature thermometer may melt) pyrometers are used for temperature measurement.

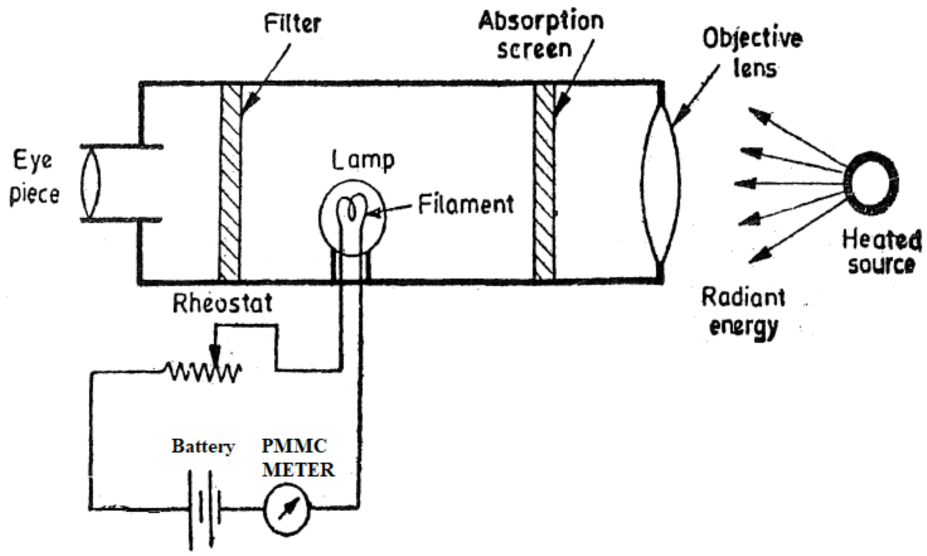
(Or)

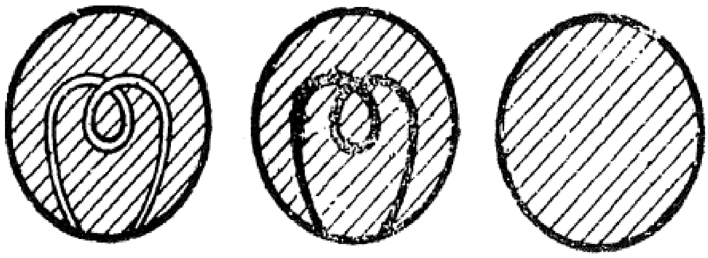
Pyrometry is the technique of measuring temperature of a body without actual physical contact. . It depends upon the relationship between the temperature of a hot body and the electromagnetic radiation emitted by the body. When a body is heated, it emits thermal energy known as heat radiation. A black matt surface (or a black body) is a very good absorber of heat radiation and, also, a very good emitter of such radiations when heated. Pyrometry is a technique for determining a body's temperature by measuring its electromagnetic radiation.

There are 2 types of pyrometers generally used in industries.

1) Optical pyrometer.
2) Radiation pyrometer.

1) Optical pyrometer:





(a) Filament too bright

(b) Filament too dark

(c) Equal brightness

Explanation:

The working principle of an optical pyrometer can be stated that the brightness of light of a given colour emitted by a hot source, gives an indication of temperature.

Working:

• It consists of a tube, one end of this tube has an objective lens and the other end has a sighting eye piece to observe the filament.
• The filament is viewed through a filter and eye piece. The lens side of the tube is projected towards the hot body whose temperature is to be measured.
• An image of radiating source is produced by a lens and made to coincide with the
filament of an electric lamp.
• The current through the lamp filament is made variable so that lamp intensity can be adjusted. The current through filament is adjusted until the filament and the image are of equal brightness. During the operation of the optical pyrometer the following conditions occur.
1) When the temperature of the filament is higher than that required for equal brightness then the filament is too bright as shown in the figure (a).
2) When the temperature of filament is lower, the filament becomes too dark as shown in figure (b)
3) When the brightness of image produced by the source and brightness produced by the `filament are equal, the outline of the filament disappears figure (c)

Application

The optical pyrometer is widely used ,for accurate measurement of temperature of furnaces, molten metals & other heated materials.

Temperature range: 700^0 C to 3000^0 C

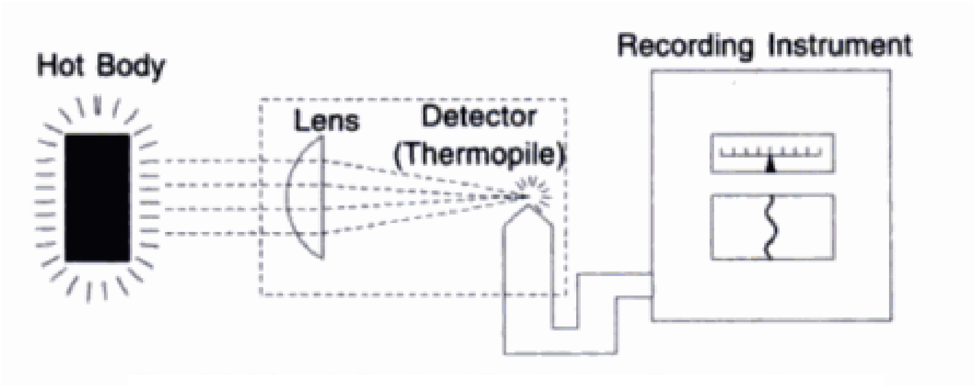
Advantages:

1) Light in weight
2) Good accuracy
3) Useful for high temperatures
4) Portable and convenient to use
5) Useful for monitoring the temperature of moving objects & distant object.

Disadvantages:

1) Expensive
2) It is prone to human error caused by operator adjustment of temperature dial.
3) It is not useful for measuring the temperatures of clean burning gases that do not radiate visible energy.

2)Radiation pyrometer.



Operation of a radiation pyrometer is based upon the measurement of radiant energy emitted by the hot body. When a hot body is heated, it emits thermal energy known as heat radiation.

Figure shows a diagram of a radiation pyrometer. It consists of a lens to focus radiated energy from the body, whose temperature is required, on to a detector or receiving element. Receiving element may be a resistance thermometer, thermocouple or thermopile.

A temperature indicator, recorder, or controller is attached with the receiving element to indicate the temperature.

When the total energy radiated by a hot body , whose temperature is to be measured, enters the pyrometer . It is focused by the lens on the detector . The detector is a thermopile whose measuring junctions are attached to a blackened disc. The disc absorbs energy when the pyrometer is focused on a hot body & its temperature rises.

The reference junction of the thermopile is attached to the pyrometer case. The difference in temperature between the measuring junction attached to the disc & the reference junction attached to the case generates a voltage that is directly related to the temperature of the blackened disc , which is indicated by the recording instrument.

Advantages:

1) They are able to measure high temperatures
2) No need for contact with target of measurement
3) Fast response
4) Have high output & moderate cost

Disadvantages:

1) Non- linear characteristics
2) Errors due to presence of intervening gases or vapours as they absorb radiating frequencies.

Applications:

1) They are used for the temperatures above the practical operating range of thermocouples
2) They can be used in the environments which contaminate or limit the life of thermocouples
3) For moving targets
4) They are used for the targets not easily accessible , such as furnace interiors.
5) Used for measurement of average temperatures of large surface areas.

List any one name of material used for

1) RTD
2) Thermistor
3) Thermocouple
4) Bimetallic strip

Sr. No.	Transducer	Material used
1	RTD	Platinum, Copper, Nickel, Tungsten Etc
2	Thermistor	sintered mixture of metallic oxides such as manganese, nickel, cobalt, copper, iron, tin & zinc
3	Thermocouple	Copper/ Constantan Chromel/Constantan Iron/Constantan Chromel/Alumel
4	Bimetallic strip	steel and copper, or in some cases steel and brass, Nickel-iron alloyed with chromium & manganese, Invar (alloy of nickel & iron)

List the range of temperature measured by-(i) RTD, (ii) Pyrometer (iii) Bimetallic thermometer,

1) RTD Range -270º C to 2800ºC
2) Pyrometer= 600ºC to 3000ºC
3) Bimetallic Thermometer=0 to 260ºC
4) Gas Filled thermometer= -50ºC to 500ºC

TYPICAL SPECIFICATION OF THERMISTOR, RTD & THERMOCOUPLE

Sensor type	Thermistor	RTD	Thermocouple
Temperature Range (typical)	-100 to 325°C	-200 to 650°C	200 to 1750°C
Accuracy (typical)	0.05 to 1.5°C	0.1 to 1°C	0.5 to 5°C
Long-term stability @ 100°C	0.2°C/year	0.05°C/year	Variable
Linearity	Exponential	Fairly linear	Non-linear
Power required	Constant voltage or current	Constant voltage or current	Self-powered
Response time	Fast 0.12 to 10s	Generally slow 1 to 50s	Fast 0.10 to 10s
Susceptibility to electrical noise	Rarely susceptible High resistance only	Rarely susceptible	Susceptible / Cold junction compensation
Cost	Low to moderate	High	Low