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DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

VII Semester

AU3008 Sensors and Actuators

UNIT – 2 - Variable Resistance and Inductance Sensors

2.3 Resistive Thermometer (RTD)

Principle of operation- Construction details- Characteristics and applications of resistive thermometer

2.3.1 Resistance Temperature Detector (RTD):

The resistance of a conductor changes when its temperature is changed. This property is utilized for measurement of temperature. The variation of resistance R with temperature T(°K) can be represented by the following relationship for most of the metals as

$$R = R_0(1 + \alpha_1 T + \alpha_1 T^2 + \cdots + \alpha_n T^n + \cdots)$$

where R_0 = resistance at temperature T = 0
and α_1 α_2, α_3,... α_n are constants.

The resistance thermometer uses the change in electrical resistance of conductor to determine the temperature. *Figure 1* shows industrial platinum resistance thermometer (RTD).

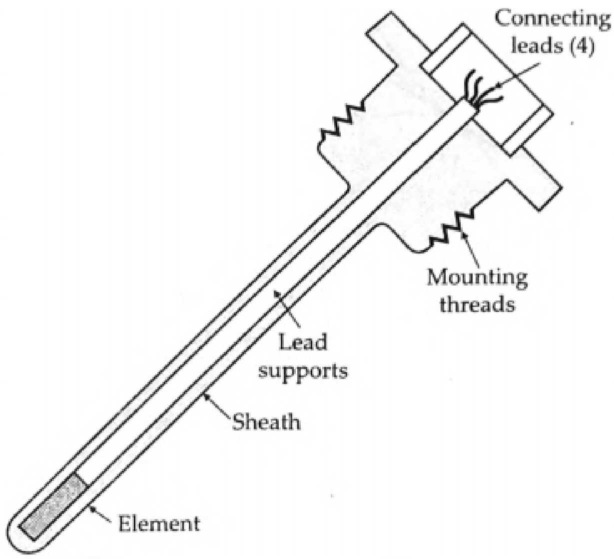

Fig. 2.3.1 Construction of RTD

The resistance of an RTD varies directly with temperature:

- As temperature increases, resistance increases.
- As temperature decreases, resistance decreases.

2.3.2 Construction of RTD:

- The RTD is constructed by wounding the resistance wire on a **mica base** to achieve small size, improving the thermal conductivity
- In the industrial RTD's, the coil is protected by a **stainless-steel** sheath or a protective tube.
- So that, the **physical strain is negligible** as the wire expands and increase the length of wire with the temperature change.
- Mica is placed in between the steel sheath and resistance wire for better **electrical insulation**.
- Due less strain in resistance wire, it should be carefully wound over mica sheet. The Figure 1 shows the structural view of an Industrial Resistance Temperature Detector.

2.3.3 RTD materials & range:

Platinum is used as the primary element in all high accuracy resistance thermometers. Platinum is especially suited for this purpose, as it can withstand high temperatures while maintaining excellent stability. As a noble metal, it shows limited susceptibility to contamination. All metals produce a positive change in resistance with temperature.

The requirements of a conductor material to be used in RTDs are:

(i) The change in resistance of material per unit change in temperature should be as large as possible.

(ii) The material should have a high value of resistivity so that minimum volume of material is used for the construction of RTD.

(iii) The resistance of materials should have a continuous and stable relationship with temperature

- **Gold and Silver** are rarely used for construction of RTDs on account of their low resistivities.
- **Tungsten** has relatively a high resistivity, but is reserved for high temperature applications as it is extremely brittle and difficult to work.
- **Copper** is used occasionally as an RTD element. Its low resistivity forces the element to be longer than the platinum element, but its low linearity and low cost make it an economical alternative. Its upper limit of temperature is about 120°C.
- The most common RTDs are made of either platinum, nickel or nickel alloys. The economical nickel wires are used over a limited temperature range.
- The common values of resistance for a platinum RTD range from 10 Ω for the bird cage model to several thousands ohm for the film RTD.
- The single most common value is 100 Q at 0°C with a resistance temperature co-efficient of 0.00385/°C. The more chemically pure platinum wire has a resistance temperature co-efficient of 0.00392/°C.
- The characteristics of various materials used for resistance thermometers are plotted in *Figure 2.*

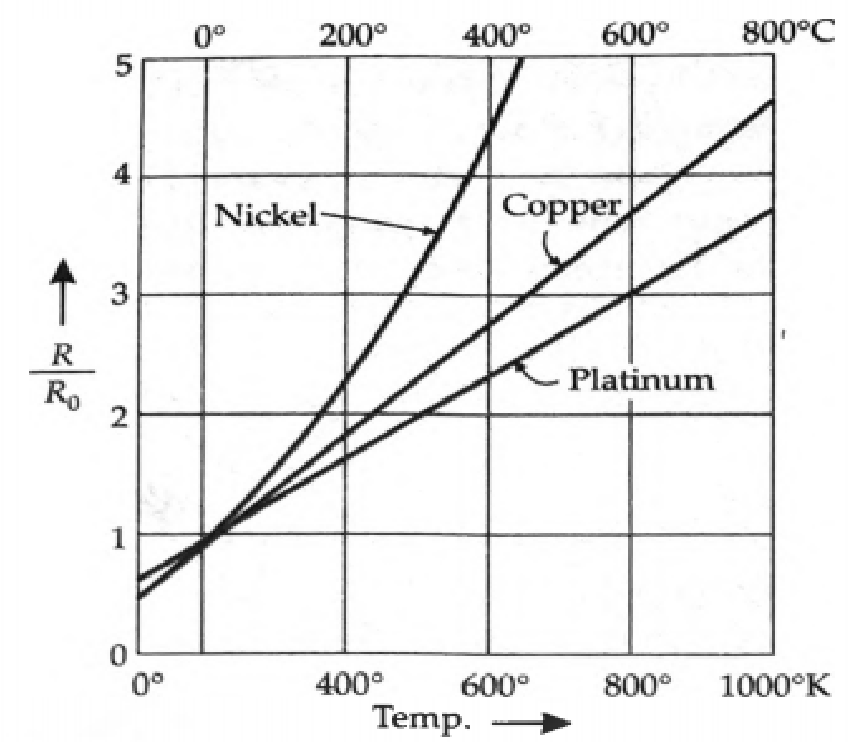

***Fig. 2.3.2** Characteristics of materials used for resistance thermometers.*

An examination of the resistance versus temperature curves of Figure 2, shows that the curves are nearly linear. If fact, when only short temperature spans are considered, the linearity is more evident.

2.3.4 Relative resistance vs. temperature characteristics of RTD:

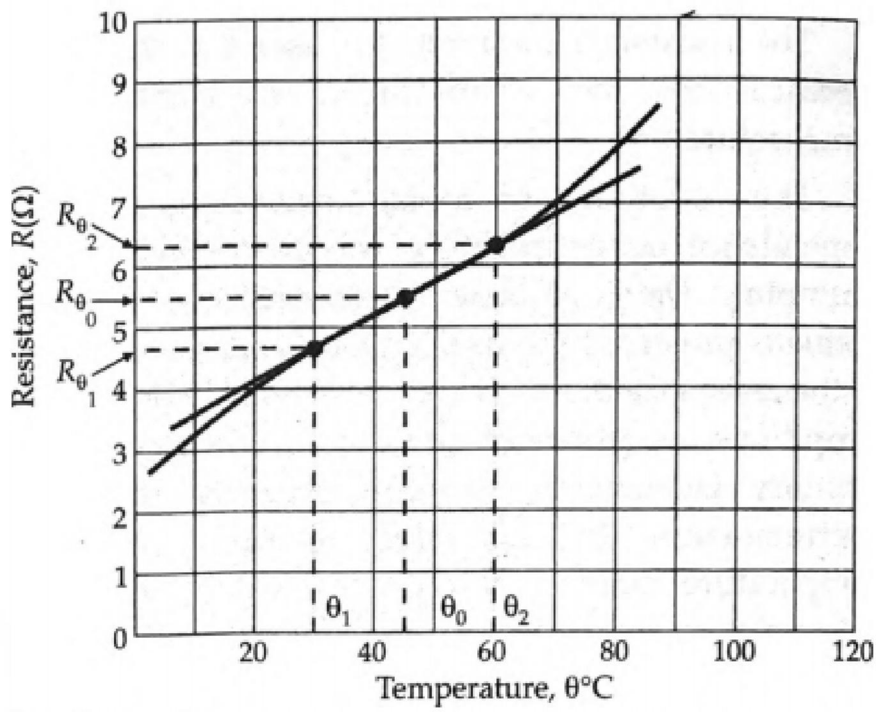

Fig. 2.3.3 *A straight line representing an approximate relationship between resistance R. and temperature θ.*

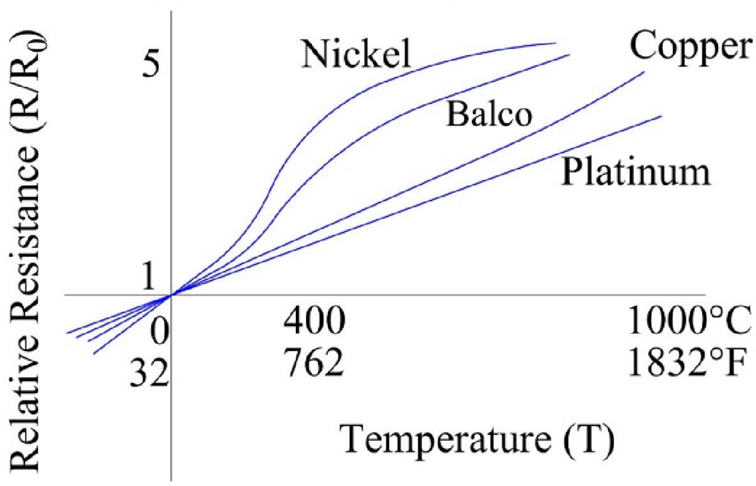

Fig. 2.3.4 *Characteristics for copper, platinum, Nickel and Balco.*

Figure 4 depicts the Relative resistance Vs temperature characteristics for copper, platinum, Nickel and Balco. It can be seen that; platinum is having the linear relationship up to 1000 °C. This is one of the reason that it is preferred material for temperature sensing element.

2.3.5 Wheatstone Bridge:

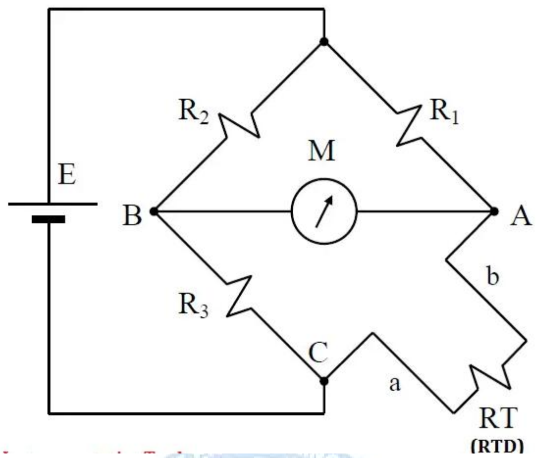

Fig. 2.3.5 Wheatstone bridge circuit for measurement of RTD

- The simplest way to measure the resistance of a RTD, is to inject a constant current into the RTD and to measure the voltage that develops across the RTD. A Wheatstone bridge circuit, shown in Figure, is however generally used to detect the changes in resistance of a resistance thermometer (RTD).
- The values of the fixed resistors, Rs1,R2 and R3, are very accurately known, while RT represents the resistance of RTD with leads a and b. The bridge is said to be in null balance, when the voltage across points A and B is zero. This occurs when RT = R3×(R1/R2) , causing VAC = VBC, resulting in the reading on Multimeter M, to become zero.

2.3.6 Temperature Coefficients of Resistance:

The temperature coefficient of resistance is generally defined as the change in electrical resistance of a substance with respect to per degree change in temperature. The "alpha" (α) constant is known as the ***temperature coefficients of resistance*** and symbolizes the resistance change factor per degree of temperature change.

$$R = R_{ref}\left[1 + \alpha\left(T - T_{ref}\right)\right]$$

Where, R – Resistance of RTD at temperature, T

R_{ref} – Resistance of RTD at reference temperature T_{ref} , usually 20^0 C, but sometimes 0^0 C

α - Temperature coefficient of resistance of RTD material

T - Temperature o RTD in degree Celsius

T_{ref} – Reference temperature that α is specified at for RTD material

For pure metals, the temperature coefficient of resistance α is a positive number, meaning that resistance increases with increasing temperature. or the elements carbon, silicon, and germanium, this coefficient is a negative number, meaning that resistance decreases with increasing temperature.

2.3.7 Advantages of Resistance Temperature Detector (RTD):

1. The RTD can be easily installed and replaced.
2. It is available in wide range.
3. The RTD can be used to measure differential temperature.
4. They are suitable for remote indication.
5. Stability maintained over long period of time.
6. No necessity of temperature compensation.

2.3.8 Limitations of Resistance Temperature Detector (RTD):

1. The RTD require more complex measurement circuit.
2. It is affected by shock and vibration.
3. Bridge circuit is needed with power supply.
4. Slower response time than a thermocouple.
5. Large bulb size.
6. Possibility of self heating.
7. Higher Initial cost.
8. Sensitivity is low.

2.3.9 Applications of Resistance Temperature Detector (RTD):

The applications of Resistance Temperature Detectors in various industries include:

1. **In Automotive Industry** – As audio amplifiers and engine oil temperature sensors.
2. **In Communication and Instrumentation** – As temperature sensors and amplifiers.
3. **In Consumer Electronics** – For small appliance controls and Fire Detectors.
4. **In Industrial Electronics** – For gas flow indicators and Plastic laminating equipment.
5. **In Medical Electronics** – For blood dialysis equipment and Infant incubators.

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