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Instrumentation and Controls

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Module 1: Resistance Temperature Detectors (RTDs)

Learning Objectives

By the end of this section, you will be able to:

- **Describe** the construction of a basic RTD, including major component arrangements and materials used.
- **Explain** how RTD resistance varies with both increases and decreases in temperature.
- **Identify** the mechanism by which an RTD provides an output representative of the measured temperature.

Executive Summary: Resistance Temperature Detectors (RTDs) operate on the principle that the electrical resistance of certain metals changes predictably as temperature changes. By utilizing pure metals with linear resistance-temperature characteristics, these devices act as electrical transducers to provide accurate and reproducible temperature measurements in industrial and nuclear facilities.

Temperature Fundamentals

Temperature is a measure of the kinetic energy of a material, which depends upon its molecular activity. To measure the kinetic energy of a system, temperature measuring devices typically use the energy of the system to raise or lower the kinetic energy of the device itself.

While a standard household thermometer uses liquid expansion to indicate temperature, industrial applications often require more precise instruments like the **Resistance Temperature Detector (RTD)**. RTDs are utilized at many DOE nuclear facilities to monitor process or material temperatures.


RTD Construction and Materials

The RTD incorporates pure metals or certain alloys that increase in resistance as temperature increases and decrease in resistance as temperature decreases. These metals must be pure, of uniform quality, and stable within a given temperature range to provide reproducible resistance-temperature readings.

Sensor Elements

RTD elements are typically constructed from metals that offer linear resistance-temperature characteristics and a high coefficient of resistance.

- **Platinum:** Commonly used for its stability and linearity.
- **Copper:** Utilized for specific linear applications.
- **Nickel:** Chosen for its high coefficient of resistance.

 **Calculation Note:** The **coefficient of resistance** is defined as the change in resistance per degree change in temperature, usually expressed as a percentage per degree of temperature.

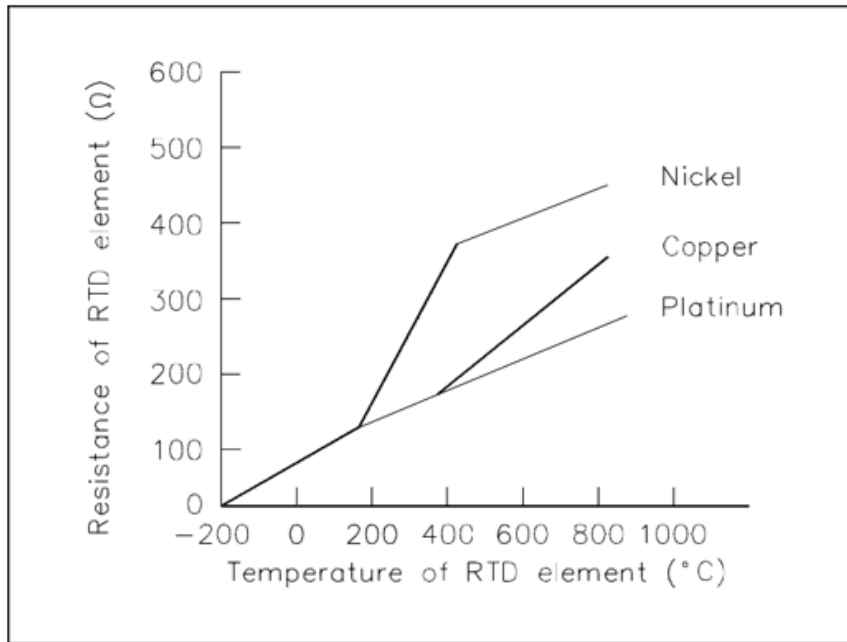


Figure 1: Electrical Resistance-Temperature Curves

Internal Component Arrangement

The internal construction of a typical RTD involves fine wires protected by insulating and sheathing materials to ensure accuracy and durability.

- **Active Element:** Long, spring-like wires capable of being drawn fine for construction.
- **Insulator:** Surrounds the wire (often made of **porcelain**) to prevent a short circuit between the wire and the metal sheath.
- **Sheath:** Encloses the element and insulator; typically made of **Inconel** (a nickel-iron-chromium alloy) for its inherent corrosion resistance.

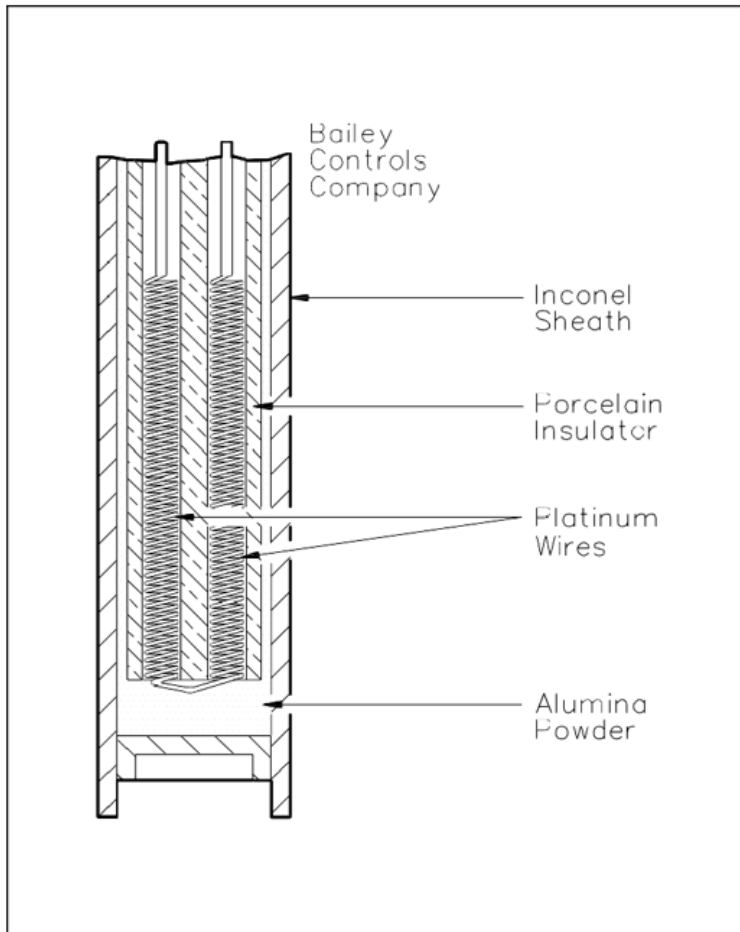


Figure 2: Internal Construction of a Typical RTD

External Protection and Housing

To operate in liquid or gas mediums without damage, the RTD is often housed in a protective well.

- **Protective Well (Thermowell):** Protects the RTD from damage by the medium being measured. These are commonly made of stainless steel, carbon steel, Inconel, or cast iron.
- **Temperature Limits:** Protecting wells are suitable for temperatures up to **1100°C**.
- **Terminal Head:** Houses the connection points for the RTD assembly.

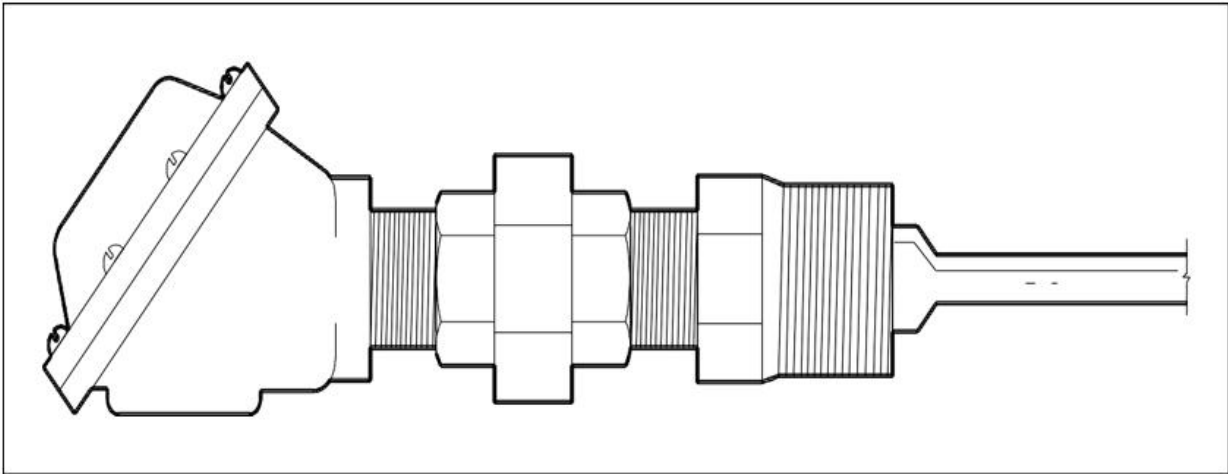



Figure 3: RTD Protective Well and Terminal Head

Operational Mechanism

When an RTD is placed in a liquid or gas medium, the Inconel sheath quickly reaches the temperature of that medium. The change in temperature causes the internal sensing wire to heat or cool, resulting in a proportional change in resistance.

1. **Resistance Change:** The resistance varies directly with temperature: it increases as temperature increases and decreases as temperature decreases.
2. **Measurement:** This change is measured by a precision resistance measuring device, normally a **bridge circuit**.
3. **Calibration:** The bridge circuit is calibrated to convert the measured resistance directly into a proper temperature reading.

 **Design Tip:** Inconel is the standard material for the RTD sheath because its corrosion resistance ensures longevity even when exposed to harsh process fluids.

Checkpoint Quiz

1. How does the resistance of an RTD respond to a decrease in temperature?

- a) Resistance increases proportionally.
- b) Resistance remains constant but voltage increases.
- c) Resistance decreases.
- d) Resistance becomes infinite.

Answer: (c). RTDs operate on a direct relationship between temperature and resistance. As specified in the summary, when temperature decreases, resistance decreases accordingly.

2. Which material is primarily used for the RTD sheath to ensure corrosion resistance?

- a) Porcelain
- b) Platinum
- c) Copper
- d) Inconel

Answer: (d). Inconel is a nickel-iron-chromium alloy utilized specifically for its inherent corrosion resistance, which protects the internal RTD components from the measuring medium.

3. What is the purpose of the porcelain insulator in RTD construction?

- a) To increase the coefficient of resistance.
- b) To prevent a short circuit between the wire and the metal sheath.
- c) To protect the terminal head from high temperatures.
- d) To act as the primary sensing element.

Answer: (b). The platinum element is surrounded by a porcelain insulator to isolate it electrically from the metal sheath, ensuring that the resistance measurement is not compromised by a short circuit.



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