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Review Article

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A MODERN THERMAL SENSOR IN PHARMACEUTICAL INDUSTRY: A REVIEW

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ABSTRACT

Temperature measurement is a critical aspect of various industries, including healthcare, aerospace, and manufacturing. The ability to accurately measure temperature is essential for ensuring the safety, efficiency, and reliability of systems and processes. Temperature sensors play a vital role in this regard, converting thermal energy into electrical signals that can be easily interpreted. With the increasing adoption of automation, IoT, and smart technologies, the demand for high-performance temperature sensors has grown significantly. This review article focuses on the development of the temperature sensor, its features, and its applications.

KEYWORD:- Resistance temperature detectors, pharmaceutical applications, Temperature measurement, Process control, Quality control, Validation, Calibration, Accuracy and Precision.

INTRODUCTION[1,2,3]

Accurate temperature control and monitoring are crucial in pharmaceutical manufacturing, significantly impacting the quality, safety, and efficacy of medicinal products (Singh et al., 2018). Resistance Temperature Detectors (RTDs) have become a reliable and precise means of temperature measurement in the pharmaceutical industry (Kumar et al., 2020). Offering high precision, stability, and repeatability, RTDs are widely used in various pharmaceutical 2019).

Resistance Temperature Detectors (RTDs)[4]

Resistance Thermometers, also known as Resistance Temperature Detectors (RTDs), are sensors used to measure temperature. Many RTD elements consist of a length of fine wire wrapped around a heat-resistant ceramic or glass core, but other constructions are also used. The RTD wire is made of a pure material, typically platinum (Pt), nickel (Ni), or copper (Cu). The material has an accurate resistance/temperature relationship, which is used to provide an indication of temperature. As RTD elements are fragile, they are often housed in protective probes. RTDs, which have higher accuracy and repeatability, are slowly replacing thermocouples in industrial applications below 600 °C.

Types of Resistance Thermometers[5]

1. Platinum RTDs (Pt100, Pt500, Pt1000): The most common type, which uses platinum as the resistive element.
2. Copper RTDs: Less expensive, uses copper as the resistive element.
3. Nickel RTDs: For high-temperature applications, uses nickel as the resistive element.
4. Balco RTDs: Uses a nickel-iron alloy, offers high accuracy and stability.
5. Thermoplastic RTDs: Uses a thermoplastic material, suitable for high-temperature applications.
6. Thin-Film RTDs: Deposits a thin layer of resistive material on a substrate, offers high accuracy and fast response.
7. Wire-Wound RTDs: Uses a wire-wound resistive element, offers high accuracy and stability.
8. Foil RTDs: Uses a thin foil resistive element, offers high accuracy and fast response.
9. Surface-Mount RTDs: Designed for surface-mount technology, offers high accuracy and small size.
10. Sanitary RTDs: Designed for hygienic applications, uses materials resistant to corrosion and contamination.

RTDs can also be classified based on their temperature range

1. Low-temperature RTDs: Measures temperatures below -200°C.
2. Standard RTDs: Measures temperatures between -200°C and 500°C.
3. High-temperature RTDs: Measures temperatures above 500°C.

Invention of RTDs

The first-ever RTD, invented by Carl Wilhelm Siemens in 1860, used a piece of copper wire. Siemens' discovery led to the development of platinum RTDs, which became the standard for high-accuracy temperature measurement. Platinum RTDs remain widely used today due to their exceptional performance and reliability.

Working principle[6]

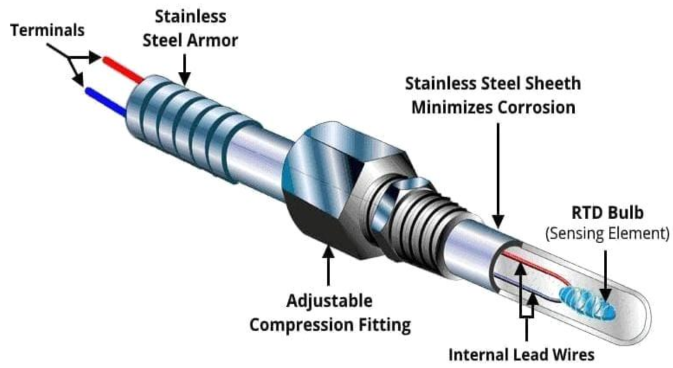

Figure 1: Resistance temperature detectors.

Resistance Temperature Detector (RTD) is a device whose resistance varies with temperature. RTDs work on the principle of resistance, which changes uniformly with changes in temperature, i.e., resistance is directly proportional to temperature. RTDs are precise temperature sensors made up of high-purity conducting metals such as platinum, copper, or nickel wound into a coil. The electrical resistance of an RTD changes similarly to that of a thermistor. An electrical current is passed through the sensor; the resistance element measures the resistance of the current being passed through it. As the temperature of the resistance element increases, the electrical resistance also increases. The electrical resistance is measured in Ohms. The resistance value can then be converted into temperature based on the characteristics of the element. Usually, the response time for an RTD is between 0.5 and 5 seconds.

Construction of RTDs[7]

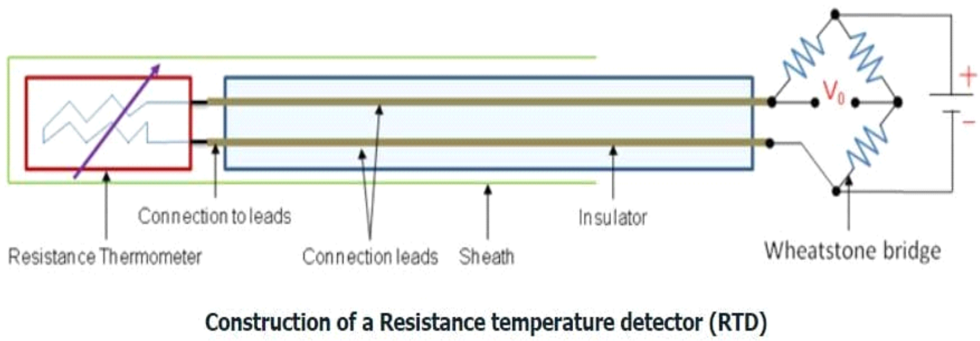

Figure 2: Construction of RTDs.

The RTD element consists of a thin wire made of a pure metal, usually platinum, wound around a ceramic or glass core. The RTD element is designed to exhibit a specific resistance at a reference temperature, typically 0°C or 100°C. A known electrical current is passed through the RTD element, typically using a Wheatstone bridge circuit. The electrical resistance of the RTD element causes a voltage drop across it, which can be measured. The resistance of the RTD element is measured using a bridge circuit, which compares the RTD resistance with known reference resistances. The bridge circuit is typically balanced, meaning the voltages across its arms are equal, when the RTD element is at the reference temperature. As the temperature changes, the electrical resistance of the RTD element changes proportionally. This change in resistance causes an imbalance in the Wheatstone bridge circuit, resulting in a measurable voltage difference. The voltage difference obtained from the Wheatstone bridge circuit is used to calculate the temperature using a calibration curve or a mathematical formula that relates the resistance of the RTD element to temperature. The calibration curve is typically determined during the manufacturing process and is specific to the RTD element being used. The calculated temperature is then typically converted into a standardized output signal, such as a 4-20 mA current loop, a voltage signal, or a digital signal, depending on the application and the requirements of the system where the RTD sensor is being used.

Advantages[1,2,3]

1. High accuracy: RTDs provide accurate temperature measurements, ensuring compliance with regulatory requirements.
2. Reliability: RTDs are robust and reliable, minimizing downtime and ensuring continuous production.
3. Easy to clean: RTDs are designed for easy cleaning and sanitation, reducing the risk of contamination.
4. Long-term stability: RTDs maintain their accuracy over time, reducing the need for frequent calibration.
5. By utilizing RTDs, pharmaceutical manufacturers can ensure accurate temperature control, reduce the risk of contamination, and maintain compliance with regulatory requirements.

Disadvantages[1,2,3]

- It requires a current source.
- Its accuracy depends on the battery's health.
- Heat is generated due to I2R losses in the element also known as self-heating which inflicts error in the measurement thus affecting the accuracy.
- It has a large size, therefore, unable to sense temperature at small points.
- It is affected by physical shock and vibration.
- It has a limited temperature operating range as compared to thermocouple.
- It has a higher initial cost as compared to thermocouple.

Applications of RTD[1,2,3]

- Temperature monitoring: RTDs guarantee precise temperature control throughout storage, transportation, and industrial operations.
- Process control: To guarantee constant product quality, RTDs manage the temperature in reactors, mixers, and other machinery.
- Validation and calibration: Temperature-controlled environments, such ovens and autoclaves, are validated and calibrated using RTDs.
- Freeze drying: To stop product deterioration during freeze-drying procedures, RTDs keep an eye on the temperature.
- Vaccine manufacture: To preserve product efficacy, RTDs guarantee exact temperature control throughout vaccine production.
- Lyophilization: To guarantee product stability, RTDs keep an eye on pressure and temperature during lyophilization.
- Cleanroom monitoring: To guarantee product sterility, RTDs keep precise temperature and humidity levels in cleanrooms.
- Cold chain monitoring: RTDs monitor the temperature of temperature-sensitive goods while they are being transported and stored.
- Autoclave monitoring: During sterilization procedures, RTDs guarantee precise temperature control.
- Quality control: RTDs are used to measure and regulate temperatures precisely in laboratory settings. In the pharmaceutical sector, RTDs are essential for guaranteeing product safety, quality, and regulatory compliance.

CONCLUSION

Temperature sensors are essential components in a vast array of applications, ranging from everyday household devices to critical industrial systems. Their ability to accurately measure and monitor temperature ensures the optimal functioning, safety, and efficiency of processes in sectors such as healthcare, automotive, environmental monitoring, and consumer electronics. With advancements in technology, temperature sensors have become more precise, reliable, and versatile, accommodating diverse environments and requirements. However, challenges such as sensitivity to extreme conditions, calibration needs, and potential interference must be addressed to maintain their effectiveness. Overall, temperature sensors play a pivotal role in modern technology, enabling better control, innovation, and quality of life by providing crucial data for informed decision-making and system management.

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