Resistance temperature detectors (RTDs) operate on the inherent propensity of metals to exhibit a change in electrical resistance as a result of a change in temperature. We are all aware that metals are conductive materials. It is actually the inverse of a metal's conductivity, or its resistivity, that brought about the development of RTDs. Each metal has a specific and unique resistivity that can be determined experimentally. This resistance, R, is directly proportional to a metal wire's length, L, and inversely proportional to the cross-sectional area, A:

Fabrication

RTD elements take either of two forms: wire wound (see Figure 1) or thin film. Wire-wound elements are made primarily by winding a very fine strand of platinum wire into a coil until there is enough material to equal 100 Ω of resistance. The coil is then inserted into a mandrel and powder is packed around it to prevent the sensor from shorting and to provide vibration resistance. This is a time-consuming method and all work is done manually under a microscope, but the result is a strain-free design.

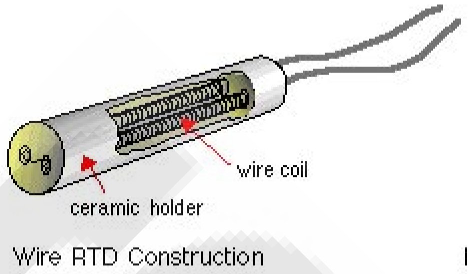


Figure 1. The wire-wound element is built by winding a small-diameter platinum sensing wire around a nonconducting mandrel.

Thin film elements (see Figure 2) are manufactured by depositing a thin layer of platinum or its alloys on a ceramic substrate. The metal is deposited in a specific pattern and trimmed to the final resistance. The elements are then coated with a glass or epoxy for moisture resistance. An advantage of the thin film sensor is that a greater resistance can be placed in a smaller area; 1000 Ω RTD sensors are readily available. Thin film sensors are susceptible to some strain, however, and have a maximum temperature coefficient of 0.00385 Ω/Ω/°C. On the plus side, 1000 Ω elements offer the advantage of increased resolution per degree of temperature, and errors due to lead wire resistance are minimized. Although thin film elements would appear preferable, most of the older electronics are designed to accept only the 100 Ω sensor.

Specifications

When discussing RTDs, several specifications must be considered:

- Wiring configuration (two-, three-, or four-wire)
- Self-heating
- Accuracy
- Stability
- Repeatability
- Response time

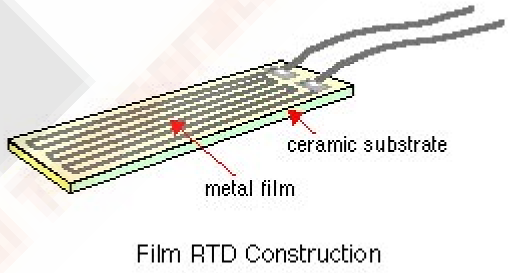


Figure 2. The thin film sensing element is made by depositing a thin layer of platinum in a resistance pattern on a ceramic substrate. A layer of glass or epoxy is applied for moisture protection.

Wiring Configuration.

Serious lead wire resistance errors can occur when using a two-wire RTD especially in a 100 Ω sensor. In a two-wire circuit, a current is passed through the sensor. As the temperature of the sensor increases, the resistance increases. This increase in resistance will be detected by an increase in the voltage ($V = I \cdot R$). The actual resistance causing the voltage increase is the total resistance of the sensor and the resistance introduced by the lead wires. As long as the lead wire resistance remains constant, it will not affect the temperature measurement. The wire resistance will change with temperature, however, so as the ambient conditions change, the wire resistance will also change, introducing errors. If the wire is very long, this source of error could be significant. Two-wire RTDs are typically used only with very short lead wires, or with a 1000 Ω element.

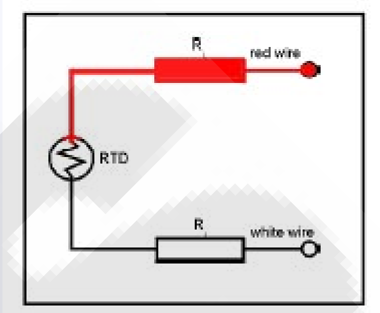
In a three-wire RTD there are three leads coming from the RTD instead of two. L1 and L3 carry the measuring current, while L2 acts only as a potential lead. Ideally, the resistances of L1 and L3 are perfectly matched and therefore cancelled. The resistance in R3 is equal to the resistance of the sensor, R_t, at a given temperature (usually the midpoint of the temperature range). At this point, no current passes through the centre lead. As the temperature of the sensor increases, the resistance of the sensor increases, causing the resistance to be out of balance. Current then flows in the centre lead and will indicate an offset temperature.

The optimum form of connection for RTDs is a four-wire circuit It removes the error caused by mismatched resistance of the lead wires. A constant current is passed through L1 and L4; L2 and L3 measure the voltage drop across the RTD. With a constant current, the voltage is strictly a function of the resistance and a true measurement is achieved. This design is slightly more expensive than two- or three-wire configurations, but is the best choice when a high degree of accuracy is required.

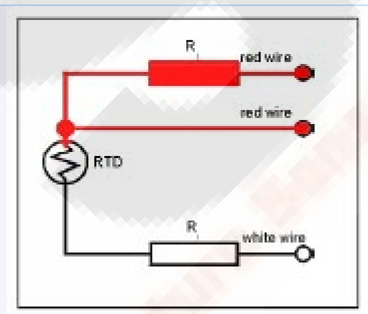
Self-Heating. To measure resistance, it is necessary to pass a current through the RTD. The resultant voltage drop across the resistor heats the device in an effect known as the I^2R, or Joule heating. The sensor's indicated temperature is therefore slightly higher than the actual temperature. The amount of self-heating also depends heavily on the medium in which the RTD is immersed. An RTD can self-heat up to 100 3 higher in still air than in moving water.

Wiring Configuration.

Two Wire
When accuracy is not critical, a two-wire RTD is the least expensive; offering. Using lead wires to place any distance between a two wire RTD and a receiving device will further compromise its accuracy. The potential for poor accuracy from a two-wire RTD stems from its inability to compensate for lead length, resistance that changes the ohm value of the original signal. A two-wire RTD should be used only in applications where the receiving device connects directly to the sensor



Three Wire RTD
Three-wire RTD's compensate for resistance resulting from length differences by adding a third lead to the RTD. To accomplish this requires that the wires match exactly. Any difference in resistance between the lead wires will cause an imbalance, which will compromise the accuracy of the RTD. Lead length variance, work hardening or corrosion, and manufacturing irregularities are errors to avoid. Quality manufacturing is critical to insure balance of all three leads.



Four Wire RTD
Errors caused by resistance imbalance between leads are cancelled out in a four-wire RTD circuit. Four-wire RTD's are used where superior accuracy is critical or if the sensor is installed far from the receiving device. In a four-wire RTD one pair of wires carries the current through the RTD the other pair senses the voltage across the RTD. 2- and three-wire RTD's require heavier lead wire because thicker wire, by creating less resistance to the measured signal, reduces measurement distortion. Therefore lighter gauge wire, less expensive, may be used in four-wire RTD applications. RTD's are limited to temperatures of 1200 ° F and because of the construction of the sensing element, RTD's do not do well in high-vibration and severe mechanical shock environments. When selecting a temperature sensor for an application you should consult your temperature sensor manufacturer for recommendations.