
RTD THEORY

Resistance temperature detectors or RTD's as they are more commonly known, are another common way to measure temperature. RTD's were developed in Europe about a century ago but have only become popular in the United States in the last 25 years. RTD's are very similar in appearance to thermocouples but they function completely different.

As you may remember, thermocouples produce a very small voltage when heated. An RTD does not produce any voltage and so it relies on an instrument for power. RTD's are electrical resistors that change resistance as temperature changes. With all common types of RTD's, the resistance increases as the temperature increases. This is referred to as a *positive temperature coefficient*.

MATERIALS OF CONSTRUCTION

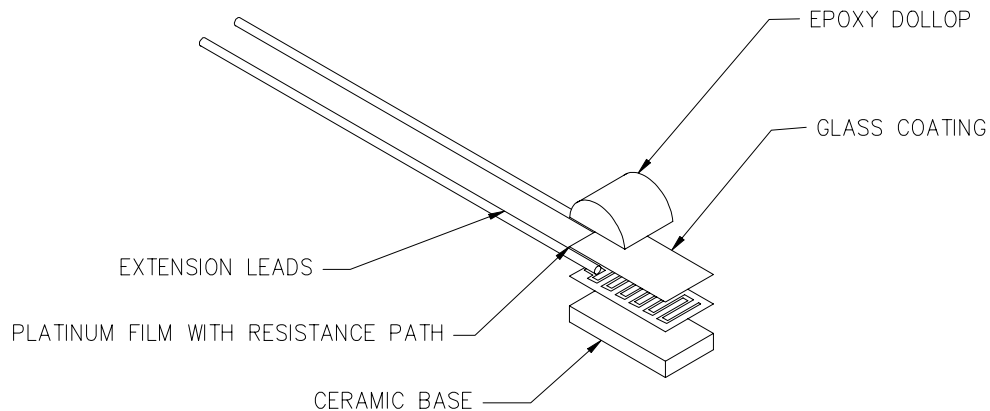
RTD's are manufactured using several different materials as the sensing element. The most common by far is the Platinum RTD. Platinum is used for several different reasons including high temperature rating, very stable, and very repeatable. Other materials used to make RTD's are nickel, copper, and nickel-iron. These materials are becoming less common now that the cost of platinum RTD's is coming down.

CONSTRUCTION

RTD's are manufactured in 3 basic types of construction. Each of these different types has advantages and disadvantages.

Platinum Thin Film RTD

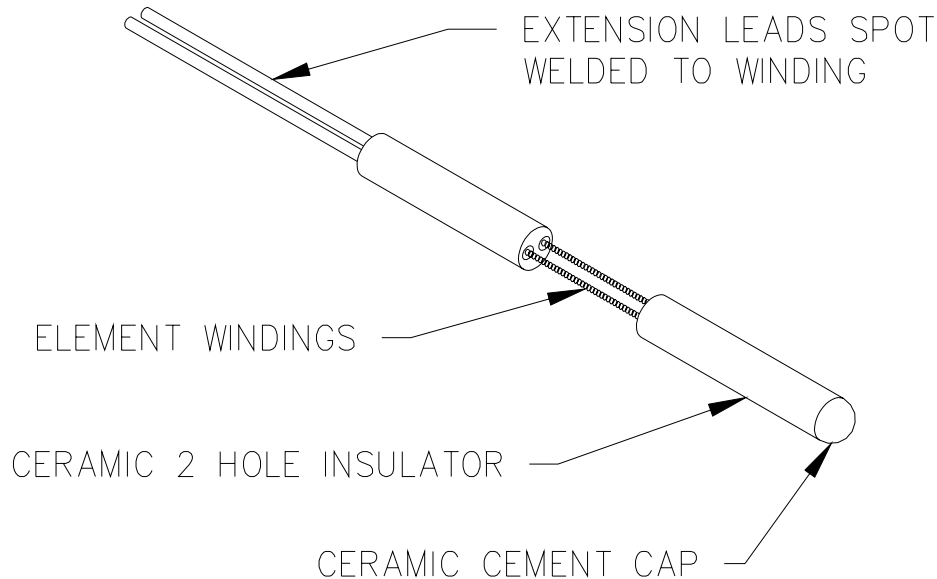
The thin film style of RTD is probably the most popular design because of their rugged design and low cost. The thin film element is manufactured by coating a small ceramic chip with a very thin (.0001") film of platinum and then laser cutting or chemical etching a resistance path in the platinum film. The element is then coated with a thin layer of glass to protect it from harmful chemicals and gases. Larger extension lead wires are spot welded to the chip and this junction is then covered with a drop of epoxy to help hold the wires to the element.



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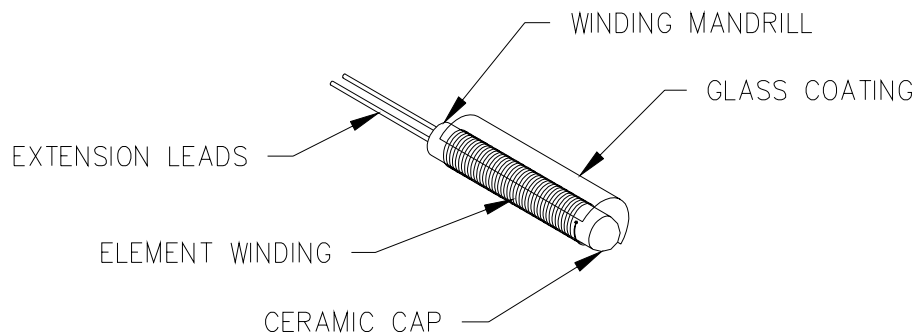
Inner Coil Wire Wound RTD

This type of element is normally manufactured using platinum wire. Very small platinum wire (.0002") is coiled and then slid into a small 2 hole ceramic insulator. Larger extension leads are then spot welded to the ends of the platinum wire and cemented in place. Some manufacturers backfill the bores of the insulator with ceramic powder once the coils have been inserted. This keeps the coils from moving and shorting against each other. The end opposite the extension leads is capped with ceramic cement also.



Outer Wound RTD Element

The outer wound RTD element is made by winding the sensing element wire around a center mandrill, which is usually made of ceramic. This winding is then coated with glass or some other insulating material to protect and secure the windings. The winding wires are then spot welded to extension leads and secured to the body with ceramic cement or epoxy.

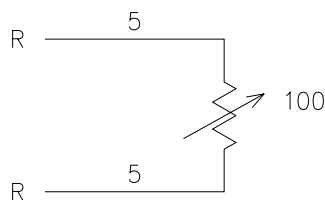


Each of the types has their advantages. The thin film is the least expensive to manufacture and also the most rugged. They also can be manufactured in very small sizes. The inner coil wire wound style is the most accurate. It is however, more expensive to manufacture and does not perform well in high vibration applications. The outer wound element is similar in cost to the inner coil element. It is not as accurate as the inner coil style but is more rugged.

RTD THEORY

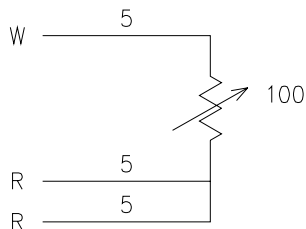
FUNCTION

To use an RTD, a small voltage is passed through the element and then measured. The resistance of the element reduces the voltage and this voltage drop can be converted into a temperature measurement. With most RTD's, the higher the temperature, the higher the resistance. The following diagram represents a simple 2-wire RTD circuit. An instrument is hooked to one red wire and sends a voltage thru that red wire, through the element and back thru the other red wire. This reading is then converted to a temperature by the instrument. The only problem with this simple *2-wire circuit* is that you read the resistance of the lead wire along with the resistance of the element. There is no way to separate the three resistances.



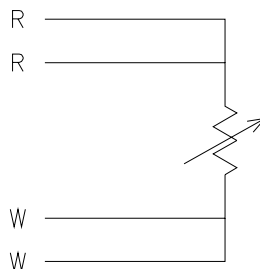
$$\text{Resistance of circuit} = 5 + 100 + 5 = 110 \text{ ohms}$$

The *3-wire circuit* does allow for compensation of lead wire resistance, which is normally done by the measuring instrument. The instrument measures the resistance between the red and the white leads and then subtracts the resistance between the two reds.



$$5 (w) + 100 + 5 (r) = 110 - (5 (w) + 5 (r)) = 100$$

The problem with the *3-wire circuit* is that the formula assumes that all three wires are the same resistance. This is not a problem on short lead wire lengths but can become a problem as the length of the extension lead wires increases. The *4-wire circuit* is a true 4-wire bridge circuit that eliminates any differences in lead resistances. The 4-wire bridge circuit eliminates lead wires resistance electrically instead of mathematically.



RTD THEORY

ELEMENT RESISTANCES

RTD'S are manufactured with a base resistance at some temperature point. This temperature is most commonly 0°C (32°F). The most common base resistance is 100 ohms, which means that if the RTD is at 0°C, the resistance would be 100 ohms. There are other resistances and temperatures. Some of these are:

10 ohm copper @ 25°C

1000 ohm platinum @ 0°C

200 ohm platinum @ 0°C

604 ohm nickel/iron

500 ohm platinum @ 0°C

TEMPERATURE COEFFICIENT

Another common term used with RTD's is *temperature coefficient*. This refers to the change in resistance vs. change in temperature. There are 2 common coefficients for platinum RTD's' and several others for the copper and nickel types. The most common platinum RTD has a temperature coefficient of .00385 ohms/ohms/°C. This means that a 100 ohm platinum RTD will increase in resistance .385 ohms for every 1°C increase in temperature.

TEMPERATURE RATING

The maximum temperature rating for RTD's is based on 2 different factors. First is the element material. Platinum RTD's can be used as high as 650°C (1202°F). Other materials are much lower in temperature rating and vary from material to material. The other determining factor for temperature rating is probe construction. SensorTec offer three different constructions for maximum temperatures of 200°C (392°F), 450°C (842°F) and 650°C (1202°F). There are construction considerations used in each of these different styles making them ideal for use in each of those ranges. No one styles is good for all ranges.

RTD TOLERANCES

The tolerance or accuracy for RTD sensors is stated at one point only, which is usually 0°C (32°F). ASTM publications recognize 2 *grades* of platinum RTD elements while DIN (Europe's version of ASTM) recognizes 2 *classes* of elements. They are as follows:

ASTM E-1137 grade B = ± .10% @ 0°C (32°F)

ASTM E-1137 grade A = ± .05% @ 0°C (32°F)

DIN 43760 class B = ± .12% @ 0°C (32°F)

DIN 43760 class A = ± .06% @ 0°C (32°F)

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RTD TIDBITS

- ◆ RTD's are generally more expensive to manufacture or purchase than thermocouples.
- ◆ Since the RTD circuit is just a resistance circuit, no special extension leadwires or connectors are required making this portion of the circuit less expensive than that of a thermocouple.
- ◆ Although some types of RTD elements are rated to fairly high temperatures (650°C (1202°F)), they become quite fragile at temperatures above 320°C (600°F). A RTD sensor will not hold up well at these elevated temperatures if there is any vibration present.
- ◆ The tolerance or accuracy of an RTD generally decreases as temperature increases.