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Resistance Temperature Detectors (RTDs)

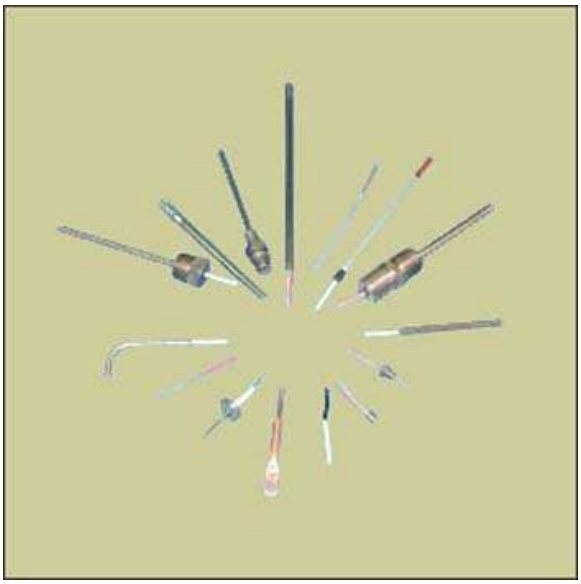
Note: RTD Product Vendors are listed on seperate pages.

What are RTDs?

Resistance Temperature Detectors or RTDs for short, are wire wound and thin film devices that measure temperature because of the physical principle of the positive temperature coefficient of electrical resistance of metals. The hotter they become, the larger or higher the value of their electrical resistance.

They, in the case of Platinum known variously as PRTs and PRT100s, are the most popular RTD type, nearly linear over a wide range of temperatures and some small enough to have response times of a fraction of a second. They are among the most precise temperature sensors available with resolution and measurement uncertanties or ±0.1 °C or better possible in special desions.

Usually they are provided encapsulated in probes for temperature sensing and measurement with an external indicator, controller or transmitter, or enclosed inside other devices where they measure temperature as a part of the device's function, such as a temperature controller or precision thermostat.



General Purpose RTD Probes courtesy RTD Company

The Advantages of RTDs

The advantages of RTDs include stable output for long period of time, ease of recalibration and accurate readings over relatively narrow temperature spans. Their disadvantages, compared to the thermocouples, are: smaller overall temperature range, higher initial cost and less rugged in high vibration lenvironments.

They are active devices requiring an electrical current to produce a voltage drop across the sensor that can be then measured by a calibrated read-out device.

RTD Error Sources

The lead wires used to connect the RTD to a readout can contribute to their measurement error, especially when there are long lead lengths involved, as often happens in remote temperature measurement locations. Those calculations

are straight forward and there exist 3-wire and 4-wire designs to help minimize or limit such errors, when needed.

Often the lead error can be minimized through use of a temperature transmitter mounted close to the RTD. Transmitters convert the resistance measurement to an analog current or serial digital signal that can be sent long distances by wire or rf to a data aquisition or control system and/or indicator.

RTDs, as mentioned above, work in a relatively small temperature domain, compared to thermocouples, typically from about -200 °C to a practical maximum of about 650 to 700 °C. Some makers claim wider ranges and some construction designs are limited to only a small portion of the usual range.

Insulation resistance is always a function of temperature and at relatively high temperature the shunt resistance of the insulator introduces errors into measurement. Again, error estimates are straight forward, provided one has a good estimate of the thermal properties of the insulator.

Insulator material such as powdered magnesia (MgO), alumina (Al2O3) and similar coumpounds are carefully dried and sealed when encapsulated in probes along with an RTD element.

ASTM has standards related to insulation resistance testing to help determine the performance of such sealed probes, specifically E 1652-00.

RTDs Other Than Platinum

RTDs can be made cheaply in Copper and Nickel, but the latter have restricted ranges because of non-linearities and wire oxidation problems in the case of Copper.

Platinum is the preferred material for precision measurement because in its pure form the Temperature Coefficient of Resistance is nearly linear; enough so that temperature measurements with precision of ±0.1 °C can be readily acheived with moderately priced devices. Better resolution is possible, but equipment costs escalate rapidly at smaller error levels.

All RTDs used in precise temperature measurements are made of Platinum and they are sometimes called PRTs to distinguish them.

Standard Platinum RTDs(SPRTs)

The ITS-90 (International Temperature Scale of 1990- used as a worldwide practical temperature scale in national metrology labs like NIST, NPL et al) is made up of a number of fixed reference points with various interpolating devices used to define the scale between points. A special set of PRTs, called SPRTs, are used to perform the interpolation in such labs over the ranges 13.8033 K (Triple point of Equilibrium Hydrogen) to the Freezing point of Silver, 971.78 °C.

The Hart Scientific website provides a glimpse into the realm of precision SPRTs and readout equipment used in calibration labs. They operate one of the very few labs in the USA with accreditation under NVLAP to the ISO/IEC 17025 standard.

Featured Link
Burns Engineering, Inc. (USA), a global supplier of high performance temperature measurement solutions.

1. ## RTD Types, Calibration Tables, Construction

   There are some excellent references online, but none seems totally complete simply because there are so many different types of device calibrations.

   The Minco Products website has lots of very useful information in a pdf Technical Reference file; you can download it here. It contains technical detail about a number of RTD types including platinum (PRTs), copper and nickel. An online resistance calculator is also located here and provides the temperature-resistance values for 23 different RTDs types, including some nickel and copper ones.

Burns Engineering Company has a downloadable RTD resistance Vs. Temperature calculator they call DINcalc (it's a zipped file). It is based on the 100 Ohm, 385 Temperature Coefficient Platinum RTD that is nearly a universal standard in the process control world.

The German DIN standard DIN 751 for RTDs recognizes only platinum material with a temperature coefficient of resistance of 0.00385

Platinum RTD Output Equation

ASTM Standards E 1137 for Industrial Platinum Resistance Thermometers specifies that the resistance-temperature relationship for such devices for the range 0 °C to 650°C, to within the tolerances given below, will be described by the equation:

$$R(t) = R(0)[1 + At + Bt^2]$$

Where:
t = temperature (to ITS-90), °C,
R(t) = resistance at temperature t,
R(0) = resistance at 0°C
A = 3.9083 * 10^-3(°C), and,
B = -5.775 * 10^-7(°C^-2).

More details and the equation for -200 °C to 0°C as well as the inverse, temperature as a function of resistance are provided in the standard. The standard is a copyright product of the ASTM and may be purchased at their website, http://www.astm.org/.

In Europe, the former German DIN standard, DIN 43760, had been the major, recognised source for RTD properties. Not withstanding this fact, the British have long had standard BS 1904:1964. Both recognize the 0.003850 temperature coefficient for platinum RTDs. Now the IEC adminiters the "DIN" standard as IEC Standard 60751.

The **Callendar-Van Dusen equation** and others are used to correct for the nonlinearity of the resistance-temperature relationship for very high accuracy measuments, such as those performed in a metrology or calibration laboratory

2. Recommended Use Limits and Tolerances:

In the USA, ASTM Specification E1137 "Standards Specification for Industrial Platinum Resistance Thermometers" gives many details and specifications for them over the range from -200 °C to 650°C.

It defines two RTD grades, A and B with a resistance-temperature relatiionship that has the following tolerances:

Grade A Tolerance = ±[0.13 +0.0017 *|t|] °C

Grade B tolerance =±[0.25 +0.0042 *|t|] °C
where |t| is the absolute value of the RTD's temperature in °C.
Below are examples of these tolerances for a nominal 100 ohm (at 0°C) Platinum RTD. The actual ASTM document includes more examples.

RTD Classifications And Tolerance Limits per ASTM E1137

Temperature Degrees C	Grade A Limits		Grade B Limits	
	°C	Ohms	°C	Ohms
-200	0.47	0.20	1.1	0.47
0	0.13	0.05	0.25	0.10

100	0.30	0.11	0.67	0.25
400	0.81	0.28	1.9	0.66
650	1.24	0.40	3.0	0.94

The DIN Standard recognizes three different tolerance classes, they are:

DIN Class A tolerance: ±[0.15 + 0.002*|t|] °C
DIN Class B tolerance: ±[0.30 + 0.005*|t|] °C
DIN Class C tolerance: ±[1.20 + 0.005*|t|] °C

3. ## Standards

Our pages on RTD standards.

4. ## Calibration & Traceability

This link takes you to other pages on this website for details.

5. ## Training Courses and Other Resources

Training courses and other resources pages may be reached by clicking on the link above.
Sensor Scientific's web site has comparison of four popular contact temperature sensor types, Thermocouples, Resistance, Thermistors and Semiconductor, shown on a one page chart and in a very readable article.

6. ## Some RTD Vendors

Our RTD vendor lists are long and spread over several pages, arranged alphabetically by company.

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