Industrial RTD Sensors

When accurate temperature measurement is required, a Resistance Temperature Detector (RTD) is often selected. Platinum is the most widely used material for RTD's today. As long as the temperature relationship with resistance is predictable, smooth and stable, the phenomenon can be used for accurate temperature measurement. To ensure high accuracy the resistance effects due to impurities must be small and the resistance versus temperature must be known and repeatable. The standard platinum resistance to temperature relationship follows the straightforward quadratic equation. This is normally covered by second order functions and at most third order.

The main purpose of this article is to identify potential sources of error. The equations and constants used come from standards. The most recent standards are ASTM 1137 and IEC 60751. Some older standards that should not be used today are DIN 43760, BS 1904(1984), SAMA RC-4 (1966).

Above 0 Degree C Platinum RTD's are specified by R0 (resistance 0 Degrees C) and either the following: 1) A and B coefficients, 2) alpha and delta coefficients. Below 0 Degree C RTD's are specified by R0 and either the following: 1) A, B and C coefficients, 2) alpha, delta and beta coefficients.

Before 1990 (i.e. IPTS-68 and before), alpha, delta, and beta were used exclusively to define a PRT curve (using the Callendar Van Dusen equation). The Callendar Van Dusen is still used, but it is now more common for manufacturers to use the A, B, and C coefficients instead of alpha, delta, and beta. (A, B, C, alpha, delta, and beta are all related using simple equations).

Over the years, and especially before 1990, there were LOTS of different "standards" for industrial PRT's. Many had unique coefficients, due to unique doping of the platinum. Today there are only two that are common: ASTM 1137 (American) and IEC 751 (European).

The differences in these coefficients is a source of error applicable to both sensor and transmitter. The sensor resistance versus temperature curve must be accurate and the transmitter linearization must match the sensor.

When specifying an RTD be sure to indicate the most recent reference standards are to be followed. Specify the accuracy required. IEC 60751 Class A is 100 ohm +/- 0.06% and Class B is +/- 0.12%. Class B is used most often. Class C and D (each doubling the prior tolerance level) are also used. Request a calibration table including the constants which may be able to be configured into some smart transmitters for optimum accuracy.

The standard IEC 60751 RTD 100 ohm at 0 Deg C has an 'A' coefficient of 3.851

Example using IEC equation and coefficients:
$R_t = R_0 (1 + At + Bt^2)$ for 0 to 850 Deg C.
Where: $A = 3.9083 \times 10^{-3}$°C; $B = -5.775 \times 10^{-7}$ °C
Rt is the resistance in at temperature t
t is the temperature in °C.

At 100 Deg C Rt = 100.00 (1+(0.0039083 * 100) + (-0.0000005775 * 100^2)
Rt = 100.00 (1+ 0.39083 - 0.005775)

$R_t = 100\ (1.385055) = 138.5055$ ohms.
The standard ASTM 1137 RTD 100 ohm at 0 Deg C has an ‘A’ coefficient of 3.911.
Example using IEC equation and coefficients:

$R_t = R_0\ (1 + At + Bt^2)$ for 0 to 850 Deg C.
Where: $A = 3.9692 \times 10\text{-}3°C$; $B=-5.8495 \times 10\text{-}7\ °C$

At 100 Deg C $R_t = 100.00\ (1+(0.0039692 * 100) + (-0.00000058495 * 100^2)$
$R_t = 100.00\ (1+ 0.39692 - 0.0058495)$
$R_t = 100\ (1.385055) = 139.1071$ ohms.

The error by using the wrong equation is (139.107 - 138.5055) ohms = 1.0043 ohms.
With a coefficient of 0.385 ohm / Deg C this equates to an error of 1.0043 / 0.385 = 2.61 Deg C.
This is a significant error of 2.61 / 100 * 100% = 2.61%.

Other selection issues with RTD’s are stability, rise time, self-heating, thermal shunting and time constant. Stability is the acceptable limit of drift over a specified time. This can range from <0.005 Deg C/year to <0.25 Deg C/year. Rise time refers to the time required for the sensor to reach some fraction of final resistance in response to a step change in temperature. Self-heating occurs whenever current flows through an RTD. Heat generated causes the sensor resistance to rise and create a false temperature which adds to the real measured temperature. Normally a constant current is passed through the resistance element so that the voltage can be measured. The smaller the current the smaller the self-heating effect and voltage drop.
Thermal shunting

Lead wires connect the RTD to a transmitter or other receiving instrument. Leadwire resistance adds to the sensor resistance which can cause measurement errors. Errors can be balanced out by using 3-wire or 4-wire sensors. Compensating sensor and leadwires are used to nullify the resistance in bridge type measuring circuits. The 4-wire sensors are the most effective for reducing the errors due to leadwire resistance when used with a 4-wire bridge circuit. The one disadvantage is that one more extension wire is required.

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