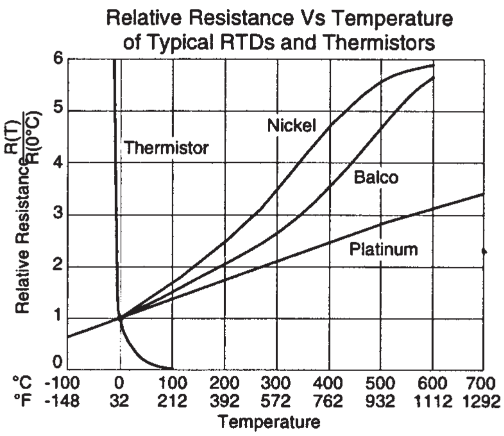
PLATINUM RTD RESISTANCE VS. TEMPERATURE FUNCTION

PLATINUM is a precious metal with a very stable and near linear resistance versus temperature function. While intrinsically less sensitive than thermistors or other metals, thin film RTDs provide very high base resistance and high device sensitivity.



Platinum's resistance versus temperature function is accurately modeled by the Callendar-Van Dusen equation. This equation uses constants A, B and C, derived from resistance measurements at 0°C, 100°C and 260°C.

Callendar-Van Dusen Equation:

$$R_T = R_0(1+AT+BT^2-100CT^3+CT^4)$$

R_T = Resistance (Ω) at temperature T (°C)
R_0 = Resistance (Ω) at 0°C
T = Temperature in °C

For T>0°C, the quadratic formula can be used to solve for Temperature as a function of measured resistance with the result:

$$0 = R_0BT^2+R_0AT+(R_0-R_T) \text{ implies...}$$

$$T_R = \frac{-R_0A+\sqrt{R_0^2A^2-4R_0B(R_0-R_T)}}{2R_0B}$$

Platinum RTDs are specified by resistance at 0°C, $\mathbf{R_0}$, and alpha, α, a term related to the temperature coefficient of resistance, or TCR. The Callendar-Van Dusen constants A, B and C are derived from alpha α and other constants, delta δ and beta β, which are obtained from actual resistance measurements. Common Callendar-Van Dusen constant values are shown in the table below:

CALLENDAR-VAN DUSEN CONSTANTS†

Alpha, α (°C^{-1})	.003750 ± .00003	.003850 ± .0001
Delta, δ (°C)	1.605 ± 0.009	1.4999 ± 0.007
Beta, β* (°C)	0.16	0.10863
A (°C^{-1})	3.81×10^{-3}	3.908×10^{-3}
B (°C^{-2})	-6.02×10^{-7}	-5.775×10^{-7}
C (°C^{-4})*	-6.0×10^{-12}	-4.183×10^{-12}

*Both β = 0 and C = 0 for T>0°C

The definitions of the Callendar Van Dusen constants: A, B, C, and alpha, delta and beta (α, δ and β), and their inter-relationships are given by the equations below. In all cases, the values of the constants and the fundamental accuracy and repeatability performance of an RTD is determined by the repeatability of the empirically measured resistance values:

$R_O \pm \Delta R_O R_{100} \pm \Delta R_{100}$ and $R_{260} \pm \Delta R_{260}$

$$A = \alpha+\frac{\alpha \cdot \delta}{100} \qquad B = \frac{-\alpha \cdot \delta}{100^2} \qquad C_{T<0} = \frac{-\alpha \cdot \beta}{100^4}$$

$$\alpha = \frac{R_{100} - R_0}{100 \cdot R_0} \qquad \delta = \frac{R_0 \cdot (1 + \alpha \cdot 260) - R_{260}}{4.16 \cdot R_0 \cdot \alpha}$$

$$\beta = \text{Constant for } T<0°C$$

TOLERANCE STANDARDS AND ACCURACY

IEC 751, the most commonly used standard for Platinum RTDs defines two performance classes for 100Ω, 0.00385 alpha Pt TRDs, **Class A** and **Class B**. These performance classes (also known as **DIN A** and **DIN B** due to DIN 43760) define tolerances on ice point and temperature accuracy. These tolerances are also often applied to Pt RTDs with ice point resistance outside of IEC 751's 100Ω assumption.

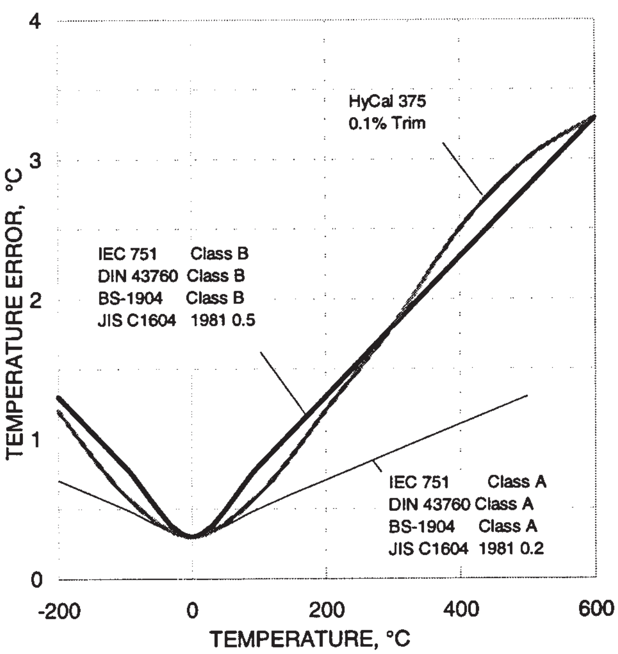
Class C and **Class D** (*each doubling the prior tolerance level*) are also used.

INTERNATIONAL STANDARDS

Standard	Comment	
IEC 751	Defines Class A and B performance for 100Ω 0.00385 alpha Pt RTDs.	
DIN 43760	Matches IEC 751.	
BS-1904	Matches IEC 751.	
JIS C1604	Matches IEC 751. Adds 0.003916 alpha.	
ITS-90	Defines temperature scale and transfer standard.	
Parameter	**IEC 751 Class A**	**IEC 751 Class B**
R_0	100Ω ± 0.06%	100Ω ± 0.12%
Alpha, α	.00385 ± .000063	.00385 ± .000063
Range	−200°C to 650°C	−200°C to 850°C
Res., R_T*	±(.06+.0008|T|−2E-7T²)	±(.12+.0019|T|−6E-7T²)
Temp, T**	±(0.3+0.002|T|)°C	±(0.3+0.005|T|)°C

*Units are Ωs. Values apply to 100Ω Pt RTDs only. Scale by ratio of the R_0s to apply to other ice point resistances.
*Applies to all 0.00385 alpha Pt RTDs independent of ice point, R_0.

PRTD TEMPERATURE ACCURACY



While IEC 751 only addresses 100Ω 385 alpha RTDs, its temperature accuracy requirements are often applied to such other platinum RTDs. However, manufacturers generally present both resistance-vs-temperature accuracies and temperature accuracies in tabular form for direct review.

The Callendar Van Dusen equation analytically addresses the tolerance and accuracy of a Pt RTD at any point within its operating temperature range independent of alpha and ice point resistance. The Resistance Limit-of-Error function (i.e. sensor resistance interchangeability as a function of temperature) can be calculated by taking the differential of the Callendar Van Dusen equation w.r.t. R_0, α and δ and applying the associated uncertainties. While an Expected (RMS) Error function can also be calculated, design engineers are typically interested only in the Limit-of-Error (LOE) function since it characterizes worst case behavior. The LOE function for resistance for T>0°C is:

$$\Delta R_{LOE} = \Delta R_0(1+AT+BT^2) + \Delta A R_0 T + \Delta B R_0 T$$

$$= \Delta R_0 + \Delta\alpha T + (\Delta\alpha\delta + \alpha\Delta\delta)\left[\frac{T}{100} + \frac{T^2}{100^2}\right]$$

Similarly, obtain the Temperature Limit-of-Error (i.e. temperature interchangeability) function using two approaches:

1. Multiply the derivative of R_T by the uncertainty ΔR_T

$$\Delta T_{T_1} = \Delta R_{T_1} \times \left.\frac{\partial R_T}{\partial T}\right|_{T_1}$$

2. Solve the Callendar Van Dusen equation for T, take the differential w.r.t. R_0, α and δ, then apply the appropriate uncertainties. In practice, it is ''easier'' to take the differential w.r.t. A and B and then apply ΔA and ΔB as calculated from α, Δα, δ and Δδ.

$$\Delta T_{LOE} = \frac{\Delta A}{2B} + \frac{A\Delta B}{2B^2} + \frac{\Delta B\sqrt{R_0^2A^2-4R_0B(R_0-R_T)}}{2R_0^2B^2} +$$

$$\frac{[R_0^2A^2-4R_0B(R_0-R_T)]^{-\frac{1}{2}}\ [A\Delta AR_0^2+2R_0\Delta B(R_0-R_T]}{2R_0B}$$

The second relationship could also be calculated in terms of the basic empirical data: $R_0 \pm \Delta R_0$, $R_{100} \pm \Delta R_{100}$ and $R_{260} \pm \Delta R_{260}$.

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