Error Sources
That Effect Platinum Resistance Thermometer Accuracy
Part 1 - Interchangeability

Introduction

There are many sources of error that affect the performance of Platinum Resistance Thermometers (PRTs). These error sources are inherent in the design and manufacture of all PRTs, but the magnitude of the resulting error in use can vary greatly depending on the specific PRT design and environment that it is used in. It is important for users of PRTs to know and understand what these error sources are so they can make intelligent decisions related to PRT selection and use. The most common error sources fall within the following categories: Interchangeability, Insulation Resistance, Stability, Repeatability, Stem Conduction, Hysteresis, Calibration and Interpolation, Lead Wire Resistance, Self-Heating, Time Response, and Thermal EMF. This paper will discuss the topic of Interchangeability.

Interchangeability

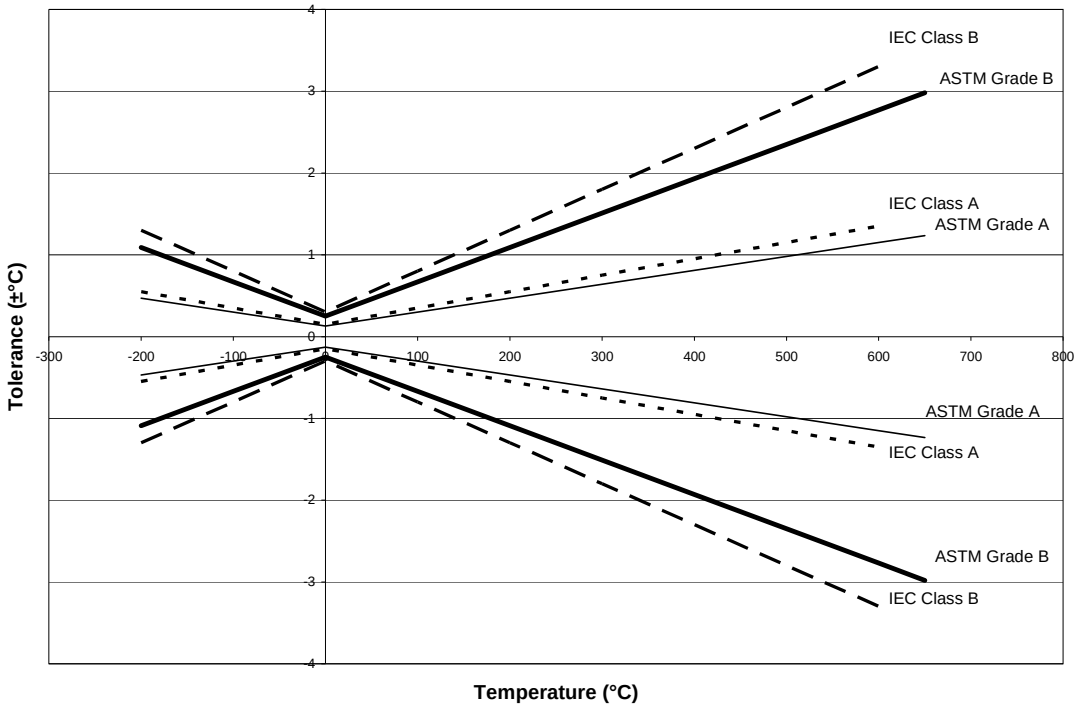
Interchangeability refers to the "closeness of agreement" in the resistance vs temperature (R vs T) relationship of a PRT to a pre-defined nominal R vs T relationship. Since it is not possible to manufacture a PRT that exactly replicates a pre-defined nominal R vs T relationship, a tolerance band about the relationship must be established, and this is what is called the "interchangeability" of the PRT.

The two most widely used industrial PRT standards in the United States are ASTM E1137 and IEC 60751. Fortunately both of these standards have the same nominal R vs T relationship, but unfortunately they do not have the same interchangeability tolerance. Both of these standards use the term "tolerance" to describe the permissible variation in the R vs T relationship, and both define this tolerance as a function of temperature in °C. Both standards offer multiple tolerance levels and refer to them by either a tolerance "Class" or tolerance "Grade". Table 1.1 below shows the interchangeability tolerances for these two industry standards while Figure 1.1 shows a comparison of the interchangeability levels graphically.

Table 1.1
Standard PRT Interchangeability Equations

Standard	Tolerance Nomenclature	Defining Equation[1]
ASTM E1137	Grade A	± [.13 + 0.0017 | t |]
ASTM E1137	Grade B	± [.25 + 0.0042 | t |]
IEC 60751	Class A	± [.15 + 0.002 | t |]
IEC 60751	Class B	± [.3 + 0.005 | t |]
Note 1: | t | = the value of temperature in °C without regard to sign		

Figure 1.1
Standard PRT Interchangeability



It is worth noting that many times manufacturers will define interchangeability in terms of a percent, such as .06%. In these cases the percent refers to a percent of resistance valid only at 0°C. For example, .06% interchangeability is ±.06 ohms (±.15°C) for a 100 ohm PRT. This is not enough information to know what the tolerance is at other temperatures. The user should be provided with either a statement that the tolerance meets one of the industry standard Classes or Grades, or a table showing the tolerances, or an equation similar to the ones shown in Table 1.1 that define the tolerance over the entire rated temperature range of the PRT.

Causes of Interchangeability Error

Many factors contribute to the interchangeability of any given PRT. One factor to consider is that the nominal R vs T relationship contained in the standards is only an approximation of how PRTs actually behave, it is based on the best fit that could be obtained using a second order equation for temperatures above 0°C, and a third order equation for temperatures below 0°C. Another factor, and arguably the largest contributor, has to do with the specific design, materials, and manufacturing details used to construct a PRT. Variations in the composition and purity of the platinum used, differences and variation between insulating materials, the amount of precision in adjusting the resistance during manufacture, and assembly process resistance shifts all affect the specific R vs T performance for any given PRT. Other factors to consider are the affect that external influences have on the resistance. PRTs must withstand exposure to basic levels of pressure, vibration, mechanical shock, and temperature extremes while remaining within the resistance tolerance band.

How to Reduce Interchangeability Error

The most obvious way to reduce interchangeability error is to use a PRT with a tight interchangeability tolerance. The user should select the appropriate interchangeability necessary for the application as price will increase as the tolerance is reduced. In general, PRTs with tighter interchangeability tolerances may have limited temperature ranges so it may not be possible to use a tighter tolerance part for all applications.

One way to nearly eliminate interchangeability error in the measurement system is to use a PRT along with a transmitter which has “matching” capability, i.e., one that is capable of being matched to a specific R vs T relationship through adjustment of potentiometers, programming of coefficients, or other means. This method will increase the system cost as it will require the use of a transmitter with sensor matching capability, and it will require calibration of the PRT over the operating temperature range. The benefit is that this method will virtually eliminate the interchangeability error, however, errors due to calibration and some external influence effects will still be present. If this method is used it is not necessary to specify a tight interchangeability tolerance since the actual R vs T relationship is used. The example shown in Table 1.2 below demonstrates the improvement that can be achieved using these methods.

Table 1.2: Example of system accuracy for a process with a critical temperature of 121°C using a transmitter with .10°C accuracy.

	Grade B Sensor	Grade A Sensor	Calibrated Sensor
Sensor Tolerance at 121°C	± 0.76°C	± 0.34°C	± 0.05°C
Transmitter Accuracy	± 0.10°C	± 0.10°C	± 0.10°C
Combined System Accuracy[1]	± 0.77°C	± 0.35°C	± 0.11°C

Note 1: Typically errors are combined using an RSS method as follows: Combined Accuracy = [Sensor Accuracy^2 + Trans Accuracy^2]$^{1/2}$

Summary
PRT interchangeability, also referred to as resistance tolerance, is the “closeness of agreement” in the R vs T relationship of a PRT to a pre-defined nominal R vs T relationship. Prominent industry standards such as ASTM E1137 and IEC 60751 offer several tolerance options to choose from, and manufacturers may offer other options. The interchangeability of a PRT may be a significant source of the total error when measuring temperature. Two ways to reduce this error are to select a PRT with a tight interchangeability specification, and to use a transmitter that can be matched to a specific PRT R vs T relationship which can virtually eliminate this error.

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