

Error Sources That Effect Platinum Resistance Thermometer Accuracy Part 2 – Insulation Resistance

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 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 Insulation Resistance.

Insulation Resistance

Insulation Resistance (IR) refers to the electrical resistance between the sensing circuit and the metallic sheath of a PRT. It is important for the sensing element circuit to be insulated from the sheath because electrical leakage can cause an error when measuring the resistance of the sensing element. Any error in measuring the resistance will translate to an error in the indicated temperature.

Resistance is a parameter that cannot be measured directly, it is calculated by either applying a constant current and measuring the voltage drop, or by applying a constant voltage and measuring the current. The typical method used to measure the resistance of an industrial PRT is to apply a constant current, typically between .050 mA and 2 mA, and measure the voltage drop to determine the resistance. The formula required to make this calculation is simply Ohms Law, however the details of this calculation are not necessary for the purpose of understanding this concept. What is important to know is that if a portion of the applied current has the opportunity to leak out of the circuit, through a low insulation resistance, then a false resistance reading will be obtained for the sensing element.

As discussed in [Part 1 on Interchangeability](#), the two most widely used industrial PRT standards in the United States are ASTM E1137 and IEC 60751. These standards specify minimum IR values at ambient temperature (25°C) as well as at elevated temperatures. Table 2.1 shows the minimum insulation resistance values required by these standards and the estimated temperature error values calculated for a 100 ohm PRT using the estimating method described in Equation 2.1 below. It is easy to see by examining this

table that the minimum IR requirement decreases as the temperature increases. This represents the typical behavior of an industrial PRT and is a reason why the ambient temperature IR requirements are generally much higher than necessary for accurate operation at ambient temperature.

Table 2.1
PRT Insulation Resistance Requirements

Standard	Rated Temperature (°C)	Minimum IR (MΩ)	Test Voltage (VDC)	Estimated Error for 100 ohm PRT (°C)
ASTM E1137	25	100	10 to 50	.0003
ASTM E1137	300	10	10 to 50	.013
ASTM E1137	650	2	10 to 50	.17
IEC 60751	25	100	10 to 100	.0003
IEC 60751	100 to 300	10	10	.013
IEC 60751	301 to 500	2	10	.12
IEC 60751	501 to 850	.5	10	1.0

Estimating the Error Caused by Insulation Resistance

One method that has been used to estimate the magnitude of the error due to IR affect is to treat the PRT element resistance and the IR value as two resistors in parallel. This method is not completely accurate however, since electrical leakage can occur not only from lead wire to sheath, but from lead wire to lead wire. The lead to lead leakage also acts as a resistor in parallel and this type of leakage cannot be tested because the sensing element is in the circuit. Nevertheless, treating the PRT element resistance and IR as two resistors in parallel has become a common way to estimate the magnitude of the error due to IR. It is worthwhile noting that IR almost always results in a lower indicated temperature with few exceptions, such as installations where current may actually leak into the circuit.

The measured resistance can be estimated by equation 2.1, which is the formula for the resultant resistance of two resistors in parallel

Equation 2.1

$$R_{Measured} = \frac{[R_{PRT} \times R_{IR}]}{[R_{PRT} + R_{IR}]}$$

Where: $R_{Measured}$ = Resultant measured resistance
 R_{PRT} = Resistance of PRT element
 R_{IR} = Insulation resistance value

For example, a PRT that has exactly 100 ohms of resistance at 0°C when the IR is sufficiently high would have a $R_{Measured}$ of 99.990 ohms if the IR were to degrade to 1 megohm, this is the equivalent of .025°C error. If this same sensor was to be used at

250°C and the IR degraded to a level of .2 megohms, the error would be the equivalent of approximately .5°C.

A common misconception about IR is that the effect due to IR is included when the part is calibrated. This is only true if the IR does not change after calibration, or remains sufficiently high. If the IR degrades but remains above the required minimum, there can still be a significant change in the indicated temperature, especially at higher temperatures where it is acceptable to have IR of less than 1 megohm. As an example, a PRT that may have an IR of 100 megohms at 550°C degrades over time to an IR of .5 megohms, this can result in a change in the resistance which is the equivalent of .54°C.

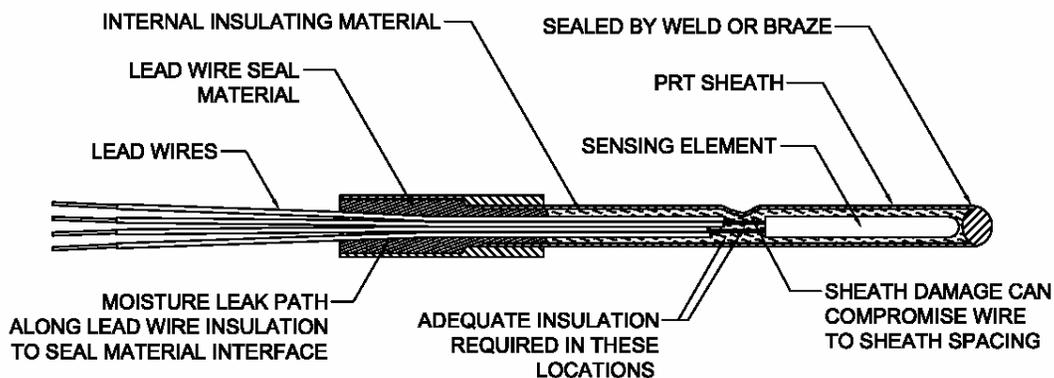
Causes of Low Insulation Resistance

Insulation resistance values can degrade due to several sources. The most common source is moisture inside the PRT. The moisture may be trapped within the PRT during manufacture or generated within the PRT through outgassing of some material used in the construction of the PRT. Moisture may also enter the PRT through a leak path, most typically through the lead wire seal area.

Low IR could also be due to contamination within the PRT from sources other than moisture. In addition, bending, denting, vibration and mechanical shock of the PRT may result in displacement or migration of insulating materials producing inadequate spacing between the lead wire and sheath resulting in low IR.

In any case, it is impractical to repair PRTs with low IR. In some instances heating the PRT in an oven can “bake out” moisture that is within the sensor but if the moisture entered the PRT through a leak path, then the repair will only be temporary and moisture will most likely reenter through the same leak path. Refer to Figure 2.1 for additional details.

Figure 2.1 Cross Sectional View of a Typical Industrial PRT Showing Pertinent Insulation Resistance Information.



How to Reduce Insulation Resistance Error

The best way to reduce the possibility of an IR error is to select a PRT that has been designed properly, is mechanically and thermally robust enough to handle the process it will be used in, and is sealed well. Many industrial PRTs have all welded or brazed construction with the exception of the lead wire exit area, which is usually sealed with some type of epoxy. This makes the seal location the weakest link in keeping moisture out. Avoid exposing the seal area to temperature extremes as this can degrade the seal. Also avoid exposure of the sensor to cryogenic temperatures as this can produce a reduced pressure within the sheath and actually draw in moisture from the surrounding air. When in doubt, check with the manufacturer about the temperature rating of the seal area. Lastly, it is good practice to routinely test the IR to make sure it is acceptable. This can easily be performed during regularly scheduled maintenance or calibration. The manufacturer should be able to provide a test procedure, or refer to ASTM Standard E644 (*Standard Test Methods for Testing Industrial Resistance Thermometers*) which contains a detailed IR test procedure. Detecting the degradation of IR allows for corrective action to occur before the error reaches a critical level.

Summary

Insulation resistance refers to the electrical resistance between the sensing circuit and metallic sheath of a PRT. Errors in temperature measurement occur because the resistance of the sensing element cannot be accurately determined due to a portion of the sensing current leaking out of the circuit. IR decreases as temperature increases and the overall result is that the error due to IR increases as the temperature increases. The best way to reduce or avoid errors from IR is to select a PRT with a robust design and not to apply any unnecessary stress to the lead wire seal area. It is good practice to measure the IR on a regular interval to detect degradation of the IR before the error reaches a critical level.

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