A Practical Approach to *As Found* Calibration Data For Secondary Standard Platinum Resistance Thermometers

Introduction

One of the most important pieces of information that can be obtained from calibrating a Secondary Standard Platinum Resistance Thermometer (SSPRT) is the *As Found* data for the thermometer. This information is important because it allows the user to make a determination about the performance of the SSPRT during the prior interval of use. Several common questions arise regarding *As Found* data and how the data should be used. This paper will address some of the most common questions as well as describe some of the complications that arise when performing calibration of SSPRTs after an *In Service* period.

As Found RTPW

The most common *As Found* calibration data that is taken on a SSPRT is the resistance at the triple point of water (RTPW). The triple point of water (TPW) has been defined in the International Temperature Scale of 1990 (ITS-90) as 0.01°C. The TPW is considered the most important temperature point for all laboratory grade PRTs because the RTPW value is used to generate a thermometer's resistance vs temperature relationship over its entire operating range. To understand why this is true requires a quick explanation of the ITS-90.

How ITS-90 Defines Temperature

For the temperature range of use of nearly all SSPRTs, the ITS-90 is defined in terms of the following:

- Fixed temperature points - these are melting points, freezing points, and triple points for various materials
- Resistance ratios (W) – ratios of the resistance at temperature to the RTPW for Standard Platinum Resistance Thermometers (SPRTs)

$$\text{Ratio } (W) = (\text{Resistance at temperature}) / (\text{RTPW})$$

- Mathematical reference functions - defines the resistance ratio vs temperature relationship of what could be considered a "perfect" SPRT
- Mathematical deviation functions - defines how far an actual SPRT deviates from the reference function.

The mathematical functions for the ITS-90 actually express temperature in terms of the ratio (W), not the absolute resistance value. Given that the temperature is defined by the ratio and the RTPW is a fundamental characteristic of all W's, it is easy to see why the RTPW value is so important.

How to Use *As Found* RTPW

The *As Found* RTPW value only provides a single data point, reported in ohms, not in °C. This brings up two of the most common questions.

- How do I know how far off the sensor is at temperatures other than the TPW?
- Why is the *As Found* data reported in ohms and not in °C?

The answer to the first question is that SSPRT sensors are considered to be well behaved and perform in a predictable manner. How far off the sensor is at temperatures other than the TPW can be estimated by using the *As Found* RTPW value and prior calibration data. One way to make this estimation is to use the new RTPW value with the old deviation function coefficients to calculate resistance values at other temperatures over the range of interest. This approach requires knowing the previous coefficients, and can be somewhat math intensive.

A simpler method would be to multiply the *As Found* RTPW value by the prior *W* ratio at the temperature of interest. This approach requires having the previous RvsT table for the sensor.

It is important to note that the changes at temperatures other than the TPW are not expected to be the same as the change at the TPW. As temperature increases so does the resistance, so if a SSPRT experiences an increases in its RTPW value, it is expected to have an increase at other temperatures as well. The increase is estimated to be in direct proportion to both the magnitude of the change at the TPW, and the magnitude of the resistance ratio at the temperature of interest. This type of analysis can be considered somewhat conservative if the change at the TPW is relatively small. Users need to address actual criteria based on the expected uncertainty required *In Service*. The table below shows an example of this type of analysis.

Temperature	Prior Resistance [1] Ohms	*As Found* Resistance [2] Ohms	Change Ohms	Change [3, 4] °C
TPW	100.0429	100.0529 (measured)	.0100	.025
200°C	177.3793	177.3970 (calculated)	.0177	.047
	Factor of increase at 200°C		1.77	1.88
420°C	257.0269	257.0526 (calculated)	.0257	.073
	Factor of increase at 420°C		2.57	2.92

Note 1 – This data may be taken from the R vs T table provided with previous calibration report, or calculated using the previous coefficients. Note 2 – The value at TPW is the only measured value, values at other temperatures are estimated by multiplying the *As Found* RTPW by the prior *W* ratio. Note 3 – Change in °C is calculated by dividing the ohm value by the sensitivity (dR/dT) at the temperature under analysis. Note 4 – Consideration for combining the calibration uncertainties for the two measurements used to obtain the change should be addressed and is a topic for future discussion.

The second question has to do with reporting the *As Found* results in ohms instead of °C. The calibration is actually a characterization of the SSPRT, and the parameter measured is resistance in ohms. Reporting the value in ohms insures the purist measure, and is the most accurate characteristic of the SSPRT's current performance. To achieve an assessment of the sensors *In Service* performance, the change in RTPW can be converted to a change in °C. For the data to be properly converted from ohms to °C requires calculations using the sensors coefficients from the prior calibration as discussed in the paragraph above. The calculated change in °C can be assessed by the user based on the user's quality system and calibration uncertainty targets.

Addressing the various calibration uncertainties which can influence the analysis are topics for future discussion.

Complications of Taking Additional *As Found* Data on SSPRTs

One concern with taking multiple calibration points for the *As Found* data is that exposure of the SSPRT to elevated temperatures may cause the SSPRT resistance to change through annealing or other effects, particularly if the calibration temperature is higher than the typical temperature of use. As a result, the data taken after the highest temperature calibration point may not represent the true *As Found* condition of the SSPRT. The estimation technique described above is a practical approach to determine *As Found* data at temperatures above the TPW. *As Found* data could be acquired at temperatures below the TPW, although typically the effect of a RTPW shift is greater at elevated temperatures.

***As Found* Data on System Calibrations**

When an SSPRT and digital indicating thermometer are calibrated as a system, the approach to calibration is handled differently. Since digital indicators can use the sensor coefficients to calculate and display temperature in temperature units, *As Found* data can be provided in °C and a correction factor for the system can be reported. Since most indicators are programmed with the SSPRT coefficients, there is no question as to what coefficients were being used with the sensor. Typically, system calibrations are performed as systems at successive intervals so there is no need for the user to compare RTPW values of just the SSPRT, the only interest is in how the SSPRT and readout perform as a system. For this reason *As Found* data for system calibrations is taken at multiple points. While exposing the SSPRT to elevated temperatures may cause some shifting of the *As Found* condition, users prefer to have multiple points taken over the entire temperature range, thereby eliminating the need to calculate the sensor shift and readout shift separately, and then combining them into an overall system shift.

Summary

The *As Found* RTPW value is one of the most important pieces of information that is obtained during calibration of an SSPRT. The RTPW is important because the ITS-90 defines temperature based on a ratio of resistance at temperature to the RTPW. The *As Found* RTPW value must be used along with the prior calibration data to determine the performance of the sensor during its prior *In Service* interval. The As Found RTPW value may also be used to estimate the performance of the SSPRT at temperatures other than the TPW.

What's Next?

Watch for practical approaches to other calibration topics such as:

- system calibration
- how uncertainty should be considered in the interpretation of *As Found* data
- selection of temperatures for calibration
- fixed point temperatures vs common temperatures by comparison

What's on your mind? Visit the BEblog and let us know, or email John.

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