Making the Right Choice for Your Temperature Readout

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When performing temperature calibrations, the right choice of readout for your reference probe and units under test is critical. Consider the following:

Accuracy

Most readout devices for resistance thermometers provide a specification in parts per million (ppm), ohms, and/or temperature. Converting ohms or ppm to temperature depends on the thermometer being used. For a 100W probe at 0°C, 0.001W (1 mW) equals 0.0025°C or 2.5 mK. One ppm would be the same as 0.1mW or 0.25 mK. You should also note whether the specification is 'of reading' or 'of full range'. For example, 1 ppm of reading at 100W is 0.1mW . However, 1 ppm of full range, where full range is 400W , is 0.4mW . A big difference!

When reviewing accuracy specifications, remember that the readout uncertainty can be a small contribution to the total calibration system uncertainty and that it may not always make economic sense to buy the lowest uncertainty readout. The bridge-versus-Super-Thermometer analysis is an excellent case in point. A 0.1-ppm bridge may cost in excess of $40,000, whereas a 1-ppm Super-Thermometer costs less than $15,000. Reviewing total system uncertainties, it's clear that the bridge offers very little improvement—in this case, 0.000006°C—particularly considering its cost.

Sources of Uncertainty - Comparison Calibration of PRTs –196°C to 420°C		
SPRT	0.001000°C	0.001000°C
1-ppm Super Thermometer (1 ppm)	0.000250°C	
0.1-ppm Bridge		0.000025°C
Bath Uniformity / Stability	0.005000°C	0.005000°C
Estimated Total Uncertainty (k=2)*	**0.005105°C**	**0.005099°C**
*RSS, assuming uncertainty components were statistically evaluated.		

Measurement Errors

When making the high-accuracy resistance measurements, be sure the readout is eliminating the thermal EMF errors that are generated at the dissimilar metal junctions within the measurement system. A common technique for removing EMF errors uses a switched DC or low-frequency AC current supply.

Resolution

Be careful with this specification. Some readout manufacturers confuse resolution and accuracy. Having 0.001° resolution does not mean the unit is accurate to 0.001°. In general, a readout accurate to 0.01° should have a resolution of at least 0.001°. Display resolution is important when detecting small temperature changes—for example, when monitoring the freeze plateau of a fixed-point cell or checking the stability of a calibration bath.

Linearity

Most readout manufacturers provide an accuracy specification at one temperature, typically 0°C. This is helpful, but you normally measure a wide range of temperatures, so it's important to know the readout accuracy over your working range. If the readout were perfectly linear, its accuracy specification would be the same across its entire range. However, all readout devices have some non-linearity component and are not perfectly linear. Be sure the manufacturer provides an accuracy specification over your working range or provides a linearity specification for you to include in your uncertainty calculations.

Stability

Readout stability is important, since you'll be making measurements in a wide variety of ambient conditions and over varying lengths of time. Be sure to review the temperature coefficient and long-term stability specifications. Make sure the variations in your ambient conditions will not affect the readout's accuracy. Reputable readout manufacturers provide a temperature coefficient specification. The long-term stability specifications are sometimes tied to the accuracy specification—for example, "1 ppm for one year" or "0.01°C for 90 days." Calibration every 90 days is inconvenient, so calculate a one-year specification and use that in your uncertainty analysis. Be wary of the supplier who quotes 'zero drift' specifications. Every readout has at least one drift component.

Calibration

Some readout specifications state "no re-calibration necessary." However, under the latest ISO guides, calibration of all measuring equipment is required. Some readout devices are easier to re-calibrate than others. Look for a readout that can be calibrated through its front panel without special software. Some older readouts hold their calibration data on an EPROM that is programmed with custom software. This means the readout must be returned to the manufacturer for re-calibration—which could be in another country! Avoid readouts that still use manual potentiometer adjustments, since re-calibration is time-consuming and expensive. Most DC readouts are calibrated using a set of high-stability DC standard resistors. Calibration of an AC readout or bridge is more complicated, requiring a reference inductive voltage divider and accurate AC standard resistors.

Traceability

Measurement traceability is another concern. Traceability of DC readouts is extremely simple through well-established DC resistance standards. Traceability of AC readouts and bridges is more problematic. Many countries have no established AC resistance traceability. Many other countries that have traceable AC standards rely on AC resistors calibrated with ten times the uncertainty of the readout or bridge, which significantly increases the bridge's own measurement uncertainty.

Convenience Features

The push for increased productivity is endless. As a result, you'll need a readout with as many time-saving features as possible.

Direct display in temperature – Many readouts display only raw resistance or voltage. Temperature is the most useful display, so look for a readout that converts resistance or voltage to temperature and be sure it offers a variety of conversion methods—ITS-90 for SPRTs, Callendar van-Dusen for industrial PRTs, etc.

Variety of input types – It's highly likely that you'll be calibrating a variety of temperature sensors, including 3- and 4-wire PRTs, thermistors and thermocouples. A readout that measures multiple input types provides the best value and maximum flexibility.

Learning curve – Look for a readout that's simple to use. Bridges have been around for many years and provide good measurement performance, but require a significant investment in training to operate (and an external PC to compute temperature from resistance).

Multiplexers for expansion – When your calibration work includes batches of the same probe type, the ability to expand the measurement system with multiplexer units can also improve productivity dramatically.

Digital interfaces – For automated data acquisition and calibrations, computer interfaces are essential. Look for RS-232 or IEEE-488 interfaces and calibration software that interfaces with the readout and other system components (baths and multiplexers) for automated calibrations.

You can never ask too many questions or get too much information. Be suspicious of the supplier with vague specifications, who is unwilling to provide answers.