Is Your Thermometer Accurate?

By Mingjian Zhao, Metrology Engineer, and Chris Juchau, Vice President

Whether you need a reliable reference thermometer for comparison calibrations or simply need to monitor a process very closely, the evaluation of a good thermometer seems to always come down to one question: "How accurate is it?"

The word "accurate" itself is ambiguous. While ±1°C may be accurate for some situations, others may require ±0.001°C or better. "Accuracy" is also a difficult concept because most metrologists reject it in favor of the preferred term "uncertainty." (Here we'll use the term "accuracy" since that still seems to be the question of greatest concern.) The purpose of this article is to point out some important factors in evaluating the accuracy of a thermometer probe. Unless we evaluate all thermometers against the same scale, there is little basis for comparison.

What seems like an apple may, in fact, be an orange. Perhaps the most important consideration in thermometer accuracy is thermometer type. Thermometers have differing capabilities for accuracy based on their design, their construction, and the thermometric principles on which they operate. This makes each type of thermometer more or less susceptible to certain causes of measurement errors. The following chart shows four types of commonly used thermometers, the factors that detract from their accuracy, and their susceptibility to each of those factors. Following the chart is a brief discussion of each factor.

		Susceptibility			
Sources of Error		**SPRTs**	**PRTs/RTDs**	**Thermistors†**	**TCs**
Calibration		High	High	High	High
Stability Problems Over Time	Stability (repeatability)	Low	Medium	Low	High
	Drift (long-term)	Low	Medium	Low	Medium
Stability Problems Due to Thermal History	Hysteresis	Low	High	Medium	Low
	Oxidation	High	High	Low	High
	Insulating material	Medium	High	Low	Medium
	Hermetic seal	Medium	Medium	Medium	n/a
Measurement Issues	Lead-wire resistance	Low	High	Low	Low
	Reference-junction compensation	n/a	n/a	n/a	High
	Readout instrument	Medium	Medium	Low	High
Usage (immersion, fit, temperature range, mechanical shock, etc.)		High	High	Medium	Medium

†All thermistor references are to high-stability, bead-in-glass type thermistors.

Calibration

If your probe was calibrated, remember not all calibrations are the same. What uncertainties were included in the calibration? Was it done by fixed point or by comparison? In many cases, the uncertainty of a temperature sensor can be improved simply by its calibration.

Short-term stability

Don't rely on your thermometer's calibration to cover the various forms of short-term stability. Many items listed below contribute to short-term stability and may be included in a stability or repeatability specification, separately listed, or—in the worst case—not accounted
for at all.

Long-term drift

Instability becomes greater with time due to environmental effects, usage, and thermal history. One of the most important specifications for any thermometer is long-term stability after a stated amount of normal usage.

Hysteresis

For temperature probes, hysteresis refers to the probe's ability to repeat a given value when that value is approached from a different thermal direction. The largest contributor to hysteresis is the strain caused by the different thermal expansion properties of the sensor and its insulating material.

Oxidation

PRT and thermocouple elements are susceptible to oxidation at high temperatures. While this process can be reversed in PRTs by annealing, excessive annealing can negatively affect them. Manufacturers address this through the materials they use and by sealing a correct gas mixture around the sensor.

Insulating material

Electrical temperature sensors must be electrically isolated from their environment. A manufacturer's choice of insulating materials is therefore critical. For example, at high temperatures, an SPRT using a quartz support system will perform better than an SPRT using mica.

Hermetic seal

The integrity of the temperature sensors discussed here can be compromised by exposure to air, water, or other environmental substances. While some of these effects can be eliminated through annealing, the better alternative is a reliable seal of the sensing element.

Lead-wire resistance

Measurements with two-wire RTDs include an error (sometimes very large) because the RTD's readout device cannot distinguish the resistance of the sensor from the resistance of the lead wires. Three-wire RTDs are better, but only four-wire RTDs can totally eliminate lead-wire effects.

Reference-junction compensation

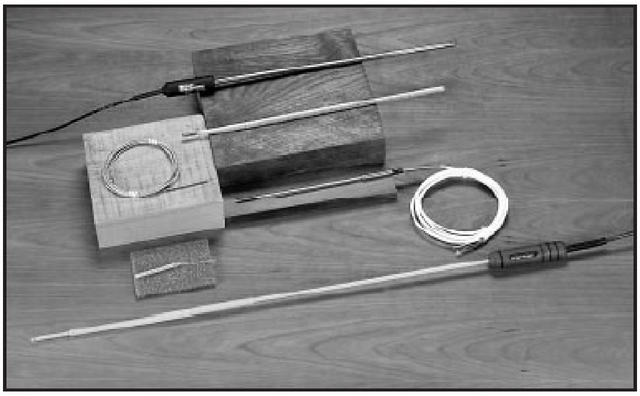
The temperature at the measuring end of a thermocouple can be known precisely only if the temperature at the reference (or "cold") junction is known precisely. For this reason, a good reference junction is a must for your thermocouple standard.

Readout instrument

Of course, the accuracy of the sensor is irrelevant if the device reading the sensor is inadequate or out of calibration. Whether as a system or as separate components, both the sensor and the readout should be calibrated.

Usage

Mechanical shock, thermal shock, temperature range in use, immersion, and a host of other usage issues that are largely outside of manufacturers' control can all have dramatic impact on probe accuracy. Since all specifications were developed under certain usage assumptions, those specifications will not be correct if your usage pattern deviates too far from what the manufacturer intended.



Many types of sensors make good reference thermometers, but each has a different set of limitations and susceptibilities.

Fluke Hart Scientific is a manufacturer and supplier of Temperature calibration products including heat sources, readout devices and probes. Please contact your local Fluke distributor for more details on the range of high performance equiptment available.