EVALUATING SYSTEM ACCURACY

Is your calibration system “accurate” enough?

In most industries within the United States, quality programs require their test and calibration laboratories to comply with ISO Guide 25 or ANSI/NCSL Z540, which require calibration systems to be at least four times more accurate than the units they are calibrating. This is commonly referred to as a “4:1 TUR” (test uncertainty ratio).

Outside the United States, quality programs call for detailed uncertainty analysis rather than relying on TURs. Uncertainty analysis relies on a detailed statistical examination of actual instrument performance, whereas TURs generally tend to rely on manufacturers’ published specifications.

In either case, the questions are the same: what is the combined uncertainty of your calibration system? and is it adequate for the items you’re calibrating?

“Uncertainty” generally refers to a statistically valid level of confidence that a measured value lies within a stated band around the actual value. This confidence level is typically 95% (technically 95.44%) and is indicated in uncertainty statements as “k=2.” For example, if a measurement of 100°C is made with a stated uncertainty (k=2) of ±0.05°C, there is a 95% chance the actual value lies between 99.95° and 100.05°C.

In answering these questions, we need to identify each contributor to system uncertainty, quantify each contribution, and sum the individual contributions to determine the total.

In a temperature calibration system, sources of uncertainty may include the stability (and perhaps uniformity) of the temperature medium, the uncertainty of the reference measurement, and the uncertainty of the device being used to read the unit under test.

After this is done, the magnitude of each contributing error needs to be quantified. This is where TURs tend to differ most dramatically from “uncertainty analysis.” Under the TUR method, manufacturers’ specifications are usually assumed to represent actual performance. Depending on the manufacturer and its level of aggressiveness in publishing specifications, this assumption may be conservative or unjustified.

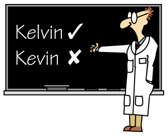
Further, manufacturers write specifications based on their assumptions regarding use of the product. Performance will likely vary from published specifications based on actual practice

The most common methods for summing the individual uncertainty components are linear addition and root-sum-squares. Under linear addition, we simply add the numbers. This assumes that all components are performing at the very edges of their performance levels and all in the same direction (too hot or too cold) at the same time. In reality, the error caused by one or more components of the system is offset by the other components because they’re not moving in the same direction at the same time. While linear addition gives us better coverage of all possible error combinations, it is generally not a true reflection of the actual situation and is more conservative than necessary.

Alternatively, we can take advantage of offsetting errors using the root-sum-squares method. This is best done if each component is expressed as a standard deviation. (Peak or limit specifications can be converted to approximate standard deviations by dividing them by the square root of 3.) Once this is done, simply take the square root of the sum of the squared components and multiply by 2 (k=2) as in this equation:

$$2\times\sqrt{a^2+b^2+c^2+d^2}$$

Once we have determined total system uncertainty, the second question remains: is it adequate? In a 4:1 TUR situation, this just means, is it less than 25% of the expected uncertainty from the unit being tested? If so, great! Otherwise, there are a few options to consider. We might improve the performance of one of the system components through calibrating it better or replacing it with a better-performing instrument. We might evaluate system performance under our own usage conditions rather than relying on manufacturers’ specifications. Or in some cases, quality systems have contingency plans that include increased tolerance for the unit under test to compensate for less than ideal system uncertainties.



Read about our calibration training courses on page 152.

Calculating System Uncertainty

Example: Calibration of a PRT Using an SPRT Reference in an Oil Bath at 200°C

Source of Uncertainty	Uncertainty	Evaluation	Type	σ	σ^2
Bath Stability	0.0020	Measured	Std Deviation	0.0020	0.0000040
Bath Uniformity	0.0025	Measured	Std Deviation	0.0025	0.0000063
SPRT	0.0020	Mfr Spec.	Limit	0.0012	0.0000013
Readout (for SPRT)	0.0080	Mfr Spec.	Limit	0.0046	0.0000213
Readout (for PRT)	0.0080	Mfr Spec.	Limit	0.0046	0.0000213
Sum				0.0149	0.0000542
Square Root					0.0074
Expanded (k=2)				**0.030**	**0.015**