FLUKE®

Calibration

Buying the right temperature calibration bath

Application Note

During a European trip a group of Fluke Calibration temperature calibration specialists visited a lab struggling through the lab accreditation process. The hold-up was their bath. They had already tested baths from two manufacturers. The first bath didn't meet specs and the maker wouldn't rectify the situation, so the bath was returned. The second bath maker delivered a working bath, but when the accreditation auditor tested the bath he downgraded the lab's accuracy class, because they couldn't meet the required stability and uniformity levels.

Most bath manufacturers tell you as little as possible about their baths' performance. In fact, a few years ago one of our competitors used to tell people that high bath stability wasn't even necessary for accurate calibrations. Some still don't publish stability specs, and some are so elusive about the meaning of their specs that you can only conclude they've got something to hide.

Lab accreditation

Accreditation guidelines published by NVLAP specify that the temperature stability and uniformity of the bath fluid should be at least 10 times better than the required uncertainty of the sensor being calibrated. If you are testing a sensor with a modest specification of ±0.05 °C over its whole range, your bath must be stable and uniform to ±0.005 °C. You will find yourself in need of a bath with performance to the third decimal place at each of the temperatures you must test. Several considerations are involved in selecting a bath, and each item impacts calibration performance.

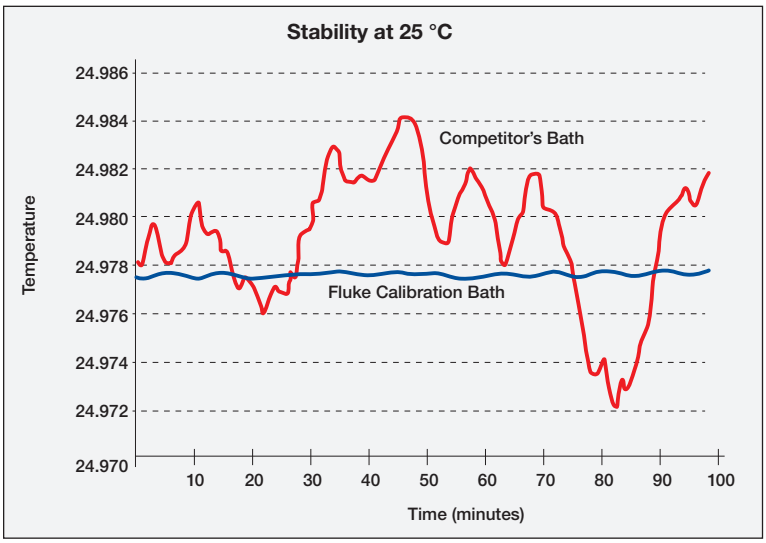
Stability

Stability is a measure of the bath's control performance. How well does it maintain a constant temperature? Short-term instability is normally seen as an oscillation around the control point with its peaks defined in a "2-sigma" or "±" statement. If the temperature of the bath fluid is changing during your measurements, you can't get reliable calibration results. Short-term stability is therefore absolutely crucial. Ask about short-term stability and define short-term as lasting at least 15 minutes. Less than that can prove very frustrating.

Long-term stability (over several hours, days or weeks) is a convenience issue. If your work requires an exact or absolute value, say 25.000 °C, and the bath has long-term drift, you must readjust the control set-point and wait for equilibration (attainment of short-term stability) before each use. So you really need to know both short-term and long-term stability before you know if a bath will meet your needs. Long-term instability normally takes the form of drift in a single direction, but in some baths it may be seen as a long-term wave or oscillation.

A bath's stability will vary at different temperatures. Most baths perform best at temperatures close to ambient. The colder or hotter the set-point, the less stability. Too many sellers give you only one spec at or near ambient. Some give a single stability spec and don't ever mention that it applies only to one temperature or a narrow range. Ask about stability over the whole range that interests you.

Bath fluid also affects stability. The higher a fluid's viscosity and the lower its heat capacity, the larger the effect on stability will be. In addition to asking the temperature, ask what fluid was used when the spec was taken. For example, at 37 °C a bath will be more stable with water as the medium. If you're going to use oil, expect somewhat larger instability. If your oil has high viscosity at 37 °C, expect even greater degradation in stability.



Fluke Calibration baths can achieve stability better than 1 mK for extended periods of time.

Uniformity

A bath can have good stability but poor uniformity. The bath must be homogenous in temperature throughout the test zone where you'll make your comparison measurements. When you place two or more thermometers in the fluid, they should be at the same temperature during your measurement. The uniformity spec defines the peak value for this error source. The more probes you're testing, the larger the test zone and the more important uniformity becomes.

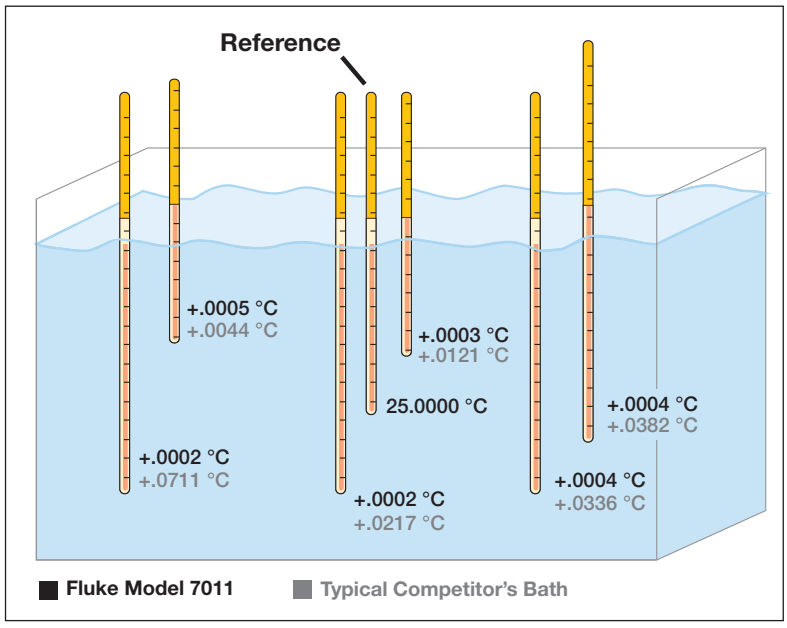
Uniformity depends mostly on the mixing of the bath fluid. Does the bath use a circulator pump for mixing? If it does, are there thermal flow patterns in the bath that interfere with uniformity? Ask about both vertical and horizontal gradients.

In a laminar flow bath (one where the fluid is stirred in a circular pattern), there may be no horizontal gradient, but because the fluid is not mixed vertically, there are gradients between different depths in the bath. This is a problem if your standards probe and the probes under test are not the same length. For example, if you're testing three-inch-long probes and your standard is a 19-inch SPRT, you've got a problem. You can only immerse the test probes to three inches, but if you immerse the SPRT to only three inches you don't have sufficient depth to avoid stem effects and light piping that will affect the measurement made by the SPRT. If you properly immerse the SPRT and your bath suffers from vertical gradients, you won't be measuring the temperature at the three-inch depth of your probes under test.

Equilibration blocks

Accreditation guidelines recommend the use of a metal equilibration block to improve short-term stability during the measurement. It's certainly true that a block can increase the stability of your measurements. However, a block can be inconvenient. The fixed location and diameter of its holes eliminate the flexibility of a bath to readily test any size or shape of thermometer. You'll need a new block for each probe type. Placing the probes in the block and the block in the bath is somewhat less convenient than simply dipping the probes directly in the liquid. Blocks also oxidize, and silicone oil will thicken and stick in the bottom of the holes. Regular cleaning is required to ensure continued performance levels. If you're testing many probes at a time, a block may not even work for you. It would be difficult to construct a block to properly test 20 thermometers at a time.

Evaluate your bath purchase on specifications taken directly in the bath's fluid. If you're given performance graphs, ask if a block was used. In your lab



Deviations from a central reference temperature taken in water with a 1/4-inch diameter PRT at 25 °C

you can always add a block for the most critical measurements. Remember: the bath that performs the best without a block will also be the bath that performs the best with a block.

Temperature range

The advertised temperature range of a bath is not necessarily the practical usable range. For example, a bath with a published range of –80 °C to 150 °C can be a bit misleading. The bath may operate over that temperature range, but currently there's no fluid to match that whole range. Those fluids that perform best at –80 °C will evaporate too rapidly long before they get to 100 °C, much less 150 °C.

An oil bath with an advertised range of 35 °C to 300 °C will be limited by the silicone oil you put in it. A good 300 °C oil will be too viscous to deliver good performance below about 80 °C, so with that fluid the bath's range is 80 °C to 300 °C. In another example, a Fluke Calibration salt bath works quite well at 40 °C with the right fluid. But salt is molten only above 150 °C.

In addition to fluid, other factors mechanically limit a bath's range. These include refrigeration, insulation, heater types and other design issues. Refrigeration gases break down above 150 °C, thus limiting the life of the system. If a refrigerated bath is advertised with a higher range, ask if you must remove the cooling coil above a certain temperature. Some baths are advertised with ranges from –80 °C to 300 °C in a single bath. However, the refrigeration gases or coils must be removed before going to the higher end of the temperature range.

Can you ask too many questions?

It's not likely that a manufacturer will have a test file covering every temperature and fluid combination that interests you, but you can look for representative numbers. How many numbers will they give you?

We recommend "the more the better." If a salesman says his bath's stability spec of ±0.005 °C applies to the whole range, ask for a graph at several temperatures. If you're buying a bath for use at 300 °C and the maker can't give you performance data above 100 °C, you need to be skeptical.

If a salesman talks about "calibration accuracy" instead of bath performance, ask for specific stability and uniformity data taken in the bath fluid. Finally, about after sale support. If you are having trouble getting what you need from the bath when it's in your lab, you need to know your supplier will be there for you.

Bath fluid affects performance

Fluke Calibration determines its bath specifications by using selected fluids for particular temperatures. Your application, however, may require different fluids over different temperatures. Considering that fluid characteristics change with temperature, some care must be taken to apply general specifications to your own application.

For example, Fluke Calibration often uses water to spec baths at 25 °C. The properties of viscosity, thermal conductivity, and heat capacity make water an ideal fluid at 25 °C. However, if you want to cover a range from –5 °C to 110 °C, water just won't work. Fluke Calibration's 5010 silicone oil fluid will more than adequately cover that range, but it may not perform as well as water at 25 °C. Carefully testing the fluid for the range you use will tell you what you need to know for your uncertainty budget.

Fluke Calibration. *Precision, performance, confidence.™*

Electrical	RF	Temperature	Pressure	Flow	Software

Fluke Calibration
PO Box 9090,
Everett, WA 98206 U.S.A.

Fluke Europe B.V.
PO Box 1186, 5602 BD
Eindhoven, The Netherlands

For more information call:
In the U.S.A. (877) 355-3225 or Fax (425) 446-5116
In Europe/M-East/Africa +31 (0) 40 2675 200 or Fax +31 (0) 40 2675 222
In Canada (800)-36-FLUKE or Fax (905) 890-6866
From other countries +1 (425) 446-5500 or Fax +1 (425) 446-5116
Web access: http://www.flukecal.com

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