Considerations for using Thermo Scientific bath circulators and water baths as calibration equipment

Dieter Raedler, Thermo Fisher Scientific, Karlsruhe, Germany and Scott Pratt, Thermo Fisher Scientific, Newington, New Hampshire, United States

Technical Note

Key Words
Calibration, calibration bath, bath circulator, water bath, DIN, stability, uniformity, accuracy

Goal

There is interest by some customers in using a standard bath circulator or water bath as a calibration instrument, instead of a purpose-built calibration bath. This technical note will review the considerations for doing so.

Calibration Baths

Purpose-built calibration baths are used to calibrate a wide variety of temperature measuring and thermostatic devices, such as thermocouples, thermistors, platinum resistance thermometers, and resistance temperature detectors. They differ from standard heated or refrigerated/heated bath circulators and non-circulating water baths primarily in the performance requirements to which they are designed, as well as the way they are tested. The cost of product development and the extensive testing needed to meet the certification requirements make calibration baths much more expensive than standard bath circulators and water baths that are intended for general lab use. So customers often ask if a standard bath circulator or water bath can be used for calibration.

Can a Standard Bath Circulator or Water Bath be Used for Calibration?

The answer is sometimes "yes" and sometimes "no." To understand why and when a standard bath circulator or water bath might be utilized for calibration, you must first understand the differences in the way they are designed and tested.

Calibration baths are typically certified to perform to temperature stability criteria established by programs such as the National Voluntary Laboratory Accreditation Program (NVLAP). Temperature stability (control scope) is a measure of the temperature fluctuation (+/- °K) from the selected temperature (setpoint), which occurs at the place of measurement. Under NVLAP guidelines, the temperature stability in the bath fluid at the point of test needs to be 10 times better than the temperature stability specification of the sensor or device being calibrated. So a sensor or device that has a published stability of +/- 0.01 °C would require a calibration bath with a stability of +/- 0.001 °C. The stability of calibration baths must also be tested and certified at a variety of temperatures, with a variety of fluids, and at a variety of locations and depths within the bath.

Thermo Scientific™ ARCTIC™ refrigerated bath circulator

Besides stability, calibration baths may include performance documentation for accuracy, annual drift, digital setting accuracy and uniformity. Some of these terms mean different things to different people, especially if they have experience calibrating other types of equipment. Here are the definitions of how these terms are used for a calibration bath:

Stability is the maximum temperature variation divided by 2. It is determined by subtracting the minimum temperature from the maximum temperature and dividing by 2 to get a plus (+) and minus (-) value. For example, at a 70 °C setpoint, if the maximum temperature is 70.03 °C and the minimum temperature is 69.97 °C, the variation is 0.06 °C. Dividing the variation by 2 gives us a stability specification of +/-0.03 °C.

Accuracy is often confused with stability and calibration. It also means different things within different industries. For our purposes, we will call it "system accuracy" and define that as a combination of "annual drift" plus "digital setting accuracy" (see definitions below). For example, if the annual drift is +/- 0.1 °C and the digital setting accuracy is +/- 0.6 °C then the system accuracy is +/- 0.7 °C.

Annual drift is the digital setting repeatability. It predicts how far the electronics (sensor and control board) might move from a calibration over one year, and is expressed as a +/- x.x °C. In other words, if you do a calibration at 70 °C today, after one year of use, what is the worst case drift in temperature from the indicated 70 °C? If it was specified as +/- 0.1 °C, then the actual temperature might be as low as 69.9 °C or as high as 70.1 °C.

Digital setting accuracy is the worst case difference between the actual temperature and the reported temperature across either the entire range of the bath or circulator, or a predefined temperature range based on what is required. This number is typically worse when it is measured in a different location than the control sensor, such as when the measuring sensor is placed in the middle of the bath. This number may be very small at ambient temperatures, but as you get much higher or lower in temperature, the ambient room temperature can either add heat or take away heat from the fluid, resulting in a different actual temperature when measured away from the reporting sensor. Also control sensors, though calibrated, are not perfectly linear in reporting temperature, so some variance can also result from the control sensor itself.

Uniformity is the homogeneity of the water within the bath and is stated as a +/- x.x °C deviation from the control sensor temperature. It can be stated at one or more locations and at one or more depths within the bath area.

How Stability is Determined According to the DIN 12876 Standard

Stability specifications for standard heated or refrigerated/heated bath circulators and water baths are typically established according to the DIN 12876 standard and are typically not better than +/- 0.01 °C for circulating baths and +/- 0.05 °C for water baths. This standard does not dictate requirements for stability; rather, it establishes a standardized test method so that the performance of bath circulators and water baths from the same or competing companies can be more directly compared.

Conditions set in DIN 12876 for measuring temperature stability are described as follows: the measuring equipment (sensor, amplifier and recording device), or a thermometer with a responding value no bigger than 10^{-3} °K and a response time of 5 +/- 1 seconds, must be used. Also required is a constant ambient temperature of 20 °C and a stable supply voltage for the bath circulator or water bath.

Factors that can significantly influence temperature stability include selected (setpoint) temperature, bath fluid, temperature control method, heating and cooling power, as well as the pump performance and length of tubing (if circulating to an external application). Stability for most heated bath circulators, water baths and heated immersion circulators are tested with water and a setpoint temperature of 70 °C with the measuring device placed in the center of the usable space of the bath.

Heated Bath Circulators and Water Baths

The bath should be filled with water to its maximum volume, with the bath cover in place.

Heated Immersion Circulators

The immersion circulator is mounted on a round vessel of approximately 250 mm in diameter and a 10 liter volume.

Heated Bath Circulator with External Circulation

A Woulff bottle is connected to a circulator with tubing 1 m in length and a 12 mm inner diameter. Measurements are carried out at the center of the Woulff bottle.

Refrigerated Bath Circulators

The bath should be filled to its maximum volume with ethanol and set to -10 °C, with the bath cover in place. Again, the measuring device is placed in the center of the usable space of the bath.

Conclusion

The difference between NVLAP and DIN 12876 is that the DIN standard only insures that the displayed temperature is the temperature at the control probe, while NVLAP requires that other points within the bath area also get measured for temperature stability. The performance difference between calibration baths and standard baths is that calibration baths can have temperature stability of + 0.001 °C or better and standard baths are usually +/- 0.01 °C at best.

What this means is that you can use a standard bath circulator or water bath if:

- Application stability rating is not tighter than +/- 0.1 °C (or +/- 2.0 °C for a non-circulating water bath)
- You establish your own testing, calibration procedure and schedule
- You use a calibrated reference temperature device to determine the stability and actual temperature at the location used within the bath

If the above applies, you may be able to save thousands of dollars by using a standard bath circulator or water bath.

How to Establish a Testing and Calibration Procedure

The minimum details to include in the procedure description are:

- **Ambient Temperature:** Depending on the bath and temperature, a change in ambient temperature can be reflected by 0.3% to 1.5% or greater deviation in the measured temperature value at the calibration point, i.e. a deviation of 10 °C in ambient temperature may result in a 1% or 0.1 °C change of temperature at the calibration point.
- **Supply Voltage:** A change in supply voltage will be reflected by 10^{-3} to 10^{-5} °K per percent deviation, i.e. a 10% change in voltage can affect the actual temperature at the calibration point by as much as +/- 0.01 °K.
- **Test Intervals:** We recommend recalibration every 4 to 6 months if a control bandwidth of +/- 0.05 °K or better is needed. For all other cases, annual recalibration should be adequate.
- **System Setup:** The volume of liquid, fluid level, type of heat transfer medium, length and diameter of tubing, position of the high-temperature cutout should be recorded, as well as, the exact adjustment of the set temperature and any noteworthy special features in your system. A drawing of the setup makes your records particularly clear and repeatable.
- **Measuring Method:** The built-in temperature sensor and its digital display are compared to a separate calibrated reference temperature device, such as a calibrated thermometer. The measuring conditions must be recorded in detail as reference conditions. Place the reference thermometer into or as close as possible to the sample. The further away the thermometer is from the sample the bigger the deviation between the measured and the actual temperature can be. This is a physical disturbance caused by the fact that depending on the arrangement of the samples in the bath the circulation and therefore the mixing of the heat transfer medium in the bath may vary.
- **Measuring Device:** The reference thermometer (or calibrated reference temperature device) must have defined properties that are traceable, i.e. traceable calibration, and a calibration certificate should be kept on record.
- **Control Point:** The control point describes the exact place in a temperature control circuit or in a temperature controlled bath in which the temperature stability and temperature are measured with a reference thermometer.
- **Documentation and/or Optional Adjustment of the Displayed Temperature:** Document the results as follows:

  1. Temperature stability as a +/- (°K) value around the respective actual temperature.
  2. Either the deviation from the actual temperature in + or – degree, referencing displayed value on the bath or note that a single point calibration was performed and the temperature it was performed at. In the case of Thermo Scientific™ ARCTIC™, GLACIER™ and SAHARA™ bath circulators, a correction value can be added to, or subtracted from, the displayed temperature so that it matches the reference thermometer. This feature is called real temperature adjustment (RTA) and, in effect, it is a single-point calibration that can be set and saved for up to 5 setpoint temperatures. In all cases the corrective value must be recorded.
  3. The measurement uncertainty (accuracy) of the reference thermometer used.

From the above description, it becomes clear that establishing a testing and calibration procedure is not very complex. But it can only be carried out onsite and under real conditions, and must be adjusted to the requirements of each particular application. Therefore, such a test cannot be carried out by the equipment manufacturer or performed offsite.

North America: USA/Canada toll free: +1 (800) 258-0830; USA: +1 (603) 436-9444 or info.tc.us@thermofisher.com
Europe: sales.tc.eu@thermofisher.com or Benelux: +31 (0) 76 579 55 55; France: +33 (0) 1 60 92 48 00; Germany: +49 (0) 721 4 09 44 44; Italy: +39 02 95059 552; Nordic/Baltic/CIS countries: +358 10 329 2200; Spain/Portugal: +34 93 223 09 18 UK/Ireland: +44 870 609 9203
Asia: China: + 81 3 5826 1616 or info.tc.china@thermofisher.com; India: +91 (22) 27 78 11 01 or contact.lpg.in@thermofisher.com; Japan: +81-3-5826-1616 or info.lpg.jp@thermofisher.com

Thermo SCIENTIFIC
A Thermo Fisher Scientific Brand

TNTCCALIBRATE 0216