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THE PRACTITIONER'S TOOL KIT

Electronic Thermometers: What Every Environmental Health Professional Should Know

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Editor's Note: **The National Environmental Health Association (NEHA) strives to provide relevant and useful information for environmental health practitioners. In a recent membership survey, we heard your request for information in the *Journal* that is more applicable to your daily work. We listened and are pleased to feature this column from a cadre of environmental health luminaries with over 300 years of combined experience in the environmental health field. This group will share their tricks of the trade to help you create a tool kit of resources for your daily work.**

The conclusions of this column are those of the authors and do not necessarily represent the official position of NEHA, nor does it imply endorsement of any products, services, or resources mentioned.

As environmental health professionals, we rely on accurate temperature measurements. Whether we are ensuring food safety, food processing regimens, or adequate storage conditions; verifying human comfort levels in group quarters or other built environments and workplace settings; monitoring water temperature for cleaning, laundering, and sanitizing; measuring pasteurization temperatures; assessing microbial growth in the laboratory or insect propagation in the field; or any other temperature-related application, we rely on versatile and rugged temperature measurement devices to provide this information.

Accurate thermometric readings are fundamental to our practice. Understanding and knowing the capabilities of the instruments that we use in the field and in the laboratory is an essential knowledge, skill, and ability.

A Bit of History

For those of us who entered the profession during the last half of the 20th century, we were easily recognizable by the bimetal dial thermometer proudly displayed in our breast pocket. Although invented in 1759, these thermometers made their appearance and rapidly gained in popularity in the 1940s, replacing the liquid-filled, armor-clad thermometers that were used up to that time.

We carried the dial probe thermometer everywhere and knew how to use it. We learned how to properly calibrate these instruments by making necessary adjustments to the nut located under the dial using a tool incorporated into the pocket-clip on the probe sheath. We took care to ensure temperatures always came to an equilibrium when taking a measurement. This process was not always easy, considering that bimetal sensors had to be completely immersed (from tip to dimple on the stem) in whatever material we were measuring. The bimetal sensor took its time to mechanically expand or contract to its surroundings.

These thermometers had a 1-in. dial and were not backlit. We were lucky if they had a magnifying lens to help us read the measurements. The readout was in 2° increments with a temperature range from 0 °F to 220 °F, and an accuracy of approximately ± 2 °F. And yet, it did its job and did it well.

Even with its many shortcomings, we took care to calibrate our thermometers frequently to ensure constant, accurate temperature readings. This upkeep went along with our sampling strategies that were science-based, repeatable, and well-documented. These little devices were highly personalized and were lent to no one. We still carry them as a handy backup because they neither experience a dead battery nor care about extreme conditions. They also make great giveaways to get an operator's attention and cooperation.

With the advent of liquid crystal displays (LCDs) and electroluminescent displays in 1974, we were introduced to the affordable digital probe thermometer. These new field instruments rapidly gained popularity for their convenience, precision, and versatility. The first one of its kind to gain favor with us was affectionately known as the "lollypop." This instrument was a waterproof, maximum-registering digital thermistor thermometer. We had to shield its display that would blacken and become unreadable when it was exposed to temperature extremes, such as sending it through a high-temperature dish-

https://doi.org/10.70387/001c.147155

washer or placing it in a freezer. At that time, a typical LCD had an operating range from its cold limit of 0 °C (32 °F) to its heat limit of 50 °C (122 °F). Even with this shortcoming, it was a marked improvement over what we had before. Since then, however, digital probe thermometers have come a long way in range, utility, and function. They are now being ruggedly built and offer quick and accurate results, making them not only ideal for our work but also an absolute necessity.

Today's Digital Thermometers

The thermometers we use today come in two basic varieties: thermocouples and thermistors. They all have something in common: all electronic probe thermometers utilize electric sensors to detect temperature variations.

Thermocouples

A thermocouple is a sensor made from two dissimilar metals joined together. The thermocouple junction creates a voltage that changes with temperature. Different metal combinations result in different thermocouple types that are suited for a specific temperature range and application (Photo 1).

Photo 1: An example of two different types of thermocouples. On the left is a thermocouple with a tip-sensitive integrated probe. On the right is a thermocouple with a detachable needle K probe and an alligator clip K probe for measuring temperature in a commercial conveyor dishwasher.

The one we most commonly use is the general-purpose K-type thermocouple (Photo 2). These thermometers can accommodate dozens of K-type probes, each with a different configuration and function. These rapid response probes include general-purpose probes (similar in configuration to the stem on a dial thermometer), needle probes, high-temperature probes, penetration probes (for measuring internal temperatures of frozen foods), surface probes, long-wire probes (ideal for monitoring dishwashers), and air oven/freezer probes, along with a wide array of thermocouple accessories. These different types of probes provide great flexibility in field use.

Photo 2: An example of a K-type wire thermocouple with a fixed-point calibration unit and male-male connectors used for calibration of both the thermocouple thermometer and K probes.

Over the past few years, we have assembled an economically priced HACCP/HARPC (hazard analysis critical control point/hazard analysis risk-based preventive control) K kit. The kit includes a thermocouple thermometer and an assortment of K-probes designed for measuring every critical temperature in a retail food setting. We will detail this kit in a future column.

Thermistors

Thermistor sensors are different from thermocouples but work in much of the same way. They are made from semiconductor materials that change resistance to temperature. They are commonly classified into two types: 1) negative temperature coefficient (NTC) thermistors, which decrease in resistance as temperature increases and 2) positive temperature coefficient (PTC) thermistors, which increase in resistance with rising temperature. For our purposes, we use the NTC type.

Thermistor probe thermometers are typically less expensive, have a narrower temperature range, and have a slower response time. Some of the less expensive types are not as accurate or suitable for our purposes. Even though thermistors are used in many low-cost applications, they are handy, everyday temperature monitoring tools for commercial kitchens (Photo 3).

Photo 3: An example of three different thermistors. On the left is the "lollypop" thermistor thermometer, which replaced the maximum-registering liquid thermometer. In the center is a general-purpose pocket thermistor thermometer. On the right is a traceable digital thermistor thermometer with calibration.

Ensuring Accuracy and Functionality

Unlike the bimetal dial probe thermometer, electronic thermometers cannot be calibrated. There is really no practical way to make any adjustments to them. We need to rely on commercial calibration service providers to do so. Since we use our thermometers and other electronic measuring equipment for enforcement, they must be sent to an accredited calibration service annually, or any time that we suspect that they are no longer providing an accurate result. These calibration services have the essential equipment to ensure continued accuracy and can make the necessary adjustments to our instruments.

All digital thermometers (as well as all our electronic field instruments) can and should be regularly validated or verified. Both validation and verification confirm that our temperature measuring devices are functioning correctly and within their specified tolerances. Validation is used to ensure that distinct parts of a system function well together to generate the needed outcomes. An example of this process is validating the thermocouple thermometer and attachable K-type probes separately. Under ideal conditions, the components are validated electronically and then subsequently reassembled and verified as a unit. On the other hand, verification ensures that processes or equipment as a whole are working the way they were originally intended to. Neither validation nor verification involves adjusting the instrument itself, but rather confirms that it meets the predefined criteria for accuracy and confirms essential and reliable measurements (i.e., tolerances), as well as yields accurate results when used in the field.

Note, the term calibration found in much of the popular literature, sales brochures, and instructional manuals is often used generically to encompass all three functions: calibration, validation, and verification. Because we are involved in regulation, terminology is important. Therefore, we use these terms separately in accordance with their definitions.

It is an absolute necessity to regularly verify our field instruments to ensure continued accuracy and proper operation. To put this concept in context, we realize that verification is more cost-effective than frequent calibration, making it both necessary and suitable for our instruments in their intended use. For us, formal calibration is only required on new equipment; as part of an annual maintenance program; after exposure of an instrument to extreme temperatures, contamination, or mechanical damage; and if it is required through regulatory compliance.

It is also vital to record all calibration, validation, and verification results in a bound book. You should also include methodology, results, date, time, and the operator's initials. This recordkeeping ensures traceability, fairness, professionalism, and legal assurance in the event of a challenge from a client or operator.

Validation and Verification Procedures

We use a traceable thermistor digital pocket thermometer with calibration, along with a National Institute of Standards and Technology (NIST) liquid thermometer for verifying the temperature accuracy of our digital thermometers. The traceable and NIST thermometers let us verify our instruments in both hot and cold water (i.e., a two-point verification) without the need for distilled water and the concern of temperature variances due to high TDS (total dissolved solids) levels. This unique approach also allows us to demonstrate verification in the field if necessary or if we are requested to do so. We provided this simple verification procedure in our column in the October 2022 issue of the *Journal* (www.neha.org/october-2022).

It should be noted that there is an exception to this simplified process. Thermocouple K-type thermometers that are used with numerous interchangeable probes should be validated separately. Both the battery-operated thermocouple thermometer and K probes are validated with a multimeter (i.e., a digital thermometer calibrator). The instrument we use is made to accommodate the K-probe male fitting, and it can be linked to the thermocouple with a male-male connector. All measurements are in mV. The calibrating instrument instructions provide temperature/voltage tables for ease of interpretation. Cleveland Electric Laboratories provided us an excellent outline for testing K-type thermocouples. We offer this information with thanks and have taken the liberty of modifying it for our application.

Validation is conducted in four stages:

1. Visual Inspection
   - Examine the thermocouple sheath for cracks, corrosion, or physical damage
   - Check wire insulation for deterioration, especially near high-temperature zones
   - Inspect the junction and connector for oxidation, contamination, or mechanical damage
   - If appropriate, verify proper wire color coding (i.e., red = positive, yellow = negative)
2. Electrical Continuity Testing
   - Equipment needed: Digital multimeter with mV capability
   - Step 1: Set the multimeter to resistance (Ω) mode
   - Step 2: Measure resistance between thermocouple wires (should read low resistance, typically <25 Ω)
   - Step 3: Test insulation resistance between each wire and sheath (should read >10 MΩ)
   - Step 4: Check for short circuits between the positive and negative wires
3. Ice Bath Verification Test
   - Equipment needed: Ice bath at 0 °C, digital thermometer, and multimeter
   - Step 1: Create the ice bath with distilled or deionized water and clean ice
   - Step 2: Insert the thermocouple junction into the ice bath
   - Step 3: Measure mV output (should read approximately 0 mV at 0 °C)
   - Step 4: Compare reading to NIST reference tables for accuracy verification
4. Comparative Testing Method
   - Step 1: Place the test thermocouple alongside a calibrated reference sensor
   - Step 2: Heat both sensors to a known temperature (100 °C boiling water works well)
   - Step 3: Compare readings between the test and reference thermocouples
   - Step 4: Calculate the deviation and determine if it is within an acceptable tolerance

Here are some conditions and reasons instrument manufacturers recommend performing the verification process. They include:

- Routine checks: Regularly verifying instruments used for less crucial measurements can ensure the instruments remain accurate.
- Ongoing monitoring: Where measurements are continuously monitored, veri-

fication checks can help detect deviations from accuracy.
- Comparative analysis: When measurements are compared between multiple instruments, verification ensures consistency among them.

Final Recommendations

Even with all the advancements in technology to make our electronic instruments armored and rugged, they will not work properly if they are subjected to temperature extremes, hard shock, or excessive vibration. The reality that we travel to our inspection sites in all seasons, and that our electronic instruments see heavy use under variable and often less-than-ideal conditions, demands that they should always be transported in a padded isothermal carrier to maintain proper function and service integrity.

After each day's use, manufacturers recommend cleaning digital thermometers, including the instrument, any cables, and the probe by using a slightly damp towel, warm water, and mild cleaner (a drop or two of dishwashing liquid). Never immerse the instrument or use harsh, abrasive cleaners on it. We also recommend using sanitizer wipes on the instrument between job sites.

We know that all this information is a lot to consider, but knowing these instruments, their capabilities, and care—along with following recommendations—will ensure that your electronic thermometers enjoy long-term effective and productive service life in the field.

Photo Credit: All photos are courtesy of Dr. Robert Powitz.

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