Hot Tips for Using and Selecting Portable Thermometers
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I hope that you can stand one more article on thermometry before we move on to some of the more esoteric topics that make up the art and science of food safety. The control of temperature in all aspects of food production rises to such a level of importance, its accurate measurement can mean the difference between a safe and an unsafe food, between freshness and spoilage of your products. Temperature influences the food's flavor and appearance, which translates into consumer acceptance and repeat business—or not. By understanding some of the portable instrumentation available to us, we can make rational selections on the safest, most accurate and expedient way to measure temperature for food safety and quality control.

The portable temperature measuring devices that are most frequently used in our industry fall into four distinct categories: bimetal dial thermometers, electronic probe thermometers, including thermocouples and thermistors; non-contact infrared thermometers; and disposable indicating thermometers. In this column, we will explore all of these different types of thermometers with a practical-use perspective.

**Bimetal Dial Thermometer**

The bimetal dial thermometer is the mainstay of most retail food establishments and caterers. It is probably the most versatile, widely used—and abused—temperature measuring device in our industry. Opinions on the use of the dial thermometer in food safety fall into opposite extremes, from heavenly praise to satanic vilification. Some food safety professionals would like to see the U.S. Food and Drug Administration (FDA) ban these tools for use in enforcement, and heaven forbid that we should use them in our Hazard Analysis Critical Control Point (HACCP) efforts. Professionals on the other side of the opinion spectrum readily distribute bimetal thermometers at food safety training seminars and encourage their use on a frequent basis.
My personal opinion falls somewhere in the middle. While I recognize the bimetal dial thermometer's shortcomings, I feel that it is still the handiest and least expensive temperature measuring device available. With proper training in its use and encouragement to use it frequently, I believe that a significant number of foodborne infections can be prevented.

When all is said and done, the bimetal dial thermometer remains the most accessible and versatile tool in our arsenal of quality control devices because of its portability, ease of use and calibration, and non-reliance on batteries. These attributes make it the ideal screening tool for nearly every food-handling environment. Measuring the internal temperature of hamburgers and Buffalo wings or any product in which the stem cannot be entirely inserted to the dimple is the notable exception.

However, for one-handed checking of temperatures in hotel pans, hot water taps, refrigerators, dry goods warehouses, soup tureens, freezers, sandwich stations, milk dispensers or anything where the thermometer can be properly used, the dial thermometer provides relatively rapid and quite accurate (±2°F) measurements. When I conduct my inspections and audits, I carry about 20 recently calibrated units with me and place one in each refrigeration and hot-holding device during my initial walk-through. These thermometers have ample time to equillibrate by the time I retrieve them during the formal inspection process. As an aside, I "forget" to pick up one or two that I have purposely placed in critical areas. They make an excellent teaching tool and serve as an inexpensive and positive souvenir of my visit. Needless to say, I take the time to show my client how to use and calibrate them properly.

The operation of a bimetal dial thermometer is quite simple. The temperature sensor consists of two different metals that are bonded together
and wound into helical coils. These coils are mounted inside the stem, below the dial and calibration nut. As the bimetal is heated or cooled it winds or unwinds due to the different expansion rates of the metals. One end of the bimetal is fixed, and the other end has a pointer attached to it that indicates the temperature on a calibrated scale.

When selecting a bimetal dial thermometer, look for several things. The most important is the NSF mark on the dial face. This indicates that the thermometer was manufactured in accordance with a recognized public health standard and that no materials were used in its manufacture that will impart a toxin when exposed to food. Second, the dimple on the stem, which indicates the depth to which the device must be immersed to obtain an accurate temperature reading, should not be more than 1 to 2 inches from the tip. I've found that those thermometers where the dimple is more than 2 or even 3 inches from the tip are more difficult to use and far less versatile. Finally, the dial should be easily readable. The numbers and the pointer should have a striking contrast against the background, so that the thermometer can be read in diffuse light or in shadow. The dials that are most readable have black, block-letter numerals on a white background with a red pointer. I also like the dials that have a magnifying lens.

**Electronic Thermometers**

Before the naysayers do away with the bimetal dial thermometer, we need something to take its place. The obvious choice is the more expensive electronic thermometer. Regulators, institutional kitchens and food production operations have come to rely on the electronic thermometer, which includes a large selection of the versatile thermocouple, along with its impressive variety of probes for every imaginable application, as well as the very portable thermistor thermometers. I rely on these devices to measure temperature of most food service operational activities, particularly the
temperature components that make up the HACCP program. Thermocouples and thermistors each play a distinct role in temperature measurement for food safety.

_Thermocouples_. The thermocouple thermometer is the most widely used temperature measuring device in enforcement and quality control applications. From outward appearances, their larger size distinguishes them from their smaller cousins, the thermistors. Thermocouples generally consist of two components: a hand-held control unit that has an on-off switch and displays the temperature in an LED window, and the probe, which is usually attached by a wire and blade connector. The heart of the thermocouple is two dissimilar alloy strips or wires that are joined at one end. Changes in the temperature at the juncture of these different metals induce a change in electromotive force (EMF) between the other ends of the strips or wires. Basically, thermocouples produce a direct-current (DC) output voltage that changes with a change in temperature. As the temperature goes up, the output EMF rises.

Two types of thermocouples are suitable for our work. The first is the Type K (chromel/alumel) thermocouple. Overall, this is the best general-purpose unit because of its wide measurement range. It is ideal for use in high-humidity atmospheres and on materials with high moisture content. Needless to say, this type best meets the needs in a food service operation. The Type T (copper/constantan) thermocouple is particularly suitable for measuring low and subzero temperatures, and when used in atmospheres with high moisture content. It is therefore ideal for use in refrigerated warehouses and freezer lockers and surprisingly, for measuring ambient temperatures in buildings. The "type" of a thermocouple has to do with the types of metals used to manufacture the probe sensor. The K-type probe is only compatible with a K-type instrument; the same holds true for the T-
type thermocouple.

Of the electronic temperature measuring devices, thermocouple thermometers are the most difficult to engineer. The thermocouples themselves exhibit three distinct disadvantages, for which both the design and the manufacture of the instrument must compensate. First, the temperature response for thermocouples is nonlinear across the temperature scale. Second, thermocouples may be affected by "incidental thermocouples," or the tin-lead-solder joint wire connections to the tinned-copper printed circuit boards. Because the incidental thermocouples consist of metals, they, too, respond electrically to changes in temperature. Third, the signal from a thermocouple is extremely small—in the millivolt range. The smallness of the signal allows circuit drift or a change in DC voltage to affect its accuracy. Therefore, it can be truly stated that you get what you pay for: the more expensive, the better the unit. Accuracy and performance are directly proportional to the unit's cost. The best units available have a total-system-accuracy (that is, the accuracy of the probe and instrument combined) of ±0.5°C (±0.9°F). As a suggestion: If you are already spending top dollar on an accurate instrument, you may want to ensure its continued utility by sending it back to the manufacturer for annual recalibration and remember to frequently validate its temperature.

Thermocouples have an excellent response time and are quite durable. For any given thermocouple type, such as the K- or T-type alloy combinations, the voltage output relative to temperature can be characterized and is highly repeatable. This means that a large variety of thermocouple probes can be used with the same instrument, even though the probe geometries differ. For instance, my HACCP temperature kit has nine probes to measure temperature of everything from hot frying oil to frozen meat, from ovens to dishwashers to griddle tops to hamburgers and chicken wings. Also,
thermocouples can be used over a wide temperature range. This feature makes them ideal devices for evaluating the entire range of temperatures encountered in food storage, preparation and service.

Handheld, portable thermocouple thermometers are larger and heavier than other food thermometers and are normally powered by either an AA or 9-volt transistor battery with a typical operating life of about 500 hours.

**Thermistors.** The electronic thermometers that fit nicely into a shirt pocket are the thermistors. Small and compact, thermistors are part of a larger family of temperature-measuring instruments known as resistive temperature devices (RTDs). The materials that make up these devices respond to temperature changes by exhibiting changes in electrical resistance. Two key types are the metallic devices, commonly referred to as RTDs, and thermistors. As its name indicates, an RTD relies on resistance change in a metal, with the resistance rising more or less linearly with temperature.

The word "thermistor" is a contraction from "thermally sensitive resistor." A thermistor is made of a temperature-sensing element composed of a sintered semiconductor material that exhibits a large change in resistance proportional to a small change in temperature. Most of the thermistors we use have negative temperature coefficients; the resistance drops nonlinearly with temperature rise.

Overall, thermistors are more stable than thermocouples, but their temperature range is not as broad, nor response time as rapid. The more restrictive temperature span of thermistors typically is between 40°F and +300°F, which makes them poor candidates for measuring the temperatures of cooking devices such as ovens, deep-fat fryers and griddle tops. At these
temperature extremes, the thermistors will dramatically lose their accuracy. However, thermistors do offer a high accuracy in the regulatory temperature range and are therefore ideal for use as compliance tools. With its thin probe, the thermistor is particularly suitable for the internal temperature of a cooked hamburger patty. The thermistors we routinely use are small and lightweight and fit easily into a shirt pocket. Typically, a 1.5-volt replaceable photoelectric battery provides ample power for an average one-year operating life.

Because the sensor tip is a ceramic bead potted in a high-thermal-conductivity epoxy, the thermistors probe must be immersed about one-half inch into the food to compensate for thermal conductivity down the stem. The volume of food required for measuring is about one-fourth inch around the tip. Also, the probe, controls and readout are in a single unit. This may hamper flexibility in taking temperature readings, and due to their small size, it can be difficult to read the temperature in the LED window.

Be aware that from an engineering standpoint, thermistors are indeed resistive devices and that, accordingly, they function by passing a current through a sensor. Even though a very small current is used, it creates a certain amount of heat that may throw off the temperature reading under certain conditions, particularly in fluids that are not agitated. This problem does not arise with thermocouples, which are essentially zero-current devices.

Selection Guide. The most significant downside of many portable electronic thermometers, particularly those requiring a two-handed operation, is their ghastly sanitary design. The worst of the lot are those that have rubber or soft plastic covers protecting the hand-held controls. These covers are usually difficult to remove, and in many cases, become a repository for food
and filth. I have also seen thermometers where the probe storage receptacle is absolutely un-cleanable, unlike the open-ended holder on a dial thermometer that can be easily cleaned and sanitized with a pipe cleaner dipped in a suitable disinfectant. Likewise, many probe covers on pen-type thermistors are catch-alls for food and filth. On some thermocouple units, the male connectors on removable probes have more nooks and crannies than an English muffin. These nut-and-bolt-configured connectors collect everything they touch. In addition, when we ask operators how they clean their units, we are generally greeted with puzzled looks as they take their instrument from their trouser pockets along with used handkerchiefs, loose change, etc. During the course of my inspections, I have cited these septic instruments as "grossly unclean food contact surfaces," and on two occasions, I actually made this an issue in court.

I also have seen electronic thermometers sold to the food industry that have probes whose geometry is no better than that of a dial thermometer, and yet they are marketed as suitable for monitoring the internal temperature of a cooked hamburger patty. All the magnificent electronics, displays and colorful plastic exteriors cannot compensate for poor design. For this reason, we would like to see the thermometer manufacturers and importers, together with users and regulators establish an ANSI standard that includes specifications not only for safe food contact materials, but that address instrument performance, sanitary design and a proscribed format for the instructional manual. In short, we need to adopt standards for portable, hand-held thermocouple and thermistor units where we are assured of their accuracy, safety, use and cleanability. We need to specify how these units are either calibrated or validated, and most importantly, we need clearly written instructions on how these units are used in the field for quality control and regulatory compliance.
Infrared Thermometers

The infrared thermometer (IRT) is the newest addition to our arsenal of temperature measuring devices. It is also the most misunderstood, and at times, the most misused. However, with practice and a good dose of knowledge about its capabilities, limitations and proper operation, it can become an invaluable screening tool.

In 1996, I bought my first hand-held infrared thermometer. It featured an 8:1 distance to spot ratio, and had neither a laser-aiming device nor minimum/maximum temperature reading capabilities. My unit was a basic, no-frills, stripped-down model: bulky, simple, inexpensive, rugged and efficient. I was sold, even though I had little knowledge about its use and limitations. However, I vowed to learn all I could and to become proficient in their use. Since my first experience with the IRT, I've learned more about this instrument than I ever could have imagined. I found numerous other applications for the IRT in my forensic environmental health practice and two years ago, I actually established the IRT as a temperature measuring device for public health compliance through court law.

My original unit has since crossed the River Styx. I have replaced it several times over with newer and newer iterations. I am simply amazed at how far the technology has come in a few short years. Except for an occasional battery change, each unit I have purchased worked flawlessly. Indeed, the hand held infrared thermometer has merited the title as the most valuable instrument in my arsenal of environmental health screening tools. The newest units have coaxial laser sighting, probe attachment capabilities, adjustable emissivity settings, maximum, minimum and data storage capabilities, and all the bells and whistles of the more sophisticated electronic thermometers.
When the IRT was first introduced to our industry, reactions were mixed. I was rather amazed and puzzled at the differing opinions on their utility. Many regulators were at first quite skeptical, but with experience, the IRT is becoming more accepted as a screening tool. The good news is that Underwriters Laboratories (UL) developed a performance consensus standard for these units, UL2333. Most importantly for our use, the standard includes mandatory informational components for the instructional manual. To place the IRT in proper perspective, here is the (mostly) good, the bad and the ugly.

**Limitations.** First, do not get rid of your bimetal dial and electronic thermometers. The infrared unit is merely a rapid screening tool, not a regulatory device. Its advantage over other thermometers is that it can quickly take many non-contact surface temperature measurements of food that is extremely hot, moving or difficult to reach. But you will still need your calibrated bimetal dial thermometer or validated electronic thermometer to verify those temperatures on the regulatory cusp, as well as to measure the internal temperatures of roasts, chicken, salads, and so on. The IRT is an excellent tool, however, to check surface temperatures of food in steam tables, buffets, salad bars, Bain-maries, stock pots, or any preparation and service containers where multiple critical temperature measurements are necessary or warranted. To check liquids like soup or gravy, simply stir or agitate the contents before taking the measurement. The IRT is useful for rapidly monitoring ambient temperatures in any area, or of anything, particularly where multiple and remote measurements are required.

**Accuracy.** The infrared temperature measuring devices are about as accurate as bimetal dial thermometers. Although all units are factory calibrated, it is still advisable to perform a simple two-point temperature
verification check (~45°F and ~140°F) when you calibrate or validate your electronic or dial thermometer. To guarantee the best possible accuracy from your IRT, never touch the silicon lens. Try to make it a habit to regularly clean the lens with a camera lens blower or lens pen (available in most sporting goods stores), or if necessary, carefully wipe the lens with a lens cleaning cloth and solution.

Field of View. The IRT works much like a flashlight shining on a wall. The spot of light gets bigger when you back away from the wall and smaller as you get closer. The field of view (FOV) works in the same way. It is expressed as a ratio of distance to spot diameter. Because the IRT averages the temperature inside the spot, the spot must be within the size of the target object for accurate measurement. So, if a unit has a high FOV ratio, you can measure a smaller spot at a greater distance. I found this to be an advantage in my institutional practice where high-reach or inaccessible temperature measurements often are necessary. Most units that are sold to the food industry have an FOV of approximately 8:1.

Temperature shock. The problem with the IRT that catches many of us off guard is temperature shock. If your application takes your thermometer from one extreme temperature to another, generally a difference of 20°F, the readings may be erratic. It is advisable to "condition" your unit by leaving it in the environment where it will be used (but not below freezing!) for about 20 minutes. I have found that I can point and shoot an IRT, going from hot kitchen to walk-in refrigerator, without suffering the thermal shock, if the thermometer is protected in a padded case. However, even with this insulation, I recommend only momentary exposure.

Reflectivity. Since the IRT measures surface temperatures only, you need to adjust for reflectivity when measuring surfaces such as shiny metals. There
are two quick and easy ways to do this. For hot measurements, coat the surfaces with a nonstick cooking spray before taking the readings. On cold surfaces, place a small piece of masking tape on the metal surface and measure that spot. Also remember, the infrared sensor will not detect temperatures through glass or plastic film, but will measure the surface temperature of the glass or film. Steam, dust, smoke and other particulates also can prevent accurate measurement by obstructing the unit's optics.

**Durability and Cleanability.** As with all field electronic equipment, IRTs are relatively rugged and will withstand some degree of punishment. However, they do have their limitations. My best advice is to buy a carrying case with the unit. The lens is particularly sensitive and should be protected whenever the unit is not in use. To clean the exterior of the unit, wipe it down with a rag that is slightly dampened with a sanitizer solution.

**Disposable Indicating Thermometers**

Finally, we have available to us a wide assortment of disposable indicating thermometers. These little paper-and-plastic, color-change devices are convenient, rapid and accurate devices for any product that requires monitoring of a maximum or minimum critical temperature. The disposable thermometer is a single-use paper or plastic strip that changes color when a predetermined temperature is reached. With most disposable thermometers, the color change is permanent. While relatively new to both the food industry and the consumer, they have been used extensively in biotechnology and electronics as a quality control adjunct in shipping of hot and/or cold sensitive materials.

In our industry, we have found them particularly useful in several applications. Probably the most widely accepted use is the rapid monitoring of the hot water rinse temperature in mechanical dishwashers. Other
Disposable thermometers are designed for checking the internal temperature of hamburgers and hot-holding temperatures of prepared foods. Other types are ideal for monitoring critical temperatures in industrial washers and dryers, autoclaves and retorts, and as a preventive maintenance tool when applied to electric motors, bearing housings and similar hardware on production equipment to spot trouble before "total meltdown" occurs.

Since these are designed for a single use (with minor exceptions), they eliminate the possibility of cross-contamination. You will find them easy to use, easy to read, relatively inexpensive, and most importantly, they offer a permanent record. This makes them particularly attractive for use in your HACCP program. Disposable thermometers are available in a wide range of temperature-sensitive end-points and are manufactured as strips, sticks, adhesive labels and tabs. By the way, we are seeing more of these thermometers being marketed to consumers in supermarkets, food specialty shops and discount stores.

**Proficiency is Key**

So there you have it, a cursory over-view of portable temperature measuring devices. My advice is to use all of them. But first, learn about the devices you choose to use in your operation. Read and understand the instructional manuals, ensure the instrument's accuracy through two-point calibration and validation, and practice, practice, practice.

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