Thermometer Calibration Guide

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Temperature is a critical measurement for ensuring the safety and quality of many food products. There are a variety of commercial temperature monitoring devices available. Whether monitoring temperatures at receiving, throughout production or final product storage and distribution, thermometer calibration is essential. The validation, verification reassessment section of the Hazard Analysis and Critical Control Point (HACCP) system stated in the Code of Federal Regulations (9CFR 3:417.4) specifies that instruments used for monitoring critical control points must be calibrated. The food industry is keenly aware of the critical nature of processing temperature requirements. Instrument calibration is not only a food safety issue, but also an economic consideration since accuracy of temperature monitoring devices also affects product yields.

The National Institute of Standards and Technology (NIST) is an agency within the U. S. Department of Commerce which provides certification and calibration for thermometers and other precision instruments. When purchasing a thermometer check for the "NIST" label. The NIST label indicates a certified instrument that will maintain accuracy within specified limits, for at least one year. Each year, an NIST thermometer must be recertified to assure accuracy. This is a service usually provided by the manufacturer of the thermometer or an NIST calibration laboratory.

Calibration is the process of standardizing a temperature monitoring instrument to ensure that it will measure within a specific temperature range in which the instrument is designed to operate. Accuracy of a thermometer is its ability to measure temperature correctly without error. A thermometer must be within ±2°F (±0.5°C) of the actual temperature to be considered an accurate device. A thermometer's ability to detect subtle changes in temperature is its sensitivity. For example, a bi-metal coil thermometer can detect a 1.0 degree temperature change, while a thermistor may detect a 0.1 degree temperature change.

It is recommended that process or product temperature monitoring equipment be calibrated daily, before use. New equipment must be calibrated upon receipt and before putting into service. Also, thermometers that have been dropped on the floor or used frequently must be calibrated more often. Depending on the instrument and intended temperature use range, an ice water method and boiling water method, when used properly, are effective calibration methods. Another technique is to use sophisticated calibration equipment available from manufacturers. These units are designed to calibrate several thermometers at one time within a specific temperature range. Many of these units are able to interface with a computer to assist with record keeping. The calibration method used at your facility depends on the temperature monitoring instrument, monitoring frequency and intended use, and whether for

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product or environmental monitoring. Other acceptable methods may also be used to calibrate temperature monitoring instruments.

Calibration methods are presented for the following temperature monitoring instruments: bi-metal coil thermometer, thermocouple thermometer, and thermistor thermometer. Calibration of non-product contact thermometers such as Resistance Temperature Detector (RTD), oven temperature recording devices and infrared thermometers are also described. A major consideration when using any thermometer is the consistency of the product and temperature distribution throughout the product. For instance, to measure the internal temperature of a hamburger patty ⅛ inch (3 mm) thick would require using an instrument having a thin probe that can detect temperature quickly and accurately. Measuring the internal temperature of a bone-in ham could be done adequately using a thick probe having a 2- to 3-inch (5.1 to 7.6 cm) temperature sensing region. The product type or the environment to be monitored will influence the selection of the most effective temperature monitoring instrument to use.

Reference Thermometers

Laboratory and industry supply catalogs market NIST reference thermometers. Local county extension agents or high school science teachers may have these catalogs. A temperature monitoring device such as a mercury-in-glass thermometer or a thermistor can be used as a reference thermometer as long as the device is NIST certified and the annual calibration and certification is maintained through an NIST laboratory.

Bi-metal Coil Thermometer

Common types of bi-metal coil thermometers are dial and instant read digital thermometers. Contained within the stem of the thermometer is a coil made of two different metals bonded together to a temperature indicator. This type of thermometer detects temperatures from the tip of the stem to a point 2 to 2½ inches (5.1 to 6.4 cm) above the tip. An indentation in the stem indicates the area of the stem that is the temperature sensing region. The temperature indicated on the dial is an average of temperatures along this region. These thermometers must be inserted 2 to 3 inches (5.1 to 7.6 cm) into the geometric center of a product. Extreme fluctuation in temperature along the sensing region can affect the extension of the bi-metal coil, which affects thermometer accuracy. Bi-metal thermometers are sensitive to physical stress such as torque on the stem, or shock from dropping on the floor. These stresses can affect the tension of the bi-metal coil, which necessitate calibration of the thermometer before reuse.

Advantages of bi-metal coil thermometers	*Disadvantages of bi-metal thermometers*
• Inexpensive, readily available • Easy to calibrate • Used for final end point temperature check	• Temperature averaged over 2-inch (5.1 cm) area of probe (sensing region) • Lose calibration with physical shock • Cannot be used over a wide range of temperature measurement • Variable product temperature in sensing region affects measurement.

Bi-metal coil thermometer calibration method

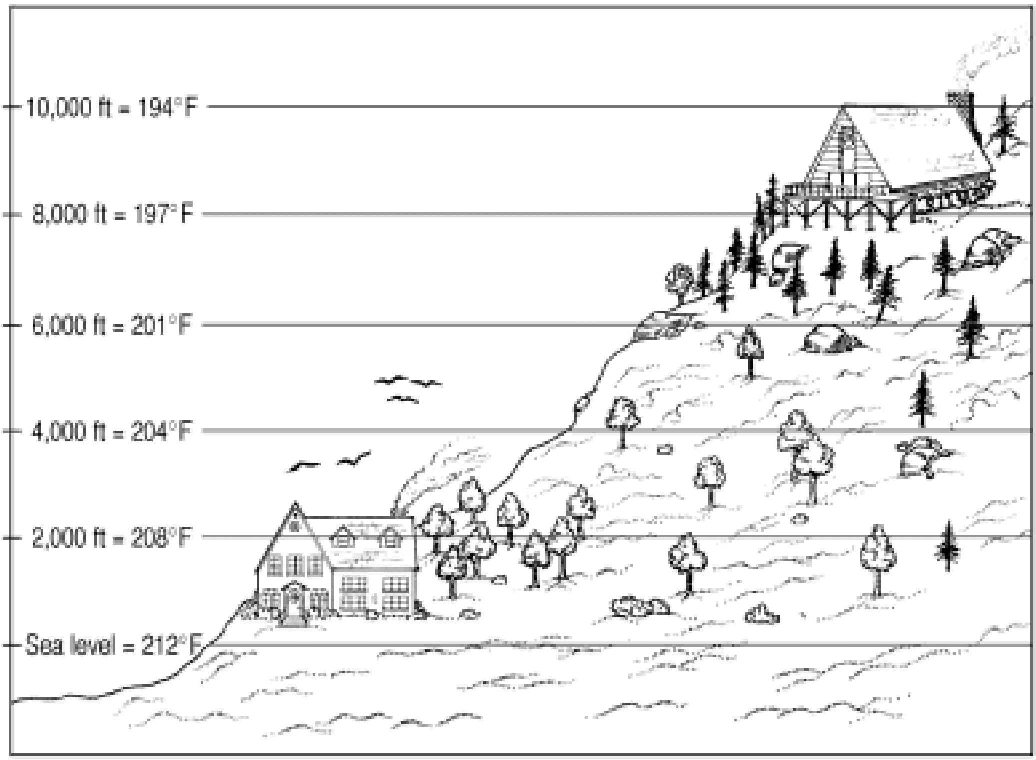
Calibration for use in hot processes and products (boiling water method):

The items needed for calibrating thermometers used in hot processes are:
- One pint (500 ml) Pyrex™ or heat tolerant container
- Distilled water
- Heat source such as a hot plate
- NIST reference thermometer

Once these supplies are assembled, the following steps are used to calibrate bi-metal coil thermometers for use in hot processes.

1. Heat distilled water to a specific reference temperature. This reference temperature can be 212°F (100°C)—described as a rolling boil at sea level altitude. The boiling point of water changes with altitude. To find the correct boiling point for your area, refer to Figure 1, Boiling point of water with relationship to altitude. An alternative reference temperature for example is the target end temperature of a product. Specifically, if the intended use of the thermometer is to measure the final internal temperature of a cooked uncured turkey roll at the end of thermal processing, then a target temperature of 160°F (71°C) should be used for the reference temperature.
2. Once the distilled water has reached the reference temperature, place the thermometer to be calibrated in the hot water bath. Immerse the stem to a minimum depth of 2½ inches (6.4 cm). Place the NIST reference thermometer in the water bath at the same time, to the same depth, as the bimetal coil thermometer. Make sure that neither thermometer comes in direct contact with the bottom of the heated container or each other.

Figure 1. Boiling point of water with relationship to altitude.
From the *Complete Guide to Home Canning,* Agriculture Information Bulletin No. 539, USDA. Reviewed 1994.



3. After one minute, compare the bi-metal coil thermometer reading to the NIST reference thermometer. Record the readings of the two instruments on a record-keeping form such as a thermometer calibration log.
4. Correct the indicator needle of the bi-metal coil thermometer. Adjust the spring on the coil by turning the hex nut directly behind the faceplate of the thermometer. Digital instant read thermometers may have a calibration button to adjust the temperature reading. If the thermometer cannot be physically calibrated and the accuracy of the unit is more than ±2°F (±0.5°C) then the unit should not be used. Contact the thermometer manufacturer for further instructions.
5. Recheck the temperature reading on the bimetal coil thermometer after making any adjustments. This is accomplished by repeating steps 1 through 3. The calibration adjustment should be noted in the thermometer calibration log.
6. Once a bi-metal coil thermometer has been calibrated for high temperature use, label the thermometer for use in this temperature range. This can be done by electroplating or etching the thermometer on the back of the faceplate with a number or letter indicating the temperature range of its intended use.

Thermometer calibration for use in cold process and products (ice water method)

A similar calibration procedure can be used for thermometers intended to be used in cold processes and products.

Materials necessary to calibrate a thermometer for cold uses are:
- Sturdy 1 pint (500 ml) container,
- Distilled water
- Crushed ice
- NIST reference thermometer

The same NIST reference thermometer used for high temperature calibration can be used for low temperature calibration as long as the thermometer is allowed to equilibrate to room temperature before use. To calibrate a thermometer for low temperature monitoring, follow these steps:

1. Place crushed ice in a beaker or container, add just enough distilled water to make a uniform slush ice

medium to facilitate even contact between thermometers and the slush ice bath.

2. Place NIST reference thermometer in the ice water bath. It is important to keep the tip of the thermometer immersed a minimum of 2½ inches (6.4 cm) without touching the bottom of the container.
3. The NIST reference thermometer should read 32°F (0°C) when placed in the slush ice bath. If the temperature is above 32°F (0°C), add more crushed ice to the beaker. If the reference thermometer is not equilibrating to 32°F (0°C) slush ice bath, start over with a clean beaker of crushed ice and distilled water. If this is still not working, check with the manufacturer of the NIST reference thermometer.
4. Place the bi-metal coil thermometer in the ice water bath for at least one minute by immersing to a minimum depth of 2½ inches (6.4 cm). Be sure the tip does not touch the bottom of the container. Compare the reading of the bi-metal coil thermometer to the NIST reference thermometer. Adjust and recheck the bimetal coil thermometer as described for the boiling point method. If the thermometer cannot be physically calibrated and the accuracy of the unit is more than ±2°F (±0.5°C), then the thermometer should not be used. Contact the thermometer manufacturer for further instructions. Note calibration adjustment in the thermometer calibration log and label the thermometer for use in low temperature ranges. This can be done by electroplating or etching the thermometer on the back of the faceplate with a number or letter indicating the temperature range of its intended use.

Thermocouple Thermometer

The thermodynamics of thermocouple temperature measurement is much different from bi-metal coil thermometers. A thermocouple measures the voltage potential difference between two dissimilar metals having different thermal conductivity, joined at one junction. When heated, each metal releases an electrical current different from the other. The temperature reading is a function of the junction between the two metals, the composition of the metals and the voltmeter measuring the current. Although calibration is possible there are many other facets to consider. There are electrical components in the digital display and the probe must be in good mechanical condition. Consider using a commercial calibration service provided by the thermocouple manufacturer or from an NIST calibration laboratory. Voltage resolution, speed and accuracy of the measurement and temperature range determine which thermocouple probe to use. Voltage resolution affects the thermocouple's ability to detect small changes in temperature. A common thermocouple type is "R," which is a combination of platinum/13% rhodium adjacent to platinum having a temperature range from 0°C to 1000°C (32°F to 1832°F) that is accurate to within 0.5°C (0.5°F). Characteristics of other standard probes are listed in Table 1. Any of the thermocouple types listed in Table 1 can be used for temperature measurement in meat and food processing environments. The most important consideration when choosing a thermocouple is selecting the appropriate probe or stainless steel sheath covering the thermocouple wire. For example, there are hypodermic probes, immersion probes and penetrating probes, each used for a specific type of food (Table 2). The cost

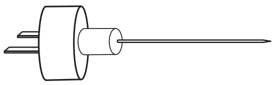
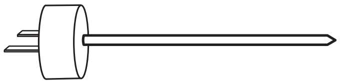
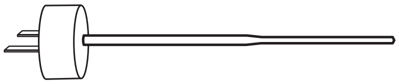
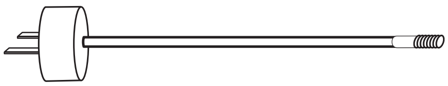
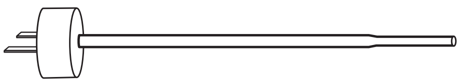
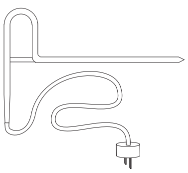
Advantages of thermocouple thermometers	*Disadvantages of thermocouple thermometers*
• Wide variety probes available over a wide temperature range • Inexpensive • Temperature sensed as the tip of the probe	• Requires internal reference • Least stable and least sensitive

Table 1. Characteristics of standard thermocouple types.

TYPE	E	J	K	R	S	T
COMPONENT	Nickel-10% Chromium VS Constantan	Iron VS Constantan	Nickel-10% Chromium VS Nickel-5% Aluminum Silicon	Platinum-13% Rhodium VS Platinum	Platinum-10% Rhodium VS Platinum	Copper VS Constantan
TEMPERATURE RANGE	-100°C to 1000°C ±0.5°C (-148°F to 1832°F) (±0.9°F)	0°C to 760°C ±0.1°C (32°F to 1400°F) (±0.2°F)	0°C to 1370°C ±0.7°C (32°F to 2498°F) (±1.3°F)	0°C to 1000°C ±0.5°C (32°F to 1832°F) (±0.9°F)	0°C to 1750°C ±1°C (32°F to 3182°F) (±1.8°F)	-160°C to 400°C ±0.5°C (-256°F to 752°F) (±0.9°F)
*SPEED ACCURACY	9	5	8	8	9	7

* A larger number indicates a more accurate instrument, however speed is lost in the process.

Table 2. Illustration of Thermocouple probe types

	Hypodermic needle probe used for thin products such as meat patties or jerky.
	Conical tip probe used for penetration into partially frozen product. Usually a 1/8 inch (3 mm) diameter tip, 5-6 inches (12-15 cm) long.
	Reduced diameter tip probe, similar to type B. 1/16 inch (1.5 mm) diameter at tip.
	Air probe to measure air temperature of refrigerated and frozen storage areas. A metal shield protects 1/16 inch (1.5 mm) tip.
	Immersion probe to measure liquid product temperatures. This probe commonly used to measure temperature of soup, brine solutions. It is approximately a 1/8 inch (3 mm) in diameter with a metal sheath protecting thermocouple from liquid environment.
	T-handle probe used for deep penetration into frozen product, 1/8 (3 mm) inch diameter.

of a thermocouple thermometer depends on the probe and the electronic component reading the voltage measurement.

Thermocouple thermometer calibration method

The calibration methods used for bi-metal coil thermometers can be used for thermocouple thermometers. Some electronic units include a calibration mode, which does an internal circuitry calibration. However, a thermocouple thermometer must be checked with external temperatures to ensure proper reading within a specified temperature range. As with any electronic equipment, check with the manufacturer for the proper method to calibrate the instrument.

Thermistor Thermometer

Thermistor is a generic term for "thermally sensitive resistors." The key word in this phrase is sensitive. Thermistor thermometers are the most sensitive temperature measuring devices, able to detect small changes in temperature. Transitional metal oxides are semi-conductive materials used in thermistors. Manganese and nickel, or manganese, nickel and cobalt are the most common component metals. Thermistors can be manufactured to fit any need and can be as small as 0.07 mm in diameter. Thermistors can be used over a wide range of temperatures without affecting accuracy.

Thermistor calibration method

Thermistors are fragile and can lose calibration at extremely high temperatures. Because of the nature of the component metals, thermistors are not easy to calibrate. These instruments may have an internal calibration setting similar to a thermocouple thermometer. Using the method described for bi-metal coil thermometers will indicate if the instrument is operating within a specified temperature. Check with the manufacturer for proper calibration methodology for thermistors.

Advantages of thermistor thermometers	*Disadvantages of thermistor thermometers*
• Highly sensitive • Small, thin probe available • Responds quickly to samll temperature changes • Tip of the probe senses temperature	• Fragile • Limited to a few hundred degree temperature range • Errors due to self-heating

Non-product Contact Thermometers

Thermometers used to monitor room temperature, cooler and refrigerator temperatures are essential in maintaining high quality products.

Depending on the HACCP plan, storage room temperature may be a critical control point for uncooked refrigerated product. Environmental conditions, especially relative humidity affect heat transfer in large coolers. This is an important consideration during the summer months. Therefore, thermometers used to monitor room temperature must be routinely checked for calibration.

Resistance Temperature Detector

A resistance temperature detector (RTD) is a thin platinum wire wrapped around a glass or ceramic rod. Platinum wire coils can also be imbedded in a ceramic matrix. A protective coating of glass or ceramic completely houses the detector. The accuracy of temperature readings for a RTD should be compared to a NIST reference thermometer at least monthly depending on use in the facility and type of device. The RTD device is stable and accurate, however it is fragile and not easy to calibrate. Once an RTD falters it is best to replace it. Remember to keep current records of all readings when taken and note temperature differential.

Advantages of RTD	*Disadvantages of RTD*
• Stable • Accurate	• Expensive • Self-heating • Difficult to calibrate

Infrared Thermometer

An infrared (IR) thermometer is a device that collects radiant infrared energy emitted from an object. The detector converts the energy signal to a temperature reading. Most IR thermometers respond within 0.5 seconds and have 100 feet (30.5 m) maximum measuring distance, depending on the environmental conditions. The ability of an object to release or absorb energy is called emissivity. IR thermometers are affected by emissivity, which is complicated by shiny surfaces. Most IR units can be adjusted for emissivity by comparing the IR thermometer surface temperature of an object to a reference thermometer temperature reading of the same surface. The IR thermometer can then be adjusted to the reference temperature.

Advantages of IR thermometers	*Disadvantages of IR thermometers*
• Fast, accurate • Surface temperature measurement • Non destructive, non contact measurement	• Surface emissivity affects accuracy • Environmental conditions, such as relative humidity affect accuracy

IR thermometer calibration method

IR thermometers are calibrated using a “Blackbody,” which emits a given amount of energy at a given temperature. A blackbody calibration instrument is expensive. However most manufacturers of NIST IR thermometers provide a calibration service for a nominal fee for yearly calibration and certification.

Smokehouse Temperature Recording Device

Batch or continuous ovens (smoke house) use either thermocouples or RTD to monitor oven temperature during thermal processing. Oven temperature must be continuously recorded by a chart recorder. Several electrical components involved in this process must be checked weekly and calibrated monthly by a certified technician or by the equipment manufacturer service technician. The accuracy of the probes can be checked by placing them into 140° to 180°F (60 to 82°C) hot water and comparing the temperature reading to a certified NIST reference thermometer. Record keeping is essential to track trends and any possible drift in temperature measurement.

Record Keeping

Record keeping is an essential component of any calibration program. To simplify record keeping, each thermometer should be marked with a permanent identification number or code. At a minimum, the following information should be included in a calibration record: thermometer identification, date, time, intended use (hot/cold product or process), temperature reading difference from reference, and initials of person testing equipment. Table 3 illustrates use of a thermometer calibration log while a blank form is provided in Table 4. A thermometer should be replaced when a temperature difference or drift is consistently greater than ±2°F (±0.5°C). When a thermometer is replaced, a note should be made on the log and a new label assigned to the replacement thermometer.

Additional Information

FDA Consumer Magazine
FDA (HFE-88)
5600 Fishers Lane; Rockville, MD 20857
888-INFO-FDA (1-888-463-6332)
Web site: http:// www.fda.gov/

Food Safety Inspection Service Food Safety Education and Communications
Room 2932-South Building
1400 Independence Ave. SW; Washington, DC 20250
Phone (202) 720-7943; FAX (202) 720-1843
Email: fsis.webmaster@usda.gov web site: http://www.fsis.usda.gov/

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U.S. Department of Agriculture. 1997. Kitchen thermometers technical information Food Safety Inspection Service. U.S. government printing office Washington D.C.

U.S. Department of Agriculture. 1997. 9 Code of Federal Regulations section 417.4 Hazard Analysis Critical Control Point system Validation verification reassessment. U.S. government printing office Washington D.C.

Table 3. Thermometer Calibration Log Example

COMPANY NAME: *Ryeleigh Meats* FORM START DATE: 2/02/99 FINISH DATE: PAGE NO. *6*

Date	Time	Thermometer identification	Use	Reference temperature	Difference from reference	Initials	Comments	Verified by/ Date
2/02/99	*6:20 a.m.*	*1*	*Hot*	*212°F*	*+1*	*NCF*	*Adjusted; rechecked ok*	*SSJ/ 2/02/99*
2/02/99	*6:20 a.m.*	*2*	*Hot*	*212°F*	*-1*	*NCF*	*Adjusted; rechecked ok*	*SSJ/ 2/02/99*
2/02/99	*6:40 a.m.*	*3*	*Cold*	*32°F*	*0*	*NCF*		*SSJ/ 2/02/99*
2/02/99	*6:40 a.m.*	*4*	*Cold*	*32°F*	*+1*	*NCF*	*Adjusted; rechecked ok*	*SSJ/ 2/02/99*
2/02/99	*11:20 a.m.*	*3*	*Cold*	*32°F*	*+2*	*NCF*	*Dropped on floor; rechecked, adjusted*	*SSJ/ 2/02/99*
2/07/99	*6:30 a.m.*	*1*	*Hot*	*212°F*	*+1*	*NCF*	*Adjusted; rechecked ok*	*SSJ/ 2/07/99*
2/07/99	*6:30 a.m.*	*2*	*Hot*	*212°F*	*-1*	*NCF*	*Adjusted; rechecked ok*	*SSJ/ 2/07/99*
2/07/99	*6:45 a.m.*	*3*	*Cold*	*32°F*	*+4*	*NCF*	*Rechecked; replaced with # 5*	*SSJ/ 2/07/99*
2/07/99	*6:45 a.m.*	*4*	*Cold*	*32°F*	*+1*	*NCF*	*Adjusted; rechecked ok*	*SSJ/ 2/07/99*
2/07/99	*6:55 a.m.*	*5*	*Cold*	*32°F*	*0*	*NCF*	*New thermometer*	*SSJ/ 2/07/99*

Table 4. Thermometer Calibration Log

COMPANY NAME: FORM START DATE: FINISH DATE: PAGE NO.

Date	Time	Thermometer identification	Use	Reference temperature	Difference from reference	Initials	Comments	Verified by/ Date

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