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PURDUE EXTENSION

Safe food guidelines for small meat and poultry processors

FS-25-W

EXPERT REVIEWED

Selection and Maintenance of Temperature Measurement Devices

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Outline

Calibration of temperature measurement devices is one of the most important verification activities a meat or poultry processor can perform. Accurate temperature measurement devices are critical for ensuring the safety of meat products.

Introduction

Accurate temperature measurement is critical for ensuring production of a safe and high-quality meat or poultry product. Millions of people each year are affected by foodborne pathogens at a cost of nearly $10 billion. Many of the microorganisms that cause foodborne disease may be eliminated by proper temperature regulation, which requires accurate and precise temperature measurement.

There are many different types of temperature measurement devices, each one tailored to meet a specific need. This fact sheet provides information on the types, use, and calibration of temperature measuring devices. It also provides guidelines for the selection and proper maintenance of common thermometers and temperature sensors.

1. Importance of accurate measurement

It is important to understand the difference between accuracy and precision. Using the simple analogy of a game of darts, accuracy is consistently hitting the true mark, or bull's-eye. Precision is consistency, but not necessarily accurate consistency. You may throw three darts and they all may hit the same area, but it may not be the true result (bull's-eye) you were aiming for. The following illustration (see page 7) demonstrates the difference between accuracy and precision.

2. Temperature units and conversions

	°C	°F
Boiling point of water (at sea level) *	100	212
Freezing point of water (at sea level)	0	32

* Boiling point of water is a function of elevation. The higher the elevation, the lower the boiling point of water. Use the following equations to calculate the boiling point of water.

Boiling Pt (°F) = 212 – (0.0018 x elevation in feet) {Eq 1}
Boiling Pt (°C) = 100 – (0.001 x elevation in feet) {Eq 2}

Example 1: The elevation of West Lafayette, Ind., is 617 feet above sea level. The adjusted boiling point of water for West Lafayette is:

°F = 212 – (0.0018 x 617 feet) = 210.9°F
°C = 100 – (0.001 x 617 feet) = 99.4°C

Consult www.topozone.com/ to find the elevation of any town in the United States.

Conversion formulas

°F = 32 + (9/5 x °C) {Eq 3}
°C = 5/9 x (°F – 32) {Eq 4}

Example 2: Convert 10°C to °F:
°F = [32 + (9/5) x 10°C] = 50°F

Example 3: Convert 45°F to °C
°C = (5/9) x (45°F – 32) = 7.2°C

3. Types of devices and how to choose

As stated above, a wide array of temperature measuring devices are suited for any number of temperature ranges, measuring environments, durability requirements, etc. For a quick reference, refer to the following table. For more detailed information, refer to the corresponding section regarding use and maintenance of the specific device.

3.1 Device comparison table

Sensor Type	Advantages	Disadvantages	Accuracy	Cost	Application
Bimetal	• Inexpensive • Simple • Easy to calibrate	• Analog display • Limited range and accuracy • Takes an average of temperatures • Slow response	±1°F or 1.0% of full scale, whichever is larger	$20-$200	General food preparation
Glass-Liquid	• Simple • Easy to calibrate • Highly accurate	• Analog display • Difficult to read • Fragile • Slow response	±0.1°F or 2.0% of full scale, whichever is larger	$25-$300	Basic temperature measurement method for fluids
Thermocouple	• Wide temperature range • Fast response • Simple • Easy to calibrate • Digital display • Standardized	• Expensive	±1°F or 0.2% of full scale, whichever is larger	$100-$300	Specialty applications – for use in meeting HACCP requirements Good for repeated use
RTD	• Fast response • Highly accurate	• Expensive	±0.4°F or 0.1% of full scale, whichever is larger	$140-$2,150	General, high-end temperature measurement
Thermistor	• Digital display • Highly sensitive	• Fragile • Limited temperature range	±1°F or 0.7% of full scale, whichever is larger	$145-$800	General food preparation and medical applications
Infrared Radiation	• Digital display • Fast response • Non-destructive	• Only measures surface temperatures • Expensive • Limited accuracy	±2°F or 1.0% of full scale, whichever is larger	$100-$2,350	Use only for surface measurement

Pricing information from Cole Parmer Catalog, Summer 2003.

Bimetal thermometer

3.2 Bimetal thermometers

Bimetal thermometers are often used in the food industry. Generally, bimetal thermometers consist of a metal stem encasing a coil of two different metals bonded together to a temperature indicator at the head. To properly use such a thermometer, insert the stem in the center of the product until the temperature-sensing region is completely immersed. A notch on the stem indicates the end of the temperature-sensing region. It is important to note that the indicated temperature is an average of temperatures along the sensing region, making proper placement critical to accurate measurement. Because of this average range, bimetal thermometers are not suited for products undergoing rapid heating or cooling.

This variety of thermometer is typically sensitive to constant use and stress on the stem, which may affect the tension of the inner coil. Bimetal thermometers should be calibrated daily to ensure accuracy.

3.2.1 Bimetal thermometer calibration

Calibration with a reference thermometer may be done at any number of temperature ranges *(see section 3.2.1.3);* however, it is strongly suggested that you use a calibration temperature close to the temperature range at which the thermometer will actually be used. Use of a reference thermometer certified by the National Institute of Standards and Technology is strongly suggested.

3.2.1.1 Hot processes – boiling water method

1. Heat distilled water to a rolling boil. See {Eq 1} to calculate boiling point.

   Enter boiling point: ___________ (1)

2. Place the thermometer to be calibrated in the hot water bath once the bath has reached the desired reference temperature. Be certain that the stem is immersed at least past the sensing region notch.
3. Allow one minute for the reading to stabilize.

   Enter observed temperature: ____________ (2)

4. Compare the reading with the calculated boiling point.
5. Correct the indicator needle of the bimetal thermometer. Typically, this is done by adjusting the coil spring by turning a hex nut behind the thermometer head. If the thermometer has a digital display, adjust the temperature with the calibration button.

   ** If there is no calibration adjustment, a correction factor must be determined. This requires taking the difference between observed (2) and actual (1) recordings above. This +/-differential then must be applied to each subsequent measurement made with the thermometer.*

   Conversion factor (3) = (1) – (2) = __________ (3)

6. Double-check the calibration by repeating steps 1-4.

3.2.1.2 Cold processes – ice bath method

1. Fill a container with crushed ice, then add water (distilled preferred) to make an ice slush bath.

   Freezing point temperature = 0°C (32°F) (1)

2. Place the bimetal thermometer in the ice slurry, making sure that the sensing region is immersed and that the thermometer is not touching the container. Slowly stir the slurry.
3. Allow one minute for the reading to stabilize.

   Enter observed temperature: ____________ (2)

4. Compare readings and adjust the bimetal thermometer appropriately. *(See step 5 above.)*

3.2.1.3 General calibration with certified reference thermometer

1. Measure the temperature of an object with the reference thermometer, allowing one minute for the reading to stabilize.
2. Place thermometer to be calibrated in test object, making sure that the sensing region is immersed and that the thermometers are not touching each other and are both in the center region of the object.
3. Allow readings to equilibrate and compare readings

   Reference thermometer reading: ____________ (1)

   Bimetal thermometer reading: ______________ (2)

4. Adjust the bimetal thermometer appropriately. *(See step 5 of 3.2.1.1 above.)*

3.3 Glass-liquid thermometers

A glass-liquid thermometer is likely what first comes to mind when most people think of temperature measurement. Typically simple, a glass-liquid thermometer consists of a glass cylinder with a capillary hole containing either mercury or alcohol. While convenient and reliable, glass-liquid thermometers are not well suited for meat and poultry products. Glass-liquid thermometers are often used as a reference thermometer, but not for food monitoring processes.

3.3.1 Glass-liquid thermometer calibration

It is suggested that the calibration of glass-liquid thermometers be checked annually. Glass-liquid thermometers are not adjustable, so a correction factor must be determined when they are calibrated.

Gass-liquid thermometer

3.4 Thermocouples

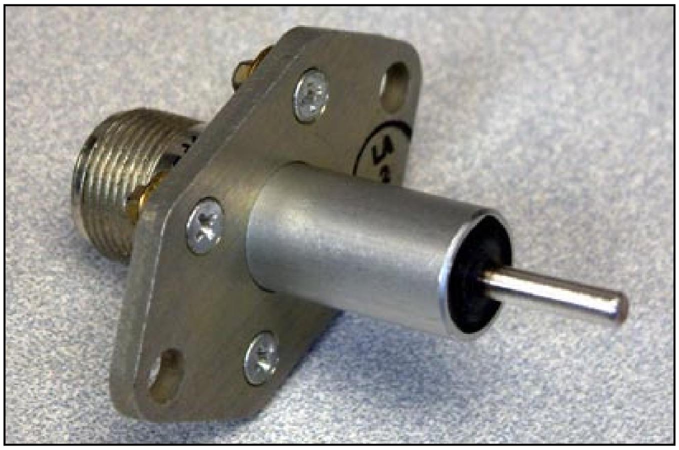
Thermocouples are made of two dissimilar metals, joined to produce a voltage when the measured temperature deviates from the reference temperature. The selection of the two metals determines the thermocouple's application temperature, measuring environment, required service life, accuracy, and cost.

There are hundreds of thermocouple designs. Many designs are tailored to a specific measurement need. Thermocouple thermometers have been standardized for use worldwide. Specifications include letter coding, color coding, voltage/temperature tables, and operational limits.

Thermocouple thermometer

3.4.1 Thermocouple selection and use

A number of issues should be considered when selecting the appropriate thermocouple construction for your specific needs. The following table lists commonly used, standardized thermocouple types, including material combinations and the corresponding application ranges. It is important to note that while the color codes are standard in the United States, other countries, such as Great Britain, France, and Germany, use different color-coding designations.



Thermistor

3.4.2 ASTM coding table for common thermocouples

Type	Color Code	Materials	Application Range
E	Purple	Chromel (+) Constantan (-)	-201 to 871°C (-330 to 1,600°F)
J	Black	Iron (+) Constantan (-)	-201 to 1,000°C (-330 to 1,832°F)
K	Yellow	Chromel (+) Alumel (-)	-250 to 1,260°C (-418 to 2,300°F)
T	Blue	Copper (+) Constantan (-)	-250 to 371°C (-418 to 700°F)

There is a wide assortment of thermocouple probes, each tailored to a specific measurement need.

3.4.3 Thermocouple Calibration

Thermocouple thermometers also require routine calibration. *(See previous section dedicated to bimetal thermometer calibration [3.2.1] or refer to section 4 on generic double-point calibration.)*

3.5 Resistance-Temperature Detectors (RTD)

RTDs are temperature sensors based on the nearly linear relationship between metal resistance and temperature. Typically, high-end RTDs are made from wire-wound or thin-film platinum, providing for a highly sensitive but expensive temperature sensor. RTDs also must be calibrated periodically. This type of thermometer is stable and highly accurate but extremely fragile, so weekly calibration is suggested.

3.6 Thermistors

Like RTDs, thermistors are temperature sensors that measure current and convert it to temperature. Where RTDs typically use expensive platinum, thermistors utilize inexpensive semiconductors. As temperature changes, the semiconductor resistance also changes. The resistance can then be converted and displayed as a temperature.

Most medical thermometers are limited-temperature thermistor-type thermometers. They are mass-produced for specific sensitivity and range requirements. Typically, these devices do not have temperature adjustment capability, thus a correction factor must be determined when they are calibrated.

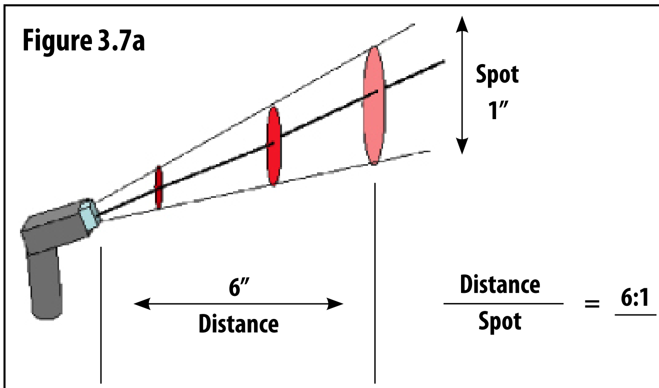
3.6.1 Thermistor calibration

Thermistor sensors are highly fragile and tend to lose calibration when used at high temperatures (greater than 220°F). Follow calibration methods previously discussed.

3.7 Infrared radiation thermometers

Infrared radiation thermometers collect radiated infrared energy emitted from the surface of an object. They measure surface temperature only. The detector converts the emitted radiation into a temperature reading and displays the temperature almost immediately. Most infrared thermometers have a range of 10 feet and respond within a half second. The easiest of all thermometers to use and read, all that is involved is to point the sensor at the desired object, press a button, and read the temperature. It doesn't get any simpler than that!

Figure 3.7a



It is essential to note that while the range may be 10 feet, the closer the sensor is to the target object the more accurate the reading will be. This is because the spot size becomes larger as the distance between target and sensor increases. *(See figure 3.7a above.)* As a general rule of thumb for accurate measurement, the target object should be at least twice the diameter of the spot size *(see previous page)*.

It is also important to be aware that infrared thermometers only measure surface temperatures. Another point to consider is emissivity, which is an object's ability to absorb or release energy. Reflective surfaces, such as metal, will show temperatures lower than the actual. Most infrared thermometers may be adjusted by using a reference thermometer to take a temperature reading of the surface in question.

3.7.1. Infrared radiation thermometer emissivity calibration

To calibrate for emissivity effects, a blackbody calibration instrument is required. Most manufacturers of infrared thermometers provide a calibration service for a yearly fee. Contact your device manufacturer for further information regarding emissivity calibration.

4. Generic double-point calibration technique

1. Prepare an ice bath. *(See instructions 3.2.1.2.)*
2. Prepare a boiling water bath. *(See instructions 3.2.1.1.)*
3. Measure with the uncalibrated thermometer the temperature of the ice bath as (A).

   Uncalibrated Ice Bath Temperature: _________(A)
4. Measure with the uncalibrated thermometer the temperature of the boiling water bath as (B).

   Uncalibrated Boiling Water Bath Temperature: ____________ (B)
5. Record X = B - A

   ____________ (X)
6. Record from a calibrated reference thermometer the actual temperature of the boiling water bath (Hot) (remember to adjust for altitude) and of the ice bath (Cold).

   Actual Ice Bath Temperature: 0°C (Cold)

   Altitude-Corrected Boiling Point of Water:

   _________ (Hot)
7. Record: Y = Hot – Cold

   ___________ (Y)
8. Record: Z = Y/X

   ___________ (Z)
9. Record: S = Cold – (A x Z)

   ___________ (S)
10. Actual Temperature = Z x Thermometer Reading + S

    = ___________ (Actual Temperature)

5. Example: Double-point calibration

1. Prepare an ice bath. *(See instructions 3.2.1.2.)*
2. Prepare a boiling water bath. *(See instructions 3.2.1.1.)*
3. Measure with the uncalibrated thermometer the temperature of the ice bath as (A).

   Uncalibrated Ice Bath Temperature: **0.5°C (A)**
4. Measure with the uncalibrated thermometer the temperature of the boiling water bath as (B).

   Uncalibrated Boiling Water Bath Temperature: **100.5°C (B)**
5. Record below: X = B - A

   100°C (X)
6. Record from a calibrated reference thermometer the actual temperature of the boiling water bath (Hot) (remember to adjust for altitude) and of the ice bath (Cold).

   Actual Ice Bath Temperature: 0°C (Cold)

   Altitude-Corrected Boiling Point of Water:

   100°C (Hot)
7. Record below: Y = Hot – Cold

   100°C (Y)
8. Record below: Z = Y/X

   1.00 (Z)
9. Record below: S = Cold – (A x Z)

   -0.5°C (S)
10. Actual Temperature = Z x Thermometer Reading + S

    = 14°C (Actual Temp)

Other publications in this series

FS-20-W, Small Meat Processing Plants: Overview of HACCP (Hazard Analysis Critical Control Point)
- www.ces.purdue.edu/extmedia/FS/FS-20-W.pdf

FS-21-W, Small Meat Processing Plants: SSOP and GMP Practices and Programs (Sanitation Standard Operating Procedures and Good Manufacturing Practices)
- www.ces.purdue.edu/extmedia/FS/FS-21-W.pdf

FS-22-W, Small Meat Processing Plants: A Pest Control Program
- www.ces.purdue.edu/extmedia/FS/FS-22-W.pdf

FS-23-W, Small Meat Processing Plants: A Recall and Traceability Program
- www.ces.purdue.edu/extmedia/FS/FS-23-W.pdf

FS-24-W, Small Meat Processing Plants: Verification Programs
- www.ces.purdue.edu/extmedia/FS/FS-24-W.pdf

Additional resources

Purdue Department of Food Science,
- www.foodsci.purdue.edu/outreach

Food Safety and Inspection Service of the USDA,
- www.fsis.usda.gov

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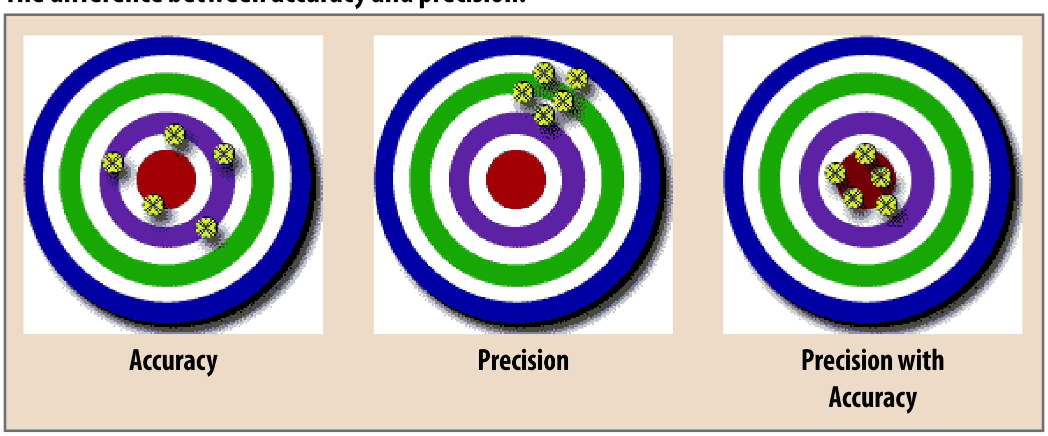
The difference between accuracy and precision.



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