Effect of Ice-Bath Temperature on USDA Probe Calibration

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1. Importance of the 0.00 °C Reference

The accuracy of the ice-bath reference temperature is critical when evaluating and calibrating USDA temperature probes.

During ice-bath calibration, the controller operates on the assumption that the probes are exposed to a valid **0.00 °C reference**. The controller has no independent means of determining whether the bath itself actually represents 0.00 °C; it relies on the reference condition being correctly established.

If the actual bath temperature differs from 0.00 °C and this deviation is not independently identified, the bath-temperature error becomes part of the observed probe reading.

This can produce two separate consequences:

1. A probe that is actually within the controller's calibration acceptance window may be rejected, or a probe outside the window may appear acceptable.

2. A probe that is successfully calibrated may receive an incorrect offset because the error of the reference bath may be incorporated into the calibration.

> **Probe acceptance and calibration accuracy are separate issues.**

2. Sources of Ice-Bath Deviation

A correctly prepared and maintained ice-point bath provides a highly reproducible temperature reference close to **0.00 °C**.

However, an improperly prepared or maintained bath can contain temperature gradients or local deviations from the ice point.

- Excess liquid water, particularly around or below the probe tips.
- Insufficient ice relative to the amount of water.
- Inadequate stabilization before measurements are taken.
- Poor positioning of probes or the reference thermometer.
- Contact with the container wall or bottom.
- Insufficient thermal equilibrium or inadequate mixing.
- Contamination of the ice or water with dissolved substances, which can depress the freezing point.

Ice taken directly from a freezer may initially be well below 0 °C. This does not mean that a correctly established ice-water equilibrium will remain below 0 °C, but sufficient time and proper preparation are required to establish a stable ice-point reference before calibration measurements are taken.

The examples below use an actual bath temperature of **+0.15 °C** for simplicity. The same principle applies, with the appropriate change of sign, when the reference temperature is below 0.00 °C.

3. Possible Rejection or Acceptance of Probes Due to an Incorrect Reference

An incorrect or unverified reference bath can cause the controller to reject a probe that would actually be within its permitted calibration range at a true 0.00 °C.

For illustration only, assume a controller calibration acceptance window of **±0.30 °C**.

The actual acceptance criterion is controller-, software- and procedure-specific and must be verified against the applicable manufacturer's documentation and regulatory requirements.

Consider a probe having an actual offset of **+0.20 °C at a true 0.00 °C**. This probe would be within the hypothetical ±0.30 °C acceptance window.

However, if the actual bath temperature were **+0.15 °C**, the controller could observe approximately:

> **+0.20 °C probe offset + 0.15 °C bath deviation = +0.35 °C indicated**

The controller could therefore reject the probe even though its actual offset at a true 0.00 °C reference is only +0.20 °C.

The Opposite Effect Is Also Possible

Consider a probe having an actual offset of **+0.40 °C**, which is outside the hypothetical ±0.30 °C acceptance window.

If the actual bath temperature were **-0.15 °C**, the controller could observe approximately:

> **+0.40 °C probe offset - 0.15 °C bath deviation = +0.25 °C indicated**

The controller could therefore accept a probe that would have been rejected at a true 0.00 °C reference.

Therefore, an indication such as **+0.30 °C or +0.40 °C in an ice bath cannot, by itself, be interpreted as a +0.30 °C or +0.40 °C probe error unless the actual reference temperature at the time of the measurement is known and documented.**

4. Effect on the Calibration Offset of Accepted Probes

For probes that remain within the controller's acceptance window, the reference-bath error may become incorporated into the stored calibration offset.

This is potentially the more important consequence because the resulting offset can subsequently affect temperature readings during the cold treatment.

The controller determines the individual probe correction based on the assumption that the reference represents **0.00 °C**.

The controller may perform its calculation correctly. However, if the reference itself is incorrect, the resulting correction does not necessarily represent only the true probe offset; it may also contain the error of the reference bath.

Example

Consider a probe whose actual error at 0.00 °C is **0.00 °C**. The probe itself is therefore correctly indicating temperature.

Now place this probe in a bath that is actually at **+0.15 °C**.

If the controller assumes that this bath represents 0.00 °C, it may interpret the observed +0.15 °C as an error originating from the probe and apply a corresponding correction.

The +0.15 °C deviation, however, originated from the **reference bath - not from the probe**.

As a result, an unnecessary correction may be incorporated into the stored calibration offset.

This principle applies regardless of whether the probe's actual initial offset is **positive, negative or zero**. Each probe may receive a different individual calibration offset, but an error in the common reference bath can affect every calibration performed using that reference.

5. Effect on Subsequent Cold-Treatment Temperature Measurements

Once the calibration offset has been established, the controller applies the corresponding correction to subsequent probe readings during the cold treatment. Therefore, an error introduced during calibration can result in an

indicated temperature that differs from the actual fruit pulp temperature.

Parameter	Value
Actual bath during calibration	+0.15 °C
Controller assumption	0.00 °C
Actual probe error	0.00 °C
Potential unnecessary correction	approximately -0.15 °C

If the actual fruit pulp temperature later becomes **+1.00 °C**, the system could indicate approximately **+0.85 °C**, subject to the controller's actual calibration algorithm, internal resolution, offset quantization and rounding rules.

> **A calibration that is successfully accepted and completed by the controller is not necessarily an accurate calibration if the temperature reference used to perform that calibration was incorrect.**

The controller can correctly calculate a correction based on the information available to it, but it cannot independently determine whether the assumed **0.00 °C reference itself is correct**.

6. Controller Resolution and Rounding

Displayed resolution and internal measurement resolution should not be assumed to be the same.

For example, **if** a controller internally measures temperature with greater resolution but displays the result rounded to the nearest **0.1 °C**, display rounding alone could produce a difference of up to approximately **±0.05 °C** between the underlying value and the displayed value.

This ±0.05 °C figure applies only when the controller actually rounds to the nearest 0.1 °C. Other controllers may use different internal resolutions, quantization steps, truncation methods or display algorithms.

Therefore, a displayed value close to an acceptance threshold should be interpreted with care.

Where a calibration result is disputed, the following should ideally be established from the controller manufacturer's documentation:

- Internal measurement resolution.
- Display resolution.
- Offset resolution or quantization.
- Rounding or truncation method.
- Exact calibration acceptance criterion.

7. Reference Thermometer and Ice-Bath Procedure

The actual reference condition should be verified using a suitable calibrated thermometer whose measurement uncertainty is small relative to the calibration acceptance limits being evaluated.

For high-quality technical verification of USDA probe calibration, recommended measurement capability would include:

- **Resolution:** 0.01 °C or better.
- **Expanded uncertainty at 0 °C:** approximately ±0.05 °C or better.
- **Calibration:** valid and traceable to an appropriate national or internationally recognized metrology standard.

These values are recommended measurement capabilities and should **not** be interpreted as universal USDA regulatory requirements.

Recommended Ice-Bath Practice

A high-quality ice-point reference should be prepared and maintained using recognized metrological practices, such as those described in **ASTM E563-22, Standard Practice for Preparation and Use of an Ice-Point Bath as a Reference Temperature**.

1. Use clean, finely divided ice prepared from distilled or deionized water.

2. Use clean water of the same quality to fill the spaces between the ice particles without creating a substantial free-water layer.

3. Allow sufficient time for thermal equilibrium to be established before taking measurements.

4. Maintain a dense ice-water mixture around the measurement zone.

5. Position the USDA probes and reference thermometer at an adequate immersion depth.

6. Position the reference thermometer close to the USDA probe tips so that both are measuring substantially the same thermal environment.

7. Avoid contact between the sensing elements and the walls or bottom of the container.

8. Verify that the reference temperature is stable before recording probe readings or initiating calibration.

9. During extended testing, maintain the ice-water mixture and remove excess water if necessary.

The objective is not merely to place the probes in a container containing ice and water.

> **The objective is to establish and maintain a valid and known 0.00 °C reference condition at the location of the probe sensing elements.**

8. Minimum Calibration Record

Each calibration should be documented sufficiently to allow any subsequent deviation to be distinguished between the probe, the reference bath and the controller. The following information is recommended:

Field	What to record
Date and time	Start and completion of the calibration
Location and operator	Test location, container identification and person performing the calibration
Controller	Manufacturer, model, serial number and software/firmware version
Reference thermometer	Manufacturer, model, serial number, calibration certificate identification and calibration due date
Reference temperature	Actual reference-thermometer reading during the probe measurements
Probe identification and readings	Identification and indicated temperature of each USDA probe before calibration
Calibration result	Accepted or rejected status for each probe and, where available, the offset determined or stored by the controller
Bath preparation	Type of water and ice used, preparation method and stabilization period

This information makes it possible to determine later whether an observed discrepancy originated from the **probe, the controller or the temperature reference**.

Conclusion

Probe acceptance and calibration accuracy are separate issues.

The controller's calibration acceptance window determines whether the calibration procedure is permitted to proceed.

The accuracy of the **0.00 °C reference** determines whether the resulting calibration is valid.

An incorrect or unverified ice-bath reference can therefore produce two distinct effects:

1. **Acceptance/rejection error:** It can cause a probe that is actually within the permitted calibration range to be rejected or, depending on the direction of the bath error, mask an error in a probe that would otherwise fall outside the permitted range.

2. **Calibration error:** For probes that are successfully calibrated, the reference-bath error may become incorporated into the stored calibration offset and subsequently affect the indicated fruit pulp temperature during the cold treatment.

For this reason, before an observed temperature deviation is attributed entirely to a USDA probe, **the actual reference temperature at the time of the test should be independently measured with a suitable calibrated reference thermometer and documented.**

Key Principle

> **The controller can correct a probe offset, but it cannot correct an unknown error in the temperature reference used to determine that offset.**

Technical note intended for general engineering and metrology guidance. Controller-specific calibration criteria should always be verified against the applicable manufacturer's documentation and current regulatory requirements.