Test Procedure for

VERIFICATION OF CALIBRATION AND STANDARDIZATION OF TEMPERATURE MEASURING DEVICES

TxDOT Designation: Tex-926-K

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1. SCOPE

1.1 This test procedure covers the verification of calibration and standardization of temperature measuring devices. Part I covers the initial visual inspection and is required for all temperature measuring devices, Part II covers the verification of calibration of reference liquid-in-glass thermometers, and Part III covers the standardization of non-reference liquid-in-glass thermometers and digital contact thermometers, including thermocouples using high precision calibration baths.

Note 1- Few thermometers are absolutely accurate. The value of errors may vary over the range of the thermometer.

Caution 1-This procedure may use hot liquids and equipment that will cause burns if improperly handled. Hot oils also can emit harmful vapors, it is the individual's responsibility to address ventilation and engineering controls. Most liquid-in-glass thermometers contain mercury. Mercury fumes may be hazardous when the thermometer is broken. This procedure does not address safety issues related to working with mercury. It is the responsibility of the individual performing these tests to use appropriate procedures and safety equipment.

1.2 The values given in parentheses (if provided) are not standard and may not exactly match mathematical conversions. Use each system of units separately. Combining values from the two systems may result in nonconformance with the standard.

2. REFERENCES

2.1 **AASHTO R 18** Standard Recommended Practice for Establishing and Implementing a Quality Management System for Construction Materials Testing Laboratories.

2.2 **ASTM E 1** Standard Specification for ASTM Liquid-in-Glass Thermometers.

2.3 **ASTM E 77** Standard Test Method for Inspection and Verification of Thermometers.

2.4 **ASTM E 563** Standard Practice for Preparation and Use of an Ice-Point Bath as a Reference Temperature.

2.5 **ASTM E 220** Standard Test Method for Calibration of Thermocouples by Comparison Techniques.

2.6 **ASTM E 230/E230M-17** Standard Specification for Temperature-Electromotive Force (emf) Tables for Standardized Thermocouples.

2.7 **ASTM E 2623-14** Standard Practice for Reporting Thermometer Calibration.

2.8 **ASTM E 344** Terminology relating to Thermometry and Hydrometry.

2.9 **NIST PUBLICATION 819-** A Procedure for the Effective Recalibration of Liquid-in-Glass Thermometers.

3. TERMINOLOGY

3.1 **Bulb.** The bulb of a liquid-in-glass thermometer is a reservoir for the thermometric liquid.

3.2 **Calibration.** The process of determining the estimated measurement of uncertainty and comparing the measured values of a thermometer to the values assigned to the reference thermometer.

3.3 **Digital Contact Thermometer.** A device that measures temperature through direct contact with a sensor and provides a digital output or display of the determined value, or both.

3.4 **Electronic Thermometer.** An instrument that provides a display of a temperature sensed using a transducer and electronic circuitry.

3.5 **Fixed Point.** In thermometry, it is a reproducible temperature of equilibrium of two or more phases under specified conditions.

3.6 **Ice Point.** Thermometric fixed point of ice and water saturated with air at a pressure which is 0°C.

3.7 **Liquid-In-Glass Thermometer.** It is a temperature measuring instrument whose indications are based on the temperature coefficient of expansion of a liquid relative to that of its containing glass bulb.

3.8 **Measurement of Uncertainty.** A numerical representation of the dispersion of values attributed to a measured quantity.

3.9 **Partial Immersion Thermometer.** It is a liquid-in-glass thermometer designed to indicate temperatures correctly when the bulb and a specified part of the stem are exposed to the temperatures being measured.

3.10 **Reference Thermometer**. High accuracy thermometer that are ideal for checking the accuracy of temperature testing equipment, such as other thermometers, dataloggers, ovens, etc.

3.11 **Standardization.** A process that determines (1) the correction to applied to the result of a measuring instrument, measuring system, material measure, or measurement standard when its values are compared with the values realized by standards, or (2) the adjustment to be applied to a piece of equipment when its performance is compared with that of an accepted standard or process.

3.12 **Stem.** It is a capillary tube through which the meniscus of the thermometric liquid moves with change of temperature.

3.13 **Thermocouple.** In thermometry, the sensor of a thermoelectric thermometer, consisting of electrically conducting circuit elements of two different thermoelectric characteristics joined at a junction.

3.14 **Tolerance.** It is the defined limits of allowable deviation from a standard in a measured quantity or other value such as temperature, relative humidity, resistance, and so forth; when the term is used for a measurement instrument or system, it refers to the permitted variation of a measured value from the correct value.

3.15 **Total Immersion Thermometer.** A liquid-in-glass thermometer designed to indicate temperatures correctly when just that portion of the thermometer containing the liquid is exposed to the temperature being measured.

3.16 **Unit Under Test (UUT).** Instrument being calibrated.

3.17 **Verification of Calibration.** A process that establishes whether the results of a previously calibrated measurement instrument, measurement system, or material measure are stable.

4. APPARATUS

4.1 **Beaker.**

4.2 **Crushed Ice.**

4.3 **Dewar or Thermally Insulated Vessel.**

4.4 **Dry Ice.**

4.5 **Gloves.**

4.6 **High Precision Calibration Bath.**

4.7 **Magnifying Lens, of at least two-power.**

4.8 **Reference Thermometers.**

4.9 **Rubbing Alcohol.**

4.10 **Safety Glass.**

5. PART I – PRELIMINARY VISUAL INSPECTION (REQUIRED FOR ALL TEMPERATURE MEASURING DEVICES)

5.1 LIQUID IN GLASS THERMOMETERS.

5.1.1 Use a magnifying lens of at least two-power to examine the thermometer for cracks or breakage to determine its condition.

5.1.2 Examine the entire length of the capillary tube to verify that there are no separations in the liquid column or filled chamber.

5.1.3 Examine all empty chambers to verify that no liquid remains in them.

Note 2- Either improper use or dropping can cause a break in the liquid column or mercury left in a chamber. When using multiple chamber liquid-in-glass thermometers, use in a vertical position.

If separation was found, there are three methods to rejoin the liquid in the column. Perform these methods carefully to prevent personal injury or breaking the thermometer:

5.1.3.1 **Method A** – Attempt to force the liquid together by tightly holding the thermometer while slinging it in a circle and jerking to a stop.

5.1.3.2 **Method B** – Holding the thermometer upright, slowly, and gradually immerse only the bulb of the instrument into a solution of dry ice and alcohol contained in a beaker. During this gradual insertion, the mercury should begin to solidify. Be careful to not immerse the stem or column of the thermometer into the cooling solution or allow the mercury to freeze as that can cause the bulb to fracture. If necessary, moving the bulb in and out of the solution many times can slow down and better control the cooling action. When all the separated portions have been brought into the bulb, take the thermometer out of the container, and swing it in a short arc to force the mercury into the bulb.

5.1.3.3 **Method C** – Immerse the bulb and stem into the heated liquid and stir with the thermometer until the separation and part of the main column just begin to enter the expansion chamber. The expansion chamber should never be more than two-thirds full. Once the fluid is in the chamber, remove the thermometer from the beaker and hold it upright vertically. Gently tap it into the palm of your gloved hand to reunite the column. Allow the thermometer to cool slowly.

Caution– Never use an open flame, as the thermometer will almost always break. When heating, the technician must use safety equipment including gloves and face protection.

5.1.4 Allow the thermometer to equalize to the rooms ambient temperature for at least 72 hours before performing standardization or verification of calibration.

5.2 DIGITAL CONTACT THERMOMETERS.

5.2.1 Examine the device, probe, and lead wires for damage.

5.2.2 Ensure that the leads or probe are properly connected to the device.

5.2.3 Be certain that the batteries are adequately charged to avoid any errors in the display.

5.2.4 Turn on the device and ensure that the readings on the display are satisfactory compared to the working environment and make sure the reading is stable in the display.

5.2.5 Verify that the thermocouple and the connector are of the same type and ensure that the appropriate selection is also made in the device to get accurate reading.

EXAMPLE: If the thermocouple is a 'K' type, ensure that device is set to 'K' Type and the lead connector is of the same type as well.

5.2.6 In the case of a digital contact thermometer, both the leads or probe and the device is considered one single unit. If the leads, probe, or the device fail inspection, they must be repaired or replaced before proceeding.

6. PART II – VERIFICATION OF CALIBRATION OF REFERENCE LIQUID-IN-GLASS THERMOMETERS USING ICE POINT

6.1 The unit under test (UUT) must be a mercury-in-glass thermometer with a calibration certificate traceable to NIST.

6.2 The ice-point bath described by this practice consist of an intimate mixture, without voids of pure shaved ice or ice particles and distilled water in a thermally insulated vessel opened to the atmosphere. The ice-point bath prepared for this practice typically has a temperature of 0.000°C ± 002°C at a barometric pressure of 101,325 Pa.

6.3 Select clear pieces of ice or ice made from distilled or pure water. Discard any cloudy or unsound portions. Rinse the ice with distilled water and shave or crush into pieces no larger than 1/2 in diameter.

6.4 Fill the Dewar vessel or insulated flask with crushed ice and add enough distilled, (preferably precooled) water to form a slush, but not enough to float the ice. As the ice melts, it will be necessary to drain or remove some of the water and add more crushed ice. Constantly stir the ice and water to maintain uniform distribution.

6.5 Do not allow clumps of ice or water pockets to form. When ice particles clump together, the water between them freezes, and the temperature drops. If a pocket of water forms, the temperature in it will rise. A water and ice cube mixture will not cool the water between the cubes sufficiently.

6.6 Do not allow a thermometer or temperature sensor in the bath to touch any part of the bath wall or any other thermometer or sensor. For partial immersion liquid-in-glass thermometers, immerse to the immersion line or stated immersion depth. For total immersion liquid-in-glass thermometers, immerse to the 0°C (32°F) mark. Avoid the zone at the bottom where denser melted water tends to accumulate.

6.7 Suspend each thermometer from above and hold at the proper immersion depth. It will be easier to read the liquid column of a glass thermometer if the container is almost full.

6.8 Constantly stir the bath to distribute the ice particles and water uniformly.

6.9 Allow the thermometer or sensor to stabilize at the temperature of the bath a minimum of 3 min.

6.10 Read the thermometer, wait at least 1 minute, and read again. If the two consecutive readings are not within one tenth of a division repeat the step.

6.11 Record the indicated value.

6.12 Find the error by subtracting the ice point (0°C [32°F]) from the indicated value. The correction has the same numerical value as the error but with opposite sign. Also adding the correction with the indicated temperature must equal the true temperature.

EXAMPLE: The true temperature is 32°F and the indicated temperature is 31.6°F; the thermometer reads low with an error of -0.4°F, so the correction to be applied at that point is +0.4°F.

6.13 When the indicated value from 6.11 is different than the indicated ice point temperature in the original calibration document, the difference should be calculated. This value should be annotated as the correction due to change in ice point. This value should be added to all the corrections from the original calibration certificate to compensate for changes and determine the true temperature.

EXAMPLE: Consider Table 1 below.

Table 1
Correction Due to Change in Ice Point Example

True Temperature	Original Indicated Temperature	Original Correction	Correction Due to Change in Ice Point	New correction (Original correction + Correction Due to Change in Ice Point)	New Indicated Temperature
32.00°F	32.15°F	-0.15°F	0.15°F	0.00°F	32.00°F
300.00°F	300.10°F	-0.10°F	0.15°F	0.05°F	299.95°F
340.00°F	340.00°F	0.00°F	0.15°F	0.15°F	339.85°F
370.00°F	370.05°F	-0.05°F	0.15°F	0.10°F	369.90°F
400.00°F	400.25°F	-0.25°F	0.15°F	-0.10°F	400.10°F

6.14 If the ice point verification reveals that the ice point varies by more than the maximum allowable scale error identified in ASTM E1, document the thermometer as failed.

7. PART III – STANDARDIZATION OF NON-REFERENCE LIQUID-IN-GLASS THERMOMETERS AND DIGITAL CONTACT THERMOMETERS, INCLUDING THERMOCOUPLES

7.1 This procedure is a comparison of the test thermometers to a reference thermometer utilizing a controlled temperature bath and must be executed every 12 mo. The temperature points for testing mercury liquid-in glass thermometers can be found in ASTM E1. The temperature points for testing thermocouple must be no more than every 100°F covering the range of laboratory use.

7.2 Set the calibration bath at the lowest temperature to be tested.

7.3 For mercury liquid-in-glass thermometers suspend the thermometer to the required immersion depth in the bath. For digital contact thermometers support the electronic sensors by the sheath or wire leads. Immerse sheathed sensors to just short of the leads. Ensure leads do not touch the bath walls, if testing multiple leads ensure leads do not touch each other.

7.4 View the mercury liquid-in-glass thermometers using a magnifying lens perpendicular to the level of mercury, to reduce parallax. The bath is stable when two consecutive readings, a minimum of 30 sec. apart, on the reference thermometer are equal.

7.5 Read the reference thermometer, then the test thermometer and then the reference thermometer again. If the reference thermometer temperature did not change, record the temperature of each thermometer.

7.6 To calculate the true temperature from the reference thermometer indicated temperature apply the correction available from the latest calibration or standardization certificate.

7.7 Record the true temperature and the test thermometer indicated temperature. Calculate the error at each point by subtracting true temperature from the indicated temperature of the test thermometer. Record the errors.

7.8 The correction has the same numerical value as the error but with the opposite sign. Record the correction for each calibration temperature.

EXAMPLE: True temperature is 100.0°F, indicated temperature is 100.8°F, the thermometer reads high, and the error is 0.8°F. The correction to be applied at this temperature is -0.8°F. [100.8°+(-0.8°) =100.0°F]

7.9 If the error is more than the tolerance specified in ASTM E1 Table 3 for mercury liquid-in-glass thermometers or more than the tolerance specified in Table 2 shown below for thermocouples, record the thermometer as fail, set the bath to the next calibration temperature and repeat the above steps.

7.10 Consider Table 1 regarding the tolerances for thermocouples and digital contact thermometers. The temperature points used to standardize the mercury in glass thermometers used at similar range may be used for the digital in contact thermometers.

Table 2
Tolerance of Thermocouple

Thermocouple Type	Temperature Range		Standard Tolerance	
	°C	°F	°C	°F
T	0 to 370	32 to 700	The greater of ±1.0 °C or ±0.75 %	The greater of ±1.8°F or ±1.35% of the temperature being measured
J	0 to 760	32 to 1400	The greater of ±2.2 °C or ±0.75	The greater of ±3.96°F or ±1.35% of the temperature being measured
K or N	0 to 1260	32 to 2300	The greater of ±2.2 °C or ±0.75 %	The greater of ±3.96°F or ±1.35% of the temperature being measured

8. CERTIFICATE OF STANDARDIZATION

The certificate must include the following data:

- make, model, type, serial number, location, and temperature range of the unit under test,
- name of the technician performing the task,
- date and location where the procedure was performed,
- details of the reference thermometers and test temperatures used, and

- reading of the unit under test, true temperature, and correction.

9. CERTIFICATE OF VERIFCATION AT ICE POINT

The certificate must include the following data:

- make, model, type, serial number, location, and temperature range of the unit under test,
- name of the technician performing the task,
- date and location where the procedure was performed,
- date of calibration,
- test number or report number in the calibration document, and
- correction at 0°C or 32°F from the calibration document.