New Thermometer Guidance Document from AASHTO Accreditation Program

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Asphalt Binder ETG Meeting

May 10, 2018

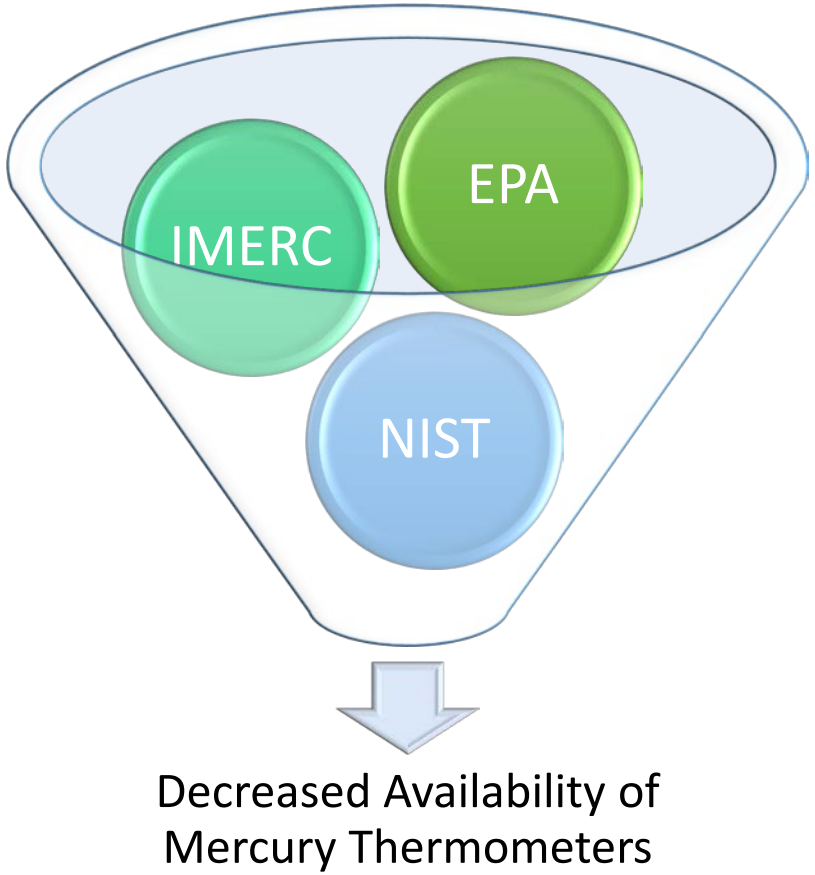
AASHTO re:source (formerly AMRL)

Background

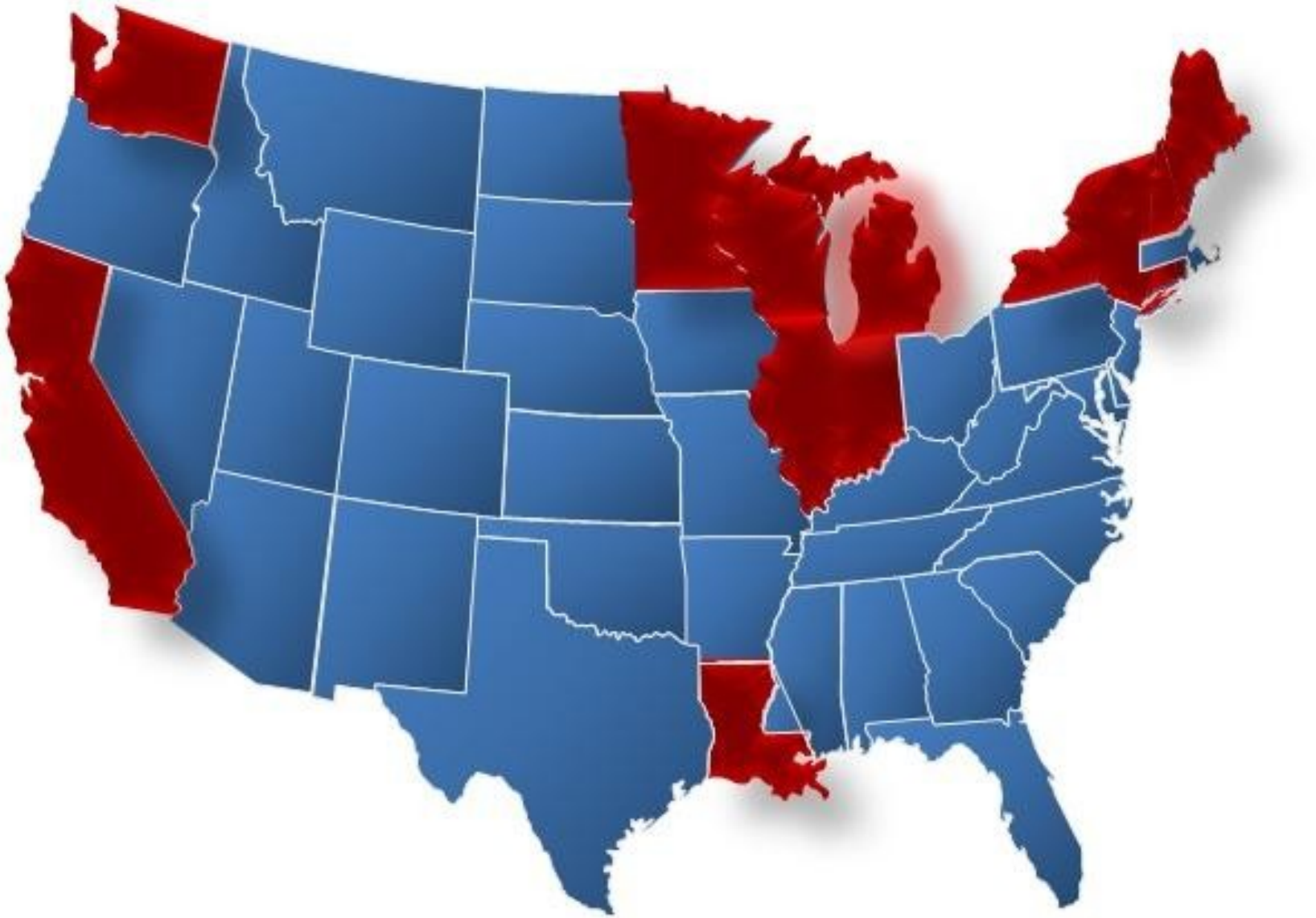
- Mercury reduction initiatives have hastened the need to find suitable replacements.
- Misconceptions exist about digital thermometers.

Mercury Reduction Initiatives

- Interstate Mercury Education and Reduction Clearing House (IMERC)
- Pressure from EPA
- NIST ceased calibration services for mercury thermometers in March 2011.



States With Mercury Thermometer Restrictions



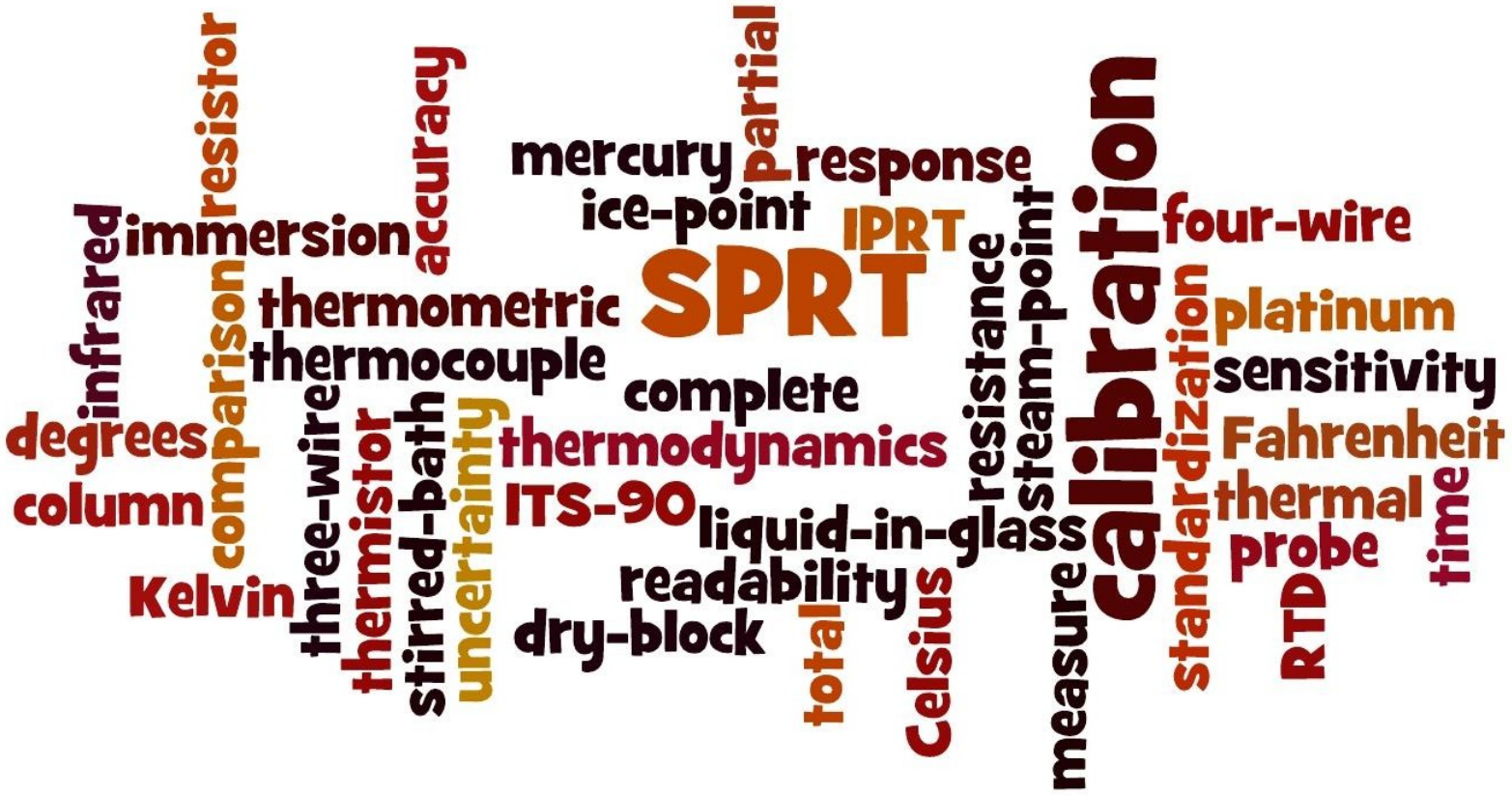
LET'S GET DIGITAL

Unraveling the Tangled World of Digital Thermometers

Type of Device	How Much?	Uncertainty	Durability	Range of Use	Benefits	Downfalls
STANDARD PLATINUM RESISTANCE THERMOMETERS	$6,000 or More	Excellent To Within 0.0001°C	Low	-200°C to 650°C	• Highly Accurate	• High Cost • Susceptible to Damage • Readings tend to drift
INDUSTRIAL PLATINUM RESISTANCE THERMOMETERS	$200 to $2000	Good 0.02 to 0.1°C	Mediocre	-200°C to 650°C	• Great Accuracy • More rugged than SPRT • Reasonable cost	• Somewhat susceptible to damage • Readings tend to drift
THERMISTORS	$200 to $2000	Great 0.01 to 0.1°C	Good	-5°C to 90ºC	• Great Accuracy • Rugged	• Limited Range of use
THERMOCOUPLES	$100 to $1000	Mediocre Over 1°C	Great	-200°C to 1800°C	• Rugged • Low Cost	• Problems with Accuracy • Readings tend to drift
INFRARED THERMOMETERS	$30 to $200	Poor Over 2°C	Fair	-50°C to 1100°C	• Low Cost • Non-Contact Measurement	• Problems with Accuracy • User Error Likely

Background

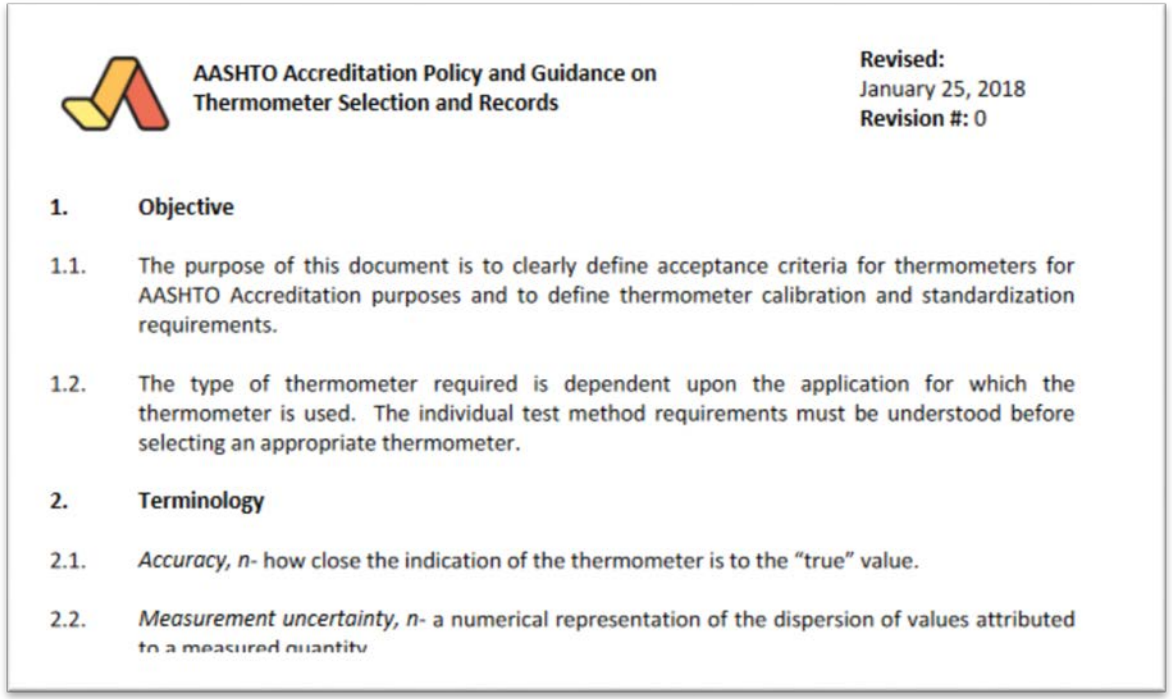
- AASHTO re:source has faced challenges in determining the suitability of mercury alternatives.
- Thermometer Committee established at AASHTO re:source in 2015, lead by Jasmine Gilmore



New Guidance Document

- Policy and Guidance Document recently published- “soft release.”
- Assistance received from thermometry and metrology experts in writing the document.
- Available here:

http://aashtoresource.org/university/document-library



AASHTO Accreditation Policy and Guidance on Thermometer Selection and Records

Revised:
January 25, 2018
Revision #: 0

1. Objective

1.1. The purpose of this document is to clearly define acceptance criteria for thermometers for AASHTO Accreditation purposes and to define thermometer calibration and standardization requirements.

1.2. The type of thermometer required is dependent upon the application for which the thermometer is used. The individual test method requirements must be understood before selecting an appropriate thermometer.

2. Terminology

2.1. *Accuracy, n-* how close the indication of the thermometer is to the “true” value.

2.2. *Measurement uncertainty, n-* a numerical representation of the dispersion of values attributed to a measured quantity

What the Document Covers:

- Terminology
- Requirements for different thermometer types:
  - Liquid in Glass
  - Digital (thermistor, PRT, thermocouple)
  - Infrared
  - Bimetallic (dial stem or spring)

What the Document Covers:

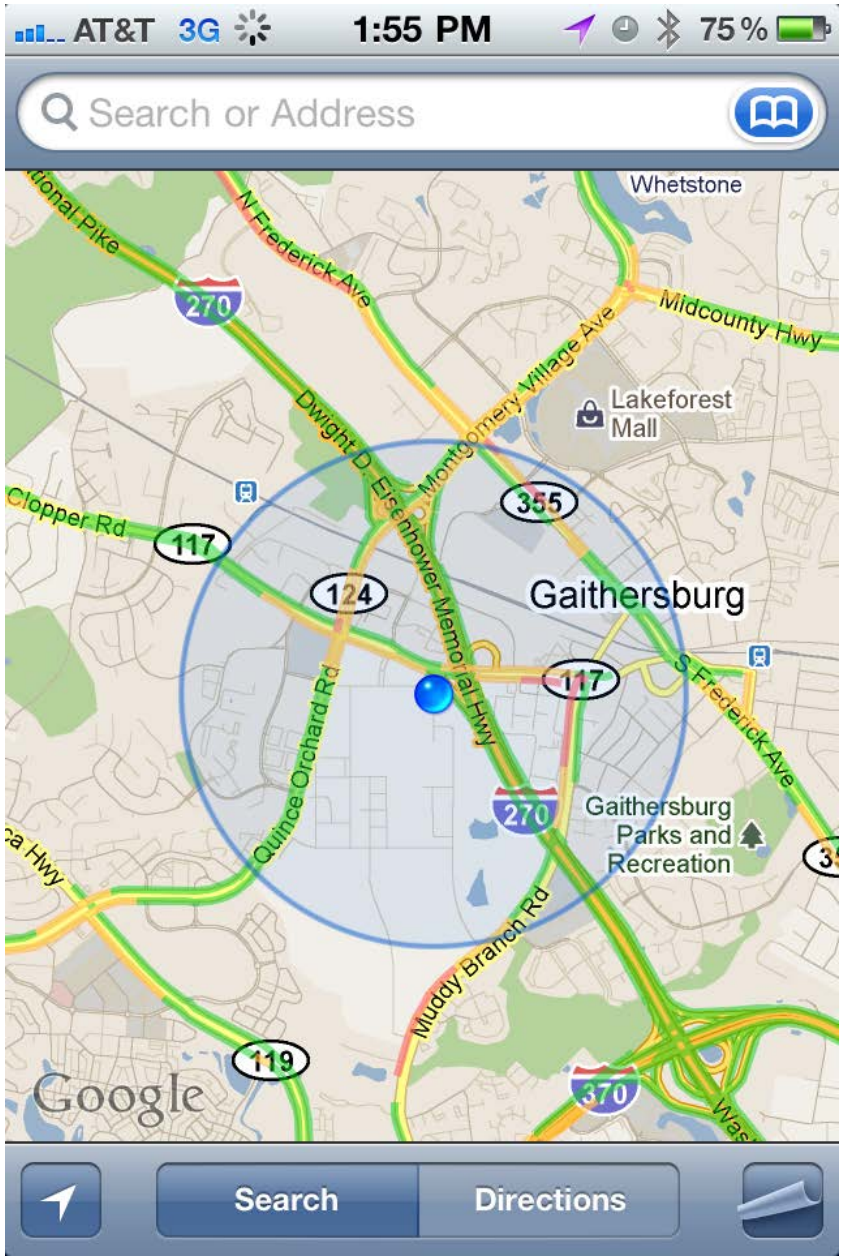
- General requirements and our process for determining suitability
- Requirements specific to Reference Thermometers
- Requirements specific to Working Thermometers
- Calibration and Standardization Requirements

Critical Terms

- Accuracy
- Estimated Measurement Uncertainty

Measurement Uncertainty

- A statement of confidence in the measurements we make.
- See series of articles on AASHTO re:source website (re:University) to learn more.



How is Measurement Uncertainty Different From Accuracy?

Measurement Uncertainty

- How confident we are in the measurement.

We use the estimated measurement uncertainty to determine if our measurement equipment is fit for its intended purpose.

Accuracy

- How close the indication is to the true value.

Accuracy requirement may be defined in a test standard or could be specified by customer or specifying agency.

How Measurement Uncertainty and Accuracy are Related

The estimated measurement uncertainty of your measurement equipment should not exceed the accuracy requirement for the equipment.

- Accuracy requirement may be defined in a test standard.
- Could be determined internally
- Could be specified by customer or specifying agency

This is an important concept!

- We use the estimated measurement uncertainty to determine if our measurement equipment is fit for its intended purpose.

Determining Suitability

Does the thermometer meet the requirements outlined in the standard test method or practice?

When the standard is specific, it is easier…

4.4 *Thermometer*—A thermometer for monitoring the temperature of the water bath. The thermometer shall be one of the following:

4.4.1 A liquid-in-glass thermometer of suitable range with subdivisions and maximum scale error of 0.1°C [0.2°F] which conforms to the requirements of Specification E1. The thermometer shall be standardized in accordance with one of the methods in Test Method E77.

4.4.2 A liquid-in-glass thermometer of suitable range with subdivisions and maximum scale error of 0.1°C [0.2°F] which conforms to the requirements of Specification E2251. The thermometer shall be standardized in accordance with one of the methods in Test Method E77.

4.4.3 A platinum resistance thermometer (PRT) with a probe which conforms to the requirements of Specification E1137/E1137M. The PRT shall have a 3- or 4-wire configuration and the overall sheath length shall be at least 50 mm [2 in.] greater than the immersion depth. The PRT system (probe and readout) shall be standardized in accordance with Test Methods E644. Corrections shall be applied to ensure measurements within 0.1°C [0.2°F].

4.4.4 A metal-sheathed thermistor with a sensor substantially similar in construction to the PRT probe described in 4.4.3. The thermistor system (sensor and readout) shall be standardized in accordance with Test Methods E644. Corrections shall be applied to ensure measurements within 0.1°C [0.2°F].

But Sometimes It’s Pretty Confusing….

Thermometric Device—accurate to 0.1°C (0.2°F). An ASTM 12C thermometer as defined in ASTM E1 is suitable. Any other thermometric device of equal accuracy may be used.

Not All Alternatives to Mercury have Equivalent Accuracy

Policy for digital thermometers:

- AASTHO re:source staff will review documentation from manufacturer to determine the type of digital thermometer presented

- If we are unable to determine the type, the thermometer will be deemed unacceptable.

If We Know What Type of Thermometer It Is…

AASHTO re:source will determine if accuracy is acceptable for the test procedure

Estimated Measurement Uncertainty (EMU)

- If Available
- Preferred
- Must be less than accuracy required

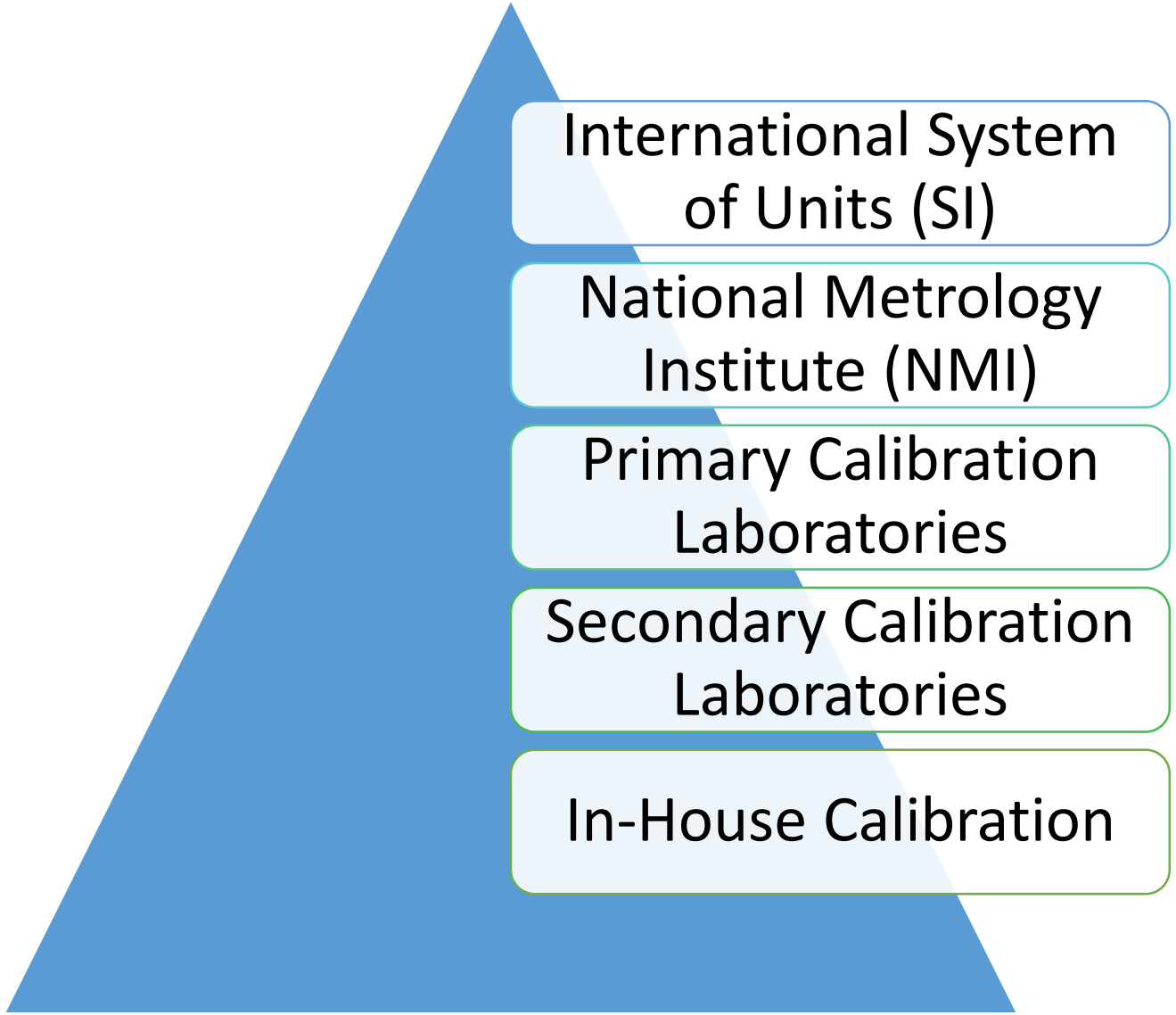
Accuracy Claim By Manufacturer

- If EMU Not Available
- Only if it is *reasonable*
- Some manufacturer's claims are suspect.

Determining if Manufacturer's Accuracy Claim is Reasonable

- These statements are not regulated or verified by a third party
- They are a marketing tool
- Manufacturers are but mere mortals

But We Know What the Best of the Best Can Do



Bureau International des Poids et Mesures (BIPM)

NIST in the U.S.

Commercial Provider

Commercial Provider

Performed in your Laboratory

NIST

BIPM and NIST Published Values

- BIPM Key Comparison Database used for mercury and digital thermometers (except thermocouples type K and N)
- NISTIR 5340 used for Thermocouples type K and N

BIPM Key Comparison Database Values

AASHTO re:source does not accept estimated measurement uncertainty statements or accuracy claims that list values lower than the values listed in the table below.

Type of Device	Measurement Uncertainty
Industrial Platinum Resistance Thermometers (IPRTs), ASTM E1137	0.0023°C
Film-Type Industrial Platinum Resistance Thermometers	0.01°C
Thermistors	0.0018°C
Thermocouples, Type B	0.3°C
Thermocouples, Type E	0.9°C
Thermocouples, Type J	0.7°C
Thermocouples, Type K*	0.02-0.2˚C*
Thermocouples, Type N*	0.02-0.2˚C*
Thermocouples, Type R	0.13°C
Thermocouples, Type S	0.13°C
Thermocouples, Type T	0.4°C
Liquid-in-Glass Thermometer, Hg, Partial, 0.1°C graduations	0.02°C

* Values obtained from NISTIR 5340

NISTR 5340 Values for Type K and N Thermocouples

Temperature (°C)	Measurement Uncertainty
-200	0.4°C
-100	0.2°C
0	0.02°C
100	0.1°C
200	0.2°C
300	0.3°C
400	0.4°C
419.58 (Zn)	0.4°C
500	0.51°C

To Summarize….

How do I know if my thermometer meets the test standard's accuracy requirement?

- If the measurement uncertainty of the thermometer exceeds the requirement for accuracy in the standard, that thermometer cannot be used for the application.
- If the estimated measurement uncertainty is not available, then a statement of accuracy listed by the manufacturer will be reviewed in lieu of the measurement uncertainty and will be compared to the KCDB or NISTIR 5340.
- We will use whichever is greater between the manufacturer's stated accuracy or the value stated on the KCDB or NISTIR 5340.

See examples on next slide

Accuracy Requirements for Test Thermometers- Example 1

Bulk Specific Gravity (D2726) Accuracy Requirement:

0.5°C (1°F)

Thermometer 1	
Thermometer Type:	Thermistor
Manufacturer's Accuracy Statement:	1.0°C
Estimated Measurement Uncertainty on Calibration Record	0.5°C
Does it Meet?	**Yes**; although the manufacturer's accuracy claim exceeds the test standard's requirements, the estimated measurement uncertainty meets the requirements.

Accuracy Requirements for Test Thermometers- Example 2

Bulk Specific Gravity (D2726) Accuracy Requirement:

0.5°C (1°F)

Thermometer 2	
Thermometer Type:	Thermistor
Manufacturer's Accuracy Statement:	1.0°C
Estimated Measurement Uncertainty on Calibration Record	Not documented on calibration record
Does it Meet?	**No**; because the estimated measurement uncertainty is not listed on the calibration record, therefore the decision is based on the accuracy statement provided by the manufacturer.

Requirements for Reference Thermometers

What is a Reference Thermometer?

The thermometer used to calibrate or standardize other thermometers that are used for daily testing by a laboratory.

If you choose to calibrate equipment in-house, there are special requirements for your reference thermometer.

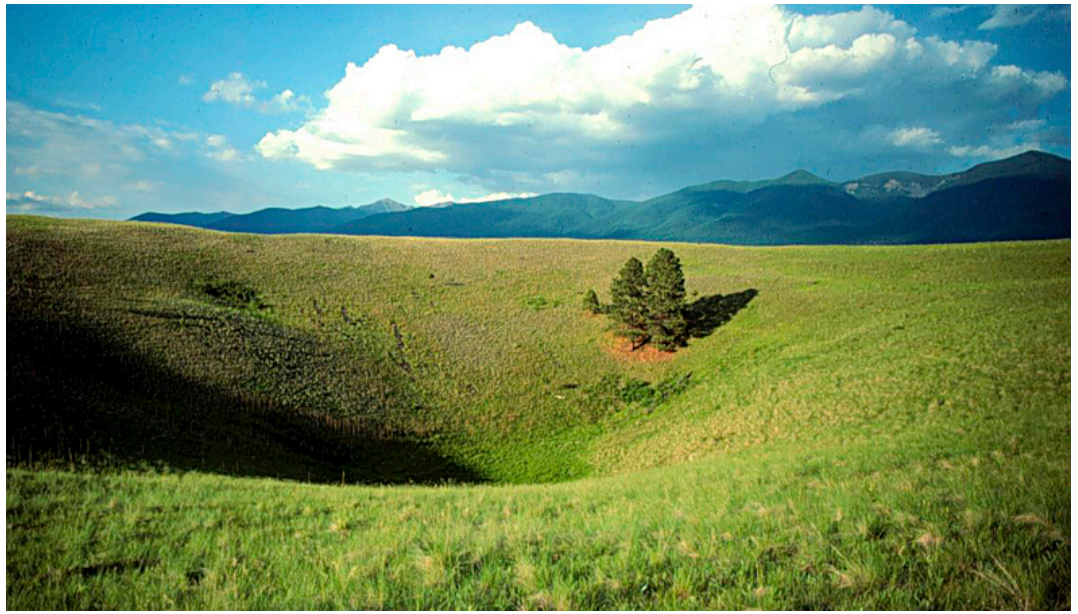
Selecting a Reference Thermometer

Must be:

- Mercury LiG
- Thermistor
- Platinum Resistance Thermometer (PRT)
- Thermocouple (in rare cases)

Range of Use of the Reference Thermometer

- The range of the reference thermometer must encompass the range of temperatures used in the testing lab.



Readability of the Reference Thermometer

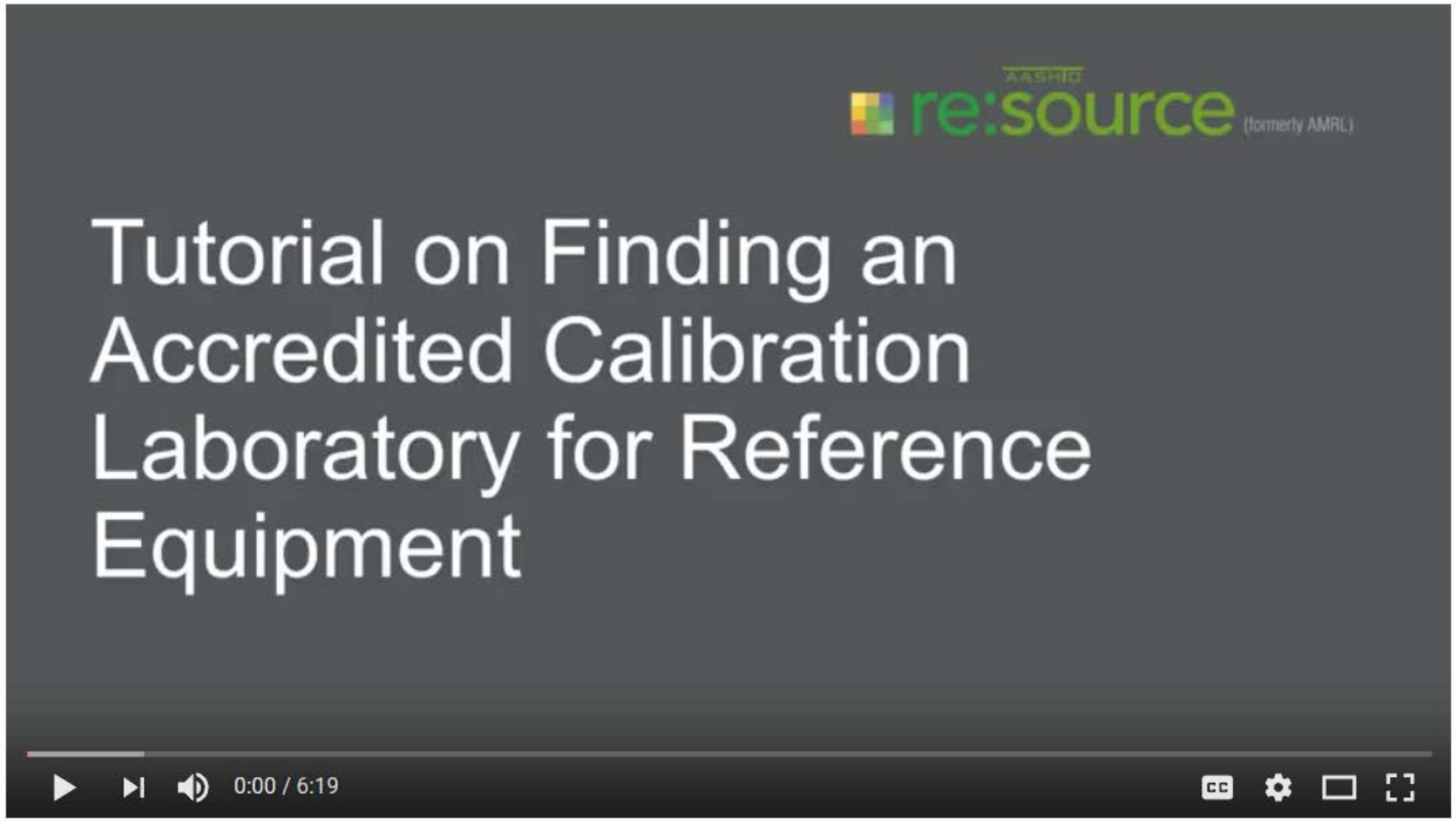
Must be the same as, or preferably better than, the testing thermometer that is being standardized.

Example: A thermistor with a readability of 0.1 C° cannot be used to calibrate a PRT with a readability of 0.01°C).

Documentation Required for Reference Thermometers

- Must be calibrated by an agency accredited for ISO/IEC 17025 for thermometer calibration.
  - Be sure to ask your calibration provider for an accredited calibration.
- An estimate of measurement uncertainty must be stated on the calibration record.

More Info on Finding an Accredited Calibration Provider – Check out our YouTube Channel



Measurement Uncertainty Requirements of the Reference Thermometer

- The estimated measurement uncertainty of the reference thermometer shall be less than or equal to half of the required accuracy of the working thermometers.
- This is a Test Uncertainty Ratio (TUR) of 2:1
- This is a lenient requirement; typically 4:1 is required

Example: If the accuracy required in a test method for the thermometer is 0.1°C, the reference thermometer must have an measurement uncertainty 0.05°C or less.

Can I Use My Reference Thermometer for Testing Too?

- No.
- Reference thermometers shall not be used as testing thermometers.
- When thermometers are used regularly, the risk of drift caused by mishandling increases greatly.

Calibration Interval for Reference Thermometers

- Must be calibrated at least every 3 years.
  - Some test methods may require shorter intervals. Use whichever interval is smaller.
- Mercury thermometers can be calibrated once, and then the calibration verified at the ice-point thereafter.

AASHTO Accreditation Program Calibration and Standardization Requirements for Thermometers

Calibration Requirements for Thermometers

- This guidelines apply to both reference thermometers and working thermometers.
- The same guidelines apply if the thermometer is calibrated in-house as if it is calibrated by an outside agency.

Calibration may be done by:

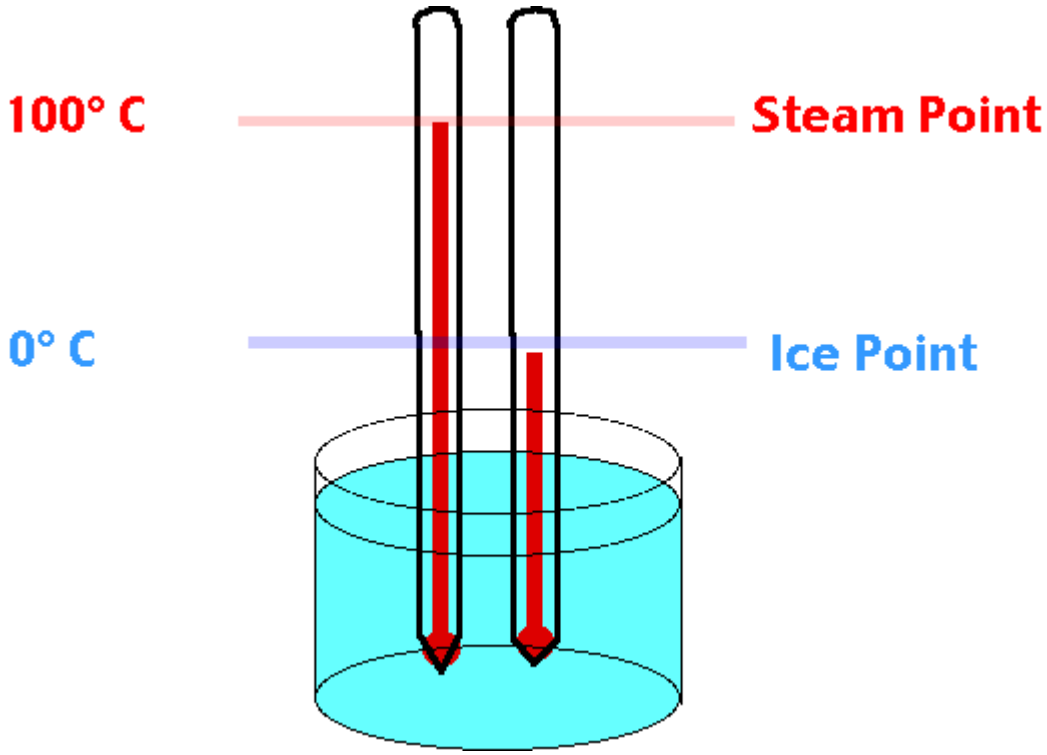
- Fixed Point Method (expensive, rare)
- Comparison (Thermodynamic)

Electrical Simulation

- A process whereby an electrical device is used to simulate temperature measurement.
- A correlation between temperature and electromotive force is used.
- An electrical signal is sent to the thermometer and the thermometer outputs the correlating temperature.
- The AASHTO Accreditation Program does not allow the use of electrical simulation as a means of calibration.

Verification of Calibration at Ice and Steam Points

- May be used in some to verify the calibration of a thermometer that has been previously calibrated.
- The AASHTO Accreditation Program only allows this for mercury thermometers.



Number of Calibration Points

If the thermometer is only used to measure temperatures at one point

- The thermometer may be calibrated at that point only.
- If the thermometer is calibrated at two or more points, one of the points must be within 20°C of the points that the thermometer is used at.

Number of Calibration Points

If the thermometer is used over a wide range of more than two temperatures, the calibration depends upon the type of thermometer.

LiG	• Minimum of 2 points bracketing range of use. • If E77 is required, no more than 100 scale divisions between test points.
Thermistors	• Every 20°C over the range of use.
PRTs & Thermocouples	• A minimum of two points bracketing the range of use. • For ranges over 100°C, at least 3 test points must be included.

Cheat Sheet

"Cliff Notes" version

AAP Policy and Guidance on Thermometer Selection and Records Cheat Sheet

General

- Thermistors only accepted for use within the range of -50 to 120°C
- Accuracy statements will be compared to the KCDB and NIST IR 5340 values and will not be accepted if it is lower than these values

Reference Thermometers

- Reference thermometers must be: Mercury-in glass, Thermocouples, Thermistors, PRTs -**No alcohol thermometers**
- Standardized working thermometers can standardize ovens and be used for volume determinations
- Readability must be equal or better than the working thermometers
- TUR must be 2:1 (The estimated measurement uncertainty of the reference thermometer must be less than or equal to one-half the accuracy required of the working thermometers), unless already defined in the test standard
- Must be calibrated at least every 3 years
- Must be calibrated by an ISO/IEC 17025 accredited agency
- The estimated Measurement Uncertainty must be on the calibration record
- Thermodynamic calibration only (no electrical simulation)- *This only applies to digital thermometers*
- Must be calibrated as one unit (probe attached to CPU)- *This only applies to digital thermometers*
- Systematic error must be documented on calibration or standardization
- Thermistors must be calibrated or standardized every 20°C throughout and bracketing the range of use.
- Platinum resistance thermometers and thermocouples must be calibrated at a minimum of two points bracketing the range of use. For ranges over 100 °C, at least 3 test points shall be included
- Liquid-in-glass thermometers must be calibrated or standardized at a minimum of two points bracketing the range of use

Working Thermometers

- Working thermometers must be: liquid-in-glass, bi-metallic (Dial thermometers), thermistors, PRTs, thermocouples -**No Infrared**
- Can be either calibrated or standardized
- Thermodynamic calibration or standardization only (no electrical simulation)- *Digital thermometers*
- Must be calibrated or standardized as one unit (probe attached to CPU)- *This only applies to digital thermometers*
- Systematic error must be documented on calibration or standardization record
- Can be used to standardize ovens and volume determinations -**No EMU required**
- Manufacturer's accuracy statement must be equal or less than the accuracy of the test method
- If the systematic error exceeds the accuracy requirement of the test method, the laboratory must apply a correction to their readings.
- Platinum resistance thermometers and thermocouples must be calibrated at a minimum of two points bracketing the range of use. For ranges over 100 °C, at least 3 test points shall be included
- Thermistors must be calibrated or standardized every 20°C throughout and bracketing the range of use

Advice for Standards Developers

- Be specific
- Band-aid wording is confusing and makes compliance difficult

Advice for Standards Developers

- Call out particular types of thermometers when possible

Maria can help!

mknake@aashtoresource.org

Use Caution When Specifying Accuracy

- Consider requiring an outside calibration and a measurement uncertainty requirement for
  - Reference thermometers
  - In cases where high-level measurements are required

- Avoid using readability and accuracy interchangeably, they are not the same.
  - A device that can be read to several hundredths of a degree is not necessarily accurate to even 1 degree.

Keep in Mind How an Auditor will Interpret

What would AASHTO re:source do?

Statements of Traceability

~~"Traceable to NIST"~~

~~"NIST Traceable~~

"Traceable to the International System Of Units"

What's Next?

- Revise current Policy and Guidance document based on member, customer, and staff feedback.
- Publish a table that lists what type of thermometers we will accepted for each standard in our available scope of accreditation.

Additional Resources

- AASHTO re:source website
- AASHTO re:source Technical Exchange – March 2019
- NSCLI International
- BIPM
- NIST Thermometry Guides
- ASTM Standards from Committee E20
- ASTM D8055 Standard Guide for Selecting an Appropriate Electronic Thermometer for Replacing Mercury Thermometers in D04 Road and Paving Materials
- *Isotech Journal of Thermometry* (Henry Sostmann)
- Thermometer article series, *Where's the "On" Button?* by Mary-Stroup Gardiner

Wrap-Up and Questions

- Please give us feedback on this Policy and Guidance Document.
- Let us know what is not clear and how to improve it.
- We can help with thermometer wording to avoid unforeseen issues with enforcement and compliance.

AASHTO re:source (formerly AMRL)