CMC review protocol for calibration of industrial thermometers

Scope

To provide a method of reviewing thermometry CMCs in the sub-field of industrial thermometry for acceptance in Appendix C of the KCDB. Covers service category numbers 2.2, 2.3, 2.4, 2.6, and 2.7 of the "CMC Service Categories for Temperature and Humidity (October 2009)" in the KCDB.

This protocol for the review of industrial thermometer CMCs supersedes the version of 1 November 2006.

Guidelines to RMOs for review of CMCs. CMCs smaller than the "flagging criteria" below are to be examined by the RMO, based on the suggested scrutiny elements.

Participation in an RMO Supplementary Comparison is desirable.

Secondary fixed point cells (service category 2.1)

See "High temperature secondary fixed point cell" protocol.

Rhodium-Iron Resistance Thermometers (service category 2.2.1)

No review criteria yet.

Industrial PRTs, thermistors and other resistive thermometers (service categories 2.2.2 and 2.2.3)

CMC entry to specify if the uncertainty applies to an interpolation equation or at the measurement points only, and whether a nominal value of hysteresis is included in the CMC estimate.

Conditions flagging RMO review

Calibration in liquid baths or heatpipes:	$U(k=2) < 4\ \text{mK} + 0.006\%\lvert t\rvert$	(i.e. 0.01 K at 100°C).
Calibration in furnaces and blocks:	$U(k=2) < 20\ \text{mK} + 0.1\%\lvert t\rvert$	(i.e. 0.12 K at 100°C).
For thermistors:	$t < -50$ °C or $t > 100$ °C.	

Scrutiny elements, if flagged

Method of evaluating hysteresis (ice point alone is insufficient for the smallest uncertainties).

Thermocouples (service category 2.3)

CMC entry to specify if the uncertainty applies to an interpolation equation or at the measurement points only, and whether a nominal value of thermoelectric inhomogeneity is included in the CMC estimate.

Conditions flagging RMO review

Base metal: $U(k=2) < 0.1\ \text{K} + 0.1\%\lvert t\rvert$ (i.e. 1.1 K at 1000°C).

Noble metal alloy (e.g., Pt-Rh/Pt):

FP calib. to Cu: $U(k=2) < 0.4$ K.

FP calib. above Cu: To the conditions flagging RMO review in the "high temperature secondary fixed point cell" protocol, add 0.02 % (k=2) (in quadrature) for thermoelectric inhomogeneity.

Comparison calib. in furnaces: $U(k=2) < 0.2\ \text{K} + 0.05\%\lvert t\rvert$ (i.e. 0.7 K at 1000°C).

Extrapolation from Au or Cu to 1200 °C and $U(k=2) < 0.8$ K.

Extrapolation from Au or Cu to > 1200 °C.

Pure metal (e.g., Au/Pt, Pt/Pd):

FP calib. to Cu: U(k=2) < 0.2 K.

FP calib. above Cu: To the conditions flagging RMO review in the "high temperature secondary fixed point cell" protocol, add 0.002 % (k=2) (in quadrature) for thermoelectric inhomogeneity.

Comparison calib. in furnaces: U(k=2) < 0.1 K + 0.05%|*t*| (i.e. 0.6 K at 1000°C).

Extrapolation from Au or Cu to > 1100 °C.

Scrutiny elements, if flagged

Assessment of DUT inhomogeneity.
Reference junction.
Assessment of stray thermal emfs.
How is extrapolation supported?

Temperature sensors with display unit (service category 2.7)

CMC entry to specify the sensor type. Review as for relevant sensor type.

Liquid-in-glass thermometers (service category 2.4)

CMC entry to specify whether the LIGT is a partial or total immersion type, fluid type, and its graduation interval.

Conditions flagging RMO review

Graduations ≥ 0.1 K: U(k=2) < 1/3 graduation.
Graduations < 0.1 K: U(k=2) < 0.02 K.

Scrutiny elements, if flagged

Ice point stability.
Emergent stem correction.
Scale non-linearity.
LIGT readings (random & systematic).

RMO Scrutiny elements applicable to all DUTs, if flagged (not an exclusive list)

1. If an RMO Supplementary Comparison has been performed, are the following criteria fulfilled?:

1.1 $$\frac{|T_{NMI} - RV|}{\sqrt{U_{CMC}{}^2(k=2) + U_{comparison}{}^2(k=2)}} < 1,$$

where T_{NMI} is the result of the NMI in the comparison, RV is the comparison reference value and $U_{comparison}$ is the combined uncertainty of the RV and any other components related to the comparison that are not included in the uncertainty of the RV or in the uncertainty quoted by the NMI in the comparison (e.g., drift of the transfer artefact),

and

1.2 $$U_{CMC}(k=2) \geq U_{NMI\_SC}(k=2),$$

where U_{NMI_SC} is the uncertainty quoted by the NMI in the comparison,

and

1.3 $$U_{CMC}(k=2) > \frac{U_{comparison}(k=2)}{3}.$$

2. If CMCs are claimed upon traceability to a higher-level service, without comparison results that directly cover the CMCs:

2.1 Traceability chart.

2.2 Evidence supporting the higher-level service, such as Key Comparison reports or CMCs on the KCDB.

3. Calibration reports need to be clear if interpolation of correction values is allowed.
4. Calibration method.
5. Details of uncertainty analysis methods:
   5.1 Sufficient redundancy in interpolation equation, together with inclusion in the uncertainty.
   5.2 Conduction error assessment for each DUT (except LIGT).
   5.3 Temperature enclosure stability and uniformity report.
   5.4 Traceability of reference standards.

References

[1] G. F. Strouse et al, "CCT WG8 CMC review protocols: development and implementation", *Int J Thermophys*, 2008, 29, 1193-1203.