25th Oct. 2019

Radiation Thermometry CMC Review Protocol

Scope: To provide a method of reviewing thermometry CMC's in the sub-field of radiation thermometry for acceptance in Appendix C of the KCDB. Covers service category numbers 7.1, 1.1.2, 1.2.2, 1.4, and 2.5 of the "CLASSIFICATION OF SERVICES IN THERMOMETRY (** 2019)" in the KCDB.

Review guidelines (cf. Table 1):

Items Used for Disseminating Thermodynamic Temperature (Service category 7.1)

IF <Criterion: OK>

THEN: Scrutiny at the level determined by Scrutiny Rule 0, 2 or 3

ELSE: RMO scrutiny and/or WG-CMC scrutiny

Items Used for Defining ITS-90 (Service categories 1.1.2, 1.2.2, 1.4)

IF <Criterion: OK>

THEN: Scrutiny at the level determined by Scrutiny Rule 0, 1 or 2

ELSE: RMO and WG-CMC scrutiny

Items Used for Disseminating ITS-90 (Service category 2.5)

IF <Criterion: OK>

THEN: Scrutiny at the level determined by Scrutiny Rule 0 or 3

ELSE: RMO scrutiny.

(Scrutiny Rule selected according to Table 1)

Scrutiny levels classified by Cut-off values ($U_{\mathrm{Table}\ X}$) of Table 1

Scrutiny Rule 0

Accept without scrutiny

Scrutiny Rule 1

IF $U_{\mathrm{CMC}} / U_{\mathrm{Table}\ X} \geq 1$ THEN: Accept without scrutiny

IF $1 > U_{\mathrm{CMC}} / U_{\mathrm{Table}\ X}$ THEN: RMO scrutiny and WG-CMC scrutiny

Scrutiny Rule 2

IF $U_{\mathrm{CMC}} / U_{\mathrm{Table}\ X} \geq 3/2$ THEN: Accept without scrutiny

IF $3/2 > U_{\mathrm{CMC}} / U_{\mathrm{Table}\ X}$ THEN: RMO scrutiny and WG-CMC scrutiny

Scrutiny Rule 3

IF $U_{\mathrm{CMC}} / U_{\mathrm{Table}\ X} \geq 1$ THEN: Accept without scrutiny

IF $1 > U_{\mathrm{CMC}} / U_{\mathrm{Table}\ X}$ THEN: RMO scrutiny

($U_{\mathrm{Table}\ X}$: U value in "Table X", where X=2 to 8 as indicated in Table 1 "Cut-off values")

Table 1a Radiation thermometry CMC review guidelines (Part 1)[*0]

Service category		Examples of instrument or artifact	Condition	Criterion	Scrutiny rule No.	Cut-off values
7. Items Used for Disseminating T						
7.1.1	Fixed-point blackbody cells and apparatus	Hg/Ga/In/Sn/Zn/Al/Ag/Au/Cu point blackbody cell/furnace, High-temperature fixed point (HTFP) blackbody cells of Co-C/Pt-C/Re-C eutectic point, Fe-C/Pd-C/Ru-C eutectic point, WC-C peritectic point, Ni-C/Rh-C/Ir-C eutectic point, Cr_3C_2-C peritectic point	Review based on protocol for corresponding service in Service Cat. 1 & 2	"ITS CMC OK"[*1]	0	–
			KC/SC of FP T[*2] available	"KC/SC result OK"	0	–
			KC/SC of RT T measurement[*2] only	"KC/SC(Scale) result OK"	0	–
				"KC/SC(Scale) result OK with $U_{\mathrm{NMI\,KC\,FP}}$"	3	Table 2, 3
			Not a primary realization / FP T assigned by ref. RT	"Ref. standard[*3] CMC OK"	3	Table 2, 3
7.1.2	Radiation thermometers (RT)	RT calibrated by *absolute primary* radiation thermometry, RT calibrated by *relative primary* radiation thermometry, RT calibrated by a VTBB against a reference thermometer	Review based on protocol for corresponding service in Service Cat. 1 & 2	"ITS CMC OK"[*1]	0	–
			KC/SC of RT T measurement[*2] available	"KC/SC result OK"	0	–
			Relative primary RT	"Ref. standard[*4] CMC OK"	2	Table 4, 5
			Not a primary realization	"Ref. standard[*5] CMC OK"	2	Table 4, 5
7.1.3	Variable temperature blackbody radiation sources (VTBB)	VTBB calibrated by a standard radiation thermometer, VTBB calibrated by radiance comparison against a standard VTBB	Review based on protocol for corresponding service in Service Cat. 1 & 2	"ITS CMC OK"[*1]	0	–
				Ref standard[*6] thermometer CMC OK	3	Table 4, 5

Table 1b Radiation thermometry CMC review guidelines (Part 2)*0

Service category		Examples of instrument or artifact	Condition	Criterion	Scrutiny rule No.	Cut-off values
1. Items Used for defining ITS-90						
1.1.2	Primary fixed point cells for radiation thermometry	Ag/Au/Cu point blackbody cell	KC of FP available	"KC(FP)*7 result OK"	0	–
			KC*8 of ITS-90 scale only	"KC(Scale)*9 result OK"	0	–
				"KC(Scale)*9 result OK with $U_{NMIKCFP}$"	1	Table 6
			Not a primary realization	"Ref. standard*5 CMC OK"	2	Table 6
1.2.2	Complete apparatus realizing fixed points for radiation thermometry	Ag/Au/Cu point blackbody furnace	KC of FP available	"KC(FP)*7 result OK"	0	–
			KC*8 of ITS-90 scale only	"KC(Scale)*9 result OK"	0	–
				"KC(Scale)*9 result OK with $U_{NMI\,KC\,FP}$"	1	Table 6
			Not a primary realization	"Ref. standard*5 CMC OK"	2	Table 6
1.4.1	Standard Radiation Thermometers	0.65 μm / 0.9 μm standard RT with direct ITS-90 realization, 0.65 μm / 0.9 μm standard RT calibrated by comparison above 962 °C	Same wavelength*10 as KC	"KC result OK"	0	–
			Not same wavelength as KC but same wavelength*10 as SC	"KC result OK"& "SC result OK"	0	–
			Not same wavelength as KC and no SC with same wavelength*10	"KC result OK"	1	Table 7
			Not a primary realization	"Ref. standard*5 CMC OK"	2	Table 7

Table 1c Radiation thermometry CMC review guidelines (Part 3)[*0]

Service category		Examples of instrument or artifact	Condition	Criterion	Scrutiny rule No.	Cut-off values
2. Items Used for Disseminating ITS-90						
2.5.1	Secondary fixed-point blackbody cells and apparatus	Hg/Ga/In/Sn/Zn/Al/Ag/Au/Cu point blackbody cell/furnace, High-temperature fixed point (HTFP) blackbody cells of Co-C/Pt-C/Re-C eutectic point, Fe-C/Pd-C/Ru-C eutectic point, WC-C peritectic point, Ni-C/Rh-C/Ir-C eutectic point, Cr_3C_2-C peritectic point	Review based on protocol for corresponding service in Service Cat. 7.1.1	"T CMC OK"[*1]	0	–
			SC of FP available	"SC(FP)[*7] result OK"	0	–
			SC[*8] of ITS-90 scale only	"SC(Scale)[*9] result OK"	0	–
				"SC(Scale)[*9] result OK with $U_{\mathrm{NMI\,SC\,FP}}$"	3	Table 2, 3
			Not a primary realization / FP T_{90} assigned by ref. RT	"Ref. standard[*3] CMC OK"	3	Table 2, 3
2.5.2	Variable temperature blackbody radiation sources (VTBB)	VTBB calibrated by a standard radiation thermometer, VTBB calibrated by radiance comparison against a standard VTBB		"Ref thermometer[*6] CMC OK"	3	Table 5, 7
2.5.3	Strip lamps	Vacuum lamps, gas filled lamps		"KC result OK"	0	–
2.5.4	Radiation thermometers (RT)	3.9 μm / 8-14 μm RT including thermal imagers calibrated by VTBB against a reference thermometer, 0.9 μm / 1.6 μm RT calibrated by 3-fixed-point / 4-fixed-point interpolation below Cu point, 0.65 μm / 0.9 μm RT calibrated by multiple high-temperature fixed point interpolation	Same wavelength[*10] as SC	"SC result OK"	0	–
			Not same wavelength[*10] as SC	"SC result OK"	3	Table 4, 5
			No SC	"Ref. standard[*11] CMC OK"	3	Table 4, 5
	Visual optical pyrometers	Disappearing filament pyrometer		"Ref. standard[*12] CMC OK"	3	Table 8

" – " means no criterion/value applicable/needed

"ITS/T CMC OK" means:

CMC of corresponding service in service categories/y (1.1, 1.2, 1.4 or 2.5) / 7.1.1 for the same temperature approved or its approval condition in Table 1 satisfied

and

$$U_{\text{NMI CMC}} \geq \sqrt{U^2_{\text{NMI ITS}/T\text{ CMC}}(k=2) + U^2_{T-\text{ITS}}(k=2)}$$

"KC/SC result OK" means[*13]:

$$\left|V_{\text{NMI,KC/SC}} - V_{\text{KC/SCRV}}\right| < \sqrt{U^2_{\text{NMI CMC}}(k=2) + U^2_{\text{KC/SC}}(k=2) + U^2_{\text{KC/SCRV}}(k=2)}$$

and

$$U_{\text{NMI CMC}} \geq U_{\text{NMI KC/SC}}$$

and

$$U_{\text{NMI CMC}} > \sqrt{U^2_{\text{KC/SC}}(k=2) + U^2_{\text{KC/SCRV}}(k=2)} \Big/ 3$$

for the temperature indicated in Table 9.

"KC/SC result OK with $U_{\text{NMI KC/SC FP}}$" means:

$$\left|V_{\text{NMI,KC/SC}} - V_{\text{KC/SCRV}}\right| < \sqrt{U^2_{\text{NMI CMC}}(k=2) + U^2_{\text{KC/SC}}(k=2) + U^2_{\text{KC/SCRV}}(k=2)}$$

and

$$U_{\text{NMI CMC}} \geq U_{\text{NMI KC/SC FP}}$$

and

$$U_{\text{NMI CMC}} > \sqrt{U^2_{\text{KC/SC}}(k=2) + U^2_{\text{KC/SCRV}}(k=2)} \Big/ 3$$

for the temperature indicated in Table 9.

"Ref. standard / thermometer CMC OK" means:

Reference standard / thermometer CMC approved for the same temperature

and

$U_{\text{NMI CMC}} > U_{\text{Ref CMC}}$

Here,

$U_{\text{NMI CMC}}$	is the NMI's CMC uncertainty.
$U_{\text{KC/SC}}$	is the uncertainty of the KC/SC
$U_{\text{KC/SC RV}}$	is the uncertainty of the KC/SC reference value
$U_{\text{NMI KC/SC}}$	is the NMI's KC/SC uncertainty
$U_{\text{NMI KC/SC FP}}$	is the uncertainty of the NMI's fixed point in the KC/SC
$U_{\text{Ref CMC}}$	is the CMC of the reference standard

$U_{\text{NMI ITS/}T\text{ CMC}}$ is the NMI's CMC uncertainty that satisfies the approval conditions of the review protocol for the corresponding service in service categories/y (1.1, 1.2, 1.4 or 2.5) / 7.1 at that temperature

$U_{T\text{-ITS}}$ is the uncertainty of the difference between thermodynamic temperature and ITS at that temperature*1

$V_{\text{NMI,KC/SC}}$ is the NMI's KC/SC result

$V_{\text{KC/SC RV}}$ is the KC/SC reference value

Notes

*0: For CMCs not requiring a KC, documented evidence may include comparisons that are not registered in the KCDB.

*1: cf. Ref [1] for conversion table and the uncertainty of the difference $U_{T\text{-ITS}}$. For temperature above the copper point, conversion table must be extrapolated from the copper point based on Planck's law, as well as the uncertainty $U_{T\text{-ITS}}$.

*2: No KC/SC of T is available at the time this protocol version is created.

*3: Reference standard in the same service category (e.g. of another NMI), to which the instrument/artifact is traceable, or the reference RT used to assign the T / T_{90} of the FP.

*4: Ref. standards are fixed-point blackbody cells and apparatus used for calibration of the RT.

*5: Reference standard in the same service category (e.g. of another NMI), to which the instrument/artifact is traceable.

*6: Reference RT that is used for calibrating the VTBB under calibration, or reference thermometer that gives the temperature of the standard VTBB.

*7: Key/supplementary comparison of fixed points such as in COOMET T-K5 and APMP T-S11.

*8: Key/supplementary comparison of a scale realized with reference to the relevant fixed point.

*9: Key/supplementary comparison of temperature scales such as in CCT-K5, EUROMET K-5, APMP T-K5, APMP T-S2, CCT-K10 and APMP T-S11/12.

*10: Wavelength range for which the effect of difference in wavelength is small enough that it has no relevance on the U_{CMC}.

*11: Reference thermometer that gives the reference temperature of the blackbody, or secondary fixed-point blackbodies.

*12: Reference strip lamp/radiation thermometer, to which the instrument is traceable.

*13: Criteria for evaluating comparison results follow those of an earlier Radiation Thermometry CMC Review Protocol.

Scrutiny items required for RMO and WG-CMC scrutiny

- Detailed analysis of calibration method and uncertainty analysis according to WG5 uncertainty documents [1, 2], and
- Other supporting evidence, such as Peer Review report or International Comparison results.

Reference

[1] “Estimates of the differences between thermodynamic temperature and the ITS-90” (https://www.bipm.org/utils/common/pdf/ITS-90/Estimates_Differences_T-T90_2010.pdf)

[2] J.Fischer, P.Saunders, M.Sadli, M.Battuello, C.W.Park, Yuan Z., H.Yoon, Wang L., E.van der Ham, F.Sakuma, Y.Yamada, M.Ballico, G.Machin, N.Fox, J.Hollandt, M.Matveyev, P.Bloembergen, S.Ugur, “CCT-WG5 on radiation thermometry, Uncertainty budgets for calibration of radiation thermometers below the silver point”, Ver. 1.71, CCT-WG5/docs-03 (2008)

[3] “Report of the CCT Task Group for Non-Contact Thermometry HTFP Uncertainties (CCT-TG-NCTh-HTFPU)” (2018)

[4] “Uncertainty estimation in primary radiometric temperature measurement” (2018) (https://www.bipm.org/utils/en/pdf/si-mep/MeP-K-2018_Absolute_Primary_Radiometry_Uncertainty.pdf)
Summary in *Int. J. Thermophys.*, vol. 29, pp.1066-1083 (2008)

[5] J.Fischer, M.Battuello, M.Sadli, M.Ballico, S.N.Park, P.Saunders, Yuan Z., B.C.Johnson, E.van der Ham, Wang L., F.Sakuma, G.Machin, N.Fox, S.Ugur, M.Matveyev “CCT-WG5 on radiation thermometry, Uncertainty budgets for realization of scales by radiation thermometry”, CCT/03-03
Summary in *Temperature, Its Measurement and Control in Science and Industry*, vol.7, D.C.Ripple ed., Melville, New York, pp.631-638 (2003)

[6] Kostkowski & Lee, “Theory and Methods of Optical Pyrometry”, in *Temperature, Its Measurement and Control in Science and Industry*, vol. 3, pp.449-481 (1962)

Appendix 1: Cut-off values

Table 2　Service Category 7.1.1/2.5.1

Fixed point	$U(k=2)$ / K
Hg	0.265
Ga	0.078
In	0.071
Sn	0.096
Zn	0.174
Al	0.149
Ag	0.267
Au	0.293
Cu	0.299

The threshold value is the arithmetic mean of the combined normal and best uncertainties*A1 for the fixed-point calibration in [2] below Ag point. Uncertainties for Au and Cu points are derived from Table 4 for "Absolute primary" divided by three. Converting to T from ITS-90 will only increase the uncertainty by 3 mK at most, and the same table is

Table 3　Service Category 7.1.1/2.5.1

Fixed point	$U(k=2)$ / K
Fe-C eutectic	1.0
Co-C eutectic	0.3
Ni-C eutectic	1.1
Pd-C eutectic	1.3
Rh-C eutectic	1.5
Pt-C eutectic	0.4
Cr_3C_2-C peritectic	1.7
Ru-C eutectic	1.9
Ir-C eutectic	2.5
Re-C eutectic	0.7
WC-C peritectic	3.3

The threshold values for Co-C, Pt-C and Re-C eutectics are the arithmetic mean of the Normal and Best uncertainty for scheme 1 in. [3]. The rest are derived from Table 4 for "Absolute primary". Converting to T from ITS-90 will only change the uncertainty values by 3 % at most, and the same table is applied for both.

Note

*A1: "Normal" is evaluated for the wavelength that gives the largest uncertainty among the possible choices of wavelength at that temperature, and "best" for the one that gives the smallest. For instance, for the Ag point, "normal" is evaluated with 3.9 μm, while "best" is evaluated with 0.9 μm.

Table 4 Service Categories 7.1.2/ 7.1.3

Temperature / °C	$U(k=2)$ / K	
	Absolute primary	Relative primary
1000	0.82	1.10
1200	0.99	0.60
1400	1.20	0.66
1600	1.43	0.86
1800	1.69	0.99
2000	1.98	1.09
2200	2.29	1.33
2400	2.64	1.88
2600	3.02	2.76
2800	3.42	3.93
3000	3.85	5.38

For the "Absolute primary", threshold values are three times the arithmetic mean of all schemes for both Normal and Best uncertainties in [4] Figs. 14 and 15.

For the "Relative primary", the uncertainties for the scale is propagated from the four fixed points of Cu point and Co-C, Pt-C, and Re-C eutectic points. The uncertainty value for the Cu point is taken from Table 2, and for the three eutectic points they are taken from Table 3, all multiplied by a factor of three. The values are to be reviewed in 5 years or after sufficient operation of the protocol.

Converting from T to ITS-90 will only increase the uncertainty by 0.5 % at most, and the same table is applied for both.

Table 5 Service Categories 7.1.2/2.5.2/2.5.4

t / °C	$U(k=2)$ / K			
	0.9 μm	1.6 μm	3.9 μm	8-12 μm
-40				0.395
0				0.322
20			0.156	0.304
30			0.151	0.299
100			0.141	0.305
150		0.095	0.151	0.312
157		0.093	0.153	0.311
200		0.091	0.166	0.303
232		0.100	0.175	0.297
300		0.129	0.192	0.286
400		0.166	0.204	0.400
420	0.108	0.171	0.204	0.458
500	0.143	0.184	0.204	0.751
600	0.196	0.186	0.209	
660	0.208	0.183	0.223	
700	0.207	0.181	0.239	
800	0.186	0.193	0.308	
900	0.202	0.250	0.416	
962	0.272	0.311	0.500	
1000	0.339			
1085	0.540			

The threshold value is the maximum value of the arithmetic mean of the combined normal and best uncertainties for the VTBB and FPBB scheme at that temperature [2]. Converting to T from ITS-90 will only increase the uncertainty by 2 mK at most, and the same table is applied for both.

Table 6 Service Categories 1.1.2/1.2.2

Fixed point	$U(k=2)$ / K
Ag, Au, Cu	0.05

The threshold value is the normal uncertainty for the Cu point calibration in [5].

Table 7 Service Categories 1.4/2.5.2

T / K	t / °C	$U(k=2)$ / K
1000	726.85	0.19
1100	826.85	0.18
1200	926.85	0.18
1300	1026.85	0.20
1400	1126.85	0.23
1500	1226.85	0.29
1600	1326.85	0.35
1700	1426.85	0.44
1800	1526.85	0.53
1900	1626.85	0.97
2000	1726.85	1.11
2100	1826.85	1.26
2200	1926.85	1.41
2300	2026.85	1.58
2400	2126.85	1.75
2500	2226.85	1.95
2600	2326.85	1.64
2700	2426.85	1.82
2800	2526.85	2.01
2900	2626.85	2.21
3000	2726.85	2.42

The threshold value is the maximum of the arithmetic mean of the combined normal and best uncertainties for the three schemes in [5].

Table 8 Service Category 2.5.4

t / °C	$U(k=2)$ / K
800	4.0
1000	3.2
1200	3.4
1400	4.0
1600	4.5
1800	5.1
2000	5.7
2200	6.3
2400	6.8
2600	7.4
2800	8.0

The threshold values are from [6].

Appendix 2: CMC service categories and supporting KCs and SCs

Table 9a CMC service categories and supporting KCs and SCs (Part 1)

	: Approved	√	: Directly supports CMC	
	: On going	Δ	: Indirectly supports CMC	
		Δ^C/ $\surd^C$	: Directly/indirectly supports CMC after ITS <-> T conversion	

		Field	Radiation Thermometry									
		Comparison name	CCT-K5	CCT-K10	APMP T- K5	EUROMET T- K5	COOMET T- K5	APMP T- S2	APMP T- S11	APMP T- S12	EUROMET T- S1	EURAMET T- S4
Key and Supplemetary Comparisons on KCDB appendix B (as of May 2019)		Range, years	Realizations of the ITS-90 between 961 ° C and 1700 ° C 1997 – 1999	Realizations of the ITS-90 between 960 ° C and 3000 ° C 2014 – 2016	Comparison of realization of the ITS-90 using radiation thermometry over the range 962 ° C and 2800 ° C 1997 – 2000	Realizations of the ITS-90 up to 1700 ° C 1999 – 2000	Realizations of the ITS-90 between 961 ° C and 1084 ° C 2008 – 2009	Calibration of radiation thermometer 2000 – 2003	Local realization of radiation thermometer scale from indium point to 2000 ° C 2013 – 2016	Local realization of radiation thermometer scale from silver point to 2800 ° C 2013 – 2016	Examination of base parameters for ITS-90 scale realisation in radiation thermometry 2003 – 2004	Comparison of measurement parameters required for the radiation thermometry medium temperature range 2007 – 2009
		Comparison type, Field	Key comparison in Thermometry, Pyrometry	Key comparison in Thermometry, Pyrometry	Key comparison in Thermometry, Pyrometry	Key comparison in Thermometry, Pyrometry	Key comparison in Thermometry, Pyrometry Freezing points of Silver, Gold, and Copper	Supplementary comparison in Thermometry, Pyrometry Temperature: 400 ° C to 2000 ° C	Supplementary comparison in Thermometry, Pyrometry Temperatures from 156 ° C to 2000 ° C, and indium, tin, zinc, aluminum, silver and copper points	Supplementary comparison in Thermometry, Pyrometry Temperature: 960 ° C to 2800 ° C	Supplementary comparison in Thermometry, Pyrometry	Supplementary comparison in Thermometry, Pyrometry Temperature: 156 ° C to 1000 ° C
		Status	Approved for equivalence, Results available	In progress	Approved for equivalence, Results available	Approved for equivalence, Results available	Approved for equivalence, Results available	Approved and published	In progress	In progress	Approved and published	Approved and published
Service category		Supporting temperature range										
7. Items Used for Disseminating T												
7.1.1	Fixed-point blackbody cells and apparatus	$T_{CMC} = T_{KC/SC}$						Δ^C	$\surd^C$			Δ^C
7.1.2	Radiation thermometers	$T_{KC/SC/WC,min} - 60\ K < T_{CMC} < T_{KC/SC/WC,max} + 60\ K$	Δ^C	Δ^C	Δ^C	Δ^C		Δ^C	Δ^C	Δ^C		Δ^C
7.1.3	Variable temperature blackbody radiation sources	$T_{KC/SC,min} - 60\ K < T_{CMC} < T_{KC/SC,max} + 60\ K$	Δ^C	Δ^C	Δ^C	Δ^C		Δ^C	Δ^C	Δ^C		Δ^C

Table9b CMC service categories and supporting KCs and SCs (Part 2)

Key and Supplemetary Comparisons on KCDB appendix B (as of May 2019)		Field	Radiation Thermometry									
		Comparison name	CCT-K5	CCT-K10	APMP T- K5	EUROMET T- K5	COOMET T- K5	APMP T- S2	APMP T- S11	APMP T- S12	EUROMET T- S1	EURAMET T- S4
		Range, years	Realizations of the ITS-90 between 961 ° C and 1700 ° C 1997 – 1999	Realizations of the ITS-90 between 960 ° C and 3000 ° C 2014 – 2016	Comparison of realization of the ITS-90 using radiation thermometry over the range 962 ° C and 2800 ° C 1997 – 2000	Realizations of the ITS-90 up to 1700 ° C 1999 – 2000	Realizations of the ITS-90 between 961 ° C and 1084 ° C 2008 – 2009	Calibration of radiation thermometer 2000 – 2003	Local realization of radiation thermometer scale from indium point to 2000 ° C 2013 – 2016	Local realization of radiation thermometer scale from silver point to 2800 ° C 2013 – 2016	Examination of base parameters for ITS-90 scale realisation in radiation thermometry 2003 – 2004	Comparison of measurement parameters required for the radiation thermometry medium temperature range 2007 – 2009
		Comparison type, Field	Key comparison in Thermometry, Pyrometry	Key comparison in Thermometry, Pyrometry	Key comparison in Thermometry, Pyrometry	Key comparison in Thermometry, Pyrometry	Key comparison in Thermometry, Pyrometry Freezing points of Silver, Gold, and Copper	Supplementary comparison in Thermometry, Pyrometry Temperature: 400 ° C to 2000 ° C	Supplementary comparison in Thermometry, Pyrometry Temperatures from 156 ° C to 2000 ° C, and indium, tin, zinc, aluminum, silver and copper points	Supplementary comparison in Thermometry, Pyrometry Temperature: 960 ° C to 2800 ° C	Supplementary comparison in Thermometry, Pyrometry	Supplementary comparison in Thermometry, Pyrometry Temperature: 156 ° C to 1000 ° C
		Status	Approved for equivalence, Results available	In progress	Approved for equivalence, Results available	Approved for equivalence, Results available	Approved for equivalence, Results available	Approved and published	In progress	In progress	Approved and published	Approved and published
Service category		Supporting temperature range										
1. Items Used for Realizing ITS-90												
1.1.2	Primary fixed point cells for radiation thermometry	$T_{CMC} = T_{KC/SC}$	Δ	Δ	Δ	Δ	√		Δ	Δ		
1.2.2	Complete apparatus realizing fixed points for radiation thermometry	$T_{CMC} = T_{KC/SC}$	Δ	Δ	Δ	Δ	√		√	Δ		
1.4.1	Standard Radiation Thermometers	$T_{KC/SC,min} - 60\ K < T_{CMC} < T_{KC/SC,max} + 60\ K$	√	√	√	√		√	√	√		
2. Items Used for Disseminating ITS-90												
2.5.1	Secondary fixed-point blackbody cells and apparatus	$T_{CMC} = T_{KC/SC}$						Δ	√			Δ
2.5.2	Variable temperature blackbody radiation sources	$T_{KC/SC,min} - 60\ K < T_{CMC} < T_{KC/SC,max} + 60\ K$	Δ	Δ	Δ	Δ		Δ	Δ	Δ		Δ
2.5.3	Strip lamps	$T_{KC/SC,min} - 60\ K < T_{CMC} < T_{KC/SC,max} + 60\ K$	√	√	√	√				√		
2.5.4	Radiation thermometers	$T_{KC/SC,min} - 60\ K < T_{CMC} < T_{KC/SC,max} + 60\ K$						√	√			√
	Visual optical pyrometers	$T_{KC/SC,min} - 60\ K < T_{CMC} < T_{KC/SC,max} + 60\ K$										