EURAMET K5 EXTENSION:
COMPARISON OF LOCAL REALIZATIONS OF THE ITS-90 BETWEEN THE SILVER POINT AND 1700 °C USING VACUUM TUNGSTEN-STRIP LAMPS AS TRANSFER STANDARDS

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Abstract

This is the final report on the Euramet RMO extension of Key Comparison 5 entitled "Comparison of local realizations of the ITS-90 between silver point and 1700 °C using vacuum tungsten strip lamps as transfer standards". The local realizations in this range of the ITS-90 and the corresponding uncertainties are given for the 8 national metrology institutes who participated in the comparison. The deviations of the participants data from the previously established and accepted CCT-K5 key comparison reference values (KCRV) are presented in this report. For some temperature scale, there are observed significant unresolved deviations (SUDs) between the participants data and the KCRV. These SUDs are briefly discussed in this report. The inter-laboratory cross-equivalence values for the different temperature realizations are also provided in this report. Prior to the finalization of this report, the draft A was presented to the participants for their comments and approval. Some minor comments received from the participants were included in the draft B. The draft B was approved by all participants for submission to the Euramet RMO for further review by the CCT WG7 working group. The comments received from the reviewers of the draft B are incorporated in this final report. This final report has been officially approved by the chairman of the CCT-WG7.

I. Introduction

The Euramet TC-T decided in 1996 to undertake an inter-laboratory comparison of the local realization of the ITS-90 above the silver point, using high-stability vacuum tungsten strip lamps as transfer standards. The local scales are directly transferred to the lamps, such as to guarantee the highest possible accuracy level. As this comparison is an extension of the CCT-K5 key comparison (KC), the same artifacts could be used including the associated CCT-K5 KCRV values on these lamps. The CCT-K5 KC measurements were finished in August 1999 with the third measurement run by the KC pilot VSL. After the stability of the lamp set was confirmed by the pilot, the lamps were, according to the protocol, sent to the first Euramet-T-K5 participant in October 1999.

The coordinating institute for this comparison was VSL (previously abbreviated by NMi-VSL in the protocol). As the number of participants were limited to eight, including the pilot, one lamp set from the CCT-K5 KC was used in a single sequential loop. The last measurement set of VSL (from the CCT-K5 KC) and the individual CCT-K5 KC reference values on each lamp were employed to link this Euramet extension to CCT-K5.

All the measurements by the participants in this comparison were completed in the early part of 2001. This is prior to the release of drafts A and B of the CCT-K5 and eventually the final report of the comparison, which was published in BIPM website in 2008. There is no way that the participants in the Euramet K5 extension comparison have knowledge of the results of the CCT-K5 prior to and during their measurements which could influence the data they submitted for this Euramet K5 extension.

This report provides an analysis of the obtained results, including differences in local realizations and the uncertainties of those differences for the 8 national metrology institutes participating in the RMO comparison. The instructions to the participants are given in the protocol of Appendix I. The measurements of the lamp standard started in October 1999 and ended in February 2001.

II. Participating metrology institutes

The following national metrology institutes (NMI) participated in this Euramet key comparison. Initially, NMA from Norway was in the early list of participants for the comparison but, at the end, did not continue with their participation.

Table 1 List of participating institutes (in alphabetical order).

Acronym	**Country**	**Institute**
CEM	Spain	*Centro Español de Metrologia*
IPQ	Portugal	*Instituto Portuguȩs da Qualidade*
MIKES (formerly CMA)	Finland	*Mittatekniikan keskus*
MKEH (formerly OMH)	Hungary	*Magyar Kereskedelmi Engedélyezési Hivatal*
SMU	Slovakia	*Slovenský metrologický ústav*
SP	Sweden	*Sverige Tekniska Forskningsinstitut*
TUBITAK-UME	Turkey	*Ulusal Metroloji Enstitüsü*
VSL (formerly NMI)	The Netherlands	*VSL*

III. Devices used in the comparison

Two GEC high-stability vacuum tungsten-strip lamps were used as transfer standards during the comparison (see Fig. 1). The set was supplied by VSL. The lamps are denoted C564 and C681. Another lamp, denoted C680, was used as a spare lamp. To verify the proper operation of the lamp, each participant was asked to perform initial tests to check for drift or damage of the lamps after receipt. These two tungsten strip lamps were the same lamps used in the previous CCT-K5 comparison. A measurement protocol (see Appendix I) was provided to each participant to enable them to familiarize themselves with the handling of the device and also on how to conduct the experiment. None of the participants reported abnormal drifts during the comparison and the spare lamp C680 was not used.

Figure 1 The GEC high-stability vacuum tungsten-strip lamp (side and front view).

The set of two lamps was mounted in a metal case and was hand-carried to each participating institute. Each strip lamp was supplied with a water-cooled base and a clear marking of the polarity of the current connectors was also provided. To monitor the possible changes in the physical constitution of the lamp element, that may be induced during transport, the room-temperature resistance R_{amb} was also monitored along with the ambient temperature T_{amb} ,which is measured with a calibrated PRT inserted in the lamp base.

In an attempt to follow the physical condition of the set of transfer standards, the ambient resistance of the tungsten filament lamp was measured upon receipt and just before sending the lamps to the next participants. Aside from this, the lamps were subjected to a test to ensure proper operation. After registration of the radiance temperature at a specific current setting (≈ 1100 °C), the lamp was set to the maximum current for a period of one hour. When operated again at the specified current, the radiance temperature should not deviate more than 50 mK. The reported values are presented in Fig 2.

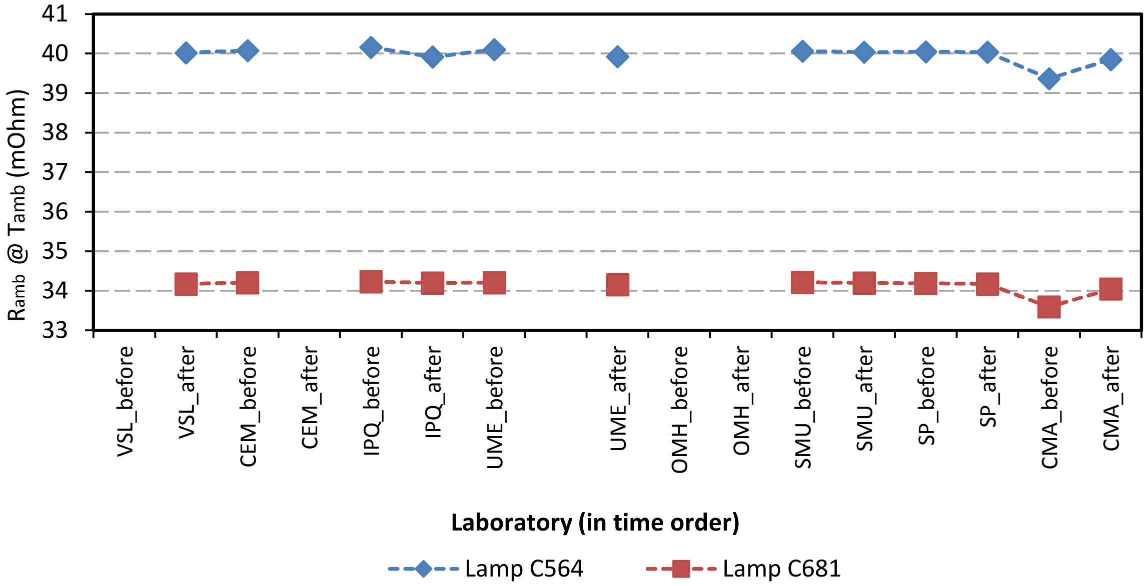


Figure 2 The reported uncorrected resistance values (at T_{amb}) of lamps C564 and C681 by each participant (upon receipt and after the measurement).

To analyze this dataset one has to correct for the temperature dependence of tungsten. A linear model for each lamp was used to calculate the measured resistance R back to a temperature of 20°C (R, t = 20°C). A Taylor expansion of the tungsten resistivity as a function of temperature t shows higher order terms being at least three orders of magnitude smaller than the linear term. The latter was confirmed by analysis of literature data from two different sources. The dataset for each lamp was used to determine the coefficients a_0 and a_1 from a fit to the relation $R = a_0 + a_1(t-20)$, where $a_0 = R(t=20\ °C)$ at a temperature of 20°C. The calculated resistance of the lamp at 20°C as a function of time is shown in Figs 3 and 4 for C564 and C681, respectively.

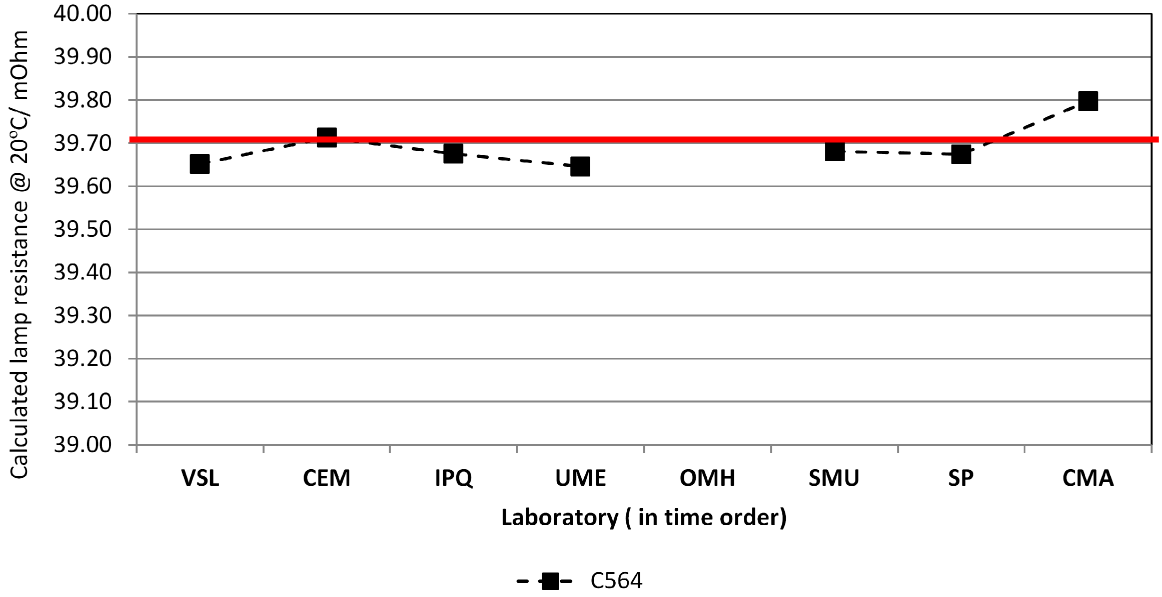


Figure 3 Calculated lamp resistances at T=20 °C during the key comparison (C564).

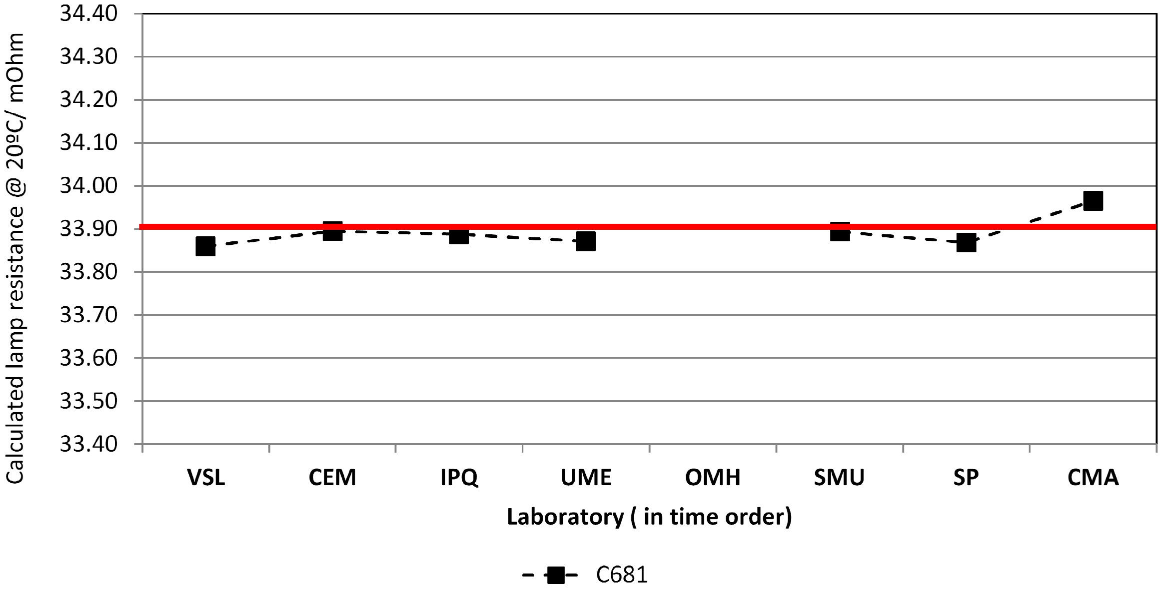


Figure 4 Calculated lamp resistances at T=20 °C during the key comparison (C681).

Comparing these results to the resistance analysis of the CCT-K5 KC just prior to this RMO extension presented in Figure 5, one can conclude that the lamp resistances are reproduced over the entire stretch of both comparisons, exhibiting a reliably good stability during both key comparisons.

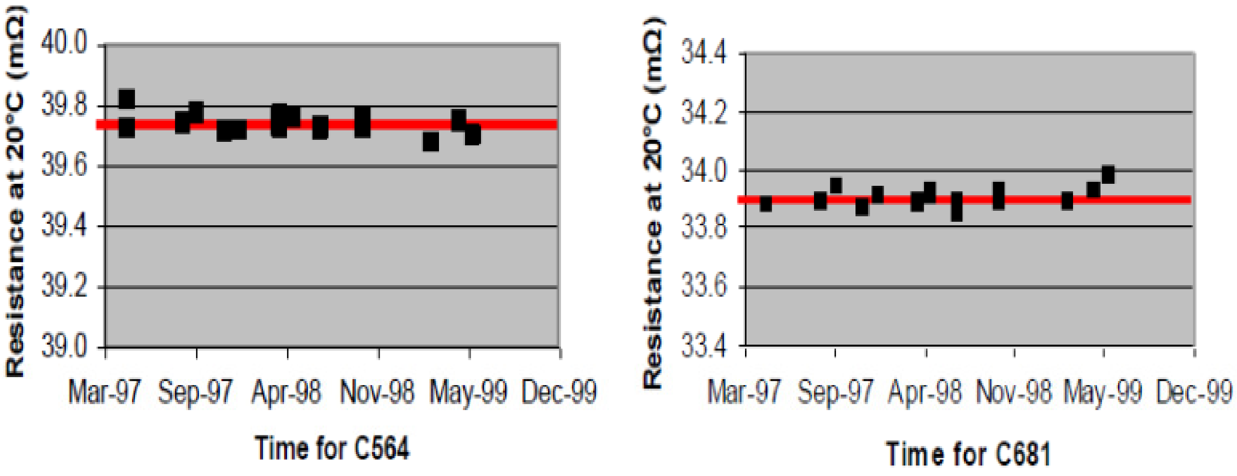


Figure 5 Calculated lamp resistances for C564 and C681 as reported in the CCT-K5 comparison (adapted from ref (1)).

Youden plot of the lamp resistances:

Figure 6 shows the Youden plot of the lamp resistances (C564 and C681) at 20°C during the CCT-K5 and Euramet-K5 comparisons. The radius of the circle encircling the data points is the 3σ from data of CCT-K5 comparison [2]. It can be seen that all the data of the lamp resistances are within this 3σ, leading us to conclude that the lamps used in the two comparisons, indeed, have not significantly drifted between the two comparisons.

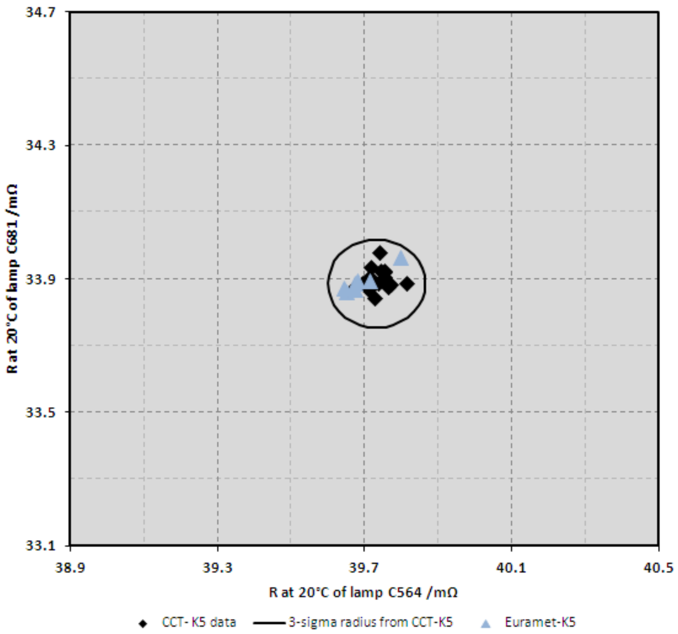


Figure 6 Youden plot of the lamp resistances during CCT-K5 (black diamond) and Euramet-K5(light blue triangle) comparisons.

IV. Brief description of the measurement conditions

Each participant was asked to study the interaction of the lamp with the calibration facility, i.e., lamp orientation with respect to the pyrometer/comparator. The relative change in photo-thermal signal due to spatial and angular displacement was determined.

Some participants reported inter-reflection effects between the lamp window and the calibration facility. However, as these effects were found well outside the acceptance angle of the devices employed, these effects were of no influence on the measurement results. Similarly, the spatial displacement measurements as reported by all participants showed no anomalies.

By measuring in the direction of increasing current only, after having re-stabilized the lamp, as indicated above, hysteresis effects could be avoided. Furthermore, minimum equilibration times were specified in the protocol varying from 15 to 30 minutes, depending on the specific temperature range.

The measurements of the participating institutes had to be corrected to a reference condition (see attached measurement protocol for details). In summary, the most important reference conditions are:

a. The orientation of the strip,
b. A base temperature of 20 °C,
c. A wavelength of 650 nm,
d. A set of eleven defined current settings (related to each lamp).

Given the properties of each specific lamp, corrections to reference conditions had to be made by each participant. These corrections were related to the orientation of the strip, the lamp base temperature, and the set of eleven defined current settings. Instructions were given in the measurement protocol (see Appendix I). Other corrections as will be outlined later, were related to the participant instrumentation and include the target-size and size-of-source characteristics of the radiation thermometer employed, the effective central wavelength, etc.

V. Participant instrumentation, techniques and other details

In the context of traceability, each participants used a calibrated radiation thermometer to transpose the scale directly onto the set of transfer lamps. Basically, three different operational schemes can be devised for maintaining the ITS-90. The working group for radiation thermometry of the CCT investigated this issue in more detail (2):

Scheme 1:

- the fixed-point calibration is transferred to a reference tungsten strip lamp; this implies the determination of a current value on the lamp corresponding to a radiance temperature equal to the fixed-point temperature;

- a series of temperatures T_{90} are established and maintained on the lamp by measurement of radiance ratios; if necessary, the radiance ratios are adjusted for the non-linearity of the thermometer; this leads to the availability of a series of current and radiance temperature values; a polynomial interpolation equation can be calculated to relate temperature to current in a continuous way.

Scheme 2:

- the fixed-point calibration is transferred to a reference tungsten strip lamp;

- temperatures T_{90} of any source are determined according to the defining equation of the ITS-90 by measuring the signal ratios between the source at T_{90} and the reference lamp at the fixed-point temperature; if necessary, the signal ratios are adjusted for the non-linearity of the thermometer.

Scheme 3:

- the fixed-point calibration is maintained on the thermometer. The output signal is assumed to be representative of T90(X);

- a series of temperatures T_{90} are established as a function of the output signals of the thermometer. Signal ratios with respect to $T_{90}(X)$ are calculated and, if necessary, adjusted for the non-linearity of the thermometer.

The three schemes for the realization and maintenance of the ITS-90 give rise to different uncertainty budgets but with many common uncertainty components. Table 2 associates with each scheme the appropriate uncertainty components by filling a grey cell. The dark grey cells refer to higher temperatures not relevant to this inter-comparison [2].

Table 2 Appropriate uncertainty components for each scheme realizing the ITS-90. The cells in grey indicate the relevant uncertainty components whereas the dominating contributions are indicated in red.

Source of uncertainty		**Scheme 1**	**Scheme 2**	**Scheme 3**
Fixed-point calibration	Impurities	▨	▨	▨
	Emissivity	▨	▨	▨
	Temperature drop	▨	▨	▨
	Plateau identification	▨	▨	▨
	Repeatability	▨	▨	▨
Spectral responsivity	Wavelength	🟥	🟥	🟥
	Reference detector	▨	▨	▨
	Scattering, Polarisation	▨	▨	▨
	Repeatability of calibration	▨	▨	▨
	Drift	▩	▩	▩
	Out-of-band-transmittance	▨	▨	▨
	Interpolation and Integration	▨	▨	▨
Output signal	SSE	▨	▨	▨
	Non-linearity	▩	▩	▩
	Drift			▨
	Ambient conditions			▨
	Gain ratios		▨	▨
	Repeatability	▨	▨	▨
Lamp	Current	▨	▨	
	Drift, Stability	🟥	▨	
	Base and ambient temperature	▨	▨	
	Positioning	▨	▨	
	Polynomial fit	▨		

The radiation thermometers employed in the comparison, either absolutely calibrated or used as a comparator, also influence the comparison data due to differences in the target-size, the size-of-source characteristic, and the effective central wavelength. Table 3 presents an overview of the specific schemes and specifications of the radiation thermometers used by each participant. More detailed information, as presented by each participant, is given in the Appendix.

Table 3 Overview of traceability schemes and the characteristic properties of the radiation thermometers used; traceability scheme, target distance, the F-number, central wavelength, the full-width half-maximum of the interference filter, type of imaging system, and reference pyrometer used

Participant	Scheme	Target Distance [mm]	Target size [mm]	F #	λ_c [nm]	FWHM [nm]	Optics	Spectral Method	Reference Pyrometer	Pyrometer ID
CEM	3	650	0.74	15	652	10	lens	λ_{eff}	IKE LP2	80-27
IPQ	3	700	0.8	-	650	10	lens	λ_{eff}	IKE - LP2	80-19
MIKES	2	600	0.7	15	653	10.9	lens	λ_{eff}	IKE LP2	80-25
MKEH	3	470	0.84	4	647	3.7	lens	λ_{eff}	In-house developed	17-06-004
SMU	3	350	0.5	5	662	12	lens	λ_{eff}	In-house developed	FIP-1
SP	3	570	0.5	15	651	11	lens	λ_{eff}	IKE LP2	80-33
TUBITAK-UME	3	400	0.6	-	650	20	lens	Integral	Vega	TSP-2
VSL	3	500	0.75	9	661	10	lens	Integral	In-house developed	NSRT

Table 4 Specific information on the fixed-point blackbody cavity configuration as employed by each participant.

Participant	Fixed Point	Purity	Emissivity	Fixed Point s/n	Furnace used	Furnace s/n
CEM	Cu	5N	0.99998	CEM1	Carbolite furnace CTF 12/65	6/90/997
IPQ	Cu	5N	0.992	001504	MIKRON	M380-Cu
MIKES	Ag	5N	0.9998	Ag1	TUT/MIKES Ag1995	Ag1
MKEH	Au	5N	0.99976	11-13-0141	In-house developed	11-13-024
SMU	Au	5N	0.99999	SMUFP-01	In-house developed	N/A
SP	Au	5N	0.999995	AUBB01	Carbolite furnace TZF 12/65/550	1/95/202
TUBITAK-	Ag	6N	0.99972	UME-Ag-98-01	Custom-built from NIST	N/A

UME						
VSL	Ag	6N	0.999994	VSL-Ag-01	Custom-built	N/A

VI. Results of the comparison and data analysis

A. Measurement results as sent by the participants

Table 5 - Table 8 present the measurement results as submitted by each participant to the pilot institute. The uncertainty values (u(t), k=1) are the measurement uncertainties from the uncertainty budgets that were provided by each participant for each lamp. The data for VSL is the data from the CCT-K5 key comparison. Each participant, except for MKEH and SMU, has provided 2 measurement runs for each lamp. The data presented for MKEH is the average data from the 3 runs they made for each lamp (as written in their report). There is no reported data from SMU, at the nominal temperature of 1085 °C, both for lamps C564 and C681. The radiance temperatures reported were measured at defined nominal current values, which are the same as the values used in CCT-K5 comparison (see Table 14).

Table 5 Submitted measurement data (T(λ, I(j)) by participating NMIs for lamp C564.

Temp	Current	VSL	VSL	CEM	CEM	MIKES	MIKES	IPQ	IPQ	MKEH	SMU	SP	SP	UME	UME
°C	A	run 2	run 3	run 1	run 2	run 1	run 2	run 1	run 2	average	average	run 1	run 2	run 1	run 2
962	4.480	964.16	964.26	964.06	964.06	963.69	963.55	966.58	966.78	963.59	963.22	963.577	963.649	962.787	962.840
1000	4.721	1002.26	1002.29	1002.11	1002.14	1001.42	1001.57	1002.20	1002.31	1001.40	1001.27	1001.651	1001.678	1000.783	1000.878
1064	5.169	1066.41	1066.41	1066.27	1066.35	1065.90	1065.75	1066.29	1066.29	1065.50	1065.48	1065.744	1065.733	1064.805	1064.880
1085	5.322	1086.80	1086.79	1086.61	1086.70	1086.28	1086.18	1086.70	1086.70	1085.85		1086.120	1086.119	1085.218	1085.287
1100	5.441	1102.22	1102.22	1102.11	1102.18	1101.70	1101.60	1102.09	1102.16	1101.21	1100.87	1101.542	1101.542	1100.682	1100.749
1200	6.272	1202.06	1202.06	1201.95	1202.10	1201.36	1201.34	1201.93	1201.98	1200.74	1200.68	1201.339	1201.329	1200.427	1200.481
1300	7.194	1302.14	1302.13	1302.20	1302.20	1301.51	1301.38	1301.90	1301.93	1300.63	1300.70	1301.287	1301.287	1300.352	1300.403
1400	8.189	1402.48	1402.47	1402.61	1402.56	1401.75	1401.61	1402.17	1402.19	1400.54	1400.96	1401.519	1401.519	1400.623	1400.666
1500	9.242	1502.71	1502.72	1502.95	1502.86	1501.94	1501.78	1502.35	1502.36	1500.35	1501.26	1501.694	1501.684	1500.899	1500.942
1600	10.347	1602.92	1602.98	1603.46	1602.35	1602.09	1601.88	1602.46	1602.50	1600.10	1601.57	1602.660	1602.660	1600.899	1600.915
1700	11.502	1703.36	1703.41	1704.04	1703.83	1702.45	1700.24	1702.78	1702.88	1700.13	1701.97	1703.100	1703.100	1701.175	1701.206

Table 6 Submitted measurement data (T(λ, I(j)) by various participating NMIs for lamp C681**.**

Temp	**Current**	**VSL**	**VSL**	**CEM**	**CEM**	**MIKES**	**MIKES**	**IPQ**	**IPQ**	**MKEH**	**SMU**	**SP**	**SP**	**UME**	**UME**
°C	A	run 2	run 3	run 1	run 2	run 1	run 2	run 1	run 2	average	average	run 1	run 2	run 1	run 2
962	5.508	963.50	963.43	963.49	963.51	963.12	962.89	963.45	963.42	963.00	963.11	963.036	963.035	962.15	962.257
1000	5.822	1001.76	1001.76	1001.78	1001.79	1001.36	1001.14	1001.73	1001.56	1001.11	1001.30	1001.296	1001.296	1000.387	1000.365
1064	6.399	1066.07	1066.08	1066.11	1066.13	1065.76	1065.55	1065.91	1065.93	1065.32	1065.67	1065.527	1065.526	1064.505	1064.617
1085	6.594	1086.46	1086.45	1086.50	1086.50	1086.16	1085.92	1086.3	1086.37	1085.62		1085.904	1085.913	1084.834	1085.056
1100	6.745	1101.86	1101.84	1101.93	1101.97	1101.54	1101.37	1101.68	1101.77	1100.94	1100.97	1101.289	1101.31	1100.341	1100.453
1200	7.795	1201.97	1201.92	1202.11	1201.97	1201.55	1200.99	1201.68	1201.80	1200.77	1200.98	1201.307	1201.316	1200.317	1200.432
1300	8.948	1302.28	1302.26	1302.45	1302.35	1301.83	1301.18	1301.82	1301.97	1300.77	1301.29	1301.507	1301.517	1300.528	1300.66
1400	10.183	1402.63	1402.62	1402.93	1402.73	1402.06	1402.32	1401.99	1402.18	1400.71	1401.57	1401.720	1401.720	1400.791	1400.865
1500	11.487	1502.90	1502.86	1503.24	1502.9	1502.16	1501.35	1502.04	1502.26	1500.53	1501.84	1501.806	1501.826	1501.065	1501.148
1600	12.852	1603.00	1602.92	1603.44	1603.06	1601.94	1601.05	1601.79	1602.04	1599.99	1601.90	1602.448	1602.468	1600.719	1600.834
1700	14.273	1702.90	1702.97	1703.64	1703.23	1701.67	1700.7	1701.47	1701.77	1699.42	1701.80	1702.250	1702.290	1700.393	1700.689

Table 7 Combined uncertainties (u(T), k=1), from the uncertainty budget, as reported by individual NMI for lamp C564.

Temp	Current	VSL	CEM	MIKES	IPQ	MKEH	SMU	SP	UME
°C	A	°C	°C	°C	°C	°C	°C	°C	°C
962	4.48	0.10	0.10	0.46	0.32	1.64	0.28	0.331	0.125
1000	4.721	0.10	0.11	0.49	0.32	1.24	0.22	0.351	0.142
1064	5.169	0.11	0.11	0.53	0.34	0.87	0.18	0.386	0.159
1085	5.322	0.11	0.10	0.54	0.36	0.86		0.398	0.165
1100	5.441	0.11	0.12	0.55	0.36	0.88	0.18	0.407	0.171
1200	6.272	0.12	0.13	0.63	0.42	0.89	0.17	0.472	0.203
1300	7.194	0.14	0.15	0.70	0.48	0.98	0.18	0.543	0.235
1400	8.189	0.16	0.18	0.78	0.55	1.06	0.20	0.623	0.271
1500	9.242	0.17	0.21	0.86	0.63	1.19	0.22	0.709	0.307
1600	10.347	0.19	0.24	0.95	0.72	1.35	0.24	0.803	0.346
1700	11.502	0.21	0.28	1.04	0.82	1.47	0.27	0.905	0.394

Table 8 Combined uncertainties (u(T),k=1) , from the uncertainty budget, provided by individual NMI for lamp C681.

Temp	Current	VSL	CEM	MIKES	IPQ	MKEH	SMU	SP	UME
°C	A	°C	°C	°C	°C	°C	°C	°C	°C
962	5.508	0.10	0.10	0.39	0.31	1.70	0.27	0.331	0.131
1000	5.822	0.10	0.11	0.40	0.32	1.24	0.22	0.351	0.135
1064	6.399	0.11	0.11	0.45	0.35	0.94	0.18	0.386	0.165
1085	6.594	0.11	0.10	0.46	0.36	0.91		0.398	0.197
1100	6.745	0.11	0.12	0.48	0.37	0.91	0.18	0.407	0.177
1200	7.795	0.12	0.13	0.54	0.42	0.97	0.17	0.472	0.210
1300	8.948	0.14	0.15	0.63	0.49	1.08	0.18	0.543	0.244
1400	10.183	0.16	0.18	0.68	0.56	1.20	0.21	0.623	0.274
1500	11.487	0.17	0.21	0.77	0.64	1.34	0.24	0.709	0.311
1600	12.852	0.19	0.24	0.95	0.74	1.52	0.25	0.803	0.352
1700	14.273	0.21	0.28	1.04	0.84	1.65	0.29	0.905	0.422

B. Descriptive Statistics

Tables 9 and 10 show the average measured temperatures, with the exception of MKEH and SMU data which were already provided as average values, from the two experimental runs performed by each institute for lamps C564 and C681, respectively. Tables 11 and 12 are the resulting combined standard uncertainties for each lamp. To have an overview of the data for this comparison, a table showing the overall mean, median and standard deviation of the average measured temperatures for lamps C564 and C681 from all participants, is presented in Table 13.

Table 9 Average measured temperature by each NMI for lamp C564

Temp	**Current**	**VSL**	**CEM**	**MIKES**	**IPQ**	**MKEH**	**SMU**	**SP**	**UME**
°C	A	°C	°C	°C	°C	°C	°C	°C	°C
962	4.48	964.21	964.06	963.62	966.68	963.59	963.22	963.61	962.81
1000	4.721	1002.28	1002.13	1001.50	1002.26	1001.40	1001.27	1001.66	1000.83
1064	5.169	1066.41	1066.31	1065.83	1066.29	1065.50	1065.48	1065.74	1064.84
1085	5.322	1086.80	1086.66	1086.23	1086.70	1085.85		1086.12	1085.25
1100	5.441	1102.22	1102.15	1101.65	1102.13	1101.21	1100.87	1101.54	1100.72
1200	6.272	1202.06	1202.03	1201.35	1201.96	1200.74	1200.68	1201.33	1200.45
1300	7.194	1302.14	1302.20	1301.45	1301.92	1300.63	1300.70	1301.29	1300.38
1400	8.189	1402.48	1402.59	1401.68	1402.18	1400.54	1400.96	1401.52	1400.64
1500	9.242	1502.72	1502.91	1501.86	1502.36	1500.35	1501.26	1501.69	1500.92
1600	10.347	1602.95	1602.91	1601.99	1602.48	1600.10	1601.57	1602.66	1600.91
1700	11.502	1703.39	1703.94	1701.35	1702.83	1700.13	1701.97	1703.10	1701.19

Table 10 Average measured temperature by each NMI for lamp C681

Temp	Current	VSL	CEM	MIKES	IPQ	MKEH	SMU	SP	UME
°C	A	°C	°C	°C	°C	°C	°C	°C	°C
962	5.508	963.47	963.50	963.01	963.44	963.00	963.11	963.04	962.20
1000	5.822	1001.76	1001.79	1001.25	1001.65	1001.11	1001.30	1001.30	1000.38
1064	6.399	1066.08	1066.12	1065.66	1065.92	1065.32	1065.67	1065.53	1064.56
1085	6.594	1086.46	1086.50	1086.04	1086.34	1085.62		1085.91	1084.95
1100	6.745	1101.85	1101.95	1101.46	1101.73	1100.94	1100.97	1101.30	1100.40
1200	7.795	1201.95	1202.04	1201.27	1201.74	1200.77	1200.98	1201.31	1200.37
1300	8.948	1302.27	1302.40	1301.51	1301.90	1300.77	1301.29	1301.51	1300.59
1400	10.183	1402.63	1402.83	1402.19	1402.09	1400.71	1401.57	1401.72	1400.83
1500	11.487	1502.88	1503.07	1501.76	1502.15	1500.53	1501.84	1501.82	1501.11
1600	12.852	1602.96	1603.25	1601.50	1601.92	1599.99	1601.90	1602.46	1600.78
1700	14.273	1702.94	1703.44	1701.19	1701.62	1699.42	1701.80	1702.27	1700.54

Table 11 Combined standard uncertainties of the measured temperatures by each NMI (lamp C564)

		VSL	CEM	MIKES	IPQ	MKEH	SMU	SP	UME
T	Current	u(T), k=1	u(T), k=1	u(T), k=1	u(T), k=1	u(T), k=1	u(T), k=1	u(T), k=1	u(T), k=1
°C	A	°C	°C	°C	°C	°C	°C	°C	°C
962	4.48	0.10	0.10	0.47	0.35	1.64	0.28	0.33	0.13
1000	4.721	0.10	0.11	0.50	0.33	1.24	0.22	0.35	0.16
1064	5.169	0.11	0.12	0.54	0.35	0.87	0.18	0.39	0.17
1085	5.322	0.11	0.12	0.54	0.36	0.86		0.40	0.17
1100	5.441	0.11	0.13	0.55	0.36	0.88	0.18	0.41	0.18
1200	6.272	0.12	0.17	0.63	0.42	0.89	0.17	0.47	0.21
1300	7.194	0.14	0.15	0.71	0.48	0.98	0.18	0.54	0.24
1400	8.189	0.16	0.18	0.79	0.55	1.06	0.20	0.62	0.27
1500	9.242	0.17	0.22	0.87	0.63	1.19	0.22	0.71	0.31
1600	10.347	0.19	0.82	0.96	0.72	1.35	0.24	0.80	0.35
1700	11.502	0.21	0.32	1.88	0.82	1.47	0.27	0.91	0.39

Table 12 Combined standard uncertainties of the measured temperatures by each NMI (lamp C681)

		VSL	CEM	MIKES	IPQ	OMH	SMU	SP	UME
Temp	Current	u(T), k=1	u(T), k=1	u(T), k=1	u(T), k=1	u(T), k=1	u(T), k=1	u(T), k=1	u(T), k=1
°C	A	°C	°C	°C	°C	°C	°C	°C	°C
962	5.508	0.10	0.10	0.42	0.31	1.70	0.27	0.33	0.15
1000	5.822	0.10	0.11	0.43	0.34	1.24	0.22	0.35	0.14
1064	6.399	0.11	0.11	0.47	0.35	0.94	0.18	0.39	0.18
1085	6.594	0.11	0.10	0.49	0.36	0.91		0.40	0.25
1100	6.745	0.11	0.12	0.49	0.38	0.91	0.18	0.41	0.19
1200	7.795	0.12	0.16	0.67	0.43	0.97	0.17	0.47	0.23
1300	8.948	0.14	0.17	0.78	0.50	1.08	0.18	0.54	0.26
1400	10.183	0.16	0.23	0.70	0.58	1.20	0.21	0.62	0.28
1500	11.487	0.17	0.32	0.96	0.66	1.34	0.24	0.71	0.32
1600	12.852	0.19	0.36	1.14	0.76	1.52	0.25	0.80	0.36
1700	14.273	0.21	0.40	1.25	0.87	1.65	0.29	0.91	0.47

Table 13 Overall mean, median and standard deviation of the average measured temperatures for lamps C564 and C681, from all participants.

Nominal Temperature	**Mean** C564	**Mean** C681	**Median** C564	**Median** C681	**Stdev** C564	**Stdev** C681
^{0} C	^{0} C	^{0} C	^{0} C	^{0} C	^{0} C	^{0} C
962	963.98	963.09	963.62	963.07	1.18	0.42
1000	1001.66	1001.32	1001.58	1001.30	0.52	0.46
1064	1065.80	1065.61	1065.78	1065.66	0.53	0.50
1085	1086.23	1085.97	1086.23	1086.04	0.55	0.55
1100	1101.56	1101.32	1101.60	1101.38	0.59	0.53
1200	1201.32	1201.30	1201.34	1201.29	0.65	0.59
1300	1301.34	1301.53	1301.37	1301.51	0.71	0.65
1400	1401.57	1401.82	1401.60	1401.90	0.80	0.77
1500	1501.76	1501.89	1501.77	1501.83	0.89	0.84
1600	1601.94	1601.84	1602.23	1601.91	1.02	1.09
1700	1702.24	1701.65	1702.40	1701.71	1.29	1.29

VII. Proposal for establishing Euramet-K5 KCRV and linking with CCT-K5 comparison:

For this key comparison, it is proposed that no Euramet K5 reference values should be established but rather the KCRV from CCT-K5 comparison should be used. The measurement data in this Euramet-K5 should be directly link to the CCT-K5 KCRV for the following reasons:

a. There is no difference in the conduct of the experiments for CCT-K5 and Euramet K5 since the protocols used in both key comparisons have the same technical content (e.g., experimental procedures for conducting the temperature measurement, guidelines for lamp calibration, guide to uncertainty determination, etc), thereby enabling a direct linking of the temperature values reported in this report to the CCT-K5 KCRV.

b. The lamps (C564 and C681) used in both comparisons (CCT-K5 loop 1 and Euramet K5) are the same and from the previous section it has been established that both lamp performances (in terms of lamp resistance stabilities) are similar during these two key comparisons and no apparent lamp degradation has been observed or reported in these two key comparisons. The uncertainty due to lamp stability, therefore, is not a cause for concern.

A. Establishing KCRV data from CCT-K5:

The key comparison reference values for the CCT-K5 comparison have been already established and definitively accepted by the participating institutes. The calculation and establishment of the KCRV are fully described in the report (1). Table 14 shows the CCT-K5 key comparison reference values for lamp C564 and C681, respectively, and the associated uncertainties.

Table 14 CCT-K5 key comparison reference values and corresponding uncertainties (k=1) for lamps C564 and C681.

Nom. Temp	Lamp C564 Nom. Current	Lamp C564 Temp, KCRV	Lamp C681 Nom. Current	Lamp C681 Temp, KCRV	Lamp C564	Lamp C681
°C	A	°C	A	°C	u(T), k=1	u(T), k=1
962	4.48	964.115	5.508	963.505	0.096	0.057
1000	4.721	1002.130	5.822	1001.760	0.117	0.038
1064	5.169	1066.290	6.399	1066.110	0.114	0.038
1085	5.322	1086.670	6.594	1086.480	0.111	0.039
1100	5.441	1102.110	6.745	1101.890	0.103	0.041
1200	6.272	1202.020	7.795	1202.050	0.087	0.046
1300	7.194	1302.090	8.948	1302.370	0.087	0.053
1400	8.189	1402.410	10.183	1402.710	0.086	0.042
1500	9.242	1502.720	11.487	1503.040	0.073	0.061
1600	10.347	1603.020	12.852	1603.110	0.049	0.078
1700	11.502	1703.560	14.273	1703.230	0.041	0.065

B. Unilateral Degree of Equivalence:

Figure 7 - Figure 17 show an overview of the temperature differences (T_{labi} - T_{KCRV}), for lamps C564 and C681, between participants and the CCT-K5 key comparison values, at different nominal temperatures. The error bars presented are the expanded uncertainty , U(D_i), k=2. It can be observed that some data from three participants have significant deviations from the CCT-K5 KCRV. Significant deviations from the KRCV are observed from the reported data by TUBITAK-UME, SMU, and MKEH. From the review of their submitted data and confirming the large deviation of these data from the KRCV, TUBITAK-UME remarked that prior to the comparison they noticed that their pyrometer (Vega made TSP-2) was likely to have a large side-band responsivity which could affect their measurements tremendously (in the order of degrees especially at high temperatures). For this reason, they did some corrections for this side-band responsivity using cut-off filters. However such corrections might have resulted to this significant unresolved deviation (SUD). For MKEH, it seems that the SSE was not exactly estimated, and the working wavelength of the pyrometer was different from the wavelength which had been measured for the filter with spectrophotometer. SMU also suspected that the cause for this SUD of their data is due to the spectral responsivity of their pyrometer.

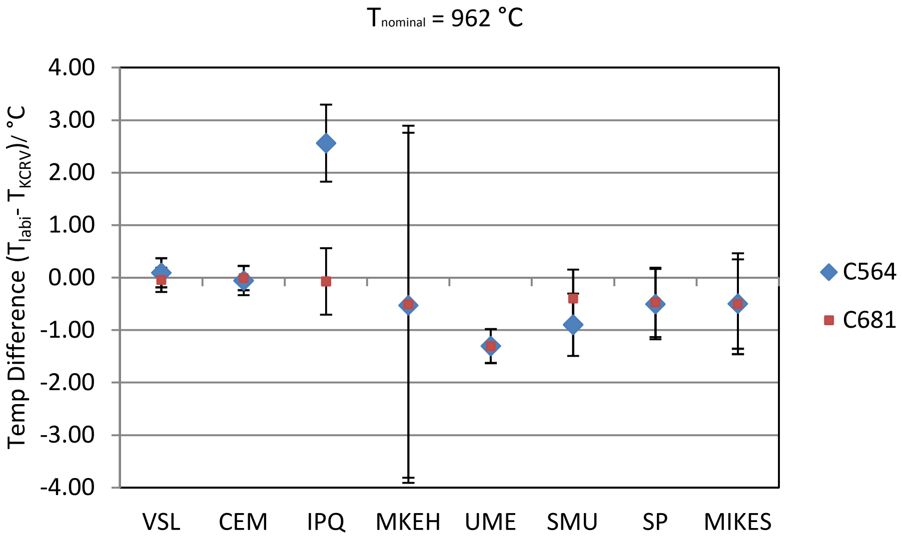


Figure 7 Overview of the temperature differences (for lamps C564 and C681) between participants and the CCT-K5 KCRV data, at nominal T= 962 °C. The uncertainties presented are at k=2.

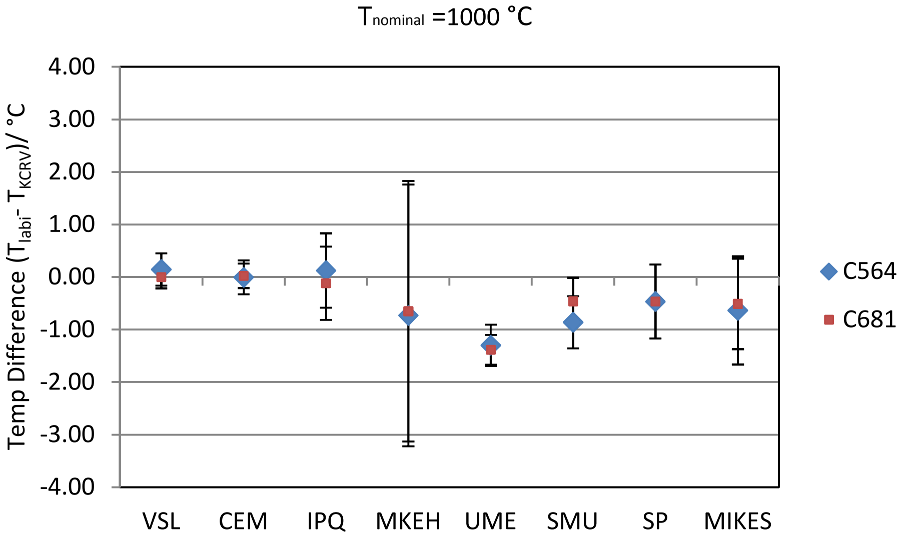


Figure 8 Overview of the temperature differences (for lamps C564 and C681) between participants and the CCT-K5 KCRV data, at nominal T = 1000 °C. The uncertainties presented are at k=2.

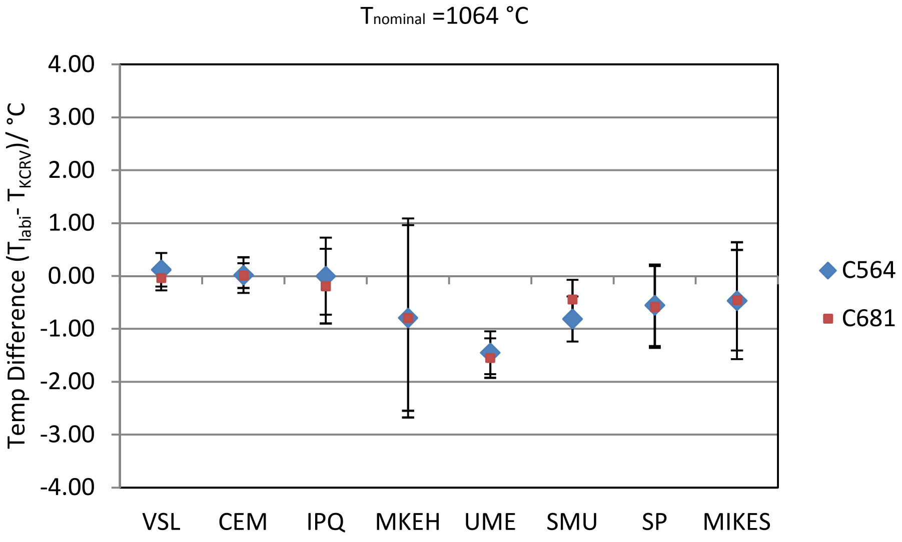


Figure 9 Overview of the temperature differences (for lamps C564 and C681) between participants and the CCT-K5 KCRV data, at nominal T= 1064 °C. The uncertainties presented are at k=2.

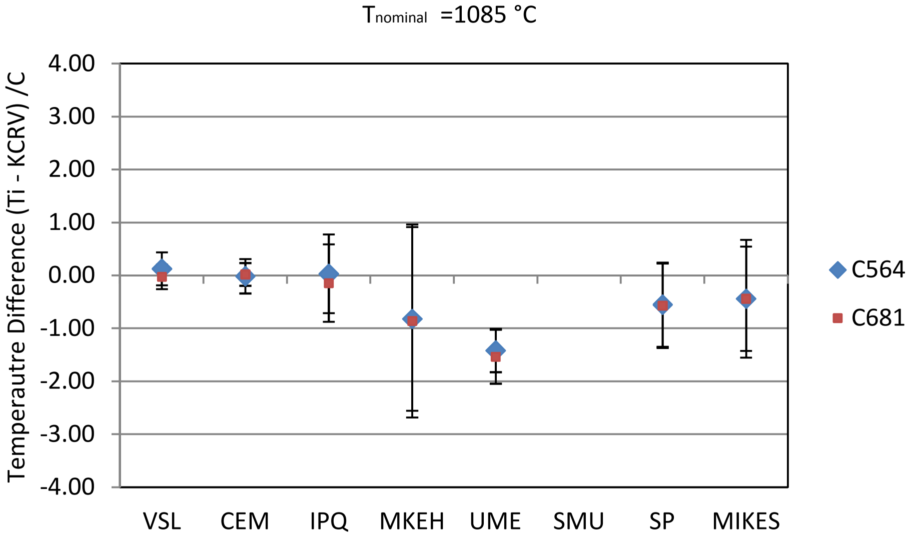


Figure 10 Overview of the temperature differences (for lamps C564 and C681) between participants and the CCT-K5 KCRV data, at nominal T= 1085 °C. The uncertainties presented are at k=2.

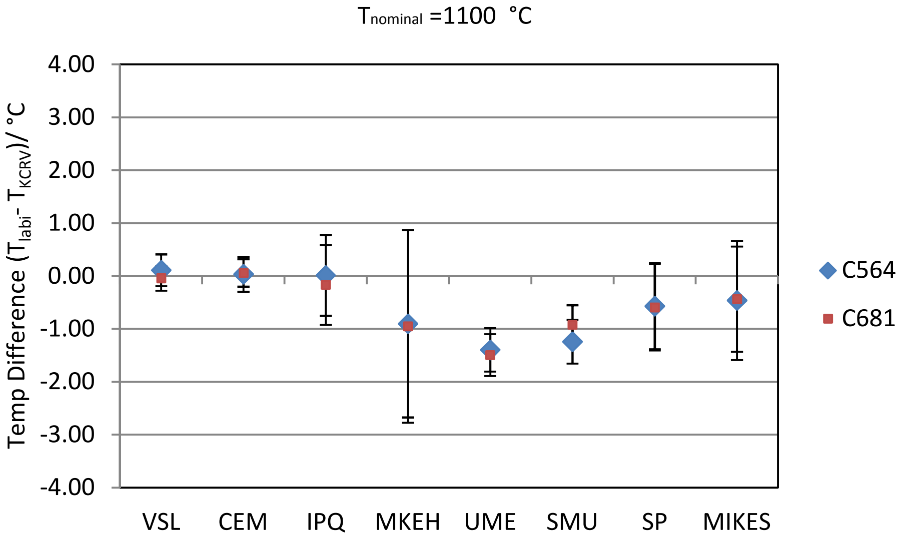


Figure 11 Overview of the temperature differences (for lamps C564 and C681) between participants and the CCT-K5 KCRV data, at nominal T= 1100 °C. The uncertainties presented are at k=2.

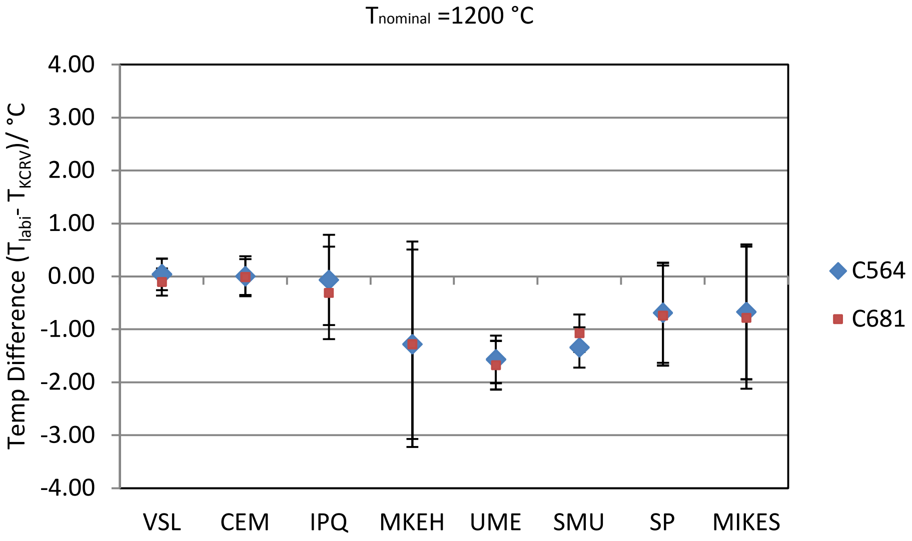


Figure 12 Overview of the temperature differences (for lamps C564 and C681) between participants and the CCT-K5 KCRV data, at nominal T= 1200 °C. The uncertainties presented are at k=2.

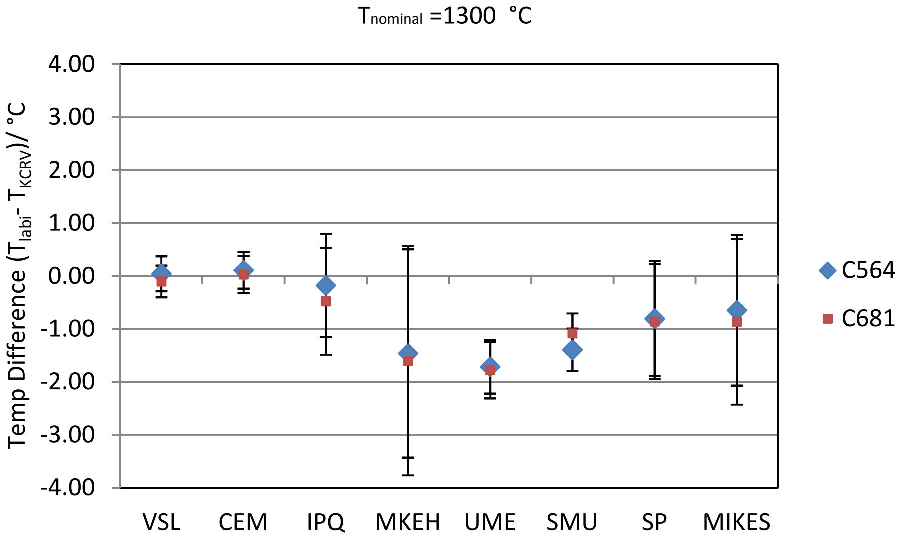


Figure 13 Overview of the temperature differences (for lamps C564 and C681) between participants and the CCT-K5 KCRV data, at nominal T= 1300 °C. The uncertainties presented are at k=2.

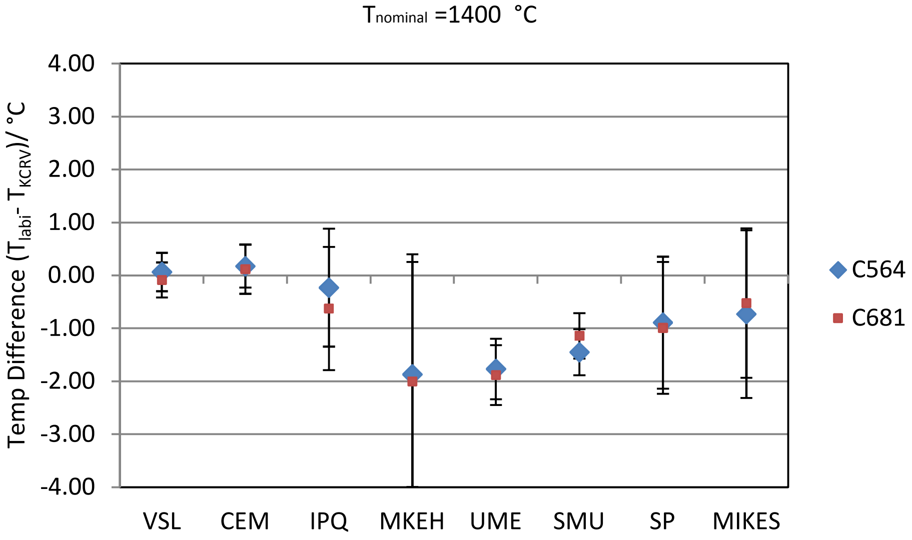


Figure 14 Overview of the temperature differences (for lamps C564 and C681) between participants and the CCT-K5 KCRV data, at nominal T= 1400 °C. The uncertainties presented are at k=2..

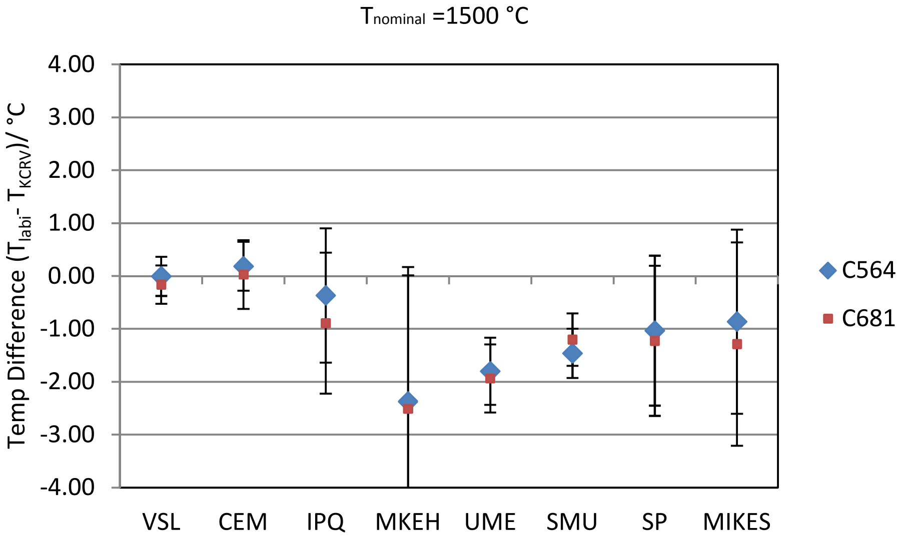


Figure 15 Overview of the temperature differences between participants and the CCT-K5 KCRV data, at nominal T= 1500 °C. The uncertainties presented are at k=2.

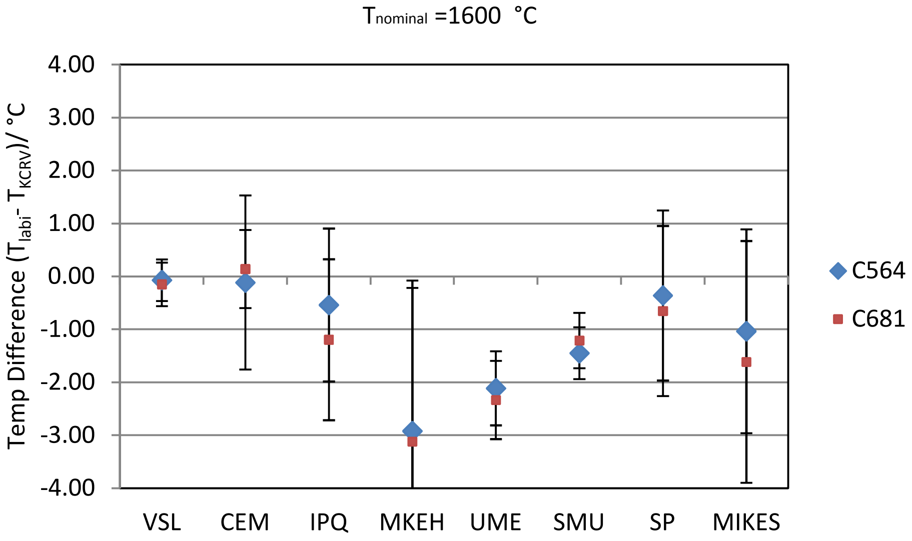


Figure 16 Overview of the temperature differences between participants and the CCT-K5 KCRV data, at nominal T= 1600 °C. The uncertainties presented are at k=2.

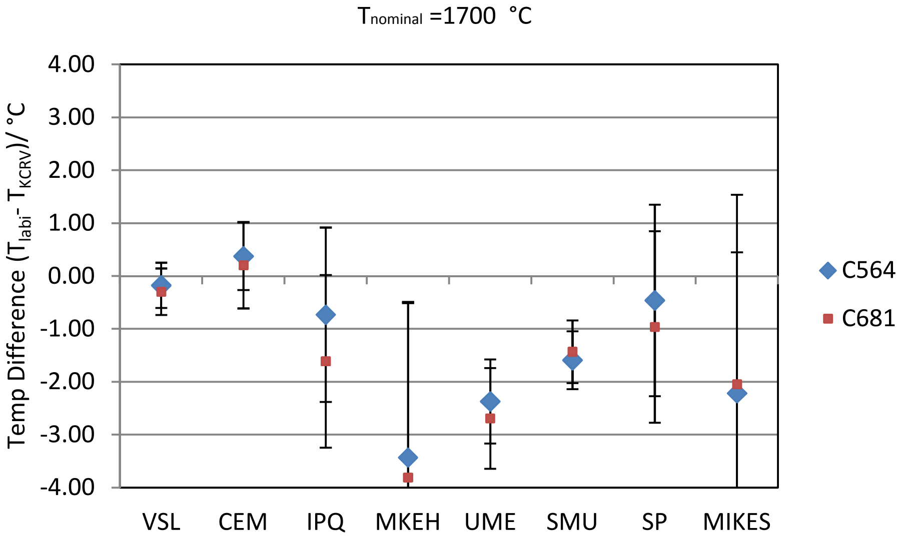


Figure 17 Overview of the temperature differences between participants and the CCT-K5 KCRV data, at nominal T= 1700 °C. The uncertainties presented are at k=2.

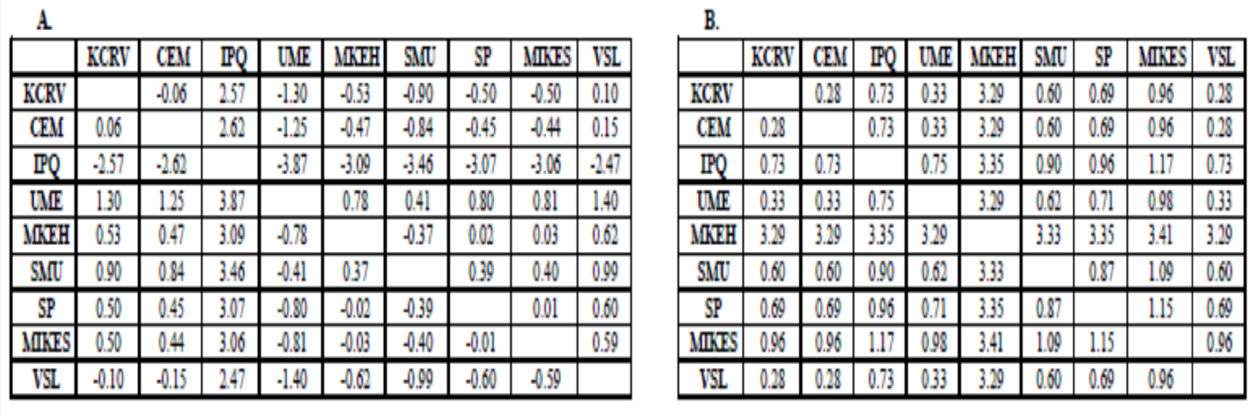
C. Inter-laboratory cross-equivalence:

Tables 15-36 show the inter-laboratory cross-equivalence values, $T_{labi,labj}$, for the temperature differences and the corresponding expanded uncertainties, ($U(T),k=2$) between institutes including the CCT-K5 KCRV values, for each nominal temperature, for lamp C564 and C681 respectively. The data used to compute the cross-equivalence are from Tables 9-10 and Table 14. In the same manner as the cross-equivalence values were computed in the CCT-K5 comparison, the following equations are used to derive the temperature cross-equivalent values and the associated expanded uncertainties for this Euramet-K5 extension.

$$T_{labi,labj} = T_{labi} - T_{labj} = (T_{labi} - T_{KCRV}) - (T_{labj} - T_{KCRV}) = (T_{labi} - T_{labj}) \quad (1),$$

$$U_{labi,labj} = 2 * \sqrt{u_i(T)^2 + u_j(T)^2} \quad (2).$$

Table 15. Inter-laboratory cross-equivalence of measured tungsten strip lamp temperature (C564) at t = 962 °C, (a. cross-equivalence value , b. expanded uncertainty, k=2).



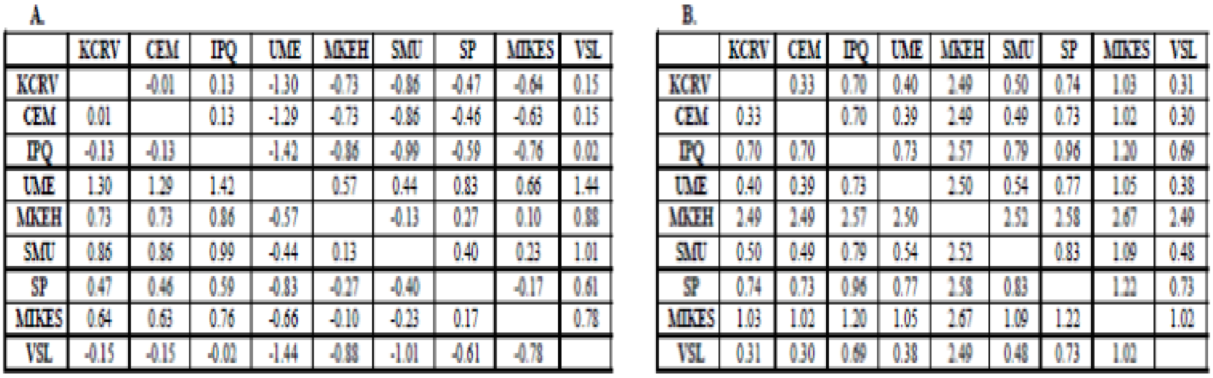
A.

	KCRV	CEM	IPQ	UME	MKEH	SMU	SP	MIKES	VSL
KCRV		-0.06	2.57	-1.30	-0.53	-0.90	-0.50	-0.50	0.10
CEM	0.06		2.62	-1.25	-0.47	-0.84	-0.45	-0.44	0.15
IPQ	-2.57	-2.62		-3.87	-3.09	-3.46	-3.07	-3.06	-2.47
UME	1.30	1.25	3.87		0.78	0.41	0.80	0.81	1.40
MKEH	0.53	0.47	3.09	-0.78		-0.37	0.02	0.03	0.62
SMU	0.90	0.84	3.46	-0.41	0.37		0.39	0.40	0.99
SP	0.50	0.45	3.07	-0.80	-0.02	-0.39		0.01	0.60
MIKES	0.50	0.44	3.06	-0.81	-0.03	-0.40	-0.01		0.59
VSL	-0.10	-0.15	2.47	-1.40	-0.62	-0.99	-0.60	-0.59	

B.

	KCRV	CEM	IPQ	UME	MKEH	SMU	SP	MIKES	VSL
KCRV		0.28	0.73	0.33	3.29	0.60	0.69	0.96	0.28
CEM	0.28		0.73	0.33	3.29	0.60	0.69	0.96	0.28
IPQ	0.73	0.73		0.75	3.35	0.90	0.96	1.17	0.73
UME	0.33	0.33	0.75		3.29	0.62	0.71	0.98	0.33
MKEH	3.29	3.29	3.35	3.29		3.33	3.35	3.41	3.29
SMU	0.60	0.60	0.90	0.62	3.33		0.87	1.09	0.60
SP	0.69	0.69	0.96	0.71	3.35	0.87		1.15	0.69
MIKES	0.96	0.96	1.17	0.98	3.41	1.09	1.15		0.96
VSL	0.28	0.28	0.73	0.33	3.29	0.60	0.69	0.96	

Table 16 Inter-laboratory cross-equivalence of measured tungsten strip lamp temperature (C564) at t = 1000 °C, (a. cross-equivalence value , b. expanded uncertainty, k=2).



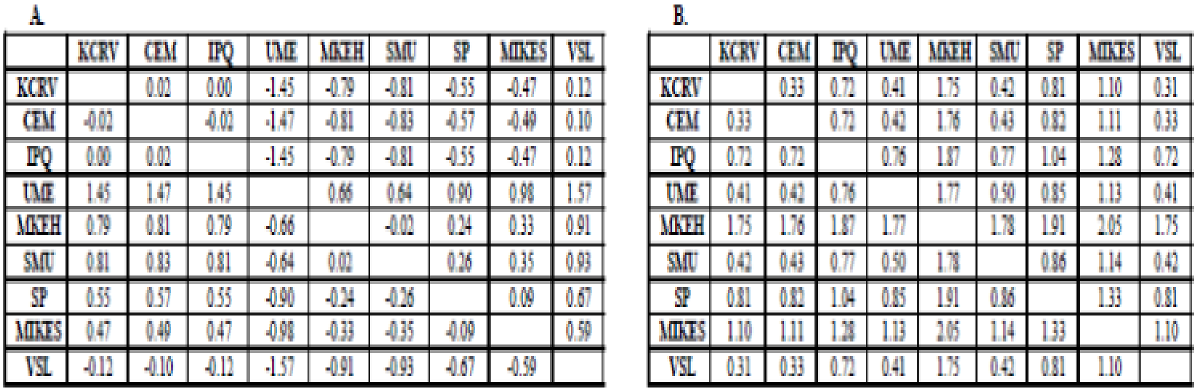
A.

	KCRV	CEM	IPQ	UME	MKEH	SMU	SP	MIKES	VSL
KCRV		-0.01	0.13	-1.30	-0.73	-0.86	-0.47	-0.64	0.15
CEM	0.01		0.13	-1.29	-0.73	-0.86	-0.46	-0.63	0.15
IPQ	-0.13	-0.13		-1.42	-0.86	-0.99	-0.59	-0.76	0.02
UME	1.30	1.29	1.42		0.57	0.44	0.83	0.66	1.44
MKEH	0.73	0.73	0.86	-0.57		-0.13	0.27	0.10	0.88
SMU	0.86	0.86	0.99	-0.44	0.13		0.40	0.23	1.01
SP	0.47	0.46	0.59	-0.83	-0.27	-0.40		-0.17	0.61
MIKES	0.64	0.63	0.76	-0.66	-0.10	-0.23	0.17		0.78
VSL	-0.15	-0.15	-0.02	-1.44	-0.88	-1.01	-0.61	-0.78	

B.

	KCRV	CEM	IPQ	UME	MKEH	SMU	SP	MIKES	VSL
KCRV		0.33	0.70	0.40	2.49	0.50	0.74	1.03	0.31
CEM	0.33		0.70	0.39	2.49	0.49	0.73	1.02	0.30
IPQ	0.70	0.70		0.73	2.57	0.79	0.96	1.20	0.69
UME	0.40	0.39	0.73		2.50	0.54	0.77	1.05	0.38
MKEH	2.49	2.49	2.57	2.50		2.52	2.58	2.67	2.49
SMU	0.50	0.49	0.79	0.54	2.52		0.83	1.09	0.48
SP	0.74	0.73	0.96	0.77	2.58	0.83		1.22	0.73
MIKES	1.03	1.02	1.20	1.05	2.67	1.09	1.22		1.02
VSL	0.31	0.30	0.69	0.38	2.49	0.48	0.73	1.02	

Table 17 Inter-laboratory cross-equivalence of cross-equivalence of measured tungsten strip lamp temperature (C564) at t = 1064 °C, (a. cross-equivalence value , b. expanded uncertainty, k=2).



A.

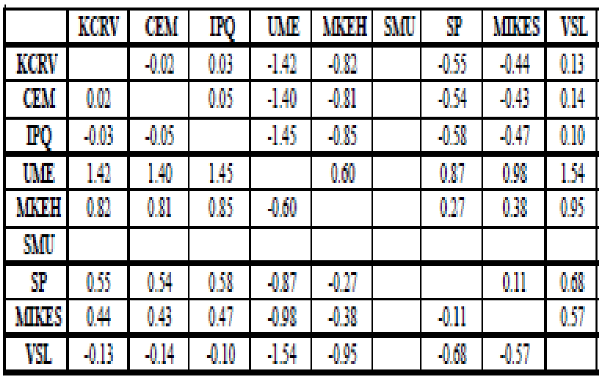
	KCRV	CEM	IPQ	UME	MKEH	SMU	SP	MIKES	VSL
KCRV		0.02	0.00	-1.45	-0.79	-0.81	-0.55	-0.47	0.12
CEM	-0.02		-0.02	-1.47	-0.81	-0.83	-0.57	-0.49	0.10
IPQ	0.00	0.02		-1.45	-0.79	-0.81	-0.55	-0.47	0.12
UME	1.45	1.47	1.45		0.66	0.64	0.90	0.98	1.57
MKEH	0.79	0.81	0.79	-0.66		-0.02	0.24	0.33	0.91
SMU	0.81	0.83	0.81	-0.64	0.02		0.26	0.35	0.93
SP	0.55	0.57	0.55	-0.90	-0.24	-0.26		0.09	0.67
MIKES	0.47	0.49	0.47	-0.98	-0.33	-0.35	-0.09		0.59
VSL	-0.12	-0.10	-0.12	-1.57	-0.91	-0.93	-0.67	-0.59	

B.

	KCRV	CEM	IPQ	UME	MKEH	SMU	SP	MIKES	VSL
KCRV		0.33	0.72	0.41	1.75	0.42	0.81	1.10	0.31
CEM	0.33		0.72	0.42	1.76	0.43	0.82	1.11	0.33
IPQ	0.72	0.72		0.76	1.87	0.77	1.04	1.28	0.72
UME	0.41	0.42	0.76		1.77	0.50	0.85	1.13	0.41
MKEH	1.75	1.76	1.87	1.77		1.78	1.91	2.05	1.75
SMU	0.42	0.43	0.77	0.50	1.78		0.86	1.14	0.42
SP	0.81	0.82	1.04	0.85	1.91	0.86		1.33	0.81
MIKES	1.10	1.11	1.28	1.13	2.05	1.14	1.33		1.10
VSL	0.31	0.33	0.72	0.41	1.75	0.42	0.81	1.10	

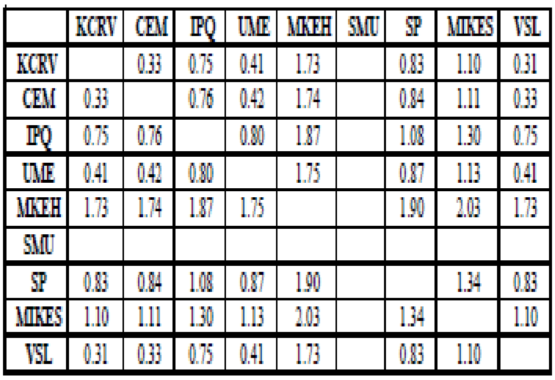
Table 18 Inter-laboratory cross-equivalence of measured tungsten strip lamp temperature (C564) at t = 1085 °C, (a. cross-equivalence value , b. expanded uncertainty, k=2).

A.



	KCRV	CEM	IPQ	UME	MKEH	SMU	SP	MIKES	VSL
KCRV		-0.02	0.03	-1.42	-0.82		-0.55	-0.44	0.13
CEM	0.02		0.05	-1.40	-0.81		-0.54	-0.43	0.14
IPQ	-0.03	-0.05		-1.45	-0.85		-0.58	-0.47	0.10
UME	1.42	1.40	1.45		0.60		0.87	0.98	1.54
MKEH	0.82	0.81	0.85	-0.60			0.27	0.38	0.95
SMU									
SP	0.55	0.54	0.58	-0.87	-0.27			0.11	0.68
MIKES	0.44	0.43	0.47	-0.98	-0.38		-0.11		0.57
VSL	-0.13	-0.14	-0.10	-1.54	-0.95		-0.68	-0.57	

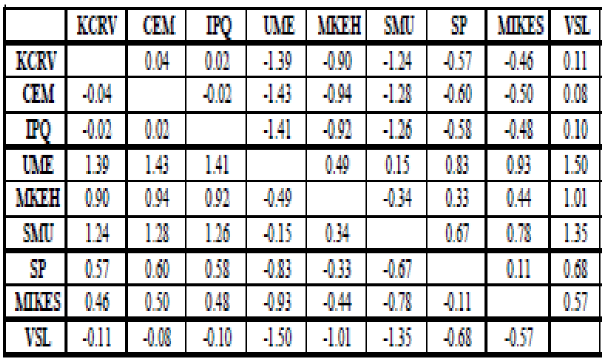
B.



	KCRV	CEM	IPQ	UME	MKEH	SMU	SP	MIKES	VSL
KCRV		0.33	0.75	0.41	1.73		0.83	1.10	0.31
CEM	0.33		0.76	0.42	1.74		0.84	1.11	0.33
IPQ	0.75	0.76		0.80	1.87		1.08	1.30	0.75
UME	0.41	0.42	0.80		1.75		0.87	1.13	0.41
MKEH	1.73	1.74	1.87	1.75			1.90	2.03	1.73
SMU									
SP	0.83	0.84	1.08	0.87	1.90			1.34	0.83
MIKES	1.10	1.11	1.30	1.13	2.03		1.34		1.10
VSL	0.31	0.33	0.75	0.41	1.73		0.83	1.10	

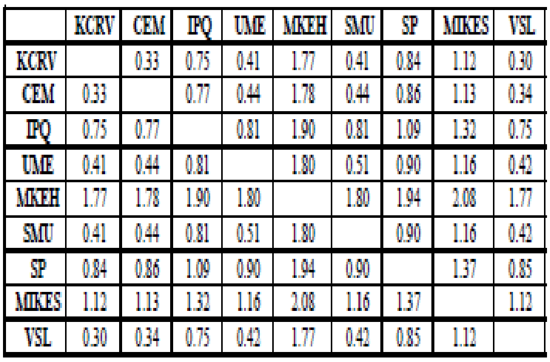
Table 19 Inter-laboratory cross-equivalence of measured tungsten strip lamp temperature (C564) at t = 1100 °C, (a. cross-equivalence value , b. expanded uncertainty, k=2).

A.



	KCRV	CEM	IPQ	UME	MKEH	SMU	SP	MIKES	VSL
KCRV		0.04	0.02	-1.39	-0.90	-1.24	-0.57	-0.46	0.11
CEM	-0.04		-0.02	-1.43	-0.94	-1.28	-0.60	-0.50	0.08
IPQ	-0.02	0.02		-1.41	-0.92	-1.26	-0.58	-0.48	0.10
UME	1.39	1.43	1.41		0.49	0.15	0.83	0.93	1.50
MKEH	0.90	0.94	0.92	-0.49		-0.34	0.33	0.44	1.01
SMU	1.24	1.28	1.26	-0.15	0.34		0.67	0.78	1.35
SP	0.57	0.60	0.58	-0.83	-0.33	-0.67		0.11	0.68
MIKES	0.46	0.50	0.48	-0.93	-0.44	-0.78	-0.11		0.57
VSL	-0.11	-0.08	-0.10	-1.50	-1.01	-1.35	-0.68	-0.57	

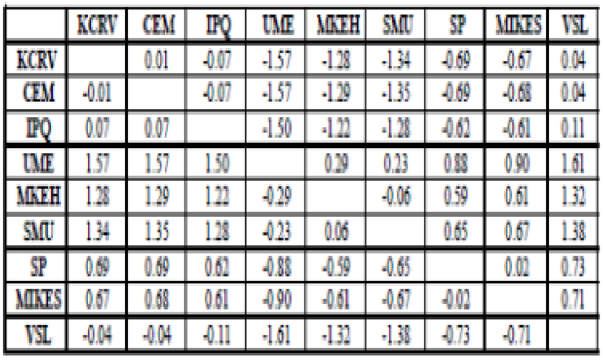
B.



	KCRV	CEM	IPQ	UME	MKEH	SMU	SP	MIKES	VSL
KCRV		0.33	0.75	0.41	1.77	0.41	0.84	1.12	0.30
CEM	0.33		0.77	0.44	1.78	0.44	0.86	1.13	0.34
IPQ	0.75	0.77		0.81	1.90	0.81	1.09	1.32	0.75
UME	0.41	0.44	0.81		1.80	0.51	0.90	1.16	0.42
MKEH	1.77	1.78	1.90	1.80		1.80	1.94	2.08	1.77
SMU	0.41	0.44	0.81	0.51	1.80		0.90	1.16	0.42
SP	0.84	0.86	1.09	0.90	1.94	0.90		1.37	0.85
MIKES	1.12	1.13	1.32	1.16	2.08	1.16	1.37		1.12
VSL	0.30	0.34	0.75	0.42	1.77	0.42	0.85	1.12	

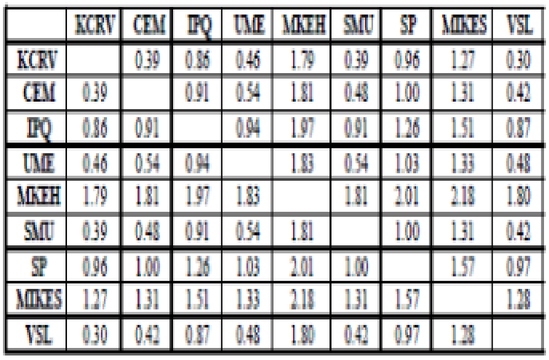
Table 20 Inter-laboratory cross-equivalence of measured tungsten strip lamp temperature (C564) at t = 1200 °C, (a. cross-equivalence value , b. expanded uncertainty, k=2).

A.



	KCRV	CEM	IPQ	UME	MKEH	SMU	SP	MIKES	VSL
KCRV		0.01	-0.07	-1.57	-1.28	-1.34	-0.69	-0.67	0.04
CEM	-0.01		-0.07	-1.57	-1.29	-1.35	-0.69	-0.68	0.04
IPQ	0.07	0.07		-1.50	-1.22	-1.28	-0.62	-0.61	0.11
UME	1.57	1.57	1.50		0.29	0.23	0.88	0.90	1.61
MKEH	1.28	1.29	1.22	-0.29		-0.06	0.59	0.61	1.32
SMU	1.34	1.35	1.28	-0.23	0.06		0.65	0.67	1.38
SP	0.69	0.69	0.62	-0.88	-0.59	-0.65		0.02	0.73
MIKES	0.67	0.68	0.61	-0.90	-0.61	-0.67	-0.02		0.71
VSL	-0.04	-0.04	-0.11	-1.61	-1.32	-1.38	-0.73	-0.71	

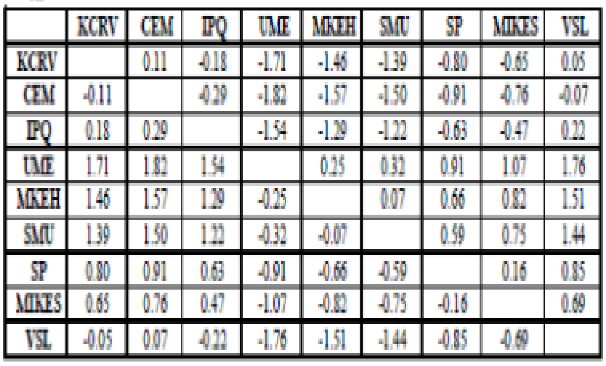
B.



	KCRV	CEM	IPQ	UME	MKEH	SMU	SP	MIKES	VSL
KCRV		0.39	0.86	0.46	1.79	0.39	0.96	1.27	0.30
CEM	0.39		0.91	0.54	1.81	0.48	1.00	1.31	0.42
IPQ	0.86	0.91		0.94	1.97	0.91	1.26	1.51	0.87
UME	0.46	0.54	0.94		1.83	0.54	1.03	1.33	0.48
MKEH	1.79	1.81	1.97	1.83		1.81	2.01	2.18	1.80
SMU	0.39	0.48	0.91	0.54	1.81		1.00	1.31	0.42
SP	0.96	1.00	1.26	1.03	2.01	1.00		1.57	0.97
MIKES	1.27	1.31	1.51	1.33	2.18	1.31	1.57		1.28
VSL	0.30	0.42	0.87	0.48	1.80	0.42	0.97	1.28	

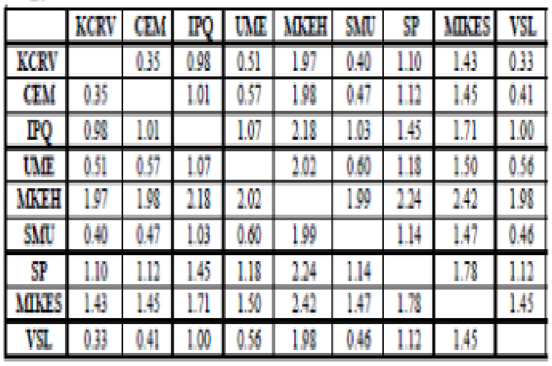
Table 21 Inter-laboratory cross-equivalence of measured tungsten strip lamp temperature (C564) at t = 1300 °C, (a. cross-equivalence value , b. expanded uncertainty, k=2).

A.



	KCRV	CEM	IPQ	UME	MKEH	SMU	SP	MIKES	VSL
KCRV		0.11	-0.18	-1.71	-1.46	-1.39	-0.80	-0.65	0.05
CEM	-0.11		-0.29	-1.82	-1.57	-1.50	-0.91	-0.76	-0.07
IPQ	0.18	0.29		-1.54	-1.29	-1.22	-0.63	-0.47	0.22
UME	1.71	1.82	1.54		0.25	0.32	0.91	1.07	1.76
MKEH	1.46	1.57	1.29	-0.25		0.07	0.66	0.82	1.51
SMU	1.39	1.50	1.22	-0.32	-0.07		0.59	0.75	1.44
SP	0.80	0.91	0.63	-0.91	-0.66	-0.59		0.16	0.85
MIKES	0.65	0.76	0.47	-1.07	-0.82	-0.75	-0.16		0.69
VSL	-0.05	0.07	-0.22	-1.76	-1.51	-1.44	-0.85	-0.69	

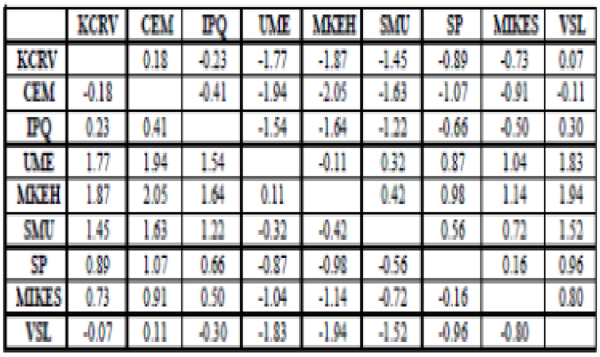
B.



	KCRV	CEM	IPQ	UME	MKEH	SMU	SP	MIKES	VSL
KCRV		0.35	0.98	0.51	1.97	0.40	1.10	1.43	0.33
CEM	0.35		1.01	0.57	1.98	0.47	1.12	1.45	0.41
IPQ	0.98	1.01		1.07	2.18	1.03	1.45	1.71	1.00
UME	0.51	0.57	1.07		2.02	0.60	1.18	1.50	0.56
MKEH	1.97	1.98	2.18	2.02		1.99	2.24	2.42	1.98
SMU	0.40	0.47	1.03	0.60	1.99		1.14	1.47	0.46
SP	1.10	1.12	1.45	1.18	2.24	1.14		1.78	1.12
MIKES	1.43	1.45	1.71	1.50	2.42	1.47	1.78		1.45
VSL	0.33	0.41	1.00	0.56	1.98	0.46	1.12	1.45	

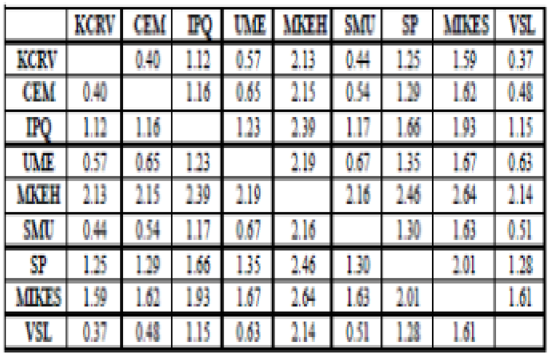
Table 22 Inter-laboratory cross-equivalence of measured tungsten strip lamp temperature (C564) at t = 1400 °C, (a. cross-equivalence value , b. expanded uncertainty, k=2).

A.



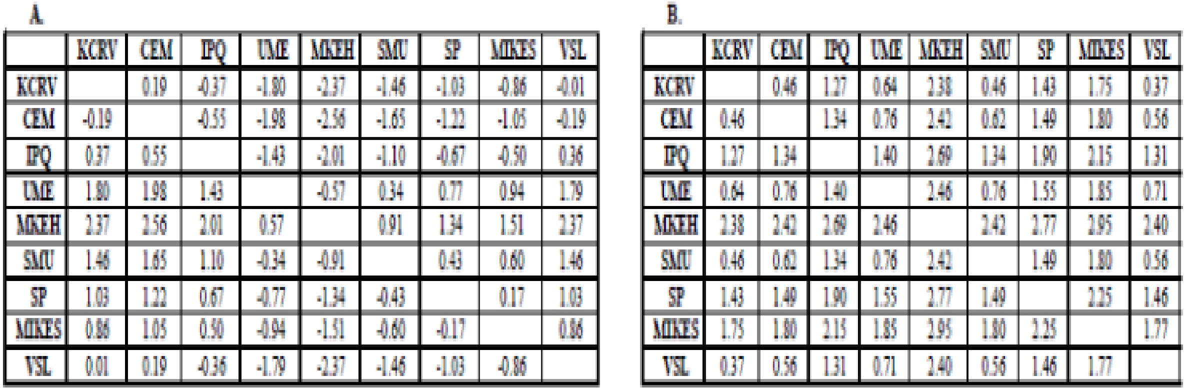
	KCRV	CEM	IPQ	UME	MKEH	SMU	SP	MIKES	VSL
KCRV		0.18	-0.23	-1.77	-1.87	-1.45	-0.89	-0.73	0.07
CEM	-0.18		-0.41	-1.94	-2.05	-1.63	-1.07	-0.91	-0.11
IPQ	0.23	0.41		-1.54	-1.64	-1.22	-0.66	-0.50	0.30
UME	1.77	1.94	1.54		-0.11	0.32	0.87	1.04	1.83
MKEH	1.87	2.05	1.64	0.11		0.42	0.98	1.14	1.94
SMU	1.45	1.63	1.22	-0.32	-0.42		0.56	0.72	1.52
SP	0.89	1.07	0.66	-0.87	-0.98	-0.56		0.16	0.96
MIKES	0.73	0.91	0.50	-1.04	-1.14	-0.72	-0.16		0.80
VSL	-0.07	0.11	-0.30	-1.83	-1.94	-1.52	-0.96	-0.80	

B.



	KCRV	CEM	IPQ	UME	MKEH	SMU	SP	MIKES	VSL
KCRV		0.40	1.12	0.57	2.13	0.44	1.25	1.59	0.37
CEM	0.40		1.16	0.65	2.15	0.54	1.29	1.62	0.48
IPQ	1.12	1.16		1.23	2.39	1.17	1.66	1.93	1.15
UME	0.57	0.65	1.23		2.19	0.67	1.35	1.67	0.63
MKEH	2.13	2.15	2.39	2.19		2.16	2.46	2.64	2.14
SMU	0.44	0.54	1.17	0.67	2.16		1.30	1.63	0.51
SP	1.25	1.29	1.66	1.35	2.46	1.30		2.01	1.28
MIKES	1.59	1.62	1.93	1.67	2.64	1.63	2.01		1.61
VSL	0.37	0.48	1.15	0.63	2.14	0.51	1.28	1.61	

Table 23 Inter-laboratory cross-equivalence of measured tungsten strip lamp temperature (C564) at t = 1500 °C, (a. cross-equivalence value , b. expanded uncertainty, k=2).



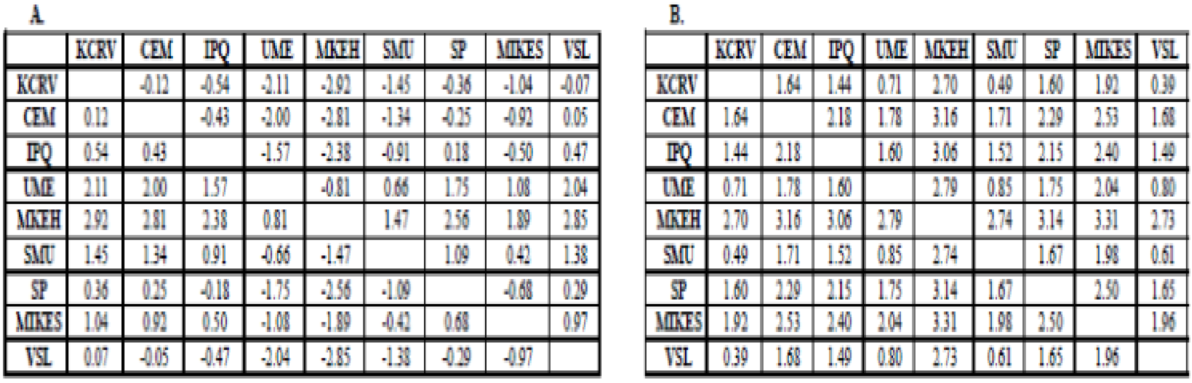
A.

	KCRV	CEM	IPQ	UME	MKEH	SMU	SP	MIKES	VSL
KCRV		0.19	-0.37	-1.80	-2.37	-1.46	-1.03	-0.86	-0.01
CEM	-0.19		-0.55	-1.98	-2.56	-1.65	-1.22	-1.05	-0.19
IPQ	0.37	0.55		-1.43	-2.01	-1.10	-0.67	-0.50	0.36
UME	1.80	1.98	1.43		-0.57	0.34	0.77	0.94	1.79
MKEH	2.37	2.56	2.01	0.57		0.91	1.34	1.51	2.37
SMU	1.46	1.65	1.10	-0.34	-0.91		0.43	0.60	1.46
SP	1.03	1.22	0.67	-0.77	-1.34	-0.43		0.17	1.03
MIKES	0.86	1.05	0.50	-0.94	-1.51	-0.60	-0.17		0.86
VSL	0.01	0.19	-0.36	-1.79	-2.37	-1.46	-1.03	-0.86	

B.

	KCRV	CEM	IPQ	UME	MKEH	SMU	SP	MIKES	VSL
KCRV		0.46	1.27	0.64	2.38	0.46	1.43	1.75	0.37
CEM	0.46		1.34	0.76	2.42	0.62	1.49	1.80	0.56
IPQ	1.27	1.34		1.40	2.69	1.34	1.90	2.15	1.31
UME	0.64	0.76	1.40		2.46	0.76	1.55	1.85	0.71
MKEH	2.38	2.42	2.69	2.46		2.42	2.77	2.95	2.40
SMU	0.46	0.62	1.34	0.76	2.42		1.49	1.80	0.56
SP	1.43	1.49	1.90	1.55	2.77	1.49		2.25	1.46
MIKES	1.75	1.80	2.15	1.85	2.95	1.80	2.25		1.77
VSL	0.37	0.56	1.31	0.71	2.40	0.56	1.46	1.77	

Table 24 Inter-laboratory cross-equivalence of measured tungsten strip lamp temperature (C564) at t = 1600 °C, (a. cross-equivalence value , b. expanded uncertainty, k=2).



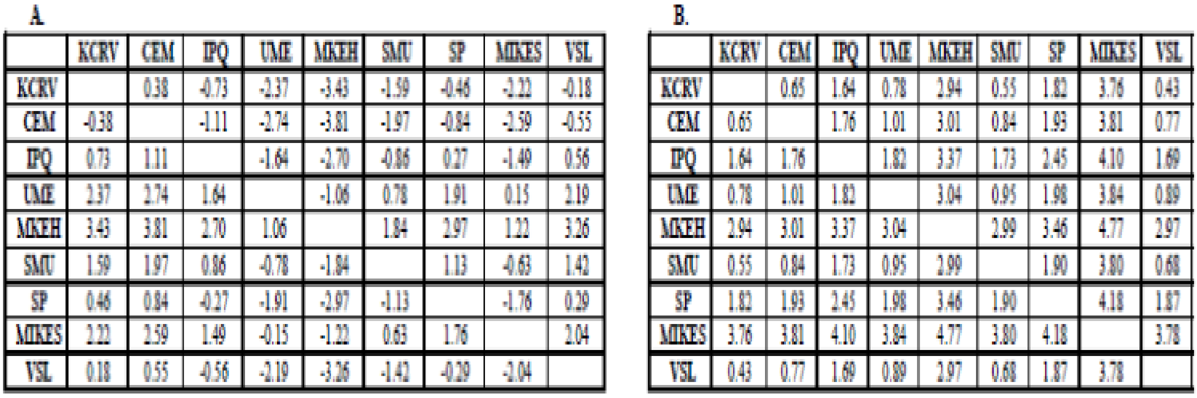
A.

	KCRV	CEM	IPQ	UME	MKEH	SMU	SP	MIKES	VSL
KCRV		-0.12	-0.54	-2.11	-2.92	-1.45	-0.36	-1.04	-0.07
CEM	0.12		-0.43	-2.00	-2.81	-1.34	-0.25	-0.92	0.05
IPQ	0.54	0.43		-1.57	-2.38	-0.91	0.18	-0.50	0.47
UME	2.11	2.00	1.57		-0.81	0.66	1.75	1.08	2.04
MKEH	2.92	2.81	2.38	0.81		1.47	2.56	1.89	2.85
SMU	1.45	1.34	0.91	-0.66	-1.47		1.09	0.42	1.38
SP	0.36	0.25	-0.18	-1.75	-2.56	-1.09		-0.68	0.29
MIKES	1.04	0.92	0.50	-1.08	-1.89	-0.42	0.68		0.97
VSL	0.07	-0.05	-0.47	-2.04	-2.85	-1.38	-0.29	-0.97	

B.

	KCRV	CEM	IPQ	UME	MKEH	SMU	SP	MIKES	VSL
KCRV		1.64	1.44	0.71	2.70	0.49	1.60	1.92	0.39
CEM	1.64		2.18	1.78	3.16	1.71	2.29	2.53	1.68
IPQ	1.44	2.18		1.60	3.06	1.52	2.15	2.40	1.49
UME	0.71	1.78	1.60		2.79	0.85	1.75	2.04	0.80
MKEH	2.70	3.16	3.06	2.79		2.74	3.14	3.31	2.73
SMU	0.49	1.71	1.52	0.85	2.74		1.67	1.98	0.61
SP	1.60	2.29	2.15	1.75	3.14	1.67		2.50	1.65
MIKES	1.92	2.53	2.40	2.04	3.31	1.98	2.50		1.96
VSL	0.39	1.68	1.49	0.80	2.73	0.61	1.65	1.96	

Table 25 Inter-laboratory cross-equivalence of measured tungsten strip lamp temperature (C564) at t = 1700 °C, (a. cross-equivalence value , b. expanded uncertainty, k=2).



A.

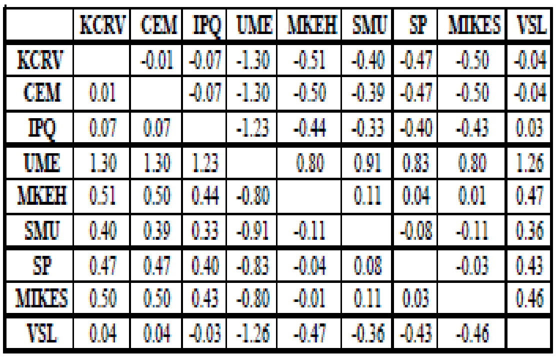
	KCRV	CEM	IPQ	UME	MKEH	SMU	SP	MIKES	VSL
KCRV		0.38	-0.73	-2.37	-3.43	-1.59	-0.46	-2.22	-0.18
CEM	-0.38		-1.11	-2.74	-3.81	-1.97	-0.84	-2.59	-0.55
IPQ	0.73	1.11		-1.64	-2.70	-0.86	0.27	-1.49	0.56
UME	2.37	2.74	1.64		-1.06	0.78	1.91	0.15	2.19
MKEH	3.43	3.81	2.70	1.06		1.84	2.97	1.22	3.26
SMU	1.59	1.97	0.86	-0.78	-1.84		1.13	-0.63	1.42
SP	0.46	0.84	-0.27	-1.91	-2.97	-1.13		-1.76	0.29
MIKES	2.22	2.59	1.49	-0.15	-1.22	0.63	1.76		2.04
VSL	0.18	0.55	-0.56	-2.19	-3.26	-1.42	-0.29	-2.04	

B.

	KCRV	CEM	IPQ	UME	MKEH	SMU	SP	MIKES	VSL
KCRV		0.65	1.64	0.78	2.94	0.55	1.82	3.76	0.43
CEM	0.65		1.76	1.01	3.01	0.84	1.93	3.81	0.77
IPQ	1.64	1.76		1.82	3.37	1.73	2.45	4.10	1.69
UME	0.78	1.01	1.82		3.04	0.95	1.98	3.84	0.89
MKEH	2.94	3.01	3.37	3.04		2.99	3.46	4.77	2.97
SMU	0.55	0.84	1.73	0.95	2.99		1.90	3.80	0.68
SP	1.82	1.93	2.45	1.98	3.46	1.90		4.18	1.87
MIKES	3.76	3.81	4.10	3.84	4.77	3.80	4.18		3.78
VSL	0.43	0.77	1.69	0.89	2.97	0.68	1.87	3.78	

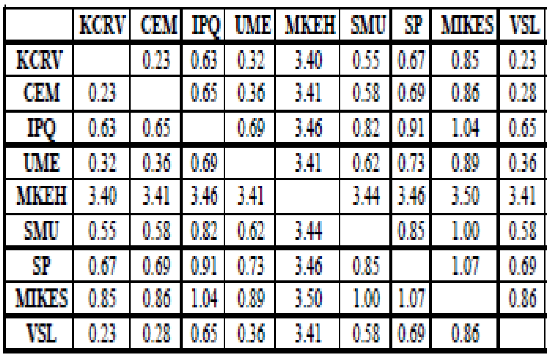
Table 26 Inter-laboratory cross-equivalence of measured tungsten strip lamp temperature (C681) at t = 962 °C, (a. cross-equivalence value , b. expanded uncertainty, k=2).

A.



	KCRV	CEM	IPQ	UME	MKEH	SMU	SP	MIKES	VSL
KCRV		-0.01	-0.07	-1.30	-0.51	-0.40	-0.47	-0.50	-0.04
CEM	0.01		-0.07	-1.30	-0.50	-0.39	-0.47	-0.50	-0.04
IPQ	0.07	0.07		-1.23	-0.44	-0.33	-0.40	-0.43	0.03
UME	1.30	1.30	1.23		0.80	0.91	0.83	0.80	1.26
MKEH	0.51	0.50	0.44	-0.80		0.11	0.04	0.01	0.47
SMU	0.40	0.39	0.33	-0.91	-0.11		-0.08	-0.11	0.36
SP	0.47	0.47	0.40	-0.83	-0.04	0.08		-0.03	0.43
MIKES	0.50	0.50	0.43	-0.80	-0.01	0.11	0.03		0.46
VSL	0.04	0.04	-0.03	-1.26	-0.47	-0.36	-0.43	-0.46	

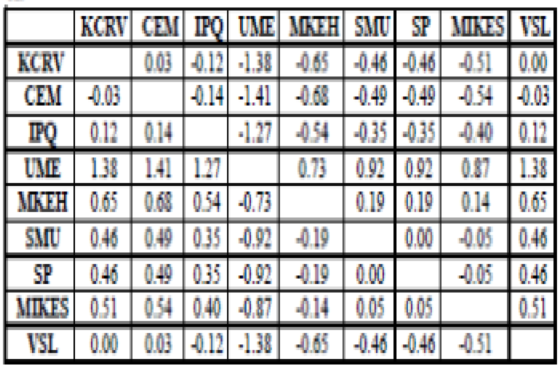
B.



	KCRV	CEM	IPQ	UME	MKEH	SMU	SP	MIKES	VSL
KCRV		0.23	0.63	0.32	3.40	0.55	0.67	0.85	0.23
CEM	0.23		0.65	0.36	3.41	0.58	0.69	0.86	0.28
IPQ	0.63	0.65		0.69	3.46	0.82	0.91	1.04	0.65
UME	0.32	0.36	0.69		3.41	0.62	0.73	0.89	0.36
MKEH	3.40	3.41	3.46	3.41		3.44	3.46	3.50	3.41
SMU	0.55	0.58	0.82	0.62	3.44		0.85	1.00	0.58
SP	0.67	0.69	0.91	0.73	3.46	0.85		1.07	0.69
MIKES	0.85	0.86	1.04	0.89	3.50	1.00	1.07		0.86
VSL	0.23	0.28	0.65	0.36	3.41	0.58	0.69	0.86	

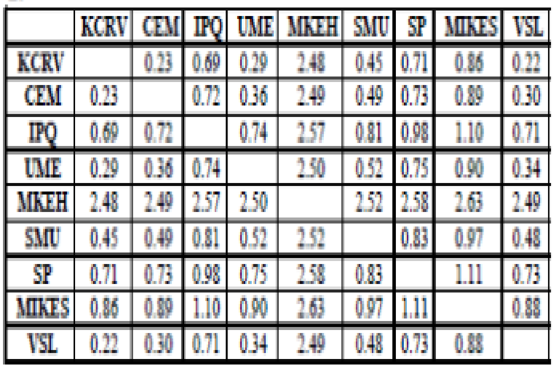
Table 27 Inter-laboratory cross-equivalence of measured tungsten strip lamp temperature (C681) at t = 1000 °C, (a. cross-equivalence value , b. expanded uncertainty, k=2).

A.



	KCRV	CEM	IPQ	UME	MKEH	SMU	SP	MIKES	VSL
KCRV		0.03	-0.12	-1.38	-0.65	-0.46	-0.46	-0.51	0.00
CEM	-0.03		-0.14	-1.41	-0.68	-0.49	-0.49	-0.54	-0.03
IPQ	0.12	0.14		-1.27	-0.54	-0.35	-0.35	-0.40	0.12
UME	1.38	1.41	1.27		0.73	0.92	0.92	0.87	1.38
MKEH	0.65	0.68	0.54	-0.73		0.19	0.19	0.14	0.65
SMU	0.46	0.49	0.35	-0.92	-0.19		0.00	-0.05	0.46
SP	0.46	0.49	0.35	-0.92	-0.19	0.00		-0.05	0.46
MIKES	0.51	0.54	0.40	-0.87	-0.14	0.05	0.05		0.51
VSL	0.00	0.03	-0.12	-1.38	-0.65	-0.46	-0.46	-0.51	

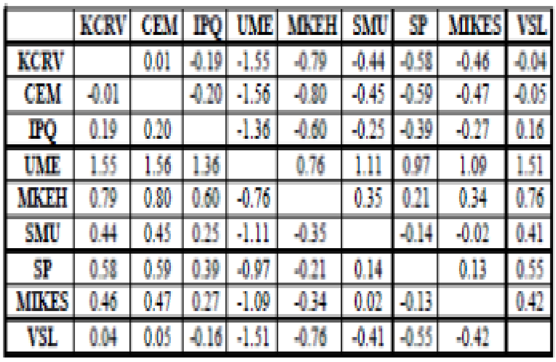
B.



	KCRV	CEM	IPQ	UME	MKEH	SMU	SP	MIKES	VSL
KCRV		0.23	0.69	0.29	2.48	0.45	0.71	0.86	0.22
CEM	0.23		0.72	0.36	2.49	0.49	0.73	0.89	0.30
IPQ	0.69	0.72		0.74	2.57	0.81	0.98	1.10	0.71
UME	0.29	0.36	0.74		2.50	0.52	0.75	0.90	0.34
MKEH	2.48	2.49	2.57	2.50		2.52	2.58	2.63	2.49
SMU	0.45	0.49	0.81	0.52	2.52		0.83	0.97	0.48
SP	0.71	0.73	0.98	0.75	2.58	0.83		1.11	0.73
MIKES	0.86	0.89	1.10	0.90	2.63	0.97	1.11		0.88
VSL	0.22	0.30	0.71	0.34	2.49	0.48	0.73	0.88	

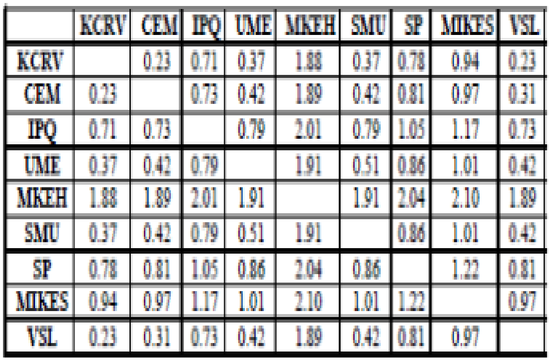
Table 28 Inter-laboratory cross-equivalence of measured tungsten strip lamp temperature (C681) at t = 1064 °C, (a. cross-equivalence value , b. expanded uncertainty, k=2).

A.



	KCRV	CEM	IPQ	UME	MKEH	SMU	SP	MIKES	VSL
KCRV		0.01	-0.19	-1.55	-0.79	-0.44	-0.58	-0.46	-0.04
CEM	-0.01		-0.20	-1.56	-0.80	-0.45	-0.59	-0.47	-0.05
IPQ	0.19	0.20		-1.36	-0.60	-0.25	-0.39	-0.27	0.16
UME	1.55	1.56	1.36		0.76	1.11	0.97	1.09	1.51
MKEH	0.79	0.80	0.60	-0.76		0.35	0.21	0.34	0.76
SMU	0.44	0.45	0.25	-1.11	-0.35		-0.14	-0.02	0.41
SP	0.58	0.59	0.39	-0.97	-0.21	0.14		0.13	0.55
MIKES	0.46	0.47	0.27	-1.09	-0.34	0.02	-0.13		0.42
VSL	0.04	0.05	-0.16	-1.51	-0.76	-0.41	-0.55	-0.42	

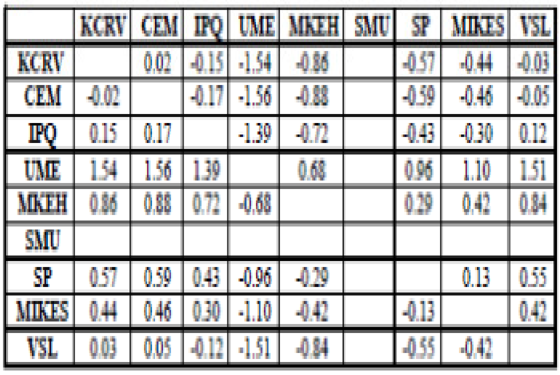
B.



	KCRV	CEM	IPQ	UME	MKEH	SMU	SP	MIKES	VSL
KCRV		0.23	0.71	0.37	1.88	0.37	0.78	0.94	0.23
CEM	0.23		0.73	0.42	1.89	0.42	0.81	0.97	0.31
IPQ	0.71	0.73		0.79	2.01	0.79	1.05	1.17	0.73
UME	0.37	0.42	0.79		1.91	0.51	0.86	1.01	0.42
MKEH	1.88	1.89	2.01	1.91		1.91	2.04	2.10	1.89
SMU	0.37	0.42	0.79	0.51	1.91		0.86	1.01	0.42
SP	0.78	0.81	1.05	0.86	2.04	0.86		1.22	0.81
MIKES	0.94	0.97	1.17	1.01	2.10	1.01	1.22		0.97
VSL	0.23	0.31	0.73	0.42	1.89	0.42	0.81	0.97	

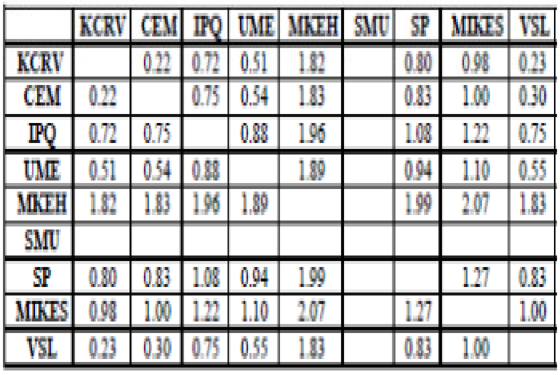
Table 29 Inter-laboratory cross-equivalence of measured tungsten strip lamp temperature (C681) at t = 1085 °C, (a. cross-equivalence value , b. expanded uncertainty, k=2).

A.



	KCRV	CEM	IPQ	UME	MKEH	SMU	SP	MIKES	VSL
KCRV		0.02	-0.15	-1.54	-0.86		-0.57	-0.44	-0.03
CEM	-0.02		-0.17	-1.56	-0.88		-0.59	-0.46	-0.05
IPQ	0.15	0.17		-1.39	-0.72		-0.43	-0.30	0.12
UME	1.54	1.56	1.39		0.68		0.96	1.10	1.51
MKEH	0.86	0.88	0.72	-0.68			0.29	0.42	0.84
SMU									
SP	0.57	0.59	0.43	-0.96	-0.29			0.13	0.55
MIKES	0.44	0.46	0.30	-1.10	-0.42		-0.13		0.42
VSL	0.03	0.05	-0.12	-1.51	-0.84		-0.55	-0.42	

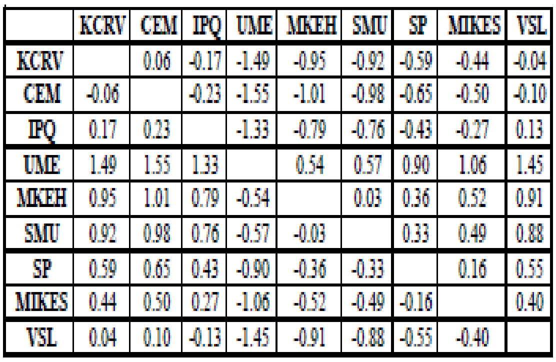
B.



	KCRV	CEM	IPQ	UME	MKEH	SMU	SP	MIKES	VSL
KCRV		0.22	0.72	0.51	1.82		0.80	0.98	0.23
CEM	0.22		0.75	0.54	1.83		0.83	1.00	0.30
IPQ	0.72	0.75		0.88	1.96		1.08	1.22	0.75
UME	0.51	0.54	0.88		1.89		0.94	1.10	0.55
MKEH	1.82	1.83	1.96	1.89			1.99	2.07	1.83
SMU									
SP	0.80	0.83	1.08	0.94	1.99			1.27	0.83
MIKES	0.98	1.00	1.22	1.10	2.07		1.27		1.00
VSL	0.23	0.30	0.75	0.55	1.83		0.83	1.00	

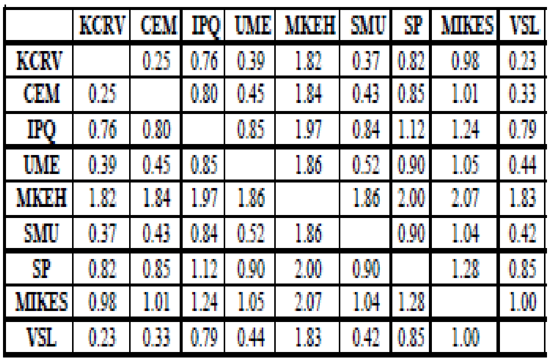
Table 30 Inter-laboratory cross-equivalence of measured tungsten strip lamp temperature (C681) at t = 1100 °C, (a. cross-equivalence value , b. expanded uncertainty, k=2).

A.



	KCRV	CEM	IPQ	UME	MKEH	SMU	SP	MIKES	VSL
KCRV		0.06	-0.17	-1.49	-0.95	-0.92	-0.59	-0.44	-0.04
CEM	-0.06		-0.23	-1.55	-1.01	-0.98	-0.65	-0.50	-0.10
IPQ	0.17	0.23		-1.33	-0.79	-0.76	-0.43	-0.27	0.13
UME	1.49	1.55	1.33		0.54	0.57	0.90	1.06	1.45
MKEH	0.95	1.01	0.79	-0.54		0.03	0.36	0.52	0.91
SMU	0.92	0.98	0.76	-0.57	-0.03		0.33	0.49	0.88
SP	0.59	0.65	0.43	-0.90	-0.36	-0.33		0.16	0.55
MIKES	0.44	0.50	0.27	-1.06	-0.52	-0.49	-0.16		0.40
VSL	0.04	0.10	-0.13	-1.45	-0.91	-0.88	-0.55	-0.40	

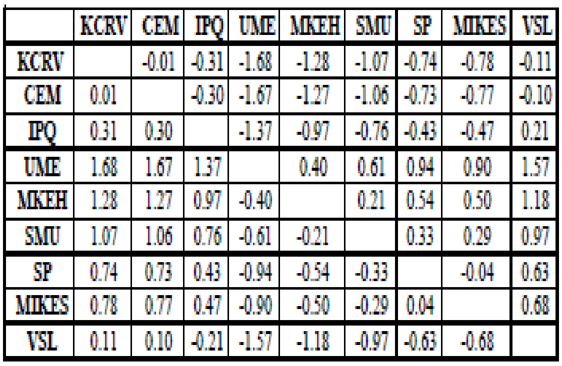
B.



	KCRV	CEM	IPQ	UME	MKEH	SMU	SP	MIKES	VSL
KCRV		0.25	0.76	0.39	1.82	0.37	0.82	0.98	0.23
CEM	0.25		0.80	0.45	1.84	0.43	0.85	1.01	0.33
IPQ	0.76	0.80		0.85	1.97	0.84	1.12	1.24	0.79
UME	0.39	0.45	0.85		1.86	0.52	0.90	1.05	0.44
MKEH	1.82	1.84	1.97	1.86		1.86	2.00	2.07	1.83
SMU	0.37	0.43	0.84	0.52	1.86		0.90	1.04	0.42
SP	0.82	0.85	1.12	0.90	2.00	0.90		1.28	0.85
MIKES	0.98	1.01	1.24	1.05	2.07	1.04	1.28		1.00
VSL	0.23	0.33	0.79	0.44	1.83	0.42	0.85	1.00	

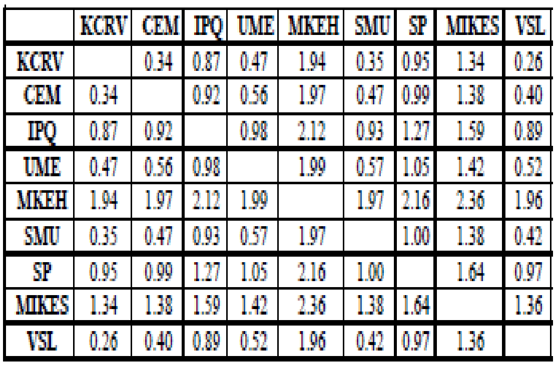
Table 31 Inter-laboratory cross-equivalence of measured tungsten strip lamp temperature (C681) at t = 1200 °C, (a. cross-equivalence value , b. expanded uncertainty, k=2).

A.



	KCRV	CEM	IPQ	UME	MKEH	SMU	SP	MIKES	VSL
KCRV		-0.01	-0.31	-1.68	-1.28	-1.07	-0.74	-0.78	-0.11
CEM	0.01		-0.30	-1.67	-1.27	-1.06	-0.73	-0.77	-0.10
IPQ	0.31	0.30		-1.37	-0.97	-0.76	-0.43	-0.47	0.21
UME	1.68	1.67	1.37		0.40	0.61	0.94	0.90	1.57
MKEH	1.28	1.27	0.97	-0.40		0.21	0.54	0.50	1.18
SMU	1.07	1.06	0.76	-0.61	-0.21		0.33	0.29	0.97
SP	0.74	0.73	0.43	-0.94	-0.54	-0.33		-0.04	0.63
MIKES	0.78	0.77	0.47	-0.90	-0.50	-0.29	0.04		0.68
VSL	0.11	0.10	-0.21	-1.57	-1.18	-0.97	-0.63	-0.68	

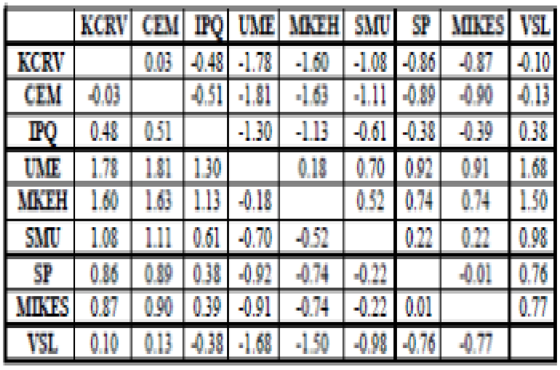
B.



	KCRV	CEM	IPQ	UME	MKEH	SMU	SP	MIKES	VSL
KCRV		0.34	0.87	0.47	1.94	0.35	0.95	1.34	0.26
CEM	0.34		0.92	0.56	1.97	0.47	0.99	1.38	0.40
IPQ	0.87	0.92		0.98	2.12	0.93	1.27	1.59	0.89
UME	0.47	0.56	0.98		1.99	0.57	1.05	1.42	0.52
MKEH	1.94	1.97	2.12	1.99		1.97	2.16	2.36	1.96
SMU	0.35	0.47	0.93	0.57	1.97		1.00	1.38	0.42
SP	0.95	0.99	1.27	1.05	2.16	1.00		1.64	0.97
MIKES	1.34	1.38	1.59	1.42	2.36	1.38	1.64		1.36
VSL	0.26	0.40	0.89	0.52	1.96	0.42	0.97	1.36	

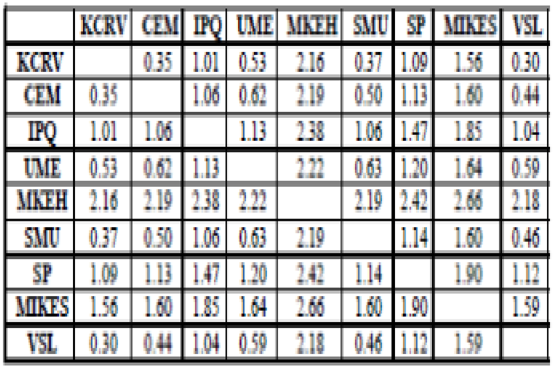
Table 32 Inter-laboratory cross-equivalence of measured tungsten strip lamp temperature (C681) at t = 1300 °C, (a. cross-equivalence value , b. expanded uncertainty, k=2).

A.



	KCRV	CEM	IPQ	UME	MKEH	SMU	SP	MIKES	VSL
KCRV		0.03	-0.48	-1.78	-1.60	-1.08	-0.86	-0.87	-0.10
CEM	-0.03		-0.51	-1.81	-1.63	-1.11	-0.89	-0.90	-0.13
IPQ	0.48	0.51		-1.30	-1.13	-0.61	-0.38	-0.39	0.38
UME	1.78	1.81	1.30		0.18	0.70	0.92	0.91	1.68
MKEH	1.60	1.63	1.13	-0.18		0.52	0.74	0.74	1.50
SMU	1.08	1.11	0.61	-0.70	-0.52		0.22	0.22	0.98
SP	0.86	0.89	0.38	-0.92	-0.74	-0.22		-0.01	0.76
MIKES	0.87	0.90	0.39	-0.91	-0.74	-0.22	0.01		0.77
VSL	0.10	0.13	-0.38	-1.68	-1.50	-0.98	-0.76	-0.77	

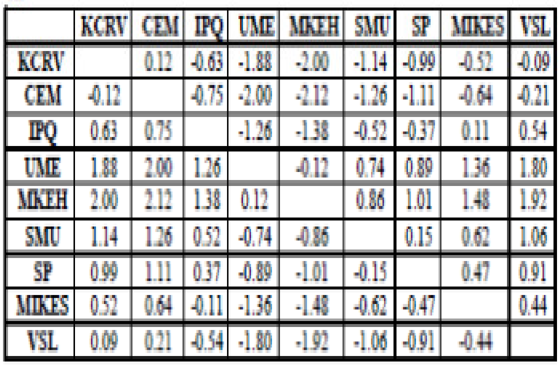
B.



	KCRV	CEM	IPQ	UME	MKEH	SMU	SP	MIKES	VSL
KCRV		0.35	1.01	0.53	2.16	0.37	1.09	1.56	0.30
CEM	0.35		1.06	0.62	2.19	0.50	1.13	1.60	0.44
IPQ	1.01	1.06		1.13	2.38	1.06	1.47	1.85	1.04
UME	0.53	0.62	1.13		2.22	0.63	1.20	1.64	0.59
MKEH	2.16	2.19	2.38	2.22		2.19	2.42	2.66	2.18
SMU	0.37	0.50	1.06	0.63	2.19		1.14	1.60	0.46
SP	1.09	1.13	1.47	1.20	2.42	1.14		1.90	1.12
MIKES	1.56	1.60	1.85	1.64	2.66	1.60	1.90		1.59
VSL	0.30	0.44	1.04	0.59	2.18	0.46	1.12	1.59	

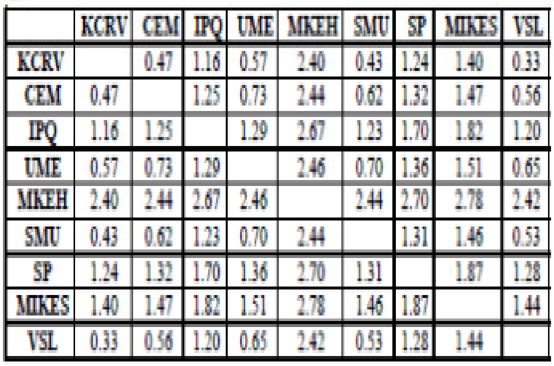
Table 33 Inter-laboratory cross-equivalence of measured tungsten strip lamp temperature (C681) at t = 1400 °C, (a. cross-equivalence value , b. expanded uncertainty, k=2).

A.



	KCRV	CEM	IPQ	UME	MKEH	SMU	SP	MIKES	VSL
KCRV		0.12	-0.63	-1.88	-2.00	-1.14	-0.99	-0.52	-0.09
CEM	-0.12		-0.75	-2.00	-2.12	-1.26	-1.11	-0.64	-0.21
IPQ	0.63	0.75		-1.26	-1.38	-0.52	-0.37	0.11	0.54
UME	1.88	2.00	1.26		-0.12	0.74	0.89	1.36	1.80
MKEH	2.00	2.12	1.38	0.12		0.86	1.01	1.48	1.92
SMU	1.14	1.26	0.52	-0.74	-0.86		0.15	0.62	1.06
SP	0.99	1.11	0.37	-0.89	-1.01	-0.15		0.47	0.91
MIKES	0.52	0.64	-0.11	-1.36	-1.48	-0.62	-0.47		0.44
VSL	0.09	0.21	-0.54	-1.80	-1.92	-1.06	-0.91	-0.44	

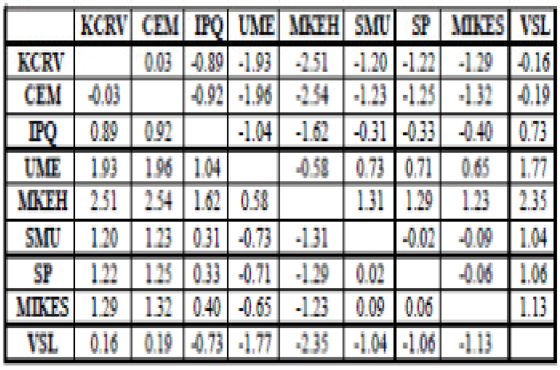
B.



	KCRV	CEM	IPQ	UME	MKEH	SMU	SP	MIKES	VSL
KCRV		0.47	1.16	0.57	2.40	0.43	1.24	1.40	0.33
CEM	0.47		1.25	0.73	2.44	0.62	1.32	1.47	0.56
IPQ	1.16	1.25		1.29	2.67	1.23	1.70	1.82	1.20
UME	0.57	0.73	1.29		2.46	0.70	1.36	1.51	0.65
MKEH	2.40	2.44	2.67	2.46		2.44	2.70	2.78	2.42
SMU	0.43	0.62	1.23	0.70	2.44		1.31	1.46	0.53
SP	1.24	1.32	1.70	1.36	2.70	1.31		1.87	1.28
MIKES	1.40	1.47	1.82	1.51	2.78	1.46	1.87		1.44
VSL	0.33	0.56	1.20	0.65	2.42	0.53	1.28	1.44	

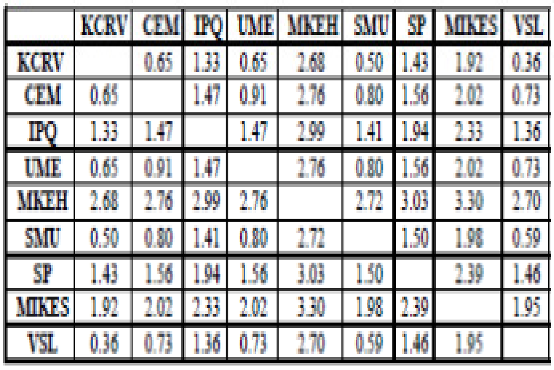
Table 34 Inter-laboratory cross-equivalence of measured tungsten strip lamp temperature (C681) at t = 1500 °C, (a. cross-equivalence value , b. expanded uncertainty, k=2).

A.



	KCRV	CEM	IPQ	UME	MKEH	SMU	SP	MIKES	VSL
KCRV		0.03	-0.89	-1.93	-2.51	-1.20	-1.22	-1.29	-0.16
CEM	-0.03		-0.92	-1.96	-2.54	-1.23	-1.25	-1.32	-0.19
IPQ	0.89	0.92		-1.04	-1.62	-0.31	-0.33	-0.40	0.73
UME	1.93	1.96	1.04		-0.58	0.73	0.71	0.65	1.77
MKEH	2.51	2.54	1.62	0.58		1.31	1.29	1.23	2.35
SMU	1.20	1.23	0.31	-0.73	-1.31		-0.02	-0.09	1.04
SP	1.22	1.25	0.33	-0.71	-1.29	0.02		-0.06	1.06
MIKES	1.29	1.32	0.40	-0.65	-1.23	0.09	0.06		1.13
VSL	0.16	0.19	-0.73	-1.77	-2.35	-1.04	-1.06	-1.13	

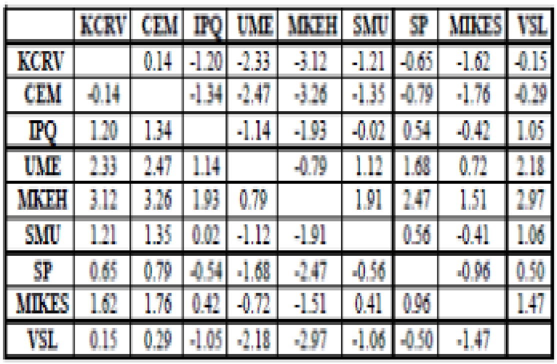
B.



	KCRV	CEM	IPQ	UME	MKEH	SMU	SP	MIKES	VSL
KCRV		0.65	1.33	0.65	2.68	0.50	1.43	1.92	0.36
CEM	0.65		1.47	0.91	2.76	0.80	1.56	2.02	0.73
IPQ	1.33	1.47		1.47	2.99	1.41	1.94	2.33	1.36
UME	0.65	0.91	1.47		2.76	0.80	1.56	2.02	0.73
MKEH	2.68	2.76	2.99	2.76		2.72	3.03	3.30	2.70
SMU	0.50	0.80	1.41	0.80	2.72		1.50	1.98	0.59
SP	1.43	1.56	1.94	1.56	3.03	1.50		2.39	1.46
MIKES	1.92	2.02	2.33	2.02	3.30	1.98	2.39		1.95
VSL	0.36	0.73	1.36	0.73	2.70	0.59	1.46	1.95	

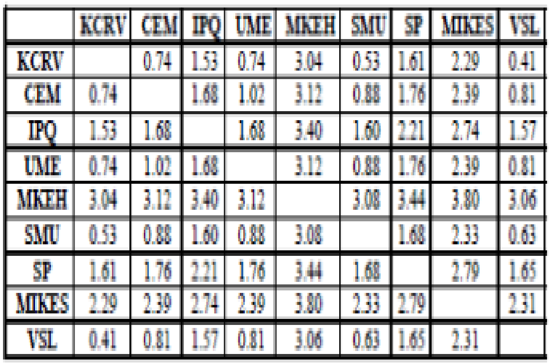
Table 35 Inter-laboratory cross-equivalence of measured tungsten strip lamp temperature (C681) at t = 1600 °C, (a. cross-equivalence value , b. expanded uncertainty, k=2).

A.



	KCRV	CEM	IPQ	UME	MKEH	SMU	SP	MIKES	VSL
KCRV		0.14	-1.20	-2.33	-3.12	-1.21	-0.65	-1.62	-0.15
CEM	-0.14		-1.34	-2.47	-3.26	-1.35	-0.79	-1.76	-0.29
IPQ	1.20	1.34		-1.14	-1.93	-0.02	0.54	-0.42	1.05
UME	2.33	2.47	1.14		-0.79	1.12	1.68	0.72	2.18
MKEH	3.12	3.26	1.93	0.79		1.91	2.47	1.51	2.97
SMU	1.21	1.35	0.02	-1.12	-1.91		0.56	-0.41	1.06
SP	0.65	0.79	-0.54	-1.68	-2.47	-0.56		-0.96	0.50
MIKES	1.62	1.76	0.42	-0.72	-1.51	0.41	0.96		1.47
VSL	0.15	0.29	-1.05	-2.18	-2.97	-1.06	-0.50	-1.47	

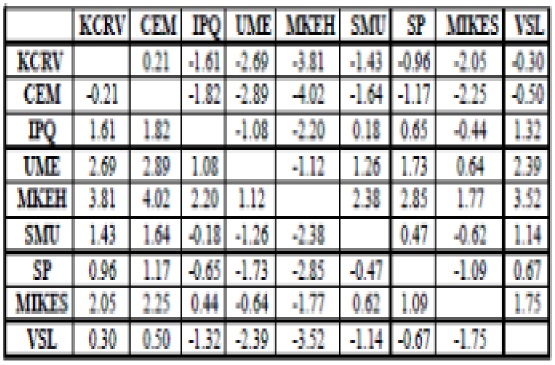
B.



	KCRV	CEM	IPQ	UME	MKEH	SMU	SP	MIKES	VSL
KCRV		0.74	1.53	0.74	3.04	0.53	1.61	2.29	0.41
CEM	0.74		1.68	1.02	3.12	0.88	1.76	2.39	0.81
IPQ	1.53	1.68		1.68	3.40	1.60	2.21	2.74	1.57
UME	0.74	1.02	1.68		3.12	0.88	1.76	2.39	0.81
MKEH	3.04	3.12	3.40	3.12		3.08	3.44	3.80	3.06
SMU	0.53	0.88	1.60	0.88	3.08		1.68	2.33	0.63
SP	1.61	1.76	2.21	1.76	3.44	1.68		2.79	1.65
MIKES	2.29	2.39	2.74	2.39	3.80	2.33	2.79		2.31
VSL	0.41	0.81	1.57	0.81	3.06	0.63	1.65	2.31	

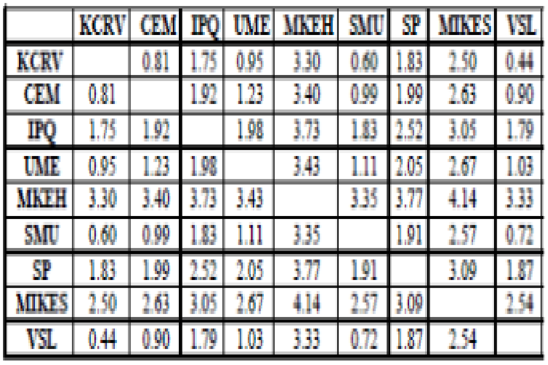
Table 36 Inter-laboratory cross-equivalence of measured tungsten strip lamp temperature (C681) at t = 1700 °C, (a. cross-equivalence value , b. expanded uncertainty, k=2).

A.



	KCRV	CEM	IPQ	UME	MKEH	SMU	SP	MIKES	VSL
KCRV		0.21	-1.61	-2.69	-3.81	-1.43	-0.96	-2.05	-0.30
CEM	-0.21		-1.82	-2.89	-4.02	-1.64	-1.17	-2.25	-0.50
IPQ	1.61	1.82		-1.08	-2.20	0.18	0.65	-0.44	1.32
UME	2.69	2.89	1.08		-1.12	1.26	1.73	0.64	2.39
MKEH	3.81	4.02	2.20	1.12		2.38	2.85	1.77	3.52
SMU	1.43	1.64	-0.18	-1.26	-2.38		0.47	-0.62	1.14
SP	0.96	1.17	-0.65	-1.73	-2.85	-0.47		-1.09	0.67
MIKES	2.05	2.25	0.44	-0.64	-1.77	0.62	1.09		1.75
VSL	0.30	0.50	-1.32	-2.39	-3.52	-1.14	-0.67	-1.75	

B.



	KCRV	CEM	IPQ	UME	MKEH	SMU	SP	MIKES	VSL
KCRV		0.81	1.75	0.95	3.30	0.60	1.83	2.50	0.44
CEM	0.81		1.92	1.23	3.40	0.99	1.99	2.63	0.90
IPQ	1.75	1.92		1.98	3.73	1.83	2.52	3.05	1.79
UME	0.95	1.23	1.98		3.43	1.11	2.05	2.67	1.03
MKEH	3.30	3.40	3.73	3.43		3.35	3.77	4.14	3.33
SMU	0.60	0.99	1.83	1.11	3.35		1.91	2.57	0.72
SP	1.83	1.99	2.52	2.05	3.77	1.91		3.09	1.87
MIKES	2.50	2.63	3.05	2.67	4.14	2.57	3.09		2.54
VSL	0.44	0.90	1.79	1.03	3.33	0.72	1.87	2.54	

Reference:

1. M.J. de Groot, E.W.M. van der Ham and R. Monshouwer. *CCT-K5: Comparison of local realizations of the ITS-90 between the silver point and 1700 °C using vacuum tungsten strip lamps as transfer standards.* 2008.

2. WJ Youden, “Graphical Diagnosis of Interlaboratory Test Results”,Industrial Quality Control, Vol XV.11, May 1959.

Appendix I: Measurement Protocol

PROTOCOL TO THE COMPARISON OF LOCAL REALIZATIONS OF THE ITS-90 BETWEEN THE SILVER POINT AND 1700°C USING VACUUM TUNGSTEN-STRIP LAMPS AS TRANSFER STANDARDS

Appendices

Appendix A:	Circulation schemes.
Appendix B:	The dependence of spectral radiance temperature on wavelength.
Appendix C:	Form to confirm the receipt of the transfer standards.
Appendix D:	- Lamp data - Instructions as to the handling of the lamps - Currents to be set during calibration of the lamps. - Temperature coefficient dTλ/dTb (Tλ).

1. Introduction

The Euromet temperature group decided in 1996 to undertake an international comparison of the local realization of the ITS-90 above the silver point, using high-stability vacuum tungsten strip lamps as transfer standard. This comparison is a follow-up of the CCT key comparison, which was finished in August 1999. The result of the comparison will be evaluated in 2001 and reported to Euromet.

2. Organization

2.1. Coordinating institute

The intercomparison will be coordinated by:

Nederlands Meetinstituut - Van Swinden Laboratorium (NMi-VSL).

P.O. Box 654

2600 AR Delft, The Netherlands

Contact Persons:

Ing. R. Bosma. Phone: - 31 15 2691 663

Dr. E.W.M. van der Ham Fax: - 31 15 261 2971

E- mail: Rbosma@NMi.nl or EvanderHam@NMi.nl

2.2. Transfer standards

2.2.1. General specification.

- The GEC high-stability vacuum tungsten-strip lamps, identified by number, strip width, supplied with a water-cooled base, the polarity of the current connectors being indicated. Both lamps are mounted in a metal case, to be hand carried when transferring the set of lamps between the participating institutes.

- Two double-wire cables are going with the lamps, essentially serving as current leads and voltage leads such that the room- temperature resistance Ramb of the lamp elements, comprising tungsten strip and its internal support, can be measured (along with the temperature Tamb, measured with a calibrated PRT inserted in the lamp base) just before calibrating them. After the calibration has been completed Ramb and Tamb should be measured again just before transferring the lamps to their next destination. All of this is to additionally monitor changes in the physical constitution of the lamp element, possibly induced during transport of the lamps (cf. 3.2.1). The procedure has been proposed by C.K. Ma of NRC.

2.2.2. Attached documentation.

- Appendix D:

  - Instructions as to the handling of the lamps, including an indication of the maximum lamp current and lamp temperature, not to be surpassed.

  - Currents to be set during calibration of the lamps.

  - Temperature coefficients dTλ/dTb, where Tλ and Tb represent the spectral radiance temperature and the lamp-base temperature, respectively.

- A pro-forma quotation as required by EC customs regulations.

- An ATA carnet when circulating the case outside the EC.

The mentioned documents are to be reattached to the case when transferred between the participating institutes.

2.3. Circulation patterns.

2.3.1. Time schedule.

-The transfer tungsten-strip lamps, as specified in 2.2, will be circulated following the circulation schemes, indicated in Appendix A.

- By 1 July 2001 the first draft report, to be made by NMi-VSL, will be distributed among the members of the comparison.

- By the end of 2001 the final report on the Euromet comparison will be completed.

2.3.2. Operations.

- Apart from the periods interfering with the holiday seasons each institute is allocated nominally two months to complete its operations. In the last week of this period at the latest the set of lamps in question has to be transferred to the next institute, indicated in the time schedule 2.3.1 (Appendix A).

- In the first week after receipt of the lamps, the ‘receipt confirmation form’, added to this protocol (Appendix C), has to be filled in and sent to VSL. Before dispatching the confirmation form Ramb (2.2.1) should have been measured and the lamps should have been restabilized and checked for their repeatability (cf. 3.2.1).

- Within two months after completion of the measurements, the final report drafted along the lines, set out below, should be sent to VSL.

2.4.Transport of the transfer lamps.

2.4.1. Means of transport between institutes: cabine baggage.

2.4.2. Customs provisions:

- EC countries: a pro forma invoice, to be shown on request of the customs officials.

- Countries outside the EC: an ATA carnet consisting of several forms applying to the exportation and importation of the transfer lamps. Customs procedures must be strictly obeyed; when leaving or entering a country the forms should be filled in carefully; this is to the responsibility of the institute which is to take the lamps to their next destination, indicated in the table. The institute to receive the lamps should carefully recheck the ATA forms, attached.

- An ATA carnet is valid for one year; in arranging the circulation schemes special care has been taken to cope with this boundary condition.

2.4.3. Insurance.

- The two sets of transfer lamps will be insured by the institutes, supplying the lamps, i.e. VSL; the insurance includes transport and stay covering the whole period of the comparison; it does not include however the operations during the actual calibration of the lamps.

- A fully characterized spare lamp will be kept stand-by. In case of damage action may be taken to replace a lamp, the precise nature of the action, to be decided by VSL, depending on the circumstances at the time of the accident.

2.5. Coordination.

- The coordination will be based upon the time schedule, given in 2.3.1, and the feed-back mechanisms specified in 2.3.2.

3. Technical aspects

Below we give just an inventory, in short form, of those aspects which should be taken into consideration when initializing or executing the comparison.

3.1. Initialization of the comparison by VSL.

3.1.1. Lamp functions

- Description and identification of lamps; strip dimensions; specifying maximum radiance temperature Tλ(Imax) and maximum lamp current (Imax) not to be surpassed when calibrating the lamp (Appendix D).

- Ageing and initial stabilization.

Ageing: to be performed at a temperature 100 K higher than the stabilization temperature; duration: 100 hrs.

Stabilization: The highest temperature of calibration (maximum radiance temperature) is to be identified as the stabilization temperature. The initial stabilization should lead to a final drift rate not higher than 0,3 K / 100 hrs. It seems that this can be obtained for a lamp of 1,5 mm nominal width of the strip at a stabilization temperature of 1700 °C, the associated ageing temperature being 1800 °C. If the drift rate of no more than 0,3 K / 100 hrs cannot be obtained, then the stabilization should be repeated at $T\lambda(Imax) = 1650$ °C.

Specifying the drift rate of the stabilized lamp: during the stabilization at $I = Imax$ the radiance temperature $T\lambda(Imax)$ is continuously monitored; from this the drift rate in K / 100 hrs can be easily determined and specified. A constant drift rate is expected after about 60 hrs.

- Determination of positioning effects.

Effects induced by the rotation of the strip around the vertical axis: for the measurement of these effects the target field and the edges of the tungsten strip must be vertical. The angular distribution of the radiance may have a maximum of some tenths of a percent and about 4 degrees width due to inter-reflection inside the lamp. The pilot lab will define an angle in the most uniform region of the horizontal angular radiance distribution as reference angle for the subsequent measurements.

The influence of tilting of the strip (through rotation around the horizontal axis perpendicular to the optical axis of the radiation thermometer viewing the strip) should be verified being sufficiently low at the reference angle, as defined in the horizontal plane.

- Specifying the variation of spectral radiance temperature with wavelength.

The function $dT\lambda/d\lambda$ versus spectral radiance temperature $T\lambda$ has been given in Appendix B in graphical and tabular display for the reference wavelengths 650 nm and 950 nm. The functions have been calculated by PTB, taking a window transmission of 0,92, from values of the spectral emissivity of tungsten reported by L.N. Latyev, V. Ya. Chekovsky and E.N. Shestakov: High Temp.- High Press.2 (1970)175-181. Estimated standard deviation (s) in $dT\lambda/d\lambda$: 10 % of its absolute value. The polynomial representations, with $T\lambda$ and $dT\lambda/d\lambda$ given in °C and K/nm, respectively, are:

$dT\lambda/d\lambda = \Sigma_i\, a[i] \,.\, [T\lambda]^i$, with i = 0 to 2, and:

For $\lambda r = 650$ nm: $a[0] = -\,0{,}35422504 \,.\, 10^{-1}$

$a[1] = 2{,}70716088 \,.\, 10^{-5}$

$a[2] = -\,0{,}10980270 \,.\, 10^{-6}$

Associated standard deviation (in $dT\lambda/d\lambda$): $s = 2,607 \cdot 10^{-4}$ K / nm

For $\lambda r = 950$ nm: $a[0] = 4,65847984 \cdot 10^{-3}$

$a[1] = - 0,81968285 \cdot 10^{-4}$

$a[2] = - 0,94845913 \cdot 10^{-7}$

Associated standard deviation (in $dT\lambda/d\lambda$): $s = 2,243 \cdot 10^{-4}$ K / nm

- Providing the temperature coefficient $dT\lambda/dTb[T\lambda]$, where Tb represents the base temperature. The corresponding data are given in Appendix D, going with the documents added to the lamps.

- Proposal as to the shape of the polynomial representation of the $T\lambda$ vs. I characteristic.

A polynome of the sixth order would be sufficient describing $T\lambda = T\lambda(I)$. Since it is proposed to perform the calibration at fixed prescribed lamp currents I no inverse function is needed (cf. 3.2.2).

3.1.2. Specification of measurement and reference conditions.

Measurement conditions

a. Orientation of the strip: in conjunction with the procedure to orient the lamp, to be specified in 3.2.

b. Target field diameter: ≈ 0,75 mm.

c. Viewing distance < 1500 mm.

d. Lamp-current settings I(j) as defined in Appendix D.

Reference conditions

Reference conditions in principle apply to the influence parameters listed below. To obtain comparable results in principle corrections should be applied whenever the actual value of a given parameter would differ from the reference value. In practice corrections will have to be applied only for the parameters listed under a and b.

a. $\lambda r = 650$ nm

b. Base temperature Tb = 20 °C

c. Tamb = 23 °C

3.2. Instructions / guidelines for lamp calibrations.

3.2.1. Preparations.

3.2.1.1. Initialization.

-Measurement of the room-temperature resistance Ramb of the lamp element.

The lamps are transported in a metal case being embedded in flexible plastic foam. Two electrically screened double-wire cables are going with the lamps, one comprising the current leads (to be connected to the current terminals of the lamp) and the other the voltage leads (to be connected to the outer in / outlet brass tubes in circulation scheme I, or to tags attached to the lamp-base in scheme II), such that the room-temperature resistance Ramb of the lamp element, comprising tungsten strip and its internal support, can be measured (along with the temperature Tamb, measured with a calibrated PRT, inserted in the lamp base). The measurement of Ramb/Tamb should be done just before starting the calibration of the lamps.

After the calibration has been completed Ramb and Tamb should be measured again just before transfer of the lamps to their next destination. All of this is to additionally monitor changes in the physical constitution of the lamp element, possibly induced during transport of the lamps.

It is suggested performing the measurement of the resistance (about 50 mΩ) using an ASL F18 bridge at currents of 50 and $50\sqrt{2}$ mA, 30 Hz, in conjunction with a reference resistor ≤ 1 Ohm, preferably 0,1 or even 0,05 Ohm, such as to arrive at an accuracy of the zero-current resistance better than 2 in 10^5. During the measurements the lamp should be placed in the case in its normal position, the case closed, as far as possible, and grounded. Further instructions are going with the lamps.

Mounting the lamps for calibration.

Current-lead connections to the lamps. Stabilizing the base temperature and monitoring its temperature Tb.

Current switching and setting (maximum 1 A / min).

3.2.1.2.Positioning and checking.

- Procedure to orient the lamp.

- The lamp is rotated around the axis of the radiation thermometer until the edges of the strip appear vertical when observed from the position of the radiation thermometer.

- The horizontal reference angle and the correct tilting angle (preferably zero degrees) are set by adjustment of the notch and of a mark on the rear window of the lamp such as to be in line with the optical axis of the radiation thermometer (e.g. by means of a pilot laser).

- The lamp is shifted sidewards to center it into the reference target position.

During the manipulations described below the radiance temperature should be set to a value ≤ 1500°C.

- Focusing.

All calibrations as well as the investigation of positioning effects require accurate focusing. The focal distances of lens thermometers (when not adequately corrected for chromatic effects) may be very different from wavelength to wavelength. A procedure, suggested by the PTB, is to define the target distance to the thermometer as the distance where the apparent width of the strip image is a minimum. For this purpose the lamp is moved in a direction perpendicular to the optical axis by a micrometer drive. There are two positions where the thermometer signal amounts to only 5 % of its value in the centered position. The difference of the respective micrometer readings is a measure for the apparent width, the minimum width defining the target distance to be set.

- Target field not centered on Tungsten strip.

It is recommended that all participants measure the horizontal spatial radiance distribution (for λ _ 650 nm) at the height of the notch. If a sufficiently flat portion is not observed, the target size (defined by the thermometer) is too large.

- Effects due to the rotation of the strip around the vertical axis.

The participants should measure the angular distribution of the radiance in the horizontal plane to provide information on whether its shape is the same for different thermometers or not.

The use of a neutral density filter helps to find the origin of an inter-reflection peak, if any. A neutral density filter with transmission ≤ 0,1 causes a peak in the angular distribution to effectively disappear if it is due to an inter-reflection between lamp and thermometer.

If an inter- reflection peak is observed around the angular coordinates, set by following the orientation procedure recommended above, measures should be taken in consultation with the pilot institute.

3.2.1.3. Restabilization of the lamp after transportation.

- The day before the actual measurements (at the latest) the lamp should be restabilized.
- Measurement of the radiance temperature at a lamp current I = I(5), defined in Appendix D, and corresponding with a radiance temperature of about 1100 °C (for λ _ 650 nm).
- Restabilization of the lamp at Tλ(Imax) _ 1700 °C for one hour.
- Measurement of the radiance temperature at I = I(5). The difference with the former temperature, to be registered, is expected not be larger than 0,05 K (650 nm). However, no further attempt should be made to achieve improved stability because it might give rise to an unacceptable total burning time when aimed at by several institutes.
- Switching off the lamp current. The lamp should be left at ‘zero current’ to settle down overnight.

3.2.2. Measurements.

- Cleaning the window: every day before starting the measurements cleaning with a few drops of pure alcohol and immediately drying subsequently using lens cleaning paper.

- Centering of the target field (at each current to be set) at the level of the notch.

- Measurements should be performed at the currents I(j) given in Appendix D which is included in the documents attached to the lamps. The currents should be set to approach I(j) within a few mA; later on the radiance temperatures, as measured, should be converted to correspond with the nominal values I(j).

By measuring in the direction of increasing current only, after having restabilized the lamp, as indicated above (3.2.1), hysteresis effects can be avoided. Minimum equilibration times: 30 minutes, and 15 minutes for radiance temperatures (650 nm) in the ranges 900°C - 1100 °C (I ≤ I(5)) and > 1100 °C (I > I(5)), respectively; I(5) is given in Appendix D. At each current the result should be obtained as the average of at least ten measurements.

The currents to be set correspond (for λ_ 650 nm) roughly with the following nominal radiance temperatures (in °C) in the order as indicated: T(Ag), 1000, T(Au), T(Cu), 1100, 1200, 1300, 1400, 1500, 1600, 1700 °C. Whenever a fixed-point radiance temperature is transferred to the lamp the corresponding (average)current(s) should be registered and eventually reported.

- After completion of the measurements at Tλ(Imax), the current should be switched off - in a controlled fashion - and the lamp left to settle down overnight.

- A second series of measurements - in the direction of increasing current only - should be performed along the lines indicated above.

- Recommended maximum burning time of the lamps: 30 hours.

- After the calibration has been completed Ramb and Tamb should be remeasured just after having packed the lamps in the case, to be transferred to its next destination. During the measurements the case should be closed, as far as possible, and grounded (cf. 3.2.1)

4.Reporting

An inventory of aspects, inherent in the reporting of each contribuant to the intercomparison is given in this section. Experimental and theoretical procedures, presentation of results and uncertainties are reviewed in concise form only.

4.1. Experimental and theoretical procedures.

4.1.1. Realization of the ITS-90.

- Description of equipment, including reference thermometer and reference fixed - point blackbody radiator.

- Description of experimental procedures.

- Formal definition/derivation of the spectral radiance temperature with explicit reference to corrections applied.

4.1.2. Transfer of radiance temperatures to strip lamps.

- Description of equipment and procedures, including corrections.

4.2. Presentation of results.

4.2.1. Local conditions to be specified.

4.2.1.1. Reference thermometer.

- Effective wavelength (λe) / local reference wavelength (λr_l).

- Half-width of spectral response function.

- Aperture ratio; f-number.

- Target distance.

- Target field dimensions.

- Size-of-source effect (SSE) covering a range in source radii (r0,rmax), with rmax > Rb, r0 < d/2, Rb and d referring to the effective aperture radius of the reference fixed-point blackbody radiator (to be specified) and the width of the tungsten strip, respectively (cf 3.1.2). The SSE should be measured at wavelengths near to each of the reference wavelengths, included in the scale definition.

- Effective source diameter φ_d of the strip, specified in conjunction with the SSE, as measured for the circular sources (cf. 3.1.2).

4.2.1.2. Transfer lamps.

- Orientation of the lamp, if and only if it differs from the reference orientation.

- Nominal base temperature and its stability.

- Total burning time.

4.2.1.3. Ambient conditions.

- Tamb, RH; mean, maximum and minimum values.

4.2.2. Measurement results.

- If using the intermediate of the (mean) effective wavelength λe, the following entries to a table surveying direct and corrected measurement results could be envisaged. Alternatively λe could be replaced by the (fixed) local reference wavelength λr_l .

Table A:

No: number of measurement; $I(j)$: lamp current as defined in Appendix D; $I(l)$: lamp current, as set; $I(j) - I(l)$; R: ratio of photo-currents $i(T\lambda)/i\{T(FP)\}$, the temperature $T(FP)$ referring to the fixed-point temperature as defined in the ITS-90; $T\lambda = T\lambda(\lambda e; Tb)$; $T\lambda(\lambda e; Tb) := T\lambda$ (corrected for the SSE); $T\lambda(\lambda e; Tb) := T\lambda$ (corrected for SSE and non-linearity); [λ _ 950 nm; $T\lambda$; RH = 0 %].

Table B:

No: number of measurement; λe; $T\lambda(\lambda e ; Tb)$; $\partial T\lambda/\partial\lambda$; $\partial T\lambda/\partial\lambda.(\lambda r - \lambda e)$; $T\lambda(\lambda r ; Tb)$; Tb(°C); $\partial T\lambda/\partial Tb$; $\partial T\lambda/\partial Tb.(20 - Tb)$; $T\lambda := T\lambda\{\lambda r ; I(l)\} := T\lambda\{\lambda r ; 20; I(l)\}$; $\partial T\lambda/ \partial I$;

$\partial T\lambda/ \partial I.\{I(j)- I(l)\}$; $T\lambda(j) := T\lambda\{\lambda r ; I(j)\}$.

- In the last column of table B the final results $T\lambda(j) = T\lambda\{\lambda r ; I(j)\}$, at the currents $I(j)$, as specified in Appendix D, are to be tabulated. The parameter $\partial T\lambda/ \partial I$, denoted in Table B, can be derived from a polynomial expansion $T\lambda = T\lambda\{\lambda r;I(l)\}$

- In addition: $T(FP)$ vs. $I\{T(FP)\}$, where the temperature $T(FP)$ refers to the ITS-90 fixed-point temperature, as transferred to the strip, should be separately reported. Two values of $I\{T(FP)\}$ should be given, i.e. the directly measured value and the value, obtained after correction for the SSE.

Finally: specify the values Ramb and Tamb, as measured upon receipt of the lamps, and just before transferring them to their next destination (cf. 3.2.1 and 3.2.2).

4.3. Uncertainties.

4.3.1. Identification of uncertainty components.

Here we confine ourselves to identifying uncertainty components through the physical parameters involved and the associated corrections.

I. Reference blackbody radiator.

- Realization of the reference temperature. Sub-components: impurities, emissivity , temperature difference ΔT across the bottom section of the cavity in view

II. Reference thermometer.

II.1. Ratio of photo-currents.

- Photo current - measurement.
- Photo current - resolution.
- Linearity

II.2. Size of source effect (SSE).

II.3. Spectral parameters

- Spectral response function, including (especially) the spectral transmission of the interference filter and the spectral responsivity of the detector. Stability of the interference filter.
- Blocking.

- Mean effective wavelength (λe), a variable, linking up additionally with the spectral characteristics of the transfer lamps around the fixed reference wavelengths λr_l (local value) and λr (reference value).

II.4. Possible additional parameters.

- Transmission of neutral density filter(s).

III. Transfer lamps.

III.1. Lamp current.

- Lamp currents I(l), as set.
- Lamp-currents I(j), as prescribed.

III.2. Radiance temperature.

- Short-term stability.
- Drift.
- Dependence on wavelength: $T\lambda = T\lambda(\lambda)$; $dT\lambda/d\lambda(\lambda)$.
- Dependence on base temperature $T\lambda = T\lambda(\lambda; Tb)$.

Residual parameters:

- Alignment (spatial and angular distribution of radiance).
- Target field
- Cleaning of the window

IV. Lamp-thermometer composite parameters

- Radiance temperature $T\lambda = T\lambda(\lambda e; Tb)$.
- $T\lambda := T\lambda(\lambda e; Tb)$, corrected for the SSE.
- $T\lambda := T\lambda(\lambda e; Tb)$, corrected for SSE and non-linearity.

Conversion to reference conditions:

- $T\lambda = T\lambda\{\lambda e; Tb; I(l)\}$, corrected to RH = 0 % (only if $\lambda r = 950$ nm).
- Reference wavelength λr: $T\lambda := T\lambda\{\lambda r; Tb; I(l)\}$.

- Base temperature 20°C: $T\lambda : = T\lambda\{\lambda r; 20; I(l)\}$.
- Lamp currents $I(j)$: $T\lambda : = T\lambda\{\lambda r; 20; I(j)\}$.

4.3.2. Specifying uncertainties.

4.3.2.1. Representation.

Uncertainties have to be specified in accordance with the ‘Guide to the expression of uncertainty in measurement’, co-edited by BIPM (1993), in terms of the (effective) standard deviations $sA(i)$, $sB(i)$, $s(i)$, for the components i to be taken into consideration. The terms to be included in the propagation of uncertainties should be fully described.

4.3.2.2. Final specifications.

- Uncertainty components arranged within the framework given in 4.3.1.

- The uncertainties $s\{T\lambda(\lambda r; I(j))\}$ vs. $I(j)$ in the specified reference conditions (3.1.2), $I(j)$ referring to the currents defined in Appendix D.

- The uncertainties $s\{T\lambda(\lambda r; I(j))\}$ vs. $T\lambda(\lambda r; I(j))$ in the specified reference conditions (3.1.2), $I(j)$ referring to the currents defined in Appendix D.

4.4.Time schedule.

- The time schedule is given in 2.3.1; in 2.3.2 the reporting has been scheduled: your final report should be sent to VSL within two months after completion of the measurements.

4.5. Editing and publication

- Format: measurement data: ASCII; text: WP 6.1 or MS Word 5.5.

- Medium:
  - Disk
  - E-mail

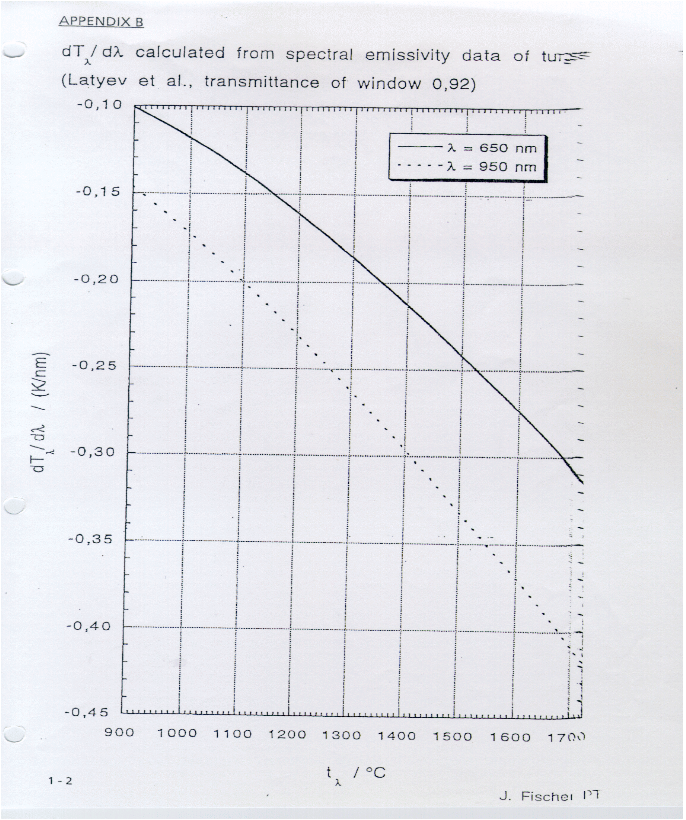
Appendix A: Circulation schemes

Laboratory	Period
CEM - Spain	1 October 1999
IPQ - Portugal	1 December 1999
UME - Turkey	1 February 2000
OMH - Hungary	1 April 2000
SMU - Slovakia	1 June 2000
NMA - Norway	1 August 2000
SP - Sweden	1 October 2000
MIKES - Finland	1 December 2000
VSL - Netherlands	1 February 2001

Remarks:

1. Data referred to are ultimate deadlines; in any case lamps should be transferred to their next destination as soon as possible after completion of the measurements.The ATA Carnet has to be use for the laboratories UME to NMA because they are outside EC.

Appendix B: The dependence of spectral radiance temperature on wavelength



APPENDIX B

$dT_\lambda / d\lambda$ calculated from spectral emissivity data of tu
(Latyev et al., transmittance of window 0,92)

1-2

J. Fischer PT

t / °C	dT/dλ /K/nm	t / °C	dT/dλ /K/nm
950	-0.109	1300	-0.186
961.78	-0.111	1400	-0.213
1000	-118	1500	-0.242
1064.18	-0.131	1600	-0.273
1084.62	-0.135	1700	-0.307
1100	-0.139		
1200	-0.161		

Appendix C: Confirmation form on the receipt and status of the transfer standards.

To be returned to: NMi/VSL

Att. R. Bosma

P.O. Box 654

2600 AR Delft

The Netherlands

Tel: +31-15-269 16 63

Fax: +31-15-261 29 71

In order to be able to monitor the progress of the intercomparison, we kindly ask every participating laboratory, on receipt of each of the set of lamps, to fill in this confirmation form.

Thank you in advance for your co-operation.

The lamp set was received on .... (date).

The ATA-Carnet was not* correctly supplied with the lamp set. (Only to be filled in by non EU members)

If ATA-Carnet not (correctly) supplied? Contact supplier of the lamps.

The lamps seem, after inspection, not* to be damaged. If damaged? Contact supplier of lamps.

Values measured for Ramb and Tamb upon receipt of the lamps:

Ramb(1) = Ohm; Tamb(1) = °C.

Ramb(2) = Ohm; Tamb(2) = °C.

The repeatability of lamp 1, at I = I(5), λ_ 650 nm, after restabilization was ......K (including sign).

The repeatability of lamp 2, at I = I(5), λ_ 650 nm, after restabilization was ......K (including sign).

If the repeatability for one of the lamps is found to be not better than 0,25 K, please contact the supplier of the lamps.

Laboratory : ....

Contact Person : ....

Telephone : ....

Telefax : ....

[*] To be erased if applicable / non-applicable.

Appendix D: Lamp data

1. Lamp data; instructions

1.1. Identification

Lamp 1: C564 Lamp 2: C681

1.2 Strip dimensions

Strip width:

Lamp 1: 1,3 mm Lamp 2: 1,5 mm

Effective strip length:

Lamp 1: 50 mm Lamp 2: 60 mm

1.3. Connections.

Current connections: polarity as indicated on the lamp base.

1.4 Maximum currents

Lamp1: Imax = 11,502 A; Tλ(650; Imax) _ 1700 °C.

Lamp2: Imax = 14,273 A; Tλ(650; Imax) _ 1700 °C.

1.5. Temperature measurement of the base.

Calibrated PRT; diameter: ≤ 3,2 mm; length: ≤ 25 mm. Thermal contact to be enhanced by means of contact grease.

2. Currents to be set.

Lamp 1	Lamp 2	Tλ (λ = 650 nm) in °C Approximately:
I(1) = 4,480 A	I(1) = 5,508 A	962
I(2) = 4,721 A	I(2) = 5,822 A	1000
I(3) = 5,169 A	I(3) = 6,399 A	1064
I(4) = 5,322 A	I(4) = 6,594 A	1085
I(5) = 5,441 A	I(5) = 6,745 A	1100
I(6) = 6,272 A	I(6) = 7,795 A	1200
I(7) = 7,194 A	I(7) = 8,948 A	1300
I(8) = 8,189 A	I(8) = 10,183 A	1400
I(9) = 9,242 A	I(9) = 11,487 A	1500
I(10) = 10,347 A	I(10) = 12,851 A	1600
I(11) = 11,502 A	I(11) = 14,273 A	1700

3. Temperature coefficients dTλ/dTb(Tλ) associated with the base temperature Tb.

The polynomial representations, with Tλ and Tb given in °C, are:

$dT\lambda/dTb = \Sigma_i \, a[i] \, . \, [T\lambda]^i$, with i = 0 to 3, and:

Lamp1

For λr = 650 nm: a[0] = 6,62175

a[1] = $-1{,}63037 \, . \, 10^{-2}$

a[2] = $1{,}35171 \, . \, 10^{-5}$

a[3] = $-3{,}76852 \, . \, 10^{-9}$

Associated standard deviation (in dTλ/dTb): s = 5 % of its absolute value.

Correction to be applied below Tλ = 1300 °C.

Lamp 2.

For λr = 650 nm: a[0] = 4,88240

a[1] = $-1{,}16483 \, . \, 10^{-2}$

a[2] = $9{,}22499 \, . \, 10^{-6}$

a[3] = $- 2{,}41666 \, . \, 10^{-9}$

Associated standard deviation (in dTλ/dTb): s = 5 % of its absolute value.

Correction to be applied below Tλ = 1200 °C

Appendix II: Uncertainty determination per participant:

The following sections present the uncertainty budget and methods used by each participants in their measurements. The following text, tables and figures are directly copied from their submitted report.

B.1 CEM uncertainty determination:

The following uncertainty determination by CEM is taken from their report.

4. - UNCERTAINTIES.

We will try to obtain a mathematical model that related the input quantities with the temperature T and the lamp current I that are the quantities in which are express the calibration of the lamp, in order to get a general expression that related the combined uncertainty with the components uncertainties and their sensitivities coefficients.

For the mathematical model we assume that the true radiance temperature of the lamp T_A for a current I, is the calculated radiance temperature T and the influence of and known amount of the current δI, which is expressed in equation 4-1.

$$T_A = T + c\delta I \qquad (4\text{-}1)$$

c is the sensitivity coefficient of $T = f(I)$, calculated in table 2 and 4

From the above we can obtain

$$u^2(T_a) = u^2(T) + c\,u^2(I) \qquad \text{for } u^2(I) = u^2(\delta I) \qquad (4\text{-}2)$$

$u(T)$ is the combined uncertainties in the determination of T
$u(I)$ is the combined uncertainties in the determination of I

4.1.- Uncertainties in the determination of *T* .

Use the Wien approximation and the mean effective wavelength represented by λ., and Q the radiance's ratio it is obtained.

$$T = \frac{C_2}{C_2 / T_{cu} - \lambda \cdot \ln(Q/\tau)} + \delta T_p + \delta T_{SSET} + \delta T_\lambda + \delta T_b \qquad (4\text{-}3)$$

with δT_p the variation in temperature due to target position in the lamp strip, τ the transmission of the neutral density filter, δT_b an unknown component in the radiance temperature T due to the uncertainty in the lamp base temperature and $\delta T_{\square}$ an unknown component in T due to the uncertainty in the lamps calibration wavelength, $u(T)$ can be expressed as:

$$u^2(T) = \left(\frac{\partial T}{\partial T_{cu}}\right)^2 u^2(T_{cu}) + \left(\frac{\partial T}{\partial \lambda}\right)^2 u^2(\lambda) + \left(\frac{\partial T}{\partial Q}\right)^2 u^2(Q) + \left(\frac{\partial T}{\partial \tau}\right)^2 u^2(\tau) + \left(\frac{\partial T}{\partial \delta T_p}\right)^2 u^2(\delta T_p) +$$

$$+ \left(\frac{\partial T}{\partial \delta T_{SSE_T}}\right)^2 u^2(SSE_T) + \left(\frac{\partial T}{\partial \delta T_\lambda}\right)^2 u^2(\lambda_c) + \left(\frac{\partial T}{\partial \delta T_b}\right)^2 u^2(T_b) \qquad (4\text{-}4)$$

it has been considered $u(SSE_T)=u(\delta T_{SSET})$, $u(\lambda_c)=u(\delta T_\lambda)$, $u(T_b)=u(\delta T_b)$

The sensitivity coefficients are:

$$\frac{\partial T}{\partial T_{cu}}=\frac{T^2}{T_{cu}^2} \quad ; \quad \frac{\partial T}{\partial \lambda}=T^2\left(\frac{1}{\lambda T_{cu}}-\frac{1}{\lambda T}\right) \quad ; \quad \frac{\partial T}{\partial Q}=\frac{\lambda}{\mathrm{C}_2}\frac{1}{Q}T^2 \ ; \quad \frac{\partial T}{\partial \tau}=\frac{\lambda}{C_2 \tau}T^2 ;$$

$$\frac{\partial T}{\partial \delta T_{\mathrm{p}}}=1 \quad ; \quad \frac{\partial T}{\partial \delta T_{SSE_{\mathrm{T}}}}=\frac{\lambda}{C_2}T^2 \quad ; \quad \frac{\partial T}{\partial \delta T_\lambda}=\text{Protocol values} \qquad (4\text{-}5)$$

Uncertainty on T_{cu} $u(T_{cu})$. Has also several components:

$$u^2(T_{cu}) = u_1^2(T_{cu}) + u_2^2(T_{cu}) + u_3^2(T_{cu}) + u_4^2(T_{cu}) \qquad (4\text{-}6)$$

$u_1^2(T_{cu})$ is the uncertainty due to impurities of the copper and the heat flux inside the BB cavity, estimated from the freezing and melting plateau, the maximum value of the estimated error is 0,1 ºC then:

$$u_1^2(T_{cu}) = (0.1 /\sqrt{3}\ ^\circ\mathrm{C})^2 \qquad (4\text{-}7)$$

$u_2^2(T_{cu})$ is the uncertainty due to emission coefficient of the cavity, it can be expressed as:

$$u_2^2(T_{cu})=\left(\frac{\partial T_{cu}}{\partial \xi}\right)^2 u^2(\xi) \qquad (4\text{-}8)$$

with $\frac{\partial T_{cu}}{\partial \xi}=\frac{\lambda}{C_2 \xi}T_{cu}^2$ as sensitivity coefficient.

$u_3^2(T_{cu})$ is the uncertainty due to SSE correction of the copper BB, it can be expressed as:

$$u_3^2(T_{cu})=\left(\frac{\partial T_{cu}}{\partial \mathrm{SSE}_{cu}}\right)^2 u^2(\mathrm{SSE}_{cu}) \qquad (4\text{-}9)$$

with $\frac{\partial T_{cu}}{\partial \mathrm{SSE}_{cu}}=\frac{\lambda}{C_2}T_{cu}^2$ as sensitivity coefficient.

We estimate that the maximum error is 20% of the SSE correction, for the copper point SSE_{cu}=0,055 % then:

$$u^2(\mathrm{SSE}_{cu})=\left(0{,}00011/\sqrt{3}\right)^2 \qquad (4\text{-}10)$$

$u_4^2(T_{cu})$ is the uncertainty due to radiation thermometer stability at the copper point during the calibration, it is estimated to have a maximum value of 0,1 ºC then:

$$u_4^2(T_{cu}) = (0.1 /\sqrt{3}\ ^\circ\mathrm{C})^2 \qquad (4\text{-}11)$$

Uncertainty on λ $u(\lambda)$. The maximum error in the determination of the wavelength of the radiance thermometer is estimated to be 0,3 nm given:

$$u^2(\lambda) = (0{,}3/\sqrt{3}\ \mathrm{nm})^2 \qquad (4\text{-}12)$$

Uncertainty on Q $u(Q)$. The radiance ratio can be expressed as 4-13

$$\frac{R}{R_{\mathrm{cu}}} = Q = \left(1+\frac{\Delta S(T)}{S(T)}\right)\left(1+\frac{\Delta V(T)}{V(T)}\right)\frac{V(T)}{V(T_{\mathrm{cu}})} \qquad (4\text{-}13)$$

with $\frac{\Delta S(T)}{S(T)}$ and $\frac{\Delta V(T)}{V(T)}$ as the linearities of the radiation thermometer and digital voltmeter. Assuming than $\frac{\Delta V(T)}{V(T)}$ is very small compare with $\frac{\Delta S(T)}{S(T)}$ (4-13) can be reduce to:

$$Q = \left(1+\frac{\Delta S(T)}{S(T)}\right)\frac{V(T)}{V(T_{\mathrm{cu}})} = \left(1+l_{\mathrm{p}}\right)\frac{V(T)}{V(T_{\mathrm{cu}})} \qquad (4\text{-}14)$$

with l_{p} the radiation thermometer linearity. From (4-14) it can we obtain $u(Q)$

$$u^2(Q) = \left(\frac{\partial Q}{\partial l_{\mathrm{p}}}\right)^2 u^2(l_{\mathrm{p}}) + \left(\frac{\partial Q}{\partial V(T)}\right)^2 u^2(V(T)) + \left(\frac{\partial Q}{\partial V(T_{cu})}\right)^2 u^2(V(T_{cu})) \qquad (4\text{-}15)$$

The sensitivity coefficients are:

$$\frac{\partial Q}{\partial l_{\mathrm{p}}} = Q \quad ; \quad \frac{\partial Q}{\partial V(T)} = Q\frac{1}{V(T)} \quad ; \quad \frac{\partial Q}{\partial V(T_{cu})} = Q\frac{1}{V(T_{cu})} \qquad (4\text{-}16)$$

Uncertainty due to the neutral density filter $u(\tau)$. We assume that the maximum error in the measurement of τ is 0,00015, then:

$$u^2(\tau) = \left(0{,}00015/\sqrt{3}\ {}^{\circ}\mathrm{C}\right)^2 \qquad (4\text{-}17)$$

Uncertainty due to the target position $u(T_{\mathrm{p}})$.This uncertainty is produce by the angular and horizontal radiance variations, from the measurements in Annex 1 it is estimated that the maximum variation is smaller than 0.1 ºC then:

$$u^2(T_{\mathrm{p}}) = (0{,}1/\sqrt{3}\ {}^{\circ}\mathrm{C})^2 \qquad (4\text{-}18)$$

Uncertainty due SSE $u(\mathrm{SSE_T})$.This uncertainty is produce by the correction of the SSE in the lamp. We estimate the maximum error is 20% of the SSE correction, for the lamp $\mathrm{SSE_T}$= 0,01 % (The biggest of the two lamps), then

$$u^2(\mathrm{SSE_T}) = (0{,}00002/\surd 3)^2 \tag{4-19}$$

With the sensitivity coefficient obtained in 4-5.

Uncertainty due to $\delta T\lambda$Is the uncertainty in the lamps calibration due to the error in the assigned wavelength value. With:

$$u^2(\lambda_c) = (0{,}3/\surd 3\ \mathrm{nm})^2 \tag{4-20}$$

as before and for the sensitivity coefficient $\partial T/\partial\delta T_\lambda$ the values given in the protocol for the dependence of spectral radiance temperature on wavelength.

Uncertainty due to δT_b. Is the uncertainty associated with the lamps base temperature T_b. The sensitivity coefficient $\dfrac{\partial T}{\partial \delta T_b}$ is obtained from the protocol , it will be used the equation of the C564 lamp that give biggest values. The uncertainty $u(T_b)$ is assume to be produced by the lamp base temperature measurement and to be smaller than 0,1 ºC.

$$u^2(T_b) = (0{,}1/\surd 3\ ºC)^2 \tag{4-21}$$

4.2.- Uncertainties in the determination of *I*.

The lamp current is determinate from the equation $I = V/R$, V is measured with the digital voltmeter and R is the shunt value. The uncertainty $u\,(I)$ is obtained from the above equation.

$$u^2(I) = \left(\frac{\partial I}{\partial V}\right)^2 u^2(V) + \left(\frac{\partial I}{\partial R}\right)^2 u^2(R) \tag{4-22}$$

The sensitivity coefficients are:

$$\frac{\partial I}{\partial V} = \frac{1}{R} = I\frac{1}{V} \quad ; \quad \frac{\partial I}{\partial R} = -\frac{V}{R^2} = -I\frac{1}{R} \tag{4-23}$$

$u(V)$ is estimated at each measurement, and $u(R)$ is obtained from the shunt calibration with $u(R)/R = 20\cdot 10^{-6}$ with a coverage factor k=2

4.3.- Combined uncertainty.

The expression of the combined uncertainty is very long and is not expressed here explicitly, it can be obtained by substitution in 4-2 all the components of uncertainty given by 4-4, 4-6, 4-7, 4-8, 4-9, 4-10, 4-11, 4-12, 4-15, 4-17, 4-18, 4-19, 4-20, 4-21 and 4-22 taken also into account all the sensitivity coefficients. It is more clear to present all the uncertainty components in a table with their parameters.

UNCERTAINTY COMPONENTS

	Component	Type	Standard Uncertainty	Probability distribution	Value	Unit	Standard uncert.	Sensitivity coefficient
1.1	Impurities, heat flux	B	$u_1(T_{cu})$	Rectangular	0,1	ºC	0,058	1
1.2	Copper BB emissivity	B	$u(\xi)$	Rectangular	0,0002		0,00012	$(\lambda/C_2\xi)T_{cu}^2$
1.3	SSE in copper BB	B	$u(SSE_{cu})$	Rectangular	0,00011		0,00006	$(\lambda/C_2)T_{cu}^2$
1.4	Thermometer stability	B	$u_4(T_{cu})$	Rectangular	0,1	ºC	0,058	1
1	**Uncertainties on T_{cu}**	Comb.[1]	$u(T_{cu})$	Combined		ºC	u(T_{cu})	T^2/T_{cu}^2
2	**Uncertainties on λ**	B	$u(\lambda)$	Rectangular	0,3	nm	0,173	$(1/\lambda T_{cu}-1/\lambda T)T^2$
3.1	Thermometer linearity	B	$u(l_p)$	Rectangular	0,001		0,0006	Q
3.2	Volt at T_{cu}	A	$u(V(T_{cu}))/V(T\,cu)$	Normal	0,00007		0,00007	Q
3.3	Volt at T	A	$u(V(T))/V(T)$	Normal				Q
3	**Uncertainties on Q**	Comb.[1]	$u(Q)$	Combined				$(\lambda/(C_2Q))T^2$
4	**Neutral density filter**	B	$u(\tau)$	Rectangular	0,00015		0,0001	$(\lambda/(C_2\tau))T^2$
5	**Target position**	B	$u(\delta T_p)$	Rectangular	0,1	ºC	0,05774	1
6	**SSE in the lamp**	B	$u(SSE_T)$	Rectangular	0,00002		0,00001	$(\lambda/C_2)T^2$
7	**λ of calibration**	B	$u(\lambda_c)$	Rectangular	0,3	nm	0,173	$\partial T/\partial\lambda$
8	**Lamp base temperat.**	B	$u(T_b)$	Rectangular	0,1	ºC	0,058	$\partial T/\partial T_b$
9.1	Voltage in the shunt	A	$u(V)/V$	Normal				I
9.2	Value of the shunt	A	$u(R)/R$	Normal	1,00E-05		1,00E-05	I
9	**Lamp intensity**	Comb.[1]	$u(I)$	Combined		A		c

(1) The uncertainties components 1, 3 and 6 are combined uncertainties, for the calculation of the final combined uncertainty it is necessary to use their sensibility coefficient and the sensibility coeficients of th components

C:Datos/Euromet/Lamparas/Report/Calc-unc.xls

4.4- Uncertainties calculation.

The uncertainties are calculated for each temperature, tables in the next pages.

Each uncertainty component is calculated using the standard uncertainty value and its sensitivity coefficient. Some of the uncertainty components are combined uncertainties, num. 1, 3 and 9. The final combined uncertainty is the composition of the components written in heavy type.

The uncertainty of $V(T_{cu})$ is expressed in relative form as $u(V(T_{cu}))/ V(T_{cu})$ in order to facilitate the calculation ; the value of $u(V(T_{cu}))$ is taken from the measurements of C564 lamp Run 1 at 1085 ºC.

The uncertainty of $V(T)$ is also expressed in relative form as $u(V(T))/ V(T)$, their values are obtained from the calibration of C564 lamp Run 1 at each temperature.

The uncertainty due to the neutral density filter appears only in the temperature where it is used 1600 ºC and 1700 ºC.

The uncertainty due to λ is calculated using the sensitivity coefficient given in the protocol for $\partial T/\partial \lambda$

The coefficient used for the lamp base temperature uncertainty, is obtained from the protocol corresponding to the lamp C564 that is the biggest.

The sensitivity coefficient, $c = \partial T/\partial I$ for $u(I)$, is obtained from the tables corresponding to the C564 lamp Run 1.

UNCERTAINTY CALCULATION

Num.	**Component**	**Type**	**Standard**	**TEMPERATURE ºC / UNCERT. CONTRIBUTION ºC**					
			Uncertainty	962	1 000	1 064	1 085	1 100	1 200
1.1	Impurities, heat flux	B	$u_1(T_{cu})$				0,058		
1.2	Copper BB emissivity	B	$u(\xi)$				0,010		
1.3	SSE in copper BB	B	$u(\mathrm{SSE}_{cu})$				0,005		
1.4	Thermometer stability	B	$u_4(T_{cu})$				0,058		
1	**Uncertainties on T_{cu}**	**Combined**	$u(T_{cu})$	**0,069**	**0,073**	**0,080**	**0,083**	**0,085**	**0,097**
2	**Uncertainties on λ**	**B**	$u(\lambda)$	**0,018**	**0,013**	**0,003**	**0,000**	**0,003**	**0,022**
3.1	Thermometer linearity	B	$u(l_p)$	0,0001	0,0002	0,0005		0,0007	0,0022
3.2	Volt at T_{cu}	A	$u(V(T_{cu}))/V(T\mathrm{cu})$	0,0000	0,0000	0,0001	0,0001	0,0001	0,0003
3.3	Volt at T	A	$u(V(T))/V(T)$	0,0000	0,0000	0,0001	0,0001	0,0001	0,0002
3	**Uncertainties on Q**	**Combined**	$u(Q)$	**0,043**	**0,045**	**0,049**	**0,008**	**0,052**	**0,059**
4	**Neutral density filter**	**B**	$u(\tau)$						
5	**Target position**	**B**	$u(\delta T_p)$	**0,058**	**0,058**	**0,058**	**0,058**	**0,058**	**0,058**
6	**SSE in the lamp**	**B**	$u(\mathrm{SSE}_T)$	**0,0007**	**0,0007**	**0,0008**	**0,0008**	**0,0009**	**0,0010**
7	**$\lambda$of calibration**	**B**	$u(\lambda_c)$	**0,019**	**0,019**	**0,023**	**0,023**	**0,024**	**0,028**
8	**Lamp base temperat.**	**B**	$u(T_b)$	**0,005**	**0,004**	**0,002**	**0,002**	**0,002**	**0,001**
9.1	Voltage in the shunt	A	$u(V)/V$	0,0001	0,0000	0,0001	0,0001	0,0000	0,0000
9.2	Value of the shunt	A	$u(R)/R$	0,00005	0,00005	0,00005	0,00005	0,00005	0,00006
9	**Lamp intensity**	**Combined**	$u(I)$	**0,012**	**0,009**	**0,010**	**0,010**	**0,009**	**0,009**
	COMBINED UNCERTAINTY		**with k = 1**	**0,10**	**0,11**	**0,11**	**0,10**	**0,12**	**0,13**
	EXPANDED UNCERTAINTY		**with k = 2**	**0,21**	**0,21**	**0,23**	**0,21**	**0,24**	**0,27**

C:Datos/Euromet/Lamparas/Report/Calc-unc.xls

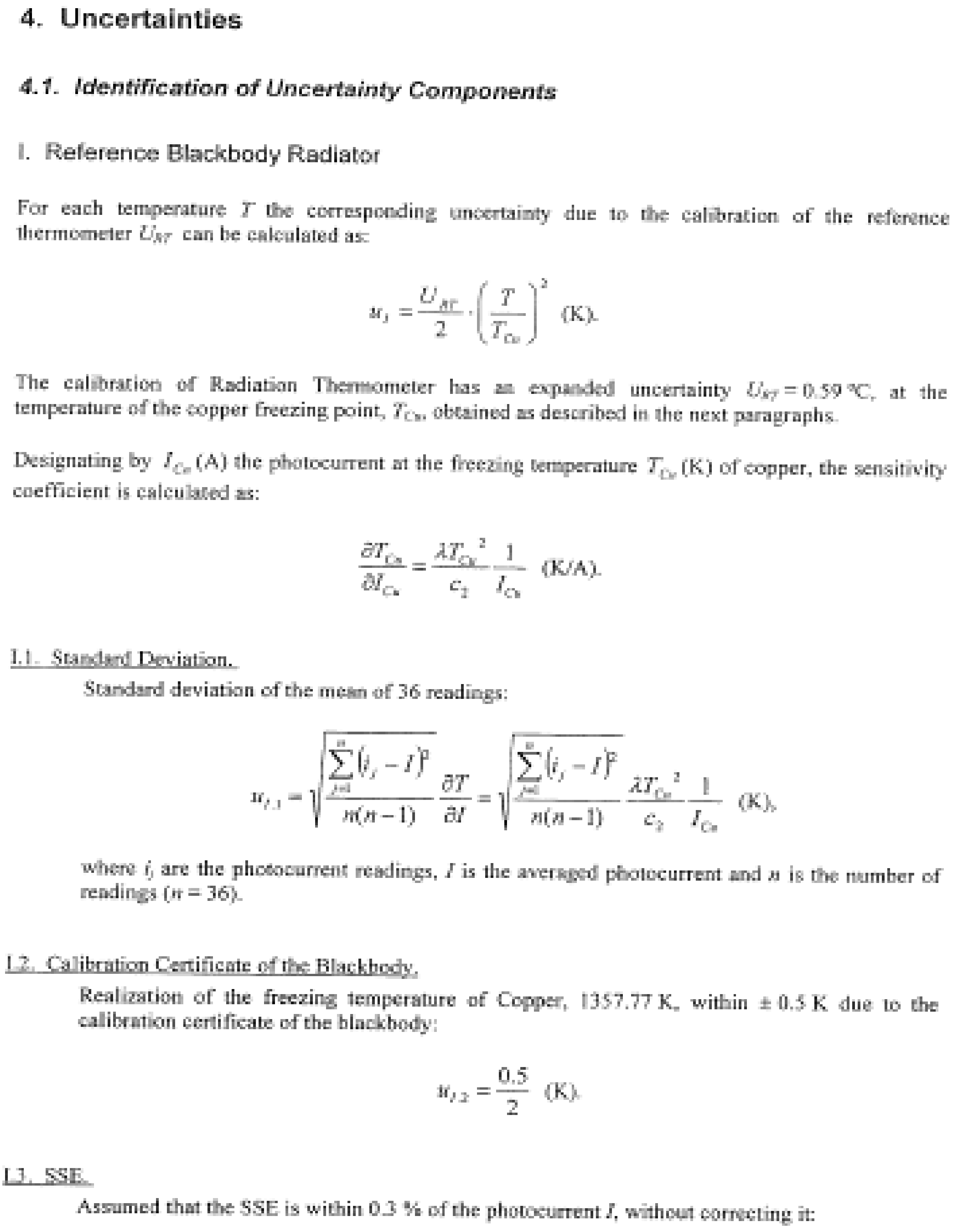
UNCERTAINTY CALCULATION

Num.	Component	Type	Standard Uncertainty	TEMPERATURE ºC / UNCERT. CONTRIBUTION ºC				
				1 300	1 400	1 500	1 600	1 700
1.1	Impurities, heat flux	B	$u_1(T_{cu})$					
1.2	Copper BB emissivity	B	$u(\xi)$					
1.3	SSE in copper BB	B	$u(\mathrm{SSE}_{cu})$					
1.4	Thermometer stability	B	$u_4(T_{cu})$					
1	**Uncertainties on T_{cu}**	**Combined**	$\boldsymbol{u}\,(\mathbf{T_{cu}})$	**0,111**	**0,126**	**0,141**	**0,158**	**0,175**
2	**Uncertainties on λ**	**B**	$\boldsymbol{u}\,(\boldsymbol{\lambda})$	**0,045**	**0,072**	**0,103**	**0,138**	**0,177**
3.1	Thermometer linearity	B	$u(l_p)$	0,0057	0,0131	0,0275	0,0052	0,0095
3.2	Volt at T_{cu}	A	$u(V(T_{cu}))/V(T\,\mathrm{cu})$	0,0007	0,0015	0,0032	0,0006	0,0011
3.3	Volt at T	A	$u(V(T))/V(T)$	0,0003	0,0010	0,0014	0,0003	0,0002
3	**Uncertainties on Q**	**Combined**	$\boldsymbol{u}\,(\mathbf{Q})$	**0,068**	**0,077**	**0,086**	**0,096**	**0,106**
4	**Neutral density filter**	**B**	$\boldsymbol{u}(\boldsymbol{\tau})$				**0,159**	**0,176**
5	**Target position**	**B**	$\boldsymbol{u}\,(\boldsymbol{\delta T_p})$	**0,058**	**0,058**	**0,058**	**0,058**	**0,058**
6	**SSE in the lamp**	**B**	$\boldsymbol{u}\,(\mathbf{SSE_T})$	**0,0011**	**0,0013**	**0,0014**	**0,0016**	**0,0018**
7	**$\boldsymbol{\lambda}$ of calibration**	**B**	$\boldsymbol{u}\,(\boldsymbol{\lambda_c})$	**0,032**	**0,037**	**0,042**	**0,047**	**0,053**
8	**Lamp base temperat.**	**B**	$\boldsymbol{u}\,(\mathbf{T_b})$					
9.1	Voltage in the shunt	A	$u(V)/V$	0,0000	0,0001	0,0000	0,0000	0,0001
9.2	Value of the shunt	A	$u(R)/R$	0,00007	0,00008	0,00009	0,00010	0,00012
9	**Lamp intensity**	**Combined**	$\boldsymbol{u}\,(\boldsymbol{I})$	**0,008**	**0,010**	**0,010**	**0,010**	**0,011**
	COMBINED UNCERTAINTY		**with k = 1**	**0,15**	**0,18**	**0,21**	**0,24**	**0,28**
	EXPANDED UNCERTAINTY		**with k = 2**	**0,31**	**0,36**	**0,42**	**0,48**	**0,56**

C:Datos/Euromet/Lamparas/Report/Calc-unc.xls

B.2 IPQ uncertainty:

The following uncertainty determination by IPQ is taken from their report.



4. Uncertainties

4.1. Identification of Uncertainty Components

I. Reference Blackbody Radiator

For each temperature T the corresponding uncertainty due to the calibration of the reference thermometer U_{RT} can be calculated as:

$$u_I = \frac{U_{RT}}{2} \cdot \left(\frac{T}{T_{Cu}} \right)^2 \quad \text{(K)}.$$

The calibration of Radiation Thermometer has an expanded uncertainty $U_{RT} = 0.59$ °C, at the temperature of the copper freezing point, T_{Cu}, obtained as described in the next paragraphs.

Designating by I_{Cu} (A) the photocurrent at the freezing temperature T_{Cu} (K) of copper, the sensitivity coefficient is calculated as:

$$\frac{\partial T_{Cu}}{\partial I_{Cu}} = \frac{\lambda T_{Cu}{}^2}{c_2} \frac{1}{I_{Cu}} \quad \text{(K/A)}.$$

I.1. Standard Deviation.

Standard deviation of the mean of 36 readings:

$$u_{I,1} = \sqrt{\frac{\sum_{j=1}^{n} (i_j - I)^2}{n(n-1)}} \frac{\partial T}{\partial I} = \sqrt{\frac{\sum_{j=1}^{n} (i_j - I)^2}{n(n-1)}} \frac{\lambda T_{Cu}{}^2}{c_2} \frac{1}{I_{Cu}} \quad \text{(K)},$$

where i_j are the photocurrent readings, I is the averaged photocurrent and n is the number of readings ($n = 36$).

I.2. Calibration Certificate of the Blackbody.

Realization of the freezing temperature of Copper, 1357.77 K, within ± 0.5 K due to the calibration certificate of the blackbody:

$$u_{I,2} = \frac{0.5}{2} \quad \text{(K)}.$$

I.3. SSE.

Assumed that the SSE is within 0.3 % of the photocurrent I, without correcting it:

$$u_{I.3} = \frac{0.003 \cdot I}{\sqrt{3}} \cdot \frac{\partial T}{\partial I} = \frac{\lambda T_{Cu}^{2}}{c_2} \cdot \frac{0.003}{\sqrt{3}} \quad \text{(K)}.$$

I.4. Emissivity Correction for the Fixed Point.

The emissivity of the blackbody cavity is calculated as 0.9992 ± 0.0003. With a wavelength of 650 nm, at the freezing temperature of the copper the correction is assumed to be within ± 0.025 K:

$$u_{I.4} = \frac{0.025}{\sqrt{3}} \quad \text{(K)}.$$

II. Reference Thermometer

II.1 Ratio of Photo-Currents

There are three main contributions to include in this paragraph:

- Standard deviation of the mean of the photo-current readings, ($u_{II.1}$);
- Photocurrent resolution, ($u_{II.2}$);
- Non-linearity, ($u_{II.3}$).

Designating by I_p (A) the photocurrent of the radiation thermometer, the sensitivity coefficient is calculated at each temperature T (K) as:

$$\frac{\partial T}{\partial I_p} = \frac{\lambda T^2}{c_2} \cdot \frac{1}{I_p} \quad \text{(K/A)}$$

The standard deviation of the mean ($u_{II.1}$) of n = 48 photo-current readings (4 minutes with 5 seconds interval) is:

$$u_{II.1} = \sqrt{\frac{\sum_{j=1}^{n}\left(i_j - I_p\right)^2}{n(n-1)}} \cdot \frac{\partial T}{\partial I_p} = \sqrt{\frac{\sum_{j=1}^{n}\left(i_j - I_p\right)^2}{n(n-1)}} \cdot \frac{\lambda T^2}{c_2}\frac{1}{I_p} \quad \text{(K)}.$$

The standard uncertainty ($u_{II.2}$) due to photocurrent resolution d is half of this value:

$$u_{II.2} = \frac{d/2}{\sqrt{3}} \cdot \frac{\partial T}{\partial I_p} = \frac{d/2}{\sqrt{3}} \cdot \frac{\lambda T^2}{c_2} \cdot \frac{1}{I_p} \quad \text{(K)}.$$

Non-linearity, ($u_{II.3}$) according to the calibration of the RT this parameter is better than 0,1% of signal:

$$u_{II.3} = \frac{0.001 \cdot I_p}{\sqrt{3}} \cdot \frac{\partial T}{\partial I_p} = \frac{0.001}{\sqrt{3}} \cdot \frac{\lambda T^2}{c_2} \quad \text{(K)}.$$

4.2. Tables of Uncertainty Results

The following tables summarize the values of the standard uncertainties, expressed in Kelvin. The order of the columns is altered to maintain the groups of uncertainties.
The degrees of freedom are expressed in the column ν_{ef}, and the expanded uncertainty in the column U (K=2).

Lamp 1

no	*u* *I*	*u* *II.1*	*u* *II.2*	*u* *II.3*	*u* *II.4*	*u* *II.5*	*u* *IV.1*	*u* *IV.2*	*u* *IV.3*
1	2.4E-1	2.2E-2	1.6E-3	4.0E-2	1.2E-1	4.8E-2	9.0E-4	3.9E-4	2.9E-4
2	2.6E-1	4.2E-3	1.0E-3	4.2E-2	1.3E-1	3.4E-2	8.8E-4	1.7E-4	2.9E-4
3	2.8E-1	1.4E-3	5.0E-4	4.7E-2	1.4E-1	8.0E-3	8.3E-4	1.7E-4	3.0E-4
4	2.9E-1	2.1E-3	4.1E-3	4.8E-2	1.4E-1	9.9E-4	8.2E-4	8.2E-5	2.2E-4
5	3.0E-1	1.1E-3	3.5E-3	4.9E-2	1.5E-1	7.9E-3	8.0E-4	1.9E-4	2.5E-4
6	3.4E-1	7.7E-4	1.3E-3	5.7E-2	1.7E-1	6.7E-2	7.1E-4	7.0E-5	2.2E-4
7	3.9E-1	1.4E-3	5.9E-3	6.5E-2	1.9E-1	1.1E-1	5.9E-4	0.0E+0	2.5E-4
8	4.4E-1	8.7E-4	2.9E-3	7.3E-2	2.2E-1	1.7E-1	4.4E-4	0.0E+0	2.9E-4
9	4.9E-1	5.5E-4	1.5E-3	8.2E-2	2.5E-1	2.4E-1	2.7E-4	0.0E+0	3.3E-
10	5.5E-1	2.1E-3	8.8E-3	9.2E-2	2.8E-1	3.2E-1	7.1E-5	0.0E+0	3.3E-4
11	6.1E-1	0.0E+0	5.4E-3	1.0E-1	3.1E-1	4.0E-1	1.6E-4	0.0E+0	3.8E-4

no	**Temp.** °C	*u* *III.1*	*u* *III.2*	*u* *III.3*	*u* *III.4*	*u* *III.5*	ν_{ef}	*U* (K=2)
1	966.68	1.7E-6	1.6E-2	3.5E-3	1.1E-1	1.2E-1	159	0.65
2	1002.25	1.4E-6	1.5E-2	3.5E-3	6.4E-2	1.2E-1	122	0.65
3	1066.29	5.0E-7	1.5E-2	3.6E-3	3.7E-2	1.2E-1	107	0.69
4	1086.70	7.3E-7	1.4E-2	3.5E-3	3.8E-2	1.2E-1	105	0.71
5	1102.13	8.5E-7	1.4E-2	3.5E-3	3.8E-2	1.2E-1	104	0.73
6	1201.95	4.4E-7	1.4E-2	3.6E-3	4.2E-2	1.2E-1	103	0.83
7	1301.92	5.0E-7	1.4E-2	3.7E-3	4.5E-2	1.2E-1	107	0.96
8	1402.18	4.1E-7	1.4E-2	4.0E-3	4.9E-2	1.2E-1	114	1.10
9	1502.36	5.6E-7	1.4E-2	4.3E-3	5.2E-2	1.2E-1	125	1.26
10	1602.48	5.9E-7	1.5E-2	4.6E-3	5.6E-2	1.2E-1	138	1.44
11	1702.83	3.6E-7	1.5E-2	4.9E-3	5.9E-2	1.2E-1	152	1.64

B.3 MIKES uncertainty determination:

The following uncertainty determination by MIKES is taken from their report submitted to VSL.

3. Uncertainty calculations

$T_{\mathrm{rad}} + \delta T_{\mathrm{rad}} = T_{\mathrm{pyro}} + \delta T_{\mathrm{Ag}} + \delta T_{\mathrm{resol}} + \delta T_{\mathrm{lin}} + \delta T_{\mathrm{filter}} + \delta T_{\mathrm{SSE}} + \delta T_{\mathrm{align}} + \delta T_{\mathrm{absorp}} + \delta T_{\mathrm{filterstab}} + \delta T_{\mathrm{base}} + \delta T_{\lambda}$

$\delta T_{\mathrm{rad}} = \partial T_{\mathrm{rad}}/\partial I \times \delta I = \partial T_{\mathrm{rad}}/\partial U \times \delta U + T_{\mathrm{rad}}/\partial R_{\mathrm{t}} \times \delta R_{\mathrm{t}} + \partial T_{\mathrm{rad}}/\partial \mathrm{R_o} \times \delta R_0 + \partial T_{\mathrm{rad}}/\partial \alpha \times \delta\alpha$

Here $R_{\mathrm{t}} = R_0 \times (1 + \alpha t)$ and $I = U/R_{\mathrm{t}}$, where t is the temperature of the reference resistor, measured with a thermocouple and an infrared thermometer.

δT_{Ag} is calculated by derivating the formula which calculates the pyrometers temperature reading from the value of the photo-current.

$\delta T_{\mathrm{resol}}$ is 0.02 °C.

δT_{lin} is the linearity correction for the pyrometer.

$\delta T_{\mathrm{filter}}$ is calculated using the calibration certificate for the filter.

δT_{SSE} is the SSE-correction (the SSE values were measured at different temperatures).

$\delta T_{\mathrm{align}}$ is the alignment correction (spatial and horizontal).

$\delta T_{\mathrm{absorp}}$ is the correction due to the absorption of the front window of the lamp. The cleanliness of the window was checked with a laser beam.

$\delta T_{\mathrm{filterstab}}$ is the short-term stability calculated from the two runs.

δT_{base} is the base temperature correction due to the departure from 20 °C.

δT_{λ} is the correction due to the dependence of the spectral radiance temperature on wavelength.

δT_{rad} is a correction due to the measurement of the voltage of the calibration lamp, the conversion of the voltage to a current, and calculating the temperature dependence on the current.

Uncertainty budget lamp 1 run 1 962 °C

quantity	estimate	standard uncertainty	probability distribution	sensitivity coefficient	uncertainty component
T_{rad}	963.69 °C	0.006992 °C	normal	1	0.006992 °C
δT_{Ag}	0	0.014848 °C	normal	1	0.014848 °C
$\delta T_{\mathrm{resol}}$	0	0.011547 °C	rectangular	1	0.011547 °C
δT_{lin}	0	1×10^{-4}	normal	1.8 °C	0.000180 °C
$\delta T_{\mathrm{filter}}$	0	0.000126 °C	normal	1	0.000126 °C
δT_{SSE}	0	0.030348 °C	normal	1	0.030348 °C
$\delta T_{\mathrm{align}}$	0	0.304686 °C	normal	1	0.304686 °C
$\delta T_{\mathrm{absorp}}$	0	0.5 %	normal	69.41 °C	0.347048 °C
$\delta T_{\mathrm{filterstab}}$	0	8E-06 A	normal	148.75 °C/A	0.001190 °C
δT_{base}	0	0.000227 °C	normal	1	0.000227 °C
δT_{λ}	0	0.205647 nm	normal	0.111 °C/nm	0.022827 °C
δT_{rad}	0	0.002496 °C	normal	1	0.002496 °C
	963.69 °C				0.46 °C

In this table T_{rad} is the final temperature including all corrections.

The uncertainty of lamp 1 run1 is thus:

T_{final}	uncertainty (k = 1)
963.69 °C	0.46 °C
1001.42 °C	0.49 °C
1065.90 °C	0.53 °C
1086.28 °C	0.54 °C
1101.70 °C	0.55 °C
1201.36 °C	0.63 °C
1301.51 °C	0.70 °C
1401.75 °C	0.78 °C
1501.94 °C	0.86 °C
1602.09 °C	0.95 °C
1702.45 °C	1.04 °C

The uncertainty of lamp 1 run 2

T_{final}	uncertainty (k = 1)
963.55 °C	0.46 °C
1001.57 °C	0.49 °C
1065.75 °C	0.53 °C
1086.18 °C	0.54 °C
1101.60 °C	0.55 °C
1201.34 °C	0.63 °C
1301.76 °C	0.70 °C
1401.60 °C	0.78 °C
1501.78 °C	0.86 °C
1601.88 °C	0.95 °C
1701.24 °C	1.04 °C

Uncertainty budget lamp 2 run 1 962 °C

quantity	estimate	standard uncertainty	probability distribution	sensitivity coefficient	uncertainty component
T_{rad}	963.12 °C	0.006992 °C	normal	1	0.006992 °C
δT_{Ag}	0	0.014848 °C	normal	1	0.014848 °C
$\delta T_{\mathrm{resol}}$	0	0.011547 °C	rectangular	1	0.011547 °C
δT_{lin}	0	1×10^{-4}	normal	1.8 °C	0.000180 °C
$\delta T_{\mathrm{filter}}$	0	0.000126 °C	normal	1	0.000126 °C
δT_{SSE}	0	0.030348 °C	normal	1	0.030348 °C
$\delta T_{\mathrm{align}}$	0	0.165328 °C	normal	1	0.165328 °C
$\delta T_{\mathrm{absorp}}$	0	0.5 %	normal	69.41 °C	0.346722 °C
$\delta T_{\mathrm{filterstab}}$	0	5.48E-05 A	normal	115.71 °C/A	0.006341 °C
δT_{base}	0	0.022827 °C	normal	1	0.022827 °C
δT_{λ}	0	0.205647 nm	normal	0.111 °C/nm	0.022827 °C
δT_{rad}	0	0.001818 °C	normal	1	0.001818 °C
	963.12 °C				0.39 °C

In this table T_{rad} is the final temperature including all corrections.

The uncertainty of lamp 2run 1

T_{final}	uncertainty (k = 1)
963.12°C	0.39 °C
1001.36 °C	0.40 °C
1065.76 °C	0.45 °C
1086.16 °C	0.46 °C
1101.54 °C	0.48 °C
1201.55 °C	0.54 °C
1301.83 °C	0.63 °C
1402.06 °C	0.68 °C
1502.16 °C	0.77 °C
1601.94° C	0.95 °C
1701.67 °C	1.04 °C

The uncertainty of lamp 2run 2

T_{final}	uncertainty (k = 1)
962.89 °C	0.39 °C
1001.14 °C	0.41 °C
1065.55 °C	0.45 °C
1085.92 °C	0.46 °C
1101.27 °C	0.48 °C
1200.99 °C	0.54 °C
1301.18 °C	0.61 °C
1401.32 °C	0.68 °C
1501.35 °C	0.77 °C
1601.05°C	0.95 °C
1700.70°C	0.97 °C

B.4 MKEH uncertainty determination:

The following uncertainty determination by MKEH is taken from their submitted report.

C564: 962

	Components	A	B	Unit	A	B	Unit
I	Impurity					0.01	K
	Emissivity		0.02	%		0.01	K
	BB ΔT					0.05	K
II/1	Photocurrent$_{Au}$	0.732		%	0.50		K
	Photocurrent res.$_{Au}$		0.006	%		0.00	K
	Photocurrent$_{T\lambda}$	2.16		%	1.48		K
	Photocurrent res.$_{T\lambda}$		0.0228	%		0.02	K
	Linearity		0.2	%		0.14	K
II/2	SSE		0.06	%		0.04	K
II/3	Blocking		0.01	%		0.01	K
	Thermometer stability		0.1	%		0.07	K
	$\Delta\lambda_e$		0.3	nm		0.04	K
III/1	Lamp current measurement		0.014	%		0.10	K
III/2	Lamp current stability	0.059		%	0.43		K
	Base temperature		0.5	K		0.02	K
	Alignment - Position		0.5	mm		0.04	K
	Alignment - Angular		1	°		0.06	K
	Targetfield		20	%		0.09	K
	Cleaning of the window		0.1	%		0.07	K
	Root sum of squares				1.62	0.24	K
	Measurement uncertainty:				**1.64**		**K**

C564: 1000

	Components	A	B	Unit	A	B	Unit
I	Impurity					0.01	K
	Emissivity		0.02	%		0.01	K
	BB ΔT					0.05	K
II/1	Photocurrent$_{Au}$	0.732		%	0.53		K
	Photocurrent res.$_{Au}$		0.006	%		0.00	K
	Photocurrent$_{T\lambda}$	1.4		%	1.02		K
	Photocurrent res.$_{T\lambda}$		0.0133	%		0.01	K

	Linearity		0.15	%		0.11	K
II/2	SSE		0.06	%		0.04	K
II/3	Blocking		0.01	%		0.01	K
	Thermometer stability		0.1	%		0.07	K
	$\Delta\lambda_e$		0.3	nm		0.04	K
III/1	Lamp current measurement		0.013	%		0.09	K
III/2	Lamp current stability	0.055		%	0.39		K
	Base temperature		0.5	K		0.01	K
	Alignment - Position		0.5	mm		0.05	K
	Alignment - Angular		1	°		0.07	K
	Targetfield		20	%		0.09	K
	Cleaning of the window		0.1	%		0.07	K
	Root sum of squares				1.22	0.23	K
	Measurement uncertainty:				**1.24**		**K**

C564, t=1064 C

	Components	A	B	Unit	A	B	Unit
I	Impurity					0.01	K
	Emissivity		0.02	%		0.016	K
	BB ΔT					0.05	K
II/1	Photocurrent$_{Au}$	0.732		%	0.59		K
	Photocurrent res.$_{Au}$		0.006	%		0.005	K
	Photocurrent$_{T\lambda}$	0.547		%	0.44		K
	Photocurrent res.$_{T\lambda}$		0.006	%		0.005	K
	Linearity		0	%		0.00	K
II/2	SSE		0.06	%		0.05	K
II/3	Blocking		0.01	%		0.01	K
	Thermometer stability		0.1	%		0.08	K
	$\Delta\lambda_e$		0.3	nm		0.04	K
III/1	Lamp current measurement		0.012	%		0.08	K
III/2	Lamp current stability	0.059		%	0.41		K
	Base temperature		0.5	K		0.01	K
	Alignment - Position		0.5	mm		0.05	K
	Alignment - Angular		1	°		0.07	K
	Targetfield		20	%		0.09	K
	Cleaning of the window		0.1	%		0.08	K
	Root sum of squares				0.84	0.21	K
	Measurement uncertainty:				**0.87**		**K**

C564, t=1085 C

	Components	A	B	Unit	A	B	Unit
I	Impurity					0.01	K
	Emissivity		0.02	%		0.02	K
	BB ΔT					0.05	K
II/1	Photocurrent$_{Au}$	0.732		%	0.61		K
	Photocurrent res.$_{Au}$		0.006	%		0.00	K
	Photocurrent$_{T\lambda}$	0.45		%	0.37		K
	Photocurrent res.$_{T\lambda}$		0.0045	%		0.00	K
	Linearity		0.03	%		0.02	K
II/2	SSE		0.06	%		0.05	K
II/3	Blocking		0.01	%		0.01	K
	Thermometer stability		0.1	%		0.08	K
	$\Delta\lambda_e$		0.3	nm		0.04	K
III/1	Lamp current measurement		0.012	%		0.08	K
III/2	Lamp current stability	0.063		%	0.44		K
	Base temperature		0.5	K		0.01	K
	Alignment - Position		0.5	mm		0.05	K
	Alignment - Angular		1	°		0.08	K
	Targetfield		20	%		0.09	K
	Cleaning of the window		0.1	%		0.08	K
	Root sum of squares				0.84	0.21	K
	Measurement uncertainty:				**0.86**		**K**

C564, t=1100 C

	Components	A	B	Unit	A	B	Unit
I	Impurity					0.01	K
	Emissivity		0.02	%		0.02	K
	BB ΔT					0.05	K
II/1	Photocurrent$_{Au}$	0.732		%	0.62		K
	Photocurrent res.$_{Au}$		0.006	%		0.01	K
	Photocurrent$_{T\lambda}$	0.4		%	0.34		K
	Photocurrent res.$_{T\lambda}$		0.0037	%		0.00	K
	Linearity		0.05	%		0.04	K
II/2	SSE		0.06	%		0.05	K
II/3	Blocking		0.01	%		0.01	K
	Thermometer stability		0.1	%		0.08	K
	$\Delta\lambda_e$		0.3	nm		0.04	K
III/1	Lamp current measurement		0.011	%		0.08	K
III/2	Lamp current stability	0.068		%	0.47		K
	Base temperature		0.5	K		0.01	K

	Alignment - Position		0.5	mm		0.05	K
	Alignment - Angular		1	°		0.08	K
	Targetfield		20	%		0.09	K
	Cleaning of the window		0.1	%		0.08	K
	Root sum of squares				0.85	0.22	K
	Measurement uncertainty:				**0.88**		**K**

C564, t=1200 C

	Components	A	B	Unit	A	B	Unit
I	Impurity					0.01	K
	Emissivity		0.02	%		0.02	K
	BB ΔT					0.05	K
II/1	Photocurrent$_{Au}$	0.732		%	0.71		K
	Photocurrent res.$_{Au}$		0.006	%		0.01	K
	Photocurrent$_{T\lambda}$	0.28		%	0.27		K
	Photocurrent res.$_{T\lambda}$		0.0012	%		0.00	K
	Linearity		0.08	%		0.08	K
II/2	SSE		0.06	%		0.06	K
II/3	Blocking		0.01	%		0.01	K
	Thermometer stability		0.1	%		0.10	K
	$\Delta\lambda_e$		0.3	nm		0.04	K
III/1	Lamp current measurement		0.010	%		0.07	K
III/2	Lamp current stability	0.054		%	0.38		K
	Base temperature		0.5	K		0.01	K
	Alignment - Position		0.5	mm		0.06	K
	Alignment - Angular		1	°		0.09	K
	Targetfield		20	%		0.09	K
	Cleaning of the window		0.1	%		0.10	K
	Root sum of squares				0.86	0.24	K
	Measurement uncertainty:				**0.89**		**K**

C564, t=1300 C

	Components	A	B	Unit	A	B	Unit
I	Impurity					0.01	K
	Emissivity		0.02	%		0.02	K
	BB ΔT					0.05	K
II/1	Photocurrent$_{Au}$	0.732		%	0.81		K
	Photocurrent res.$_{Au}$		0.006	%		0.01	K
	Photocurrent$_{T\lambda}$	0.16		%	0.18		K
	Photocurrent res.$_{T\lambda}$		0.0005	%		0.00	K
	Linearity		0.12	%		0.13	K
II/2	SSE		0.06	%		0.07	K
II/3	Blocking		0.01	%		0.01	K
	Thermometer stability		0.1	%		0.11	K
	$\Delta\lambda_e$		0.3	nm		0.04	K
III/1	Lamp current measurement		0.009	%		0.06	K
III/2	Lamp current stability	0.057		%	0.43		K
	Base temperature		0.5	K		0.00	K
	Alignment - Position		0.5	mm		0.07	K
	Alignment - Angular		1	°		0.10	K
	Targetfield		20	%		0.09	K
	Cleaning of the window		0.1	%		0.11	K
	Root sum of squares				0.94	0.28	K
	Measurement uncertainty:				**0.98**		**K**

C564, t=1400 C

	Components	A	B	Unit	A	B	Unit
I	Impurity					0.01	K
	Emissivity		0.02	%		0.03	K
	BB ΔT					0.05	K
II/1	Photocurrent$_{Au}$	0.732		%	0.92		K
	Photocurrent res.$_{Au}$		0.006	%		0.01	K
	Photocurrent$_{T\lambda}$	0.1		%	0.13		K
	Photocurrent res.$_{T\lambda}$		0.0002	%		0.00	K
	Linearity		0.12	%		0.15	K
II/2	SSE		0.06	%		0.08	K
II/3	Blocking		0.01	%		0.01	K
	Thermometer stability		0.1	%		0.13	K
	$\Delta\lambda_e$		0.3	nm		0.04	K
III/1	Lamp current measurement		0.008	%		0.06	K
III/2	Lamp current stability	0.052		%	0.41		K
	Base temperature		0.5	K		0.00	K

	Alignment - Position		0.5	mm		0.08	K
	Alignment - Angular		1	°		0.12	K
	Targetfield		20	%		0.09	K
	Cleaning of the window		0.1	%		0.13	K
	Root sum of squares				1.02	0.31	K
	Measurement uncertainty:				**1.06**		**K**

C564, t=1500 C

	Components	A	B	Unit	A	B	Unit
I	Impurity					0.01	K
	Emissivity		0.02	%		0.03	K
	BB ΔT					0.05	K
II/1	Photocurrent$_{Au}$	0.732		%	1.03		K
	Photocurrent res.$_{Au}$		0.006	%		0.01	K
	Photocurrent$_{T\lambda}$	0.011		%	0.02		K
	Photocurrent res.$_{T\lambda}$		1.E-04	%		0.00	K
	Linearity		0.12	%		0.17	K
II/2	SSE		0.06	%		0.08	K
II/3	Blocking		0.01	%		0.01	K
	Thermometer stability		0.1	%		0.14	K
	$\Delta\lambda_e$		0.3	nm		0.04	K
III/1	Lamp current measurement		0.007	%		0.06	K
III/2	Lamp current stability	0.056		%	0.48		K
	Base temperature		0.5	K		0.00	K
	Alignment - Position		0.5	mm		0.09	K
	Alignment - Angular		1	°		0.13	K
	Targetfield		20	%		0.09	K
	Cleaning of the window		0.1	%		0.14	K
	Root sum of squares				1.14	0.34	K
	Measurement uncertainty:				**1.19**		**K**

C564, t=1600 C

	Components	A	B	Unit	A	B	Unit
I	Impurity					0.01	K
	Emissivity		0.02	%		0.03	K
	BB ΔT					0.05	K

II/1	Photocurrent$_{Au}$	0.732		%	1.15		K
	Photocurrent res.$_{Au}$		0.006	%		0.01	K
	Photocurrent$_{T\lambda}$	0.08		%	0.13		K
	Photocurrent res.$_{T\lambda}$		5.E-05	%		0.00	K
	Linearity		0.2	%		0.32	K
II/2	SSE		0.06	%		0.09	K
II/3	Blocking		0.01	%		0.02	K
	Thermometer stability		0.1	%		0.16	K
	$\Delta\lambda_e$		0.3	nm		0.04	K
III/1	Lamp current measurement		0.006	%		0.06	K
III/2	Lamp current stability	0.057		%	0.52		K
	Base temperature		0.5	K		0.00	K
	Alignment - Position		0.5	mm		0.10	K
	Alignment - Angular		1	°		0.15	K
	Targetfield		20	%		0.09	K
	Cleaning of the window		0.1	%		0.16	K
	Root sum of squares				1.27	0.45	K
	Measurement uncertainty:				**1.35**		**K**

C564, t=1700 C

	Components	A	B	Unit	A	B	Unit
I	Impurity					0.01	K
	Emissivity		0.02	%		0.04	K
	BB ΔT					0.05	K
II/1	Photocurrent$_{Au}$	0.732		%	1.28		K
	Photocurrent res.$_{Au}$		0.006	%		0.01	K
	Photocurrent$_{T\lambda}$	0.09		%	0.16		K
	Photocurrent res.$_{T\lambda}$		3.E-05	%		0.00	K
	Linearity		0.2	%		0.35	K
II/2	SSE		0.06	%		0.11	K
II/3	Blocking		0.01	%		0.02	K
	Thermometer stability		0.1	%		0.18	K
	$\Delta\lambda_e$		0.3	nm		0.04	K
III/1	Lamp current measurement		0.005	%		0.05	K
III/2	Lamp current stability	0.053		%	0.50		K
	Base temperature		0.5	K		0.00	K
	Alignment - Position		0.5	mm		0.11	K
	Alignment - Angular		1	°		0.16	K
	Targetfield		20	%		0.09	K

	Cleaning of the window		0.1	%		0.18	K
	Root sum of squares				1.38	0.50	K
	Measurement uncertainty:				**1.47**		**K**

C681, t=962 C

	Components	A	B	Unit	A	B	Unit
I	Impurity					0.01	K
	Emissivity		0.02	%		0.01	K
	BB ΔT					0.05	K
II/1	Photocurrent$_{Au}$	0.732		%	0.50		K
	Photocurrent res.$_{Au}$		0.006	%		0.00	K
	Photocurrent$_{T\lambda}$	2.241		%	1.54		K
	Photocurrent res.$_{T\lambda}$		0.013	%		0.01	K
	Linearity		0.2	%		0.14	K
II/2	SSE		0.06	%		0.04	K
II/3	Blocking		0.01	%		0.01	K
	Thermometer stability		0.1	%		0.07	K
	$\Delta\lambda_e$		0.3	nm		0.04	K
III/1	Lamp current measurement		0.014	%		0.10	K
III/2	Lamp current stability	0.057		%	0.39		K
	Base temperature		0.5	K		0.01	K
	Alignment - Position		0.5	mm		0.28	K
	Alignment - Angular		1	°		0.07	K
	Targetfield		20	%		0.09	K
	Cleaning of the window		0.1	%		0.07	K
	Root sum of squares				1.66	0.37	K
	Measurement uncertainty:				**1.70**		**K**

C681, t=1000 C

	Components	A	B	Unit	A	B	Unit
I	Impurity					0.01	K
	Emissivity		0.02	%		0.01	K
	BB ΔT					0.05	K

II/1	Photocurrent$_{\mathrm{Au}}$	0.732		%	0.53		K
	Photocurrent res.$_{\mathrm{Au}}$		0.006	%		0.00	K
	Photocurrent$_{T\lambda}$	1.32		%	0.96		K
	Photocurrent res.$_{T\lambda}$		0.0133	%		0.01	K
	Linearity		0.15	%		0.11	K
II/2	SSE		0.06	%		0.04	K
II/3	Blocking		0.01	%		0.01	K
	Thermometer stability		0.1	%		0.07	K
	$\Delta\lambda_e$		0.3	nm		0.04	K
III/1	Lamp current measurement		0.013	%		0.09	K
III/2	Lamp current stability	0.061		%	0.42		K
	Base temperature		0.5	K		0.01	K
	Alignment - Position		0.5	mm		0.30	K
	Alignment - Angular		1	°		0.08	K
	Targetfield		20	%		0.09	K
	Cleaning of the window		0.1	%		0.07	K
	Root sum of squares				1.18	0.38	K
	Measurement uncertainty:				**1.24**		**K**

C681, t=1064 C

	Components	A	B	Unit	A	B	Unit
I	Impurity					0.01	K
	Emissivity		0.02	%		0.02	K
	BB ΔT					0.05	K
II/1	Photocurrent$_{\mathrm{Au}}$	0.732		%	0.59		K
	Photocurrent res.$_{\mathrm{Au}}$		0.006	%		0.00	K
	Photocurrent$_{T\lambda}$	0.552		%	0.44		K
	Photocurrent res.$_{T\lambda}$		0.023	%		0.02	K
	Linearity		0	%		0.00	K
II/2	SSE		0.06	%		0.05	K
II/3	Blocking		0.01	%		0.01	K
	Thermometer stability		0.1	%		0.08	K
	$\Delta\lambda_e$		0.3	nm		0.04	K
III/1	Lamp current measurement		0.012	%		0.08	K
III/2	Lamp current stability	0.064		%	0.43		K
	Base temperature		0.5	K		0.01	K
	Alignment - Position		0.5	mm		0.33	K
	Alignment - Angular		1	°		0.08	K
	Targetfield		20	%		0.09	K
	Cleaning of the window		0.1	%		0.08	K

	Root sum of squares				0.85	0.39	K
	Measurement uncertainty:				**0.94**		**K**

C681, t=1085 C

	Components	A	B	Unit	A	B	Unit
I	Impurity					0.01	K
	Emissivity		0.02	%		0.02	K
	BB ΔT					0.05	K
II/1	Photocurrent$_{Au}$	0.732		%	0.61		K
	Photocurrent res.$_{Au}$		0.006	%		0.00	K
	Photocurrent$_{T\lambda}$	0.437		%	0.36		K
	Photocurrent res.$_{T\lambda}$		0.0045	%		0.00	K
	Linearity		0.03	%		0.02	K
II/2	SSE		0.06	%		0.05	K
II/3	Blocking		0.01	%		0.01	K
	Thermometer stability		0.1	%		0.08	K
	$\Delta\lambda_e$		0.3	nm		0.04	K
III/1	Lamp current measurement		0.011	%		0.07	K
III/2	Lamp current stability	0.060		%	0.41		K
	Base temperature		0.5	K		0.01	K
	Alignment - Position		0.5	mm		0.34	K
	Alignment - Angular		1	°		0.09	K
	Targetfield		20	%		0.09	K
	Cleaning of the window		0.1	%		0.08	K
	Root sum of squares				0.81	0.40	K
	Measurement uncertainty:				**0.91**		**K**

C681, t=1100 C

	Components	A	B	Unit	A	B	Unit
I	Impurity					0.01	K
	Emissivity		0.02	%		0.02	K
	BB ΔT					0.05	K

II/1	Photocurrent$_{Au}$	0.732		%	0.62		K
	Photocurrent res.$_{Au}$		0.006	%		0.01	K
	Photocurrent$_{T\lambda}$	0.362		%	0.31		K
	Photocurrent res.$_{T\lambda}$		0.0037	%		0.00	K
	Linearity		0.05	%		0.04	K
II/2	SSE		0.06	%		0.05	K
II/3	Blocking		0.01	%		0.01	K
	Thermometer stability		0.1	%		0.08	K
	$\Delta\lambda_e$		0.3	nm		0.04	K
III/1	Lamp current measurement		0.011	%		0.07	K
III/2	Lamp current stability	0.063		%	0.43		K
	Base temperature		0.5	K		0.00	K
	Alignment - Position		0.5	mm		0.35	K
	Alignment - Angular		1	°		0.09	K
	Targetfield		20	%		0.09	K
	Cleaning of the window		0.1	%		0.08	K
	Root sum of squares				0.81	0.41	K
	Measurement uncertainty:				**0.91**		**K**

C681, t=1200 C

	Components	A	B	Unit	A	B	Unit
I	Impurity					0.01	K
	Emissivity		0.02	%		0.02	K
	BB ΔT					0.05	K
II/1	Photocurrent$_{Au}$	0.732		%	0.71		K
	Photocurrent res.$_{Au}$		0.006	%		0.01	K
	Photocurrent$_{T\lambda}$	0.29		%	0.28		K
	Photocurrent res.$_{T\lambda}$		0.001	%		0.00	K
	Linearity		0.08	%		0.08	K
II/2	SSE		0.06	%		0.06	K
II/3	Blocking		0.01	%		0.01	K
	Thermometer stability		0.1	%		0.10	K
	$\Delta\lambda_e$		0.3	nm		0.04	K
III/1	Lamp current measurement		0.010	%		0.07	K
III/2	Lamp current stability	0.051		%	0.36		K
	Base temperature		0.5	K		0.00	K
	Alignment - Position		0.5	mm		0.40	K
	Alignment - Angular		1	°		0.10	K
	Targetfield		20	%		0.09	K
	Cleaning of the window		0.1	%		0.10	K

	Root sum of squares				0.85	0.46	K
	Measurement uncertainty:				**0.97**		**K**

C681, t=1300 C

	Components	A	B	Unit	A	B	Unit
I	Impurity					0.01	K
	Emissivity		0.02	%		0.02	K
	BB ΔT					0.05	K
II/1	Photocurrent$_{Au}$	0.732		%	0.81		K
	Photocurrent res.$_{Au}$		0.006	%		0.01	K
	Photocurrent$_{T\lambda}$	0.17		%	0.19		K
	Photocurrent res.$_{T\lambda}$		5E-04	%		0.00	K
	Linearity		0.12	%		0.13	K
II/2	SSE		0.06	%		0.07	K
II/3	Blocking		0.01	%		0.01	K
	Thermometer stability		0.1	%		0.11	K
	$\Delta\lambda_e$		0.3	nm		0.04	K
III/1	Lamp current measurement		0.009	%		0.06	K
III/2	Lamp current stability	0.055		%	0.41		K
	Base temperature		0.5	K		0.00	K
	Alignment - Position		0.5	mm		0.46	K
	Alignment - Angular		1	°		0.11	K
	Targetfield		20	%		0.09	K
	Cleaning of the window		0.1	%		0.11	K
	Root sum of squares				0.93	0.54	K
	Measurement uncertainty:				**1.08**		**K**

C681, t=1400 C

	Components	A	B	Unit	A	B	Unit
I	Impurity					0.01	K
	Emissivity		0.02	%		0.03	K
	BB ΔT					0.05	K
II/1	Photocurrent$_{Au}$	0.732		%	0.92		K
	Photocurrent res.$_{Au}$		0.006	%		0.01	K

	Photocurrent$_{T\lambda}$	0.121		%	0.15		K
	Photocurrent res.$_{T\lambda}$		2.E-04	%		0.00	K
	Linearity		0.12	%		0.15	K
II/2	SSE		0.06	%		0.08	K
II/3	Blocking		0.01	%		0.01	K
	Thermometer stability		0.1	%		0.13	K
	$\Delta\lambda_e$		0.3	nm		0.04	K
III/1	Lamp current measurement		0.008	%		0.06	K
III/2	Lamp current stability	0.055		%	0.44		K
	Base temperature		0.5	K		0.00	K
	Alignment - Position		0.5	mm		0.52	K
	Alignment - Angular		1	°		0.13	K
	Targetfield		20	%		0.09	K
	Cleaning of the window		0.1	%		0.13	K
	Root sum of squares				1.03	0.60	K
	Measurement uncertainty:				**1.20**		**K**

C681, t=1500 C

	Components	A	B	Unit	A	B	Unit
I	Impurity					0.01	K
	Emissivity		0.02	%		0.03	K
	BB ΔT					0.05	K
II/1	Photocurrent$_{Au}$	0.732		%	1.03		K
	Photocurrent res.$_{Au}$		0.006	%		0.01	K
	Photocurrent$_{T\lambda}$	0.1		%	0.14		K
	Photocurrent res.$_{T\lambda}$		1E-04	%		0.00	K
	Linearity		0.12	%		0.17	K
II/2	SSE		0.06	%		0.08	K
II/3	Blocking		0.01	%		0.01	K
	Thermometer stability		0.1	%		0.14	K
	$\Delta\lambda_e$		0.3	nm		0.04	K
III/1	Lamp current measurement		0.007	%		0.06	K
III/2	Lamp current stability	0.059		%	0.51		K
	Base temperature		0.5	K		0.00	K
	Alignment - Position		0.5	mm		0.58	K
	Alignment - Angular		1	°		0.15	K
	Targetfield		20	%		0.09	K
	Cleaning of the window		0.1	%		0.14	K
	Root sum of squares				1.16	0.67	K

	Measurement uncertainty:				**1.34**		**K**

C681, t=1600 C

	Components	A	B	Unit	A	B	Unit
I	Impurity					0.01	K
	Emissivity		0.02	%		0.03	K
	BB ΔT					0.05	K
II/1	Photocurrent$_{Au}$	0.732		%	1.15		K
	Photocurrent res.$_{Au}$		0.006	%		0.01	K
	Photocurrent$_{T\lambda}$	0.11		%	0.17		K
	Photocurrent res.$_{T\lambda}$		5E-05	%		0.00	K
	Linearity		0.2	%		0.32	K
II/2	SSE		0.06	%		0.09	K
II/3	Blocking		0.01	%		0.02	K
	Thermometer stability		0.1	%		0.16	K
	$\Delta\lambda_e$		0.3	nm		0.04	K
III/1	Lamp current measurement		0.006	%		0.05	K
III/2	Lamp current stability	0.063		%	0.58		K
	Base temperature		0.5	K		0.00	K
	Alignment - Position		0.5	mm		0.65	K
	Alignment - Angular		1	°		0.16	K
	Targetfield		20	%		0.09	K
	Cleaning of the window		0.1	%		0.16	K
	Root sum of squares				1.30	0.79	K
	Measurement uncertainty:				**1.52**		**K**

C681, t=1700 C

	Components	A	B	Unit	A	B	Unit
I	Impurity					0.01	K
	Emissivity		0.02	%		0.04	K
	BB ΔT					0.05	K
II/1	Photocurrent$_{Au}$	0.732		%	1.28		K
	Photocurrent res.$_{Au}$		0.006	%		0.01	K
	Photocurrent$_{T\lambda}$	0.08		%	0.14		K

	Photocurrent res.$_{T\lambda}$		3E-05	%		0.00	K
	Linearity		0.2	%		0.35	K
II/2	SSE		0.06	%		0.11	K
II/3	Blocking		0.01	%		0.02	K
	Thermometer stability		0.1	%		0.18	K
	$\Delta\lambda_e$		0.3	nm		0.04	K
III/1	Lamp current measurement		0.005	%		0.05	K
III/2	Lamp current stability	0.057		%	0.56		K
	Base temperature		0.5	K		0.00	K
	Alignment - Position		0.5	mm		0.72	K
	Alignment - Angular		1	°		0.18	K
	Targetfield		20	%		0.09	K
	Cleaning of the window		0.1	%		0.18	K
	Root sum of squares				1.41	0.87	K
	Measurement uncertainty:				**1.65**		**K**

B.5 SMU uncertainty determination:

The following uncertainty determination by SMU is taken from their report.

4.3.1. Identification of uncertainty components

I. Blackbody

Impurities (ppm): Ag 1; Mg 0,1; Cu 0,2; Si 0,2; B 0,2 . Correction for temperature of freezing ΔT_{Au}= -7 mK. Metal purity 0,99999

Emissivity: $0{,}999^{+0{,}0005}_{-0{,}0001}$

Freeze point plateau duration: 10 min. with the maximal temperature change 50 mK identified by photoelectric pyrometer.

Temperature difference across the bottom section of the cavity in view: not measured

II. Reference thermometer

II.1.Photocurrent is measured by Keithley electrometer model 6517 with the resolution higher than 0,01 %. Lower limit of measurement is a noise of photodiode type EG&G 444 BQ used in the pyrometer (about 5.10^{-14} A). Correction for nonlinearity of photodiode –electrometer are lower as 0,03 % over measurement range.

II.2. Size of source effect

Measured by means of integrating sphere. Correction coefficient for blackbody and lamp are 0.995654 and 0,99881 (d=1,5mm) 0,99894 (d=1,3mm) respectively. Uncertainty of the ratio these coefficient is 0,0005.

II.3. Spectral parameters

Spectral response function of the photoelectric pyrometer is to see on the Fig.1. Temperature change of response function was measured in account the temperature of the detectors part of the pyrometer in all and the changes of spectral response are corrected. Interference filter is combine with the filter BAG 19 (h=2mm).

Uncertainty budget

	Nominal value	Uncertainty u_A	Uncertainty u_B
Second radiation constant c_2 / µm.K	14387,69		0,12
Temperature / K	1337,32		0,005
Effective emittance	0,999		0,0003
Refractive index of air	1,00028		0,00001
Wavelength of maximal responzivity λ_{max} / µm	0,66216	0,00005	0,00010
Effective wavelength λ_{eAu} / µm for T_{90}(Au)	0,66436	0,00093	0,00005
Effective wavelength λ_e / µm for t=962 to 1700°C	0,66462 – 0,66348	0,0014 – 0,00017	0,00005
Linearity	1	0,0003	
Temperature coefficient of pyrometer	1	0,0005	0,0003
Size of source effect	0,99681	0,0005	
Signal of pyrometer for S_{Au} / pA	200,51	0,05	0,1
Signal of pyrometer for t=962 to 1700°C / pA	52 – 36 000	0,05 – 1,5	0,1
Bias current of lamps / A for t=962 to 1700°C /A	4,3 – 14,3	0,0002	0,001
Lamp orientation (reproducibility) / relative to signal	1		0,001

Lamp C654			Lamp C681		
I(j) / A	$T_\lambda(\lambda_e, I(j))$ / °C	u_C / °C	I(j) / A	$T_\lambda(\lambda_e, I(j))$ / °C	u_C / °C
4.48	963.22	0.28	5.508	963.11	0.27
4.721	1001.27	0.22	5.822	1001.30	0.22
5.169	1065.48	0.18	6.399	1065.67	0.18
5.441	1100.87	0.18	6.745	1100.97	0.18
6.272	1200.68	0.17	7.795	1200.98	0.17
7.194	1300.70	0.18	8.948	1301.29	0.18
8.189	1400.96	0.2	10.183	1401.57	0.21
9.242	1501.26	0.22	11.487	1501.84	0.24
10.347	1601.57	0.24	12.851	1601.90	0.25
11.502	1701.97	0.27	14.273	1701.80	0.29

B.6 SP uncertainty determination:

Uncertainties:

Uncertainty components are presented in Table D for the specified temperature levels together with the combined standard uncertainty and the expanded uncertainty with k=2. The corresponding currents are defined in Appendix D of the protocol for the different lamps.

Here we confine ourselves to explain relevant uncertainty components.

The reducing factor k, equal to the k factor when used in a calibration report is indicating the type of uncertainty distribution used in the calculations.

I. Reference blackbody radiator

Realization of the reference temperature at the gold freezing point 1337,33 K within 0,3 °C with k=2 (black body calibration). The error is propagating in the Wien approximation according to:

$$\Delta T = \Delta T_{Au} \left(\frac{T}{T_{Au}} \right)^2$$

II. Reference thermometer

II.1. Linearity

We are assuming a pyrometer linearity of 0,2 % of radiance ratio with an uncertainty following the relation

$\Delta T = \frac{\lambda T^2}{c_2} \cdot \frac{\Delta r}{r}$ where the second radiation constant c_2 =0,014388 m·K

II.2. Size of source effect (SSE) is estimated to 0,1 % and the uncertainty is following the same relation as the linearity.

II.3. The mean effective wavelength has an estimated uncertainty not exceeding 0,4 nm. The uncertainty ΔT generated by an uncertainty Δλ in the wavelength is given by

$$\Delta T = T\left(\frac{T}{T_{Au}} - 1\right) \cdot \frac{\Delta\lambda}{\lambda}$$

III. Transfer lamps

III.1. Lamp current

- Lamp currents are measured to within 0,1 °C at the gold point.

III.2. Radiance temperature

- Short-term stability is estimated to 0,01 °C.

- Drift coming from our calibrations at the gold point is less than 0,1 °C/year.

- Dependence on wavelength used in the evaluation of the radiance ratio using Planck's law is estimated to maximum 0,5 °C.

- Dependence on base temperature is estimated to maximum 0,02 °C.

III.3. Residual parameters like alignment, target field and cleaning of window give rise to an uncertainty estimation of maximum 0,1 °C.

IV. Lamp-thermometer composite parameters

Measurements were done close to reference condition with very small or no correction. Main uncertainty comes from conversion to reference wavelength estimated to 0,02 °C.

V. The standard deviation of 20 temperature readings is below 0,01 °C.

The uncertainty components III to V are taken as propagating as proportional to T^2 like the gold point uncertainty.

Table D: Uncertainty budget

			Number of lamp current														
			I(1)	I(2)	I(3)	I(4)	I(5)	I(6)	I(7)	I(8)	I(9)	I(10)	I(11)				
Component	Component uncertainty					Component uncertainty in °C for temperature (°C and K)											
			962	1000	1064	1085	1100	1200	1300	1400	1500	1600	1700				
	Estimate	Unit	k-factor		1235	1273	1337	1358	1373	1473	1573	1673	1773	1873	1973		
Reference black body																	
I. Reference temperature			0,3	°C	2	0,128	0,136	0,150	0,155	0,158	0,182	0,208	0,235	0,264	0,294	0,327	
Reference thermometer																	
II.1. Linearity [0,2 %]			0,002	-	1,73	0,138	0,146	0,162	0,167	0,170	0,196	0,224	0,253	0,284	0,317	0,352	
II.2. Size of source [0,1 %]			0,001	-	1,73	0,069	0,073	0,081	0,083	0,085	0,098	0,112	0,126	0,142	0,158	0,176	
II.3. Mean effective wave length				0,4	nm	1,73	0,034	0,022	0,000	0,008	0,013	0,053	0,099	0,150	0,206	0,267	0,334
Transfer lamps																	
III.1. Lamp current		0,1	°C	1,73	0,049	0,052	0,058	0,060	0,061	0,070	0,080	0,091	0,102	0,113	0,126		
Radiance temperature																	
III.2a. Short term stability			0,01	°C	1,73	0,005	0,005	0,006	0,006	0,006	0,007	0,008	0,009	0,010	0,011	0,013	
III.2b. Drift	0,1	°C	1,73	0,049	0,052	0,058	0,060	0,061	0,070	0,080	0,091	0,102	0,113	0,126			
III.2c. Dependence of wave length				0,5	°C	1,73	0,247	0,262	0,289	0,298	0,305	0,351	0,400	0,453	0,508	0,567	0,629
III.2d. Dependence of base temperature				0,02	°C	1,73	0,010	0,010	0,012	0,012	0,012	0,014	0,016	0,018	0,020	0,023	0,025
III.3. Residuals		0,1	°C	1,73	0,049	0,052	0,058	0,060	0,061	0,070	0,080	0,091	0,102	0,113	0,126		
Lamp-thermometer composite parameters																	
IV. Composite parameters			0,02	°C	1,73	0,010	0,010	0,012	0,012	0,012	0,014	0,016	0,018	0,020	0,023	0,025	
Type A																	
V. Standard deviation of 20 measurement				0,01	°C	1	0,009	0,009	0,010	0,010	0,011	0,012	0,014	0,016	0,018	0,020	0,022
Combined standard uncertainty				°C		0,331	0,351	0,386	0,398	0,407	0,472	0,543	0,623	0,709	0,803	0,905	
Expanded uncertainty with k=2				°C		0,662	0,701	0,772	0,797	0,815	0,943	1,087	1,246	1,419	1,607	1,809	

B.7 TUBITAK-UME uncertainty determination:

UNCERTAINTIES

The uncertainties considered are the uncertainties originated from the measurements for realizing the scale, lamp measurements, and the uncertainties due to corrections given in the protocol. These uncertainties are:

1. Uncertainty in the fixed point reference value, u1
    - Impurities [1]
    - Emissivity Aperture uniformity
    - Temperature drop across cavity bottom [3]
    - Standard deviation of the reference signal obtained from the radiation thermometer
    - Uncertainty in the spectral response of standard thermometer
    - Resolution of reference signal
    - Uncertainty due to dark signal
    - Standard deviation of reference signal for different realizations
2. Uncertainty in the measured signal, u2
    - Standard deviation of the radiation thermometer output
    - Deviation of two measurements from the average value
    - Uncertainty in converting from the 10^7 amplification to 10^8 amplification (only for 1600 °C and 1700°C)
3. Uncertainty in SSE, u3
4. Uncertainty in the effective wavelength determination, u4
5. Uncertainty in positioning, u5
6. Uncertainty in IR cut-off filter u6
7. Uncertainty in the wavelength correction, u7
8. Uncertainty in the base temperature correction, u8 (*negligible)*
9. Uncertainty in the current correction, u9

Table 9 LAMP 1 (C564) uncertainties

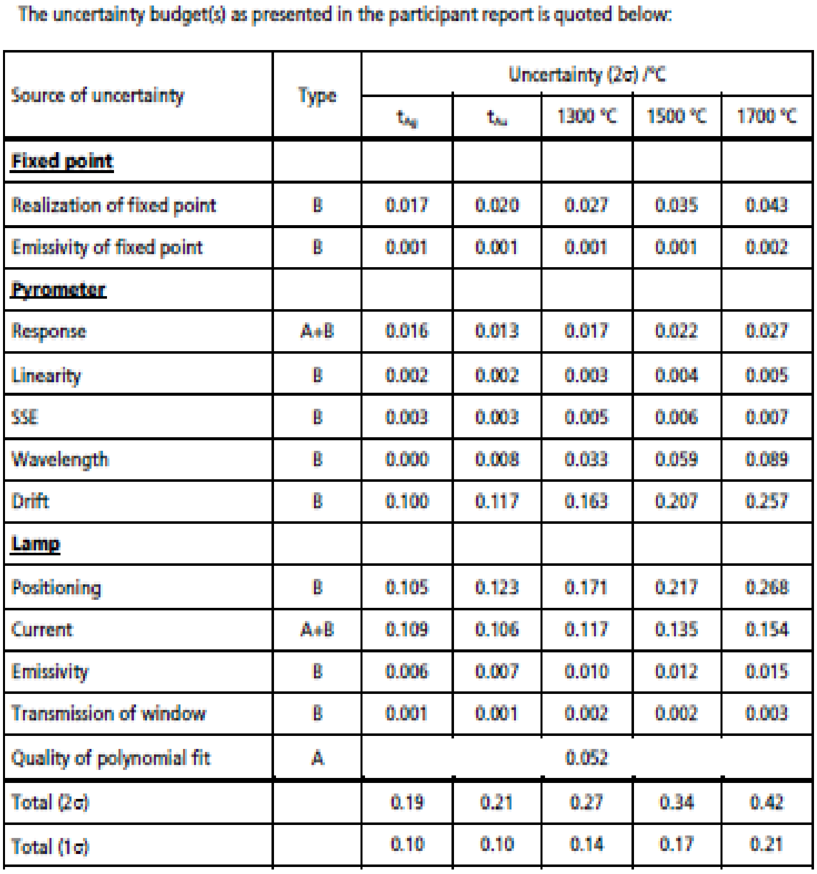
No	**T_λ** final (°C)	u1(T_{Ag}) (°C)	u2(i) (°C)	u3(SSE) (°C)	u4(λ_e) (°C)	u5(x,y,θ) (°C)	u6(filter) (°C)	u7[$T_\lambda(\lambda)$](°C)	u9[$T\lambda(I)$] (°C)	**u(total) (°C)**
I(1)	962,840	0,061	0,028	0,019	0,085	0,041	0,042	0,013	0,007	**0,125**
I(2)	1000,878	0,065	0,048	0,020	0,089	0,044	0,057	0,014	0,006	**0,142**
I(3)	1064,880	0,072	0,038	0,022	0,098	0,048	0,078	0,015	0,006	**0,159**
I(4)	1085,287	0,074	0,035	0,023	0,101	0,050	0,085	0,016	0,006	**0,165**
I(5)	1100,749	0,075	0,034	0,023	0,103	0,054	0,09	0,016	0,005	**0,171**
I(6)	1200,481	0,087	0,027	0,027	0,117	0,061	0,12	0,018	0,005	**0,203**
I(7)	1300,403	0,099	0,026	0,031	0,132	0,063	0,148	0,020	0,005	**0,235**
I(8)	1400,666	0,112	0,022	0,035	0,149	0,071	0,177	0,022	0,004	**0,271**
I(9)	1500,942	0,126	0,022	0,039	0,166	0,079	0,205	0,025	0,004	**0,307**
I(10)	1600,915	0,140	0,051	0,043	0,185	0,086	0,23	0,027	0,004	**0,346**
I(11)	1701,206	0,156	0,101	0,048	0,205	0,096	0,257	0,030	0,004	**0,394**

Table 10 LAMP 2 (C581), uncertainties

No	**T_λ** final (°C)	u1(T_{Ag}) (°C)	u2(i) (°C)	u3(SSE) (°C)	u4(λ_e) (°C)	u5(x:y,θ) (°C)	u6(filter) (°C)	u7[$T_\lambda(\lambda)$] (°C)	u9[$T\lambda(I)$] (°C)	**u(total) (°C)**
I(1)	962,204	0,061	0,054	0,018	0,085	0,032	0,042	0,013	0,005	**0,131**
I(2)	1000,376	0,065	0,011	0,019	0,089	0,046	0,057	0,014	0,005	**0,135**
I(3)	1064,561	0,072	0,056	0,021	0,098	0,051	0,078	0,015	0,005	**0,165**
I(4)	1084,945	0,074	0,111	0,022	0,101	0,053	0,085	0,016	0,004	**0,197**
I(5)	1100,397	0,075	0,056	0,022	0,103	0,057	0,09	0,016	0,004	**0,177**
I(6)	1200,375	0,087	0,058	0,026	0,117	0,065	0,12	0,018	0,004	**0,210**
I(7)	1300,594	0,099	0,066	0,029	0,132	0,068	0,148	0,020	0,004	**0,244**
I(8)	1400,828	0,112	0,037	0,033	0,149	0,077	0,177	0,022	0,004	**0,274**
I(9)	1501,107	0,126	0,042	0,037	0,166	0,086	0,205	0,025	0,004	**0,311**
I(10)	1600,777	0,140	0,076	0,041	0,185	0,094	0,23	0,027	0,004	**0,352**
I(11)	1700,541	0,156	0,179	0,046	0,205	0,105	0,257	0,030	0,004	**0,422**

B.8 VSL uncertainty:

The following table below is the uncertainty budget that was reported by VSL in CCT-K5 comparison report.



The uncertainty budget(s) as presented in the participant report is quoted below:

Source of uncertainty	Type	Uncertainty (2σ) /°C				
		t_{Ag}	t_{Au}	1300 °C	1500 °C	1700 °C
Fixed point						
Realization of fixed point	B	0.017	0.020	0.027	0.035	0.043
Emissivity of fixed point	B	0.001	0.001	0.001	0.001	0.002
Pyrometer						
Response	A+B	0.016	0.013	0.017	0.022	0.027
Linearity	B	0.002	0.002	0.003	0.004	0.005
SSE	B	0.003	0.003	0.005	0.006	0.007
Wavelength	B	0.000	0.008	0.033	0.059	0.089
Drift	B	0.100	0.117	0.163	0.207	0.257
Lamp						
Positioning	B	0.105	0.123	0.171	0.217	0.268
Current	A+B	0.109	0.106	0.117	0.135	0.154
Emissivity	B	0.006	0.007	0.010	0.012	0.015
Transmission of window	B	0.001	0.001	0.002	0.002	0.003
Quality of polynomial fit	A	0.052				
Total (2σ)		0.19	0.21	0.27	0.34	0.42
Total (1σ)		0.10	0.10	0.14	0.17	0.21