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Addendum to the final report of APMP-T-K5-1997

APMP Comparison of local realizations of the ITS-90 above the silver point using radiation thermometers as transfer standards

Linking the final results of APMP-T-K5-1997 to the KCRV of the CCT-K5

based on
- the draft B report APMP-T-K5-1997 of March 2003
- the draft B report CCT K5 of May 2005
- the addendum to draft B report K5 of April 2008
- the final report K5.1 of May 2008

Prepared by
Fumihiro Sakuma
National Metrology Institute of Japan

1. Introduction

In the CCT Key Comparison 5 (CCT KC5) standard lamps were transferred to check the agreement of radiation temperature scales between 962 °C and 1700 °C. On the other side in the APMP Temperature key Comparison 5 (APMP-T-K5-1997) radiation thermometers were transferred to check the agreement of radiation temperature scales between 962 °C and 2800 °C at the highest. Five institutes joined both comparisons. Among them four institutes (NMIJ, NIM, KRISS and CSIRO) were selected as the linking institutes between the two comparisons. In the APMP comparison, the scale difference from the NMIJ was measured. Here the differences of the seven APMP participating institutes from the Key Comparison Reference Value (KCRV) of the CCT comparison were calculated. In this calculation it is supposed that the average of the four institutes agree in the CCT and APMP comparisons.

Because the comparison and the report have taken a long time to complete, many institutes have changed their names. Therefore Table 1 shows the names of the participating institutes in 2009 and 1999.

2. Calculation method

2.1 Calculation of the difference

For each temperature T_j (j=1 to 11) between 962 °C and 1700 °C, if the institute has the data at T_j, then the data are employed. If not, the data interpolated by using the quadratic equation are employed.

In the CCT Key Comparison, the participating institute k reported the temperature as $T_k^{\mathrm{CCT}}(T_j)$. Its difference from the KCRV $T_{\mathrm{KCRV}}(T_j)$ is expressed as $dT_{\mathrm{k}}^{\mathrm{CCT}}(T_j)$.

$$dT_k^{CCT}(T_j) \equiv T_k^{CCT}(T_j) - T_{KCRV}(T_j) \tag{1}$$

The four linking institute average of the difference is expressed as $dT_{Ave}^{\mathrm{CCT}}(T_j)$.

$$\begin{aligned} dT_{Ave}^{CCT}(T_j) &\equiv \frac{1}{4}\sum_{k=1}^{4} dT_k^{CCT}(T_j) \\ &= \frac{1}{4}\sum_{k=1}^{4} T_k^{CCT}(T_j) - T_{KCRV}(T_j) \end{aligned} \tag{2}$$

In the APMP Key Comparison, the temperature of the participating institute k (k=1 to 7) and that of the pilot institute are expressed as $T_k^{\mathrm{APMP}}(T_j)$ and $T_{Pilot}^{\mathrm{APMP}}(T_j)$, respectively. The difference between the two temperature is $dT_k^{\mathrm{APMP}}(T_j)$.

$$dT_k^{APMP}(T_j) \equiv T_k^{APMP}(T_j) - T_{Pilot}^{APMP}(T_j) \tag{3}$$

The four linking institute average of the difference is expressed as $dT_{Ave}^{\mathrm{APMP}}(T_j)$.

$$\begin{aligned} dT_{Ave}^{APMP}(T_j) &\equiv \frac{1}{4}\sum_{k=1}^{4} dT_k^{APMP}(T_j) \\ &= \frac{1}{4}\sum_{k=1}^{4} T_k^{APMP}(T_j) - T_{Pilot}^{APMP}(T_j) \end{aligned} \tag{4}$$

The difference between the two averages in eqs. (2) and (4) is expessed as $\Delta(T_j)$.

$$\Delta(T_j) \equiv dT_{Ave}{}^{APMP}(T_j) - dT_{Ave}{}^{CCT}(T_j)$$
$$= \frac{1}{4}\sum_{k=1}^{4} T_k{}^{APMP}(T_j) - \frac{1}{4}\sum_{k=1}^{4} T_k{}^{CCT}(T_j) + T_{KCRV}(T_j) - T_{Pilot}{}^{APMP}(T_j) \quad (5)$$

Because the link was established by the average of the four linking institutes, the following equation applies.

$$\frac{1}{4}\sum_k T_k{}^{APMP}(T_j) = \frac{1}{4}\sum_k T_k{}^{CCT}(T_j) \quad (6)$$

Therefore the eq. (5) becomes

$$\Delta(T_j) = T_{KCRV}(T_j) - T_{Pilot}{}^{APMP}(T_j) \quad . \quad (7)$$

The difference of the APMP participant from the KCRV, $dT_k(T_j)$ (k=1 to 7) is expressed as follows.

$$dT_k(T_j) = T_k{}^{APMP}(T_j) - T_{KCRV}(T_j)$$
$$= dT_k{}^{APMP}(T_j) - \Delta(T_j) \quad (8)$$

2.2 Calculation of the uncertainty

Following factors of uncertainties are considered.

A. Uncertainty in APMP comparison

B. Uncertainty in linking APMP KC and CCT KC

C. Uncertainty of KCRV

Below each factor is described in detail.

2.2.1 Uncertainty in APMP comparison

This uncertainty is composed of the uncertainty u_k of the participant k and u_p of the pilot p. In principle two runs were carried out at each temperature T_j. The number of the run is expressed by m. The scatter in two runs is also included in this uncertainty

$$u_{1k}(T_j)^2 = \sum_m \left[u_{1km}{}^{APMP}(T_j)^2 + u_{p_m}{}^{APMP}(T_j)^2 \right] / \sum_m 1 + stdev^2(dT_{km}{}^{APMP}(T_j)) / \sum_m 1 \quad (9)$$

2.2.2 Uncertainty in linking

The difference between the differences of eq.(1) and eq(3) is expressed as $\Delta_k(T_j)$.

$$\Delta_k(T_j) \equiv dT_k{}^{APMP}(T_j) - dT_k{}^{CCT}(T_j) \quad (10)$$

Then the difference $\Delta(T_j)$ is expressed as follows.

$$\Delta(T_j) = \frac{1}{4}\sum_k (dT_k{}^{APMP}(T_j) - dT_k{}^{CCT}(T_j))$$
$$= \frac{1}{4}\sum_k \Delta_k(T_j) \quad (11)$$

The difference $\Delta(T_j)$ is the average of the four differences $\Delta_k(T_j)$. Therefore the standard deviation of the difference $\Delta_k(T_j)$ is the uncertainty in the linking.

$$u_2(T_j) = \frac{1}{\sqrt{4}} stdev(\Delta_k(T_j)) \quad k \in \{1,2,3,4\} \quad (12)$$

2.2.3 Uncertainty of KCRV

The four linking institutes participated in the loop 1 in the CCT KC5. Two lamps, C564 and C681, were used. The uncertainty of the KCRV is square-averaged.

$$u_3(T_j) \equiv \sqrt{\left\{u^{C564}(T_j)^2 + u^{C681}(T_j)^2\right\}/2} \qquad (13)$$

2.2.4 Combined standard uncertainty

$$u_k(T_j) = \sqrt{u_{1k}(T_j)^2 + u_2(T_j)^2 + u_3(T_j)^2} \quad k \in \{1,2,3,4,5,6,7\} \qquad (14)$$

3. Comment of each institute about linking CCT and APMP key comparisons

3.1 NMIA

In the view of NMIA, the ITS-90 scale realised in the CCT-K5 is equivalent to the ITS-90 scale realised in the APMP-K5 and any systematic scale errors are likely to be similar in the two realisations.

In APMP-K5 and CCT-K5, both the comparison measurements and the calibration of the transfer pyrometers was performed by Dr Ballico. APMP-K5 was performed using the transfer pyrometer HTSP, whereas the CCT-K5 was performed using the transfer pyrometer APEP-2.

Both pyrometers were constructed by NMIA and share the same design features of:

* A multi-cavity interference filter near to 650nm, with approximately a 10nm bandwidth.
* A Hamamatsu 1010BQ silicon photodiode
* Virtual-earth high linearity current to voltage amplifier
* A Lyot-stop (a stop near the detector imaged onto a virtual stop on the main objective lens)
* A simple optical system involving an objective lens, a target aperture , a collimating lens, Lyot-stop,interference filter and a windowed silicon photodiode.
* A 1:1 magnification of the aperture by the objective lens.
* A shutter system which automatically takes a zero for each measurement.
* A HP3458A precision voltmeter for measuring the amplified detector signal.

Differences between the pyrometers are:

* The HTSP has a 0.8mm target, whereas the APEP-2 had a 0.5mm target.
* The HTSP has a 50mm diameter objective , whereas the APEP-2 had a 100mm diameter objective
* The HTSP uses an additional 650nm interference filter to suppress out-of-band transmission, whereas the APEP-2 used a coloured glass pre-filter.
* The HTSP focal length is 500mm whereas the APEP-2 had a 300mm focal length

The calibration of the two pyrometers was performed using the same equipment and facilities:

* Same fixed point reference (Au point blackbody cavity Au-95). The same furnace, based on a Na heatpipe was used. The Au-95 gold-point blackbody is regularly compared to a second gold-point blackbody Au-2, with differences between the radiance temperatures always found less than 10mK.
* Same relative spectral responsivity apparatus: The pyrometer was focused onto the exit slit of a 1m McPherson single monochromator. A three element reflection trap was used as the reference detector. Coloured glass pre-filters were used to improve the measurement of out-of-band leakage. Multi-line Ne discharge lamp was used for wavelength calibration. A similar bandwidth and wavelength interval was used for both the filter bandpass regions and out-of-band measurements.
* Same linearity apparatus: A system based on using a beamsplitter to superimpose images of strip lamp filaments, together with shutters to make linearity measurements over a "doubling step", which was then performed many times to build up a linearity assessment over a wide signal range.
* Same SOSE apparatus: A system based on perspex screens with blackened metal disks, illuminated by a QTH lamp.
* Same integral calculation method for converting the radiance ratio to the reference temperature to an equivalent source temperature.

3.2 KRISS

KRISS took part in the CCT-K5 and the APMP-K5 by using the same transfer pyrometer and by same staff, Dr. Seung-Nam Park. Any systematic errors among both comparisons are likely to be similar.

3.3 NIM

In the comparisons of the CCT-K5 and the APMP-K5, the scale of ITS-90 at NIM were realized in same way (same procedure, same pyrometer, and by same person, Mr.YUAN Zundong). Of course, in the CCT-K5 the t90 was assigned to the transfer lamps of the CCT-K5, and in the APMP-K5 the t90 realized at NIM was assigned to the NIM's lamp. The uncertainties and systematic errors among the CCT-K5 and the APMP-5 are similar.

3.4 NMIJ

The radiation thermometer used for both comparisons was the same at NMIJ. It was calibrated according to ITS-90 by using the copper-point blackbody, the spectral responsivity measurement and the nonlinearity measurement by the same staff, Dr. F. Sakuma. Except for the difference of the radiation sources, the uncertainties and systematic errors among the CCT-KC5 and the APMP-TK5 were similar.

3.5 NMC

NMC has a large deviation from the KCRV in the CCT K5. This is likely due to the drift of the interference filters of the radiation thermometer after the calibration at NMIA (then NML), Australia (NMC was unable to measure the spectral responsivity at that time). NMC changed its realization method in the APMP K5 by using a new reference radiation thermometer and NMC's own spectral responsivity measurement facility. This explains the different results in the two comparisons.

4. Youden plot

Figure 9 shows the Youden plot of the temperature difference from the KCRV in CCT KC5 and APMP TK5 comparisons for the four linking institutes. KRISS lies upper, NIM lies lower left, NMIA lies near center and NMIJ lies right. All institutes were within ±0.5 °C in the whole temperature range from 1000 °C to 1700 °C. The agreement was better at lower temperatures.

Table 1 Name of participating institute

Year, A.D.	2009	1999
Rep. of Korea	KRISS	KRISS
China	NIM	NIM
Australia	NMIA	NML/CSIRO
Japan	NMIJ/AIST	NRLM
Singapore	NMC-A*STAR	NMC/SPRING
Chinese Taipei	CMS/ITRI	CMS/ITRI
Indonesia	KIM-LIPI	KIM-LIPI

Average of two runs *dt* and uncertainty u_1 of the APMP key comparison

Table 2 APMP T-K5-97 Result (KRISS-NMIJ)

t set	dt(ave)	Diff	m	uk	up	stdev/rt(m	u1	u2	u3	u
[° C]	[° C]	[° C]		[° C]	[° C]	[° C]	[° C]	[° C]	[° C]	[° C]
962	0.22							0.11	0.08	
1000	0.19	0.23	2	0.33	0.13	0.11	0.37	0.12	0.09	0.40
1064	0.30							0.14	0.08	
1085	0.31							0.14	0.08	
1100	0.32							0.16	0.08	
1200	0.45	−0.02	2	0.27	0.16	0.01	0.32	0.20	0.07	0.38
1300	0.40							0.20	0.07	
1400	0.41	−0.04	2	0.29	0.22	0.02	0.36	0.24	0.07	0.44
1500	0.41							0.25	0.07	
1600	0.36	−0.06	2	0.37	0.29	0.03	0.47	0.28	0.07	0.55
1700	0.36							0.30	0.05	

Table 3 APMP T-K5-97 Result (NIM-NMIJ)

t set	dt(ave)	Diff	m	uk	up	stdev(dt)	u1	u2	u3	u
[° C]	[° C]	[° C]		[° C]	[° C]	[° C]	[° C]	[° C]	[° C]	[° C]
962	−0.13	0.05	2	0.04	0.14	0.03	0.15	0.11	0.08	0.20
1000	−0.19	0.05	2	0.04	0.13	0.02	0.14	0.12	0.09	0.20
1064	−0.20						0.00	0.14	0.08	
1085	−0.21							0.14	0.08	
1100	−0.22	0.05	2	0.05	0.14	0.02	0.15	0.16	0.08	0.24
1200	−0.25	0.07	2	0.06	0.16	0.04	0.18	0.20	0.07	0.27
1300	−0.30	0.01	2	0.07	0.19	0.01	0.20	0.20	0.07	0.29
1400	−0.40	0.06	2	0.08	0.22	0.03	0.23	0.24	0.07	0.34
1500	−0.43	−0.04	2	0.09	0.25	0.02	0.27	0.25	0.07	0.37
1600	−0.47	0.00	2	0.10	0.29	0.00	0.30	0.28	0.07	0.42
1700	−0.46	0.08	2	0.12	0.33	0.04	0.35	0.30	0.05	0.46

Table 4 APMP T-K5-97 Result (CSIRO-NMIJ)

t set	dt(ave)	Diff	m	uk	up	stdev/rt(m	u1	u2	u3	u
[° C]	[° C]	[° C]		[° C]	[° C]	[° C]	[° C]	[° C]	[° C]	[° C]
962	−0.19							0.11	0.08	
1000	−0.12	0.03	2	0.11	0.15	0.01	0.19	0.12	0.09	0.24
1064	−0.11							0.14	0.08	
1085	−0.10							0.14	0.08	
1100	−0.07	0.20	2	0.13	0.16	0.10	0.23	0.16	0.08	0.29
1200	0.05	−0.17	2	0.14	0.19	0.08	0.25	0.20	0.07	0.32
1300	−0.02	0.15	2	0.15	0.22	0.07	0.28	0.20	0.07	0.35
1400	0.13	0.28	2	0.17	0.25	0.14	0.33	0.24	0.07	0.42
1500	−0.12	−0.01	2	0.18	0.29	0.00	0.34	0.25	0.07	0.43
1600	0.21	0.21	2	0.20	0.33	0.10	0.40	0.28	0.07	0.49
1700	0.27	0.29	2	0.21	0.37	0.15	0.45	0.30	0.05	0.54

Table 5 APMP T-K5-97 Result (NMC-NMIJ)

t set	dt(ave)	Stdev	m	uk	up	stdev/rt(m	u1	u2	u3	u
[° C]	[° C]	[° C]		[° C]	[° C]	[° C]	[° C]	[° C]	[° C]	[° C]
1000	0.04		3	0.12	0.13	0.03	0.18	0.12	0.09	0.23
1200	−0.07		1	0.14	0.16		0.22	0.20	0.07	0.30
1300	0.02		1	0.25	0.19		0.31	0.20	0.07	0.38
1400	0.10		1	0.21	0.22		0.30	0.24	0.07	0.39
1600	0.19		1	0.27	0.29		0.39	0.28	0.07	0.49

Table 6 APMP T-K5-97 Result (KIM-LIPI-NMIJ)

t set	dtAve	Diff		uk	up	stdev/rt(m	u1	u2	u3	u
[° C]	[° C]	[° C]		[° C]			[° C]	[° C]	[° C]	[° C]
1000	0.25	−0.05	2	0.92	0.13	0.02	0.93	0.12	0.09	0.94
1085	0.37	−0.02	2	0.92	0.14	0.01	0.93	0.14	0.09	0.95
1300	1.08	0.21	2	1.03	0.19	0.11	1.06	0.20	0.07	1.08
1500	1.95	−0.03	2	1.32	0.25	0.01	1.34	0.25	0.07	1.37

Table 7 APMP T-K5-97 Result (ITRI-NMIJ) (Revised)

t set	dtAve	Diff	m	uk	up	stdev/rt(m	u1	u2	u3	u
[° C]	[° C]	[° C]		[° C]	[° C]	[° C]	[° C]	[° C]	[° C]	[° C]
1000	−0.21	0.14	2	0.37	0.13	0.07	0.40	0.12	0.09	0.42
1100	0.13	0.60	2	0.37	0.14	0.30	0.50	0.16	0.08	0.53
1200	0.07	0.20	2	0.39	0.16	0.10	0.43	0.20	0.07	0.48
1300	−0.06	0.60	2	0.46	0.19	0.30	0.58	0.20	0.07	0.62
1400	−0.81	−0.27	2	0.48	0.22	0.14	0.54	0.24	0.07	0.60
1500	−1.05	0.11	2	0.55	0.25	0.06	0.61	0.25	0.07	0.66
1600	−1.42	−0.01	2	0.70	0.29	0.00	0.76	0.28	0.07	0.81
1700	−1.95	0.02	2	0.75	0.33	0.01	0.82	0.30	0.05	0.87

Table 8 APMP T-K5-97 Result (ITRI-NMIJ) (Original)

t set	dtAve	Diff	m	uk	up	stdev/rt(m	u1	u2	u3	u
[° C]	[° C]	[° C]		[° C]	[° C]	[° C]	[° C]	[° C]	[° C]	[° C]
1000	−0.48	0.14	2	0.37	0.13	0.07	0.40	0.12	0.09	0.42
1100	−0.18	0.60	2	0.37	0.14	0.30	0.50	0.16	0.08	0.53
1200	−0.40	0.20	2	0.39	0.16	0.10	0.43	0.20	0.07	0.48
1300	−0.64	0.60	2	0.46	0.19	0.30	0.58	0.20	0.07	0.62
1400	−1.52	−0.27	2	0.48	0.22	0.14	0.54	0.24	0.07	0.60
1500	−1.72	0.11	2	0.55	0.25	0.06	0.61	0.25	0.07	0.66
1600	−2.56	−0.01	2	0.70	0.29	0.00	0.76	0.28	0.07	0.81
1700	−3.51	0.02	2	0.75	0.33	0.01	0.82	0.30	0.05	0.87

Table 9 Comparison between CCT key comparison and APMP key comparison among four linking institutes

CCT KC5 — Eq(1) — Eq(2)

t set	CSIRO	KRISS	NIM	NRLM	Average
[° C]	[° C]	[° C]	[° C]	[° C]	[° C]
961	−0.10	−0.05	0.06	0.01	−0.02
1000	−0.06	−0.02	0.09	0.05	0.02
1064	−0.04	0.01	0.10	0.06	0.03
1084	−0.01	0.03	0.10	0.10	0.05
1100	−0.01	0.01	0.16	0.10	0.06
1200	−0.03	0.00	0.09	0.15	0.05
1300	0.00	0.02	0.14	0.21	0.09
1400	0.05	0.06	0.20	0.31	0.15
1500	0.06	0.03	0.21	0.35	0.16
1600	0.05	0.03	0.24	0.44	0.19
1700	0.03	0.00	0.25	0.46	0.18

APMP T K5 — Eq(3) — Eq(4)

t set	KRISS	NIM	CSIRO	NMIJ	Average
[° C]	[° C]	[° C]	[° C]	[° C]	[° C]
962	0.22	−0.13	−0.19	0.00	−0.03
1000	0.19	−0.19	−0.12	0.00	−0.03
1064	0.30	−0.20	−0.11	0.00	0.00
1085	0.31	−0.21	−0.10	0.00	0.00
1100	0.32	−0.22	−0.07	0.00	0.01
1200	0.45	−0.25	0.05	0.00	0.06
1300	0.40	−0.30	−0.02	0.00	0.02
1400	0.41	−0.40	0.13	0.00	0.03
1500	0.41	−0.43	−0.12	0.00	−0.03
1600	0.36	−0.47	0.21	0.00	0.02
1700	0.36	−0.46	0.27	0.00	0.04

dt(apmp−cct) — Eq(10) — Eq(5) — Eq(12)

t set	KRISS	NIM	CSIRO	NMIJ	Average	Stdev	Stdev/rt3
[° C]	[° C]	[° C]	[° C]	[° C]	[° C]	[° C]	[° C]
962	0.27	−0.18	−0.10	−0.01	−0.01	0.20	0.11
1000	0.22	−0.28	−0.07	−0.05	−0.05	0.20	0.12
1064	0.29	−0.30	−0.07	−0.06	−0.04	0.24	0.14
1085	0.28	−0.31	−0.08	−0.10	−0.05	0.25	0.14
1100	0.31	−0.37	−0.06	−0.10	−0.06	0.28	0.16
1200	0.45	−0.34	0.07	−0.15	0.01	0.34	0.20
1300	0.38	−0.44	−0.02	−0.21	−0.07	0.35	0.20
1400	0.36	−0.60	0.08	−0.31	−0.12	0.42	0.24
1500	0.39	−0.65	−0.17	−0.35	−0.20	0.43	0.25
1600	0.33	−0.71	0.16	−0.44	−0.17	0.49	0.28
1700	0.36	−0.71	0.24	−0.46	−0.14	0.52	0.30

Table 10 Difference of four linking institutes from CCT KCRV

Difference from KCRV Eq(8)

t set	KRISS	NIM	CSIRO	NMIJ
[° C]	[° C]	[° C]	[° C]	[° C]
962	0.23	−0.12	−0.19	0.01
1000	0.24	−0.14	−0.08	0.05
1064	0.33	−0.16	−0.08	0.04
1085	0.36	−0.16	−0.04	0.05
1100	0.37	−0.16	−0.01	0.06
1200	0.44	−0.26	0.04	−0.01
1300	0.47	−0.23	0.05	0.07
1400	0.53	−0.29	0.24	0.12
1500	0.61	−0.24	0.08	0.20
1600	0.52	−0.31	0.38	0.17
1700	0.50	−0.32	0.41	0.14

u Eq(14)

t set	KRISS	NIM	CSIRO	NMIJ
[° C]	[° C]	[° C]	[° C]	[° C]
962		0.20		0.20
1000	0.40	0.20	0.24	0.21
1064				
1085				
1100		0.24	0.29	0.25
1200	0.38	0.27	0.33	0.28
1300		0.29	0.35	0.31
1400	0.44	0.35	0.42	0.36
1500		0.37	0.43	0.39
1600	0.55	0.42	0.49	0.44
1700		0.46	0.54	0.48

U=2u

t set	KRISS	NIM	CSIRO	NMIJ
[° C]	[° C]	[° C]	[° C]	[° C]
962		0.41		0.40
1000	0.80	0.41	0.48	0.43
1064				
1085				
1100		0.47	0.59	0.49
1200	0.76	0.55	0.65	0.56
1300		0.59	0.70	0.61
1400	0.89	0.69	0.84	0.72
1500		0.75	0.86	0.78
1600	1.10	0.84	0.98	0.88
1700		0.93	1.09	0.96

Table 11 Difference of three other institutes from CCT KCRV

dtAPMP Eq(3)

t set	NMC	KIM-LIPI	ITRI (re)	ITRI
[° C]	[° C]	[° C]	[° C]	[° C]
962				
1000	0.04	0.25	−0.21	−0.48
1064				
1085		0.37		
1100			0.13	−0.18
1200	−0.07		0.07	−0.40
1300	0.02	1.08	−0.06	−0.64
1400	0.10		−0.81	−1.52
1500		1.95	−1.05	−1.72
1600	0.19		−1.42	−2.56
1700			−1.95	−3.51

dt (to CCTKCRV) Eq(8)

t set	NMC	KIM-LIPI	ITRI(re)	ITRI
[° C]	[° C]	[° C]	[° C]	[° C]
962				
1000	0.08	0.30	−0.17	−0.44
1064				
1085		0.42		
1100			0.18	−0.13
1200	−0.08		0.06	−0.41
1300	0.09	1.15	0.02	−0.56
1400	0.22		−0.69	−1.40
1500		2.15	−0.86	−1.53
1600	0.36		−1.25	−2.39
1700			−1.80	−3.36

u Eq(14)

t set	NMC	KIM-LIPI	ITRI(re)	ITRI
[° C]	[° C]	[° C]	[° C]	[° C]
962				
1000	0.30	0.92	0.53	0.53
1064				
1085		0.92		
1100			0.72	0.72
1200	0.30		0.50	0.50
1300	0.38	1.06	0.78	0.78
1400	0.40		0.65	0.65
1500		1.32	0.64	0.64
1600	0.49		0.71	0.71
1700			0.79	0.79

U=2u

t set	NMC	KIM-LIPI	ITRI(re)	ITRI
[° C]	[° C]	[° C]	[° C]	[° C]
962				
1000	0.59	1.84	1.07	1.07
1064				
1085		1.84		
1100			1.45	1.45
1200	0.60		0.99	0.99
1300	0.76	2.11	1.57	1.57
1400	0.79		1.31	1.31
1500		2.64	1.28	1.28
1600	0.98		1.42	1.42
1700			1.58	1.58

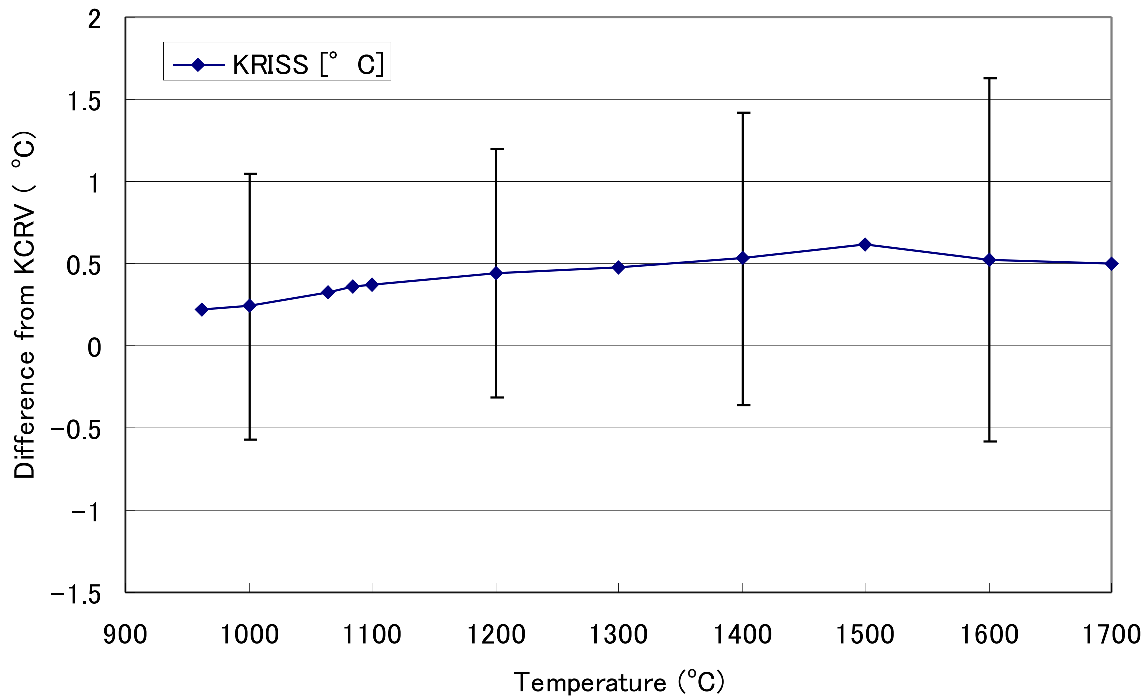


Fig. 1 Difference of KRISS from the KCRV

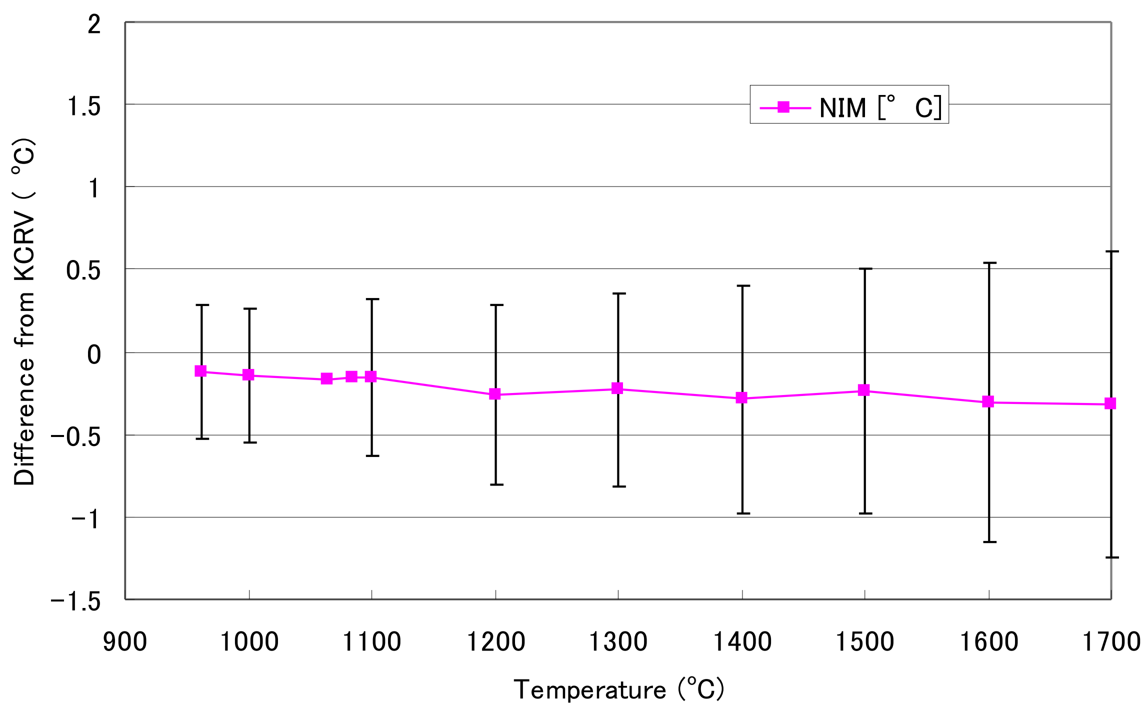


Fig. 2 Difference of NIM from the KCRV

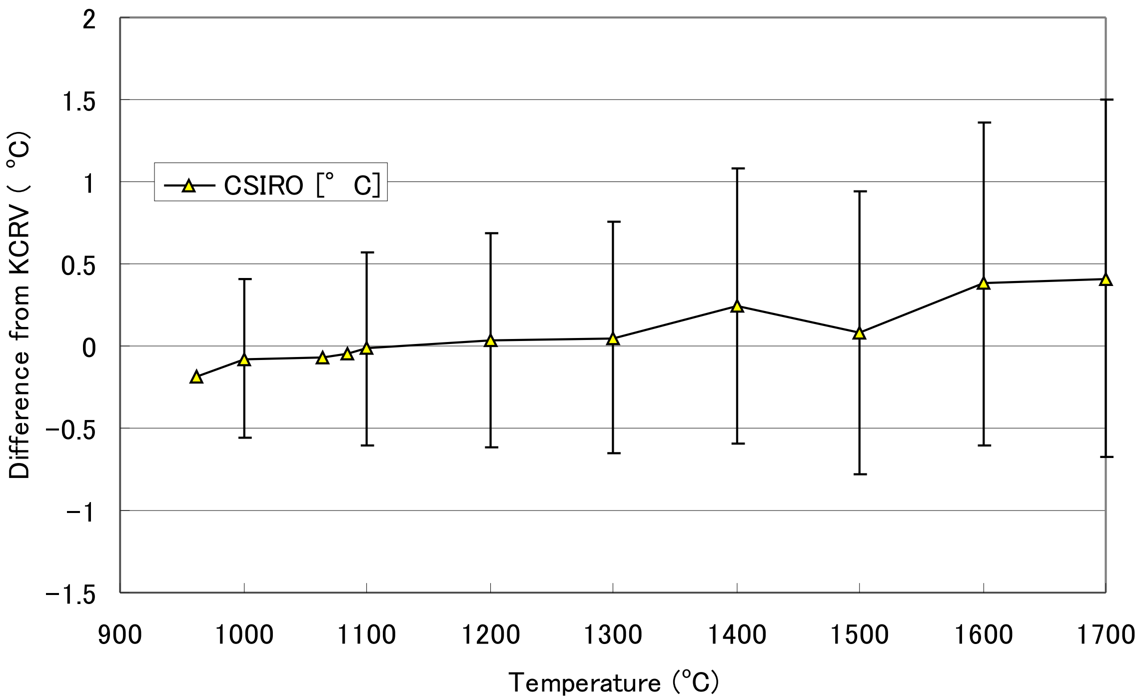


Fig. 3 Difference of CSIRO from the KCRV

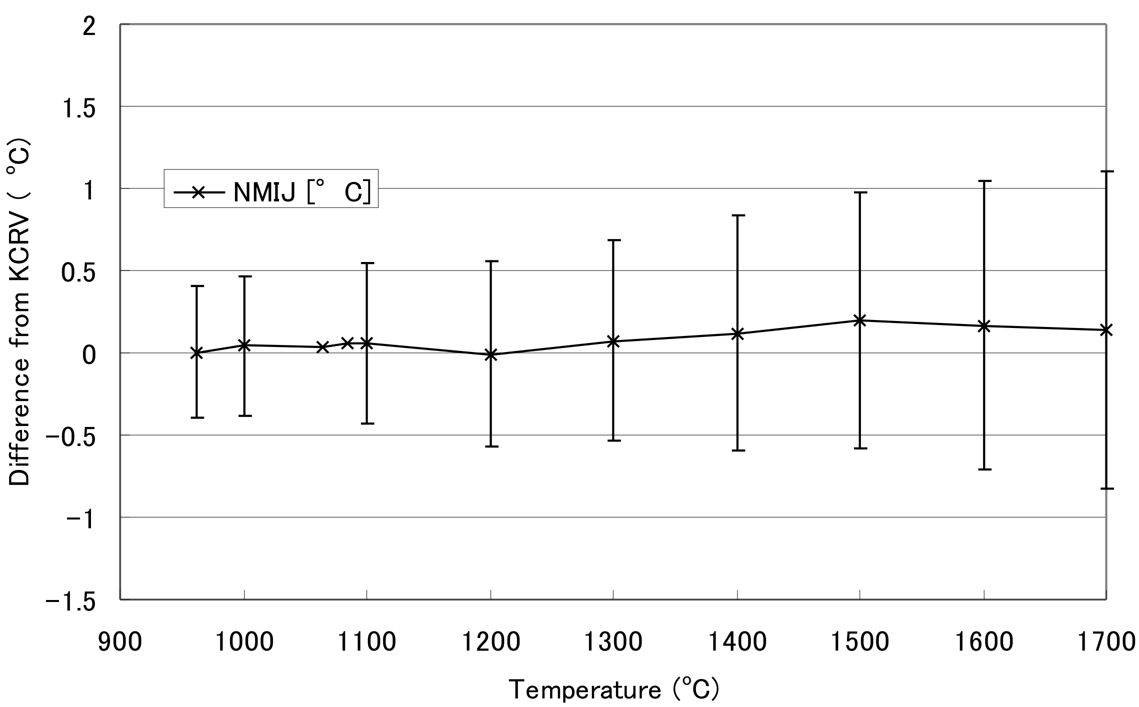


Fig. 4 Difference of NMIJ from the KCRV

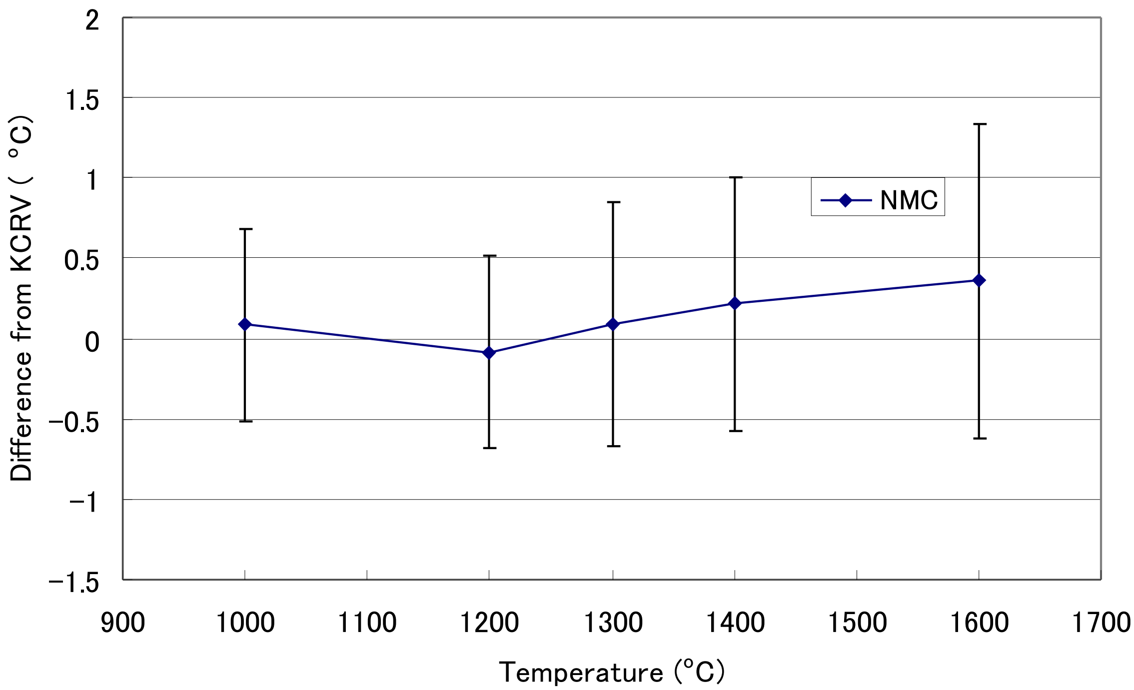


Fig. 5 Difference of NMC from the KCRV

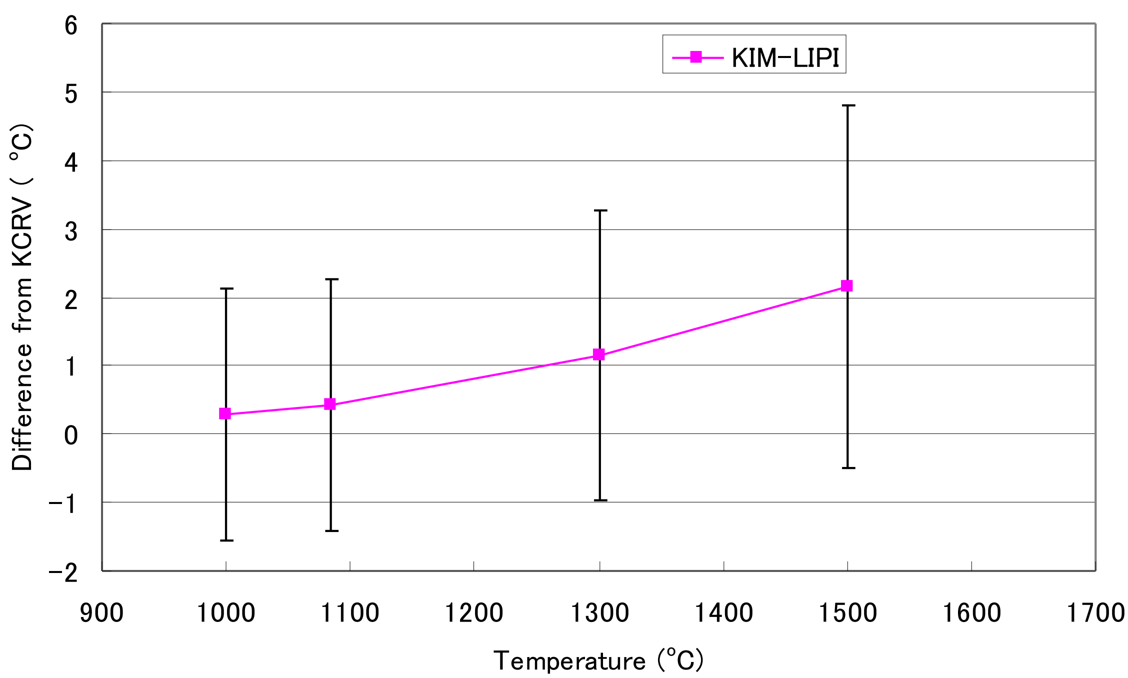


Fig. 6 Difference of KIM-LIPI from the KCRV

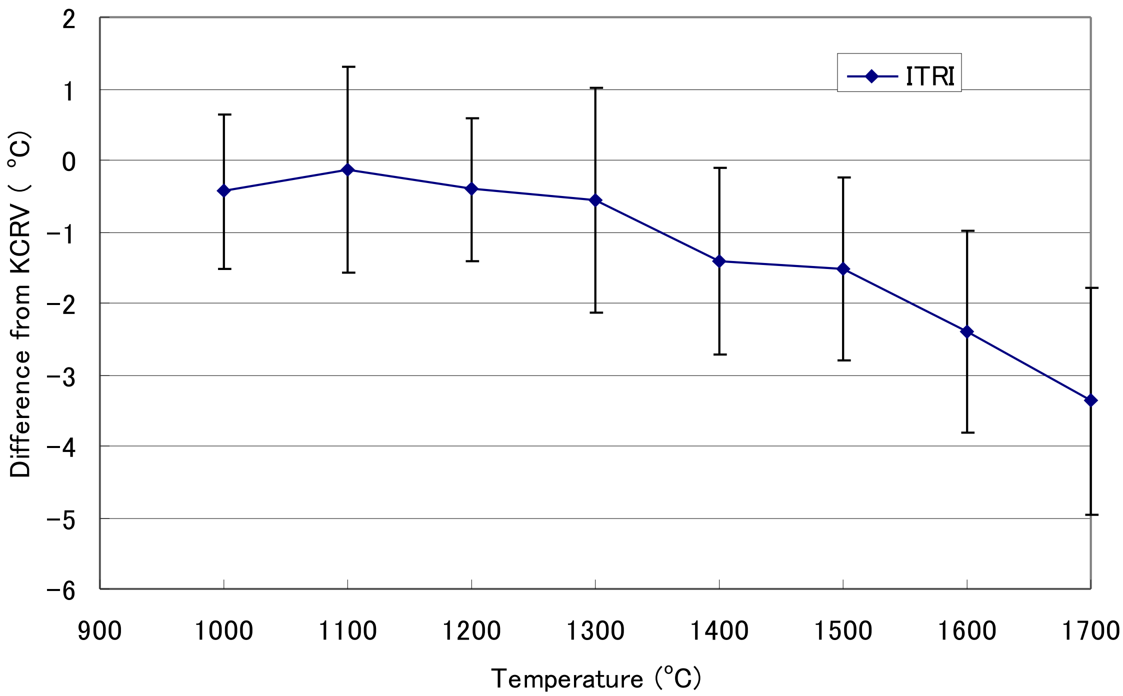


Fig. 7 Difference of ITRI from the KCRV

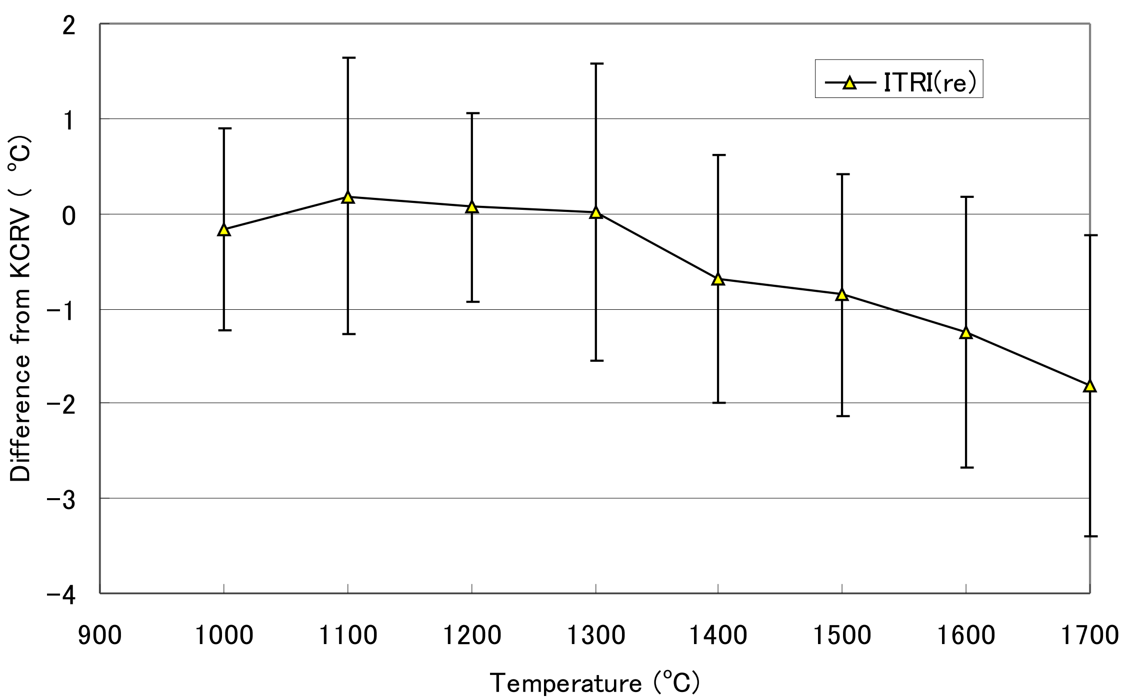
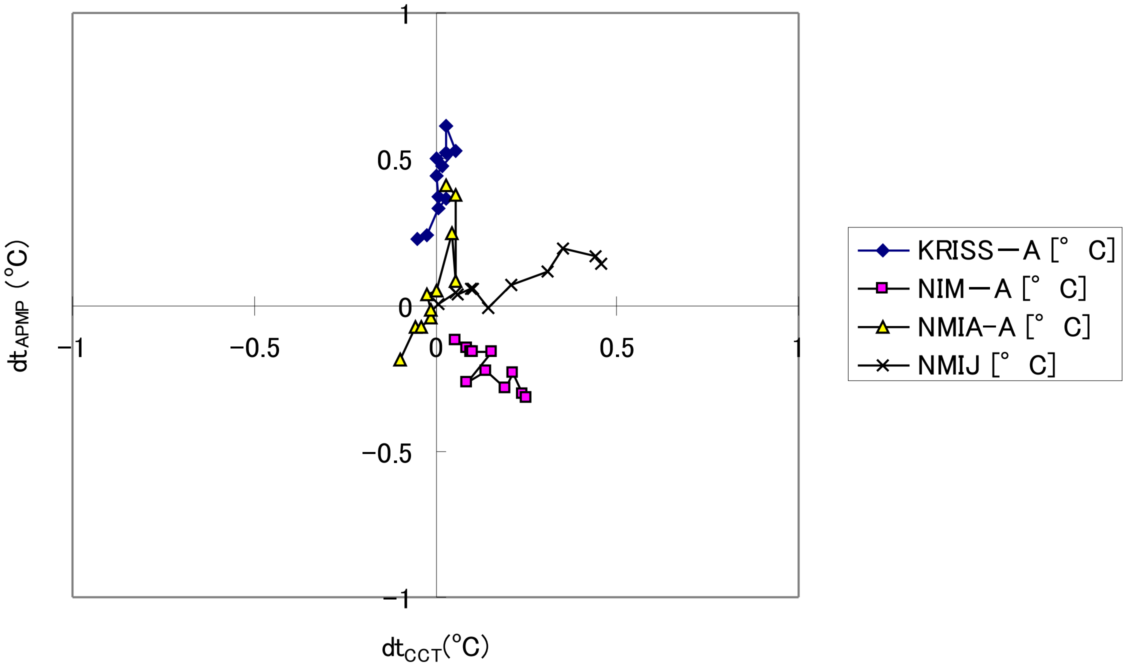


Fig. 8 Difference of ITRI (Revised) from the KCRV

Fig. 9 Youden plot of the difference from the KCRV in CCT KC5 and in APMP TK5 comparisons



That is all