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CCT-K10

FINAL REPORT FOR CCT COMPARISON OF ITS-90 REALISATIONS ABOVE THE SILVER POINT USING TWO TRANSFER RADIATION THERMOMETERS AND A SET OF HIGH TEMPERATURE FIXED-POINT BLACKBODY CELLS

INTERIM REPORT (MARCH 2024)

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ABSTRACT

This report outlines the equipment, measurement method, results and uncertainties associated with the participant measurements for the Consultative Committee of Thermometry Key Comparison K10 (CCT-K10), “ITS-90 realisations above the silver point using two transfer radiation thermometers and a set of high temperature fixed-point blackbody cells”, over the period from around summer 2014 to the final measurements made during January 2020. The report presents differences of the participant data from the KCRV values for both the radiation thermometer and HTFP measurements. **Note**: that this interim report excludes the measurement data of VNIIM, Russia – see explanation at the end of Section 6. It is the intention that an addendum to this final report will be published at a future date to include the results of VNIIM.

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Approved on behalf of NPLML by
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1 INTRODUCTION

Above the freezing point of silver (Ag, 961.78 °C) the ITS-90 is realised using a characterised radiation thermometer calibrated using a blackbody at one of the defining fixed points (i.e., silver, gold (Au, 1064.18 °C) or copper (Cu, 1084.62 °C)) and extrapolated upwards from the reference fixed point using Planck's law in ratio form. The definition can result in undetected scale realisation uncertainties which generally increase in proportion to the square of the temperature (T^2 (K^2)). In addition, there are various ways in which the scale can be realised leading to different sources of uncertainty, dependent upon the method used. It is essential to undertake Key Comparisons involving leading NMIs in different regions to substantiate claimed Calibration and Measurement Capabilities (CMCs) for the ITS-90 above the silver point.

The results of the previous CCT-led key comparison (CCT K5) for the range up to 1700 °C, which took place around 20 years ago, were unsatisfactory for the following reasons:

1. the comparison was carried out using tungsten ribbon lamps which inherently have a relatively large associated uncertainty
2. the radiance temperature of the ribbon is strongly dependent on the wavelength
3. the comparison was only up to a temperature of 1700 °C whereas NMIs can routinely realise the ITS-90 up to much higher temperatures, up to 3000 °C
4. there was evidence of some artefact instability in some of the results obtained
5. the comparison results showed differences which were thought not to be representative of participants' actual ability to realise the high temperature scale.

As a consequence, CCT K5 cannot satisfactorily substantiate NMIs' claimed CMCs, either to the required level of uncertainty or over the required temperature range. This new CCT Key Comparison (KC), designation CCT K10, was designed to address this issue, and to support CMCs for ITS-90 calibration of radiation thermometers and future CMCs for fixed point calibration above the Ag point.

CCT K10 consisted of two parts:

1. a comparison of ITS-90 scale realisations over the range from the Ag point to 3000 °C (or the highest temperature which participants were able to realise) using two transfer radiation thermometers (an IKE Linear Pyrometer LP3 and a Chino radiation thermometer IR-RST65). A transportable copper fixed-point blackbody source was circulated with the transfer thermometers to confirm their stability throughout the comparison;
2. a measurement of high temperature fixed-point (HTFP) blackbody cells. Three HTFP cells (Ru-C and WC-C along with either doped Ni-C (Ni-C-X) or doped Co-C (Co-C-X)* were circulated in order to probe scale realisation uncertainties at these particular temperatures with better precision. (*Unfortunately, due to issues with breakage of the Ni-C cells, it was decided mid-comparison to circulate a doped Co-C cell instead, which has a melting transition close to that of Ni-C)

The instruments and artefacts were circulated in the form of a semi-collapsed star or 'flower' as described below. This enabled the performance of the instruments to be regularly checked throughout the comparison by the pilot laboratory (NPL, UK); the aim of this comparison scheme was to minimise issues due to incorrect operation or drift of the transfer artefacts.

2 PARTICIPANTS

The participants were drawn from a number of metrology regions, namely EURAMET, SIM, COOMET and APMP. The details of NMI and contact person are given in Table 1 below.

Table 1 - the CCT K10 participants

Region	NMI	Details of contact person
EURAMET	NPL (pilot)	Helen McEvoy/ Graham Machin National Physical Laboratory (NPL), United Kingdom
EURAMET	CEM	Maria José Martín Centro Español de Metrologia (CEM), Spain
EURAMET	PTB	Klaus Anhalt/ Jörg Hollandt Physikalisch-Technische Bundesanstalt (PTB), Germany
EURAMET	LNE-Cnam	Mohamed Sadli/ Frederic Bourson Lab. Commun de Métrologie (LNE-Cnam), France
APMP	NMIJ	Yoshiro Yamada National Metrology Institute of Japan (NMIJ)
APMP	NIM	Xiaofeng Lu National Institute of Metrology (NIM), China
APMP	KRISS	YongShim Yoo Korea Research Institute of Standards and Science (KRISS)
SIM	NIST	Howard Yoon National Institute of Standards and Technology (NIST) United States
SIM	NRC	Andrew Todd National Research Council of Canada (NRC)
COOMET	VNIIM	Mikhail Matveyev D. I. Mendeleyev Institute for Metrology (VNIIM), Russia

3 COMPARISON SCHEME

The comparison was in the form of a ‘semi-collapsed star’ or ‘flower’. In other words, the comparison artefacts were sent from the pilot laboratory to one of the regional NMIs, the measurements were performed in a loop around that region, and then the artefacts were sent back to the pilot laboratory. Following check measurements at the pilot laboratory, the artefacts were then sent on to an NMI in the next region for a further loop.

The original comparison schedule is given in the second column of Table 2 below. Unfortunately, there were several delays during the comparison. These included delays for technical reasons (for example there were issues associated with NPL’s high temperature facility at the end of the comparison, delaying the final measurements), participant delays (participants over-running the scheduled timeslot for measurements), and transportation issues (for example preparation of customs documentation taking longer than expected). This meant that the final NPL measurements were in fact carried out in January/ February 2020 (third column of Table 2), i.e., a little over 3 years later than planned.

Table 2 - the original CCT K10 comparison schedule

NMI	Original measurement period	Actual measurement period
NPL (pilot)	to end Sept 14	Aug 14 to early Oct 14
NMIJ	to end Jan 15	Dec 14 to ~end Feb 15
NIM	end Mar 15 to end Apr 15	End Mar 15 to end May 15
KRISS	mid-June 15 to mid-July 15	End May 15 to mid-July 15
NPL (pilot)	August 15	End July 15 to ~mid-Sept 15
NRC	mid-Sept 15 to mid-Oct 15	End Sept 15 to ~mid Nov 15
NIST	Nov 15	Dec 15 to mid-Aug 16
NPL (pilot)	Mid-Dec to end Jan 16	Mid-Sept 16 to end Oct 16
VNIIM	Mid-Feb 16 to mid-Mar 16	Apr 17 to early Aug 17
NPL (pilot)	Apr 16	Nov 17 to end Jan 18
LNE-Cnam	Mid-May 16 to mid-June 16	Mid-Feb 18 to late Apr 18
PTB	July16	End Apr 18 to early Jul 18
CEM	Mid-Aug to end Sept	Mid-July 18 to mid Oct 18
NPL (pilot)	Mid-Sept 16 to mid-Nov 16	Jan 19 to Feb 20

4 CIRCULATING INSTRUMENTS

The circulating instruments were:

An IKE LP3 radiation thermometer supplied by PTB (Figure 1);
A Chino radiation thermometer IR-RST65 supplied by NMIJ (Figure 2);
A Chino copper fixed-point source (for checking the stability of the radiation thermometers prior to the measurements at each NMI) supplied by NRC.

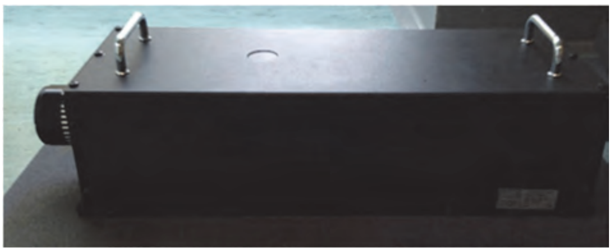


Figure 1: the PTB IKE LP3

Figure 2: the NMIJ Chino IR-RST65

Additionally, one of each type of HTFP cell (either doped Ni-C (Ni-C-X) or doped Co-C (Co-C-X), Ru-C and WC-C) were circulated to allow participants to probe the uncertainty of their primary ITS-90 scale realisation at the fixed-point temperatures.

The technical specifications for each of the instruments are given in the following Tables.

Table 3 - the specifications of the LP3 thermometer

IKE Linear Pyrometer	
Model	LP3
Serial number	80-13
Spectral range	650 nm (and 950 nm†)
Measuring temperature range (at 650 nm)	800 °C to 3030 °C Neutral density (ND) filter (filter A2) to be used above 2400 °C
Measurement ranges	R1 for photocurrents from 100 pA to 8 nA; R2 for photocurrents from 500 pA to 800 nA
Target size versus distance	1 mm at 700 mm; 1.7 mm at 1000 mm
Output	Photocurrent and temperature* via serial RS232 interface and PC using supplied LP3DE.exe software‡
Measurement distance	730 mm to 1000 mm
Working distance for the comparison	750 mm from the front of the thermometer casing to the target
Warm up time	2 hours (until cell is stabilised at 29.5 °C)
Stability over 6 months (specification)	±0.25 K at 1200 K; ±2.4 K at 2800 K
Power requirements	110 V or 220 V, 50/60 Hz. Two power units (one for 110 V, one for 220 V) were provided

† Measurements were only carried out at 650 nm for the comparison
* Only the photocurrent was used for the comparison
‡ Participants were not required to use the supplied software. It was permissible to use alternative (participant's own) software to record the LP3 photocurrent provided that the software didn't apply any data manipulation to the raw photocurrent values.

Table 4 - Specifications for the Chino radiation thermometer

Chino radiation thermometer	
Model	IR-RST65
Serial number	IS143A001
Spectral range	650 nm, FWHM 12 nm
Measuring temperature range	960 °C to 3000 °C
Distance Ratio (Distance / Target size)	650 (400 mm/ 0.6 mm Ø)
Output	Radiance signal: 0 to 10 V Internal temperature stabilisation monitor signal: 0 to 5 V (0 to 50 °C)
Measurement distance	400 mm to ∞
Working distance for the comparison	700 mm from front of the thermometer casing to the target
Warm up time	Half a day
Stability over 12 months	Not specified by manufacturer
Power requirements	24 VDC, DC power supply provided (for 100-240 VAC)

Table 5 - Specifications for the transfer Cu point source

Transportable copper fixed-point blackbody source	
Furnace model	IR-R0A
Serial number	RA12YB002
Fixed-point blackbody	Cu point
Blackbody cavity	8 mm Ø× ~53 mm, with 120 °conical end and 6 mm Ø aperture
Effective emissivity	~0.9998
Plateau duration	Approximately 10 min
Heat-up time	Approx. 120 min from room temperature to Cu point
Cool-down time	Approx. 120 min from Cu point to 150 °C
Power	110-120/ 220-240VAC, 50 – 60 Hz, 750 VA max
Gas requirements	Pure argon, 0.2 to 0.25 l/min
Temperature control	PID control by a pre-programmed controller which is used to automatically perform a number of melt/ freeze cycles

Table 6 - Dimensions and emissivity values for the high temperature fixed-point cells

High temperature fixed point cells						
HTFP cell	Identification number	Supplied by	Length/ mm	Outer diameter/ mm	Aperture diameter/ mm	Emissivity
Ru-C cell	6Ru1	LNE-Cnam	44	24	3	0.9997
Ru-C cell	6Ru2	LNE-Cnam	44	24	3	0.9997
Ru-C cell	Ru-C-4	Tubitak	24	24	3	0.9990
Ni-C-X cell	NiC #11	INMETRO	40	24	3	0.9997
Ni-C-X cell	NiC #12	INMETRO	40	24	3	0.9997
Ni-C-X cell	NiC#3	INMETRO	40	24	3	0.9997
Co-C-X cell*	Co-C_B1	NPL	44	24	3	0.9996
Co-C-X cell	Co-C ref	NPL	44	24	3	0.9996
WC-C cell	W2 6SSC-2	NIM	45	24	3	0.9997
WC-C cell	WC-C#1	NPL	44	24	3	0.9996
WC-C cell	WC-C#2	NPL	44	24	3	0.9996
WC-C cell	6WC-C2	LNE-Cnam	44	24	3	0.9997

* Replacement doped Co-C cells due to issues with breakage of the Ni-C cells

Additionally, LNE-Cnam provided WC-C cell reference 6WC-C2 towards the end of the comparison after breakage of WC-C#2 during the LNE-Cnam measurements.

The two/ three cells of each of the fixed-point types were cross-compared prior to circulation in order to determine the temperature difference between the cells. One of each type of cell (i.e., one Ni-C cell or Co-C cell, one Ru-C cell and one WC-C cell) were chosen at random for circulation among the participants. The remaining cell(s) of each type were kept at NPL in case of breakage of any transfer cell during the comparison.

5 MEASUREMENTS AT THE PILOT LABORATORY (NPL)

The pilot laboratory fully calibrated and characterised the two radiation thermometers, both prior to the start of the comparison and at the end of the comparison. Validation of the transfer Cu fixed point and measurement of the HTFPs was also carried out. The calibration/ validation measurements consisted of:

- Size-of-source effect measurements of the two KC radiation thermometers.
- Gain or range ratio measurements as appropriate.
- Measurement of the non-linearity (at the start of the comparison only).
- Measurement of the transmission of the LP3 neutral density (ND) filter.
- Measurement of the spectral response of the LP3 (the spectral response of the Chino thermometer was carried out by NMIJ prior to sending the thermometer to NPL).
- Validation/ comparison of the transfer Cu fixed-point source using the NPL primary Cu point and NPL radiation thermometer (the NPL IKE LP3).
- Measurement of the KC radiation thermometer outputs using the transfer Cu point (to provide a baseline reference signal).
- Calibration of the KC radiation thermometers at the comparison temperatures, namely 960, 1100, 1300, 1500, 1700, 1800, 2000, 2200, 2400, 2500, 2600, 2800, 2900, 3000 °C, using the NPL high temperature blackbody source and primary reference thermometer (the NPL LP3).
- Assignment of the NPL ITS-90 temperatures to a set of HTFP cells, consisting of one of each of Ni-C-X or Co-C-X, Ru-C and WC-C, using the usual NPL method for determining the point of inflection (poi) temperature of the melting transition of the HTFPs using the NPL LP3 (see e.g. [1]). This set of cells was circulated among participants. The remaining cells of each type were held at NPL, to serve as a reference to test for any possible drift of the HTFPs during the comparison and to provide a spare in case of breakage during the comparison. (Note that the temperature difference between the cells of each type was measured prior to the start of the comparison, either by the supplier of the cells or by another, volunteer, NMI).

A limited number of the above measurements were carried out by the pilot when the instruments were returned after each measurement loop to check the correct operation and stability of the instruments. These limited measurements included:

- Check of the operation of the transfer Cu fixed point using the NPL LP3 and the NPL primary Cu point.
- Check of the output of each of the two KC thermometers using the melt/ freeze transition of the transfer Cu fixed point source.
- Size-of-source effect of the two transfer thermometers.
- Re-calibration of the two KC radiation thermometers at the temperature points listed above, including check of gain and range ratios and LP3 ND filter transmission.
- Measurement of the melting transition of the circulating HTFP cells, including a cross-comparison of each of the transfer cells with the appropriate reference cell(s) being retained at NPL to check the stability of the circulating HTFPs.

6 MEASUREMENTS AT THE PARTICIPATING LABORATORIES

Full details of the inspection and calibration procedure to be carried out at each participating NMI are given in the Protocol for the comparison (Appendix 1). The measurements are summarised below. In each case the measurements were to be carried out using the usual procedure used by each participant, taking into account any particular instructions within the protocol (such as the thermometer working distance).

- Check of the output of each of the two transfer radiation thermometers using the melt/ freeze transition of the transfer Cu fixed point source. This was required to be done both after receipt of the thermometers and at the end of the measurements, before transportation to the next participant.
- Calibration of each transfer radiation thermometer, in terms of the ITS-90, at each of the calibration temperatures from 960 °C to 3000 °C (to as high a temperature as was achievable within the participant’s laboratory), using the method of ITS-90 scale realisation applicable for each participant*.

- Measurement of the size-of-source effect (SSE), gain or range ratios and the transmission of the LP3 ND filter.
- Determination of the ITS-90 temperature of the point of inflection (poi) of the melting transition of the supplied HTFPs using the primary radiation thermometer used for high temperature ITS-90 scale realisation within the participant's laboratory.
- Any additional supplementary measurements if these formed part of the usual necessary calibration procedure for a high temperature radiation thermometer (for example if they were required to fully assess the calibration uncertainties).
- Measurements of the lateral uniformity of both the high temperature furnace used for the calibration of the KC radiation thermometers and the furnace used for the HTFP measurements (to enable any additional corrections and/ or uncertainty contributions to be assessed).

*This was usually using a high temperature blackbody source and reference radiation thermometer. However, NMIJ elected to realise the ITS-90 directly using the transfer thermometer by performing a full characterisation (spectral response, non-linearity) and a calibration at an ITS-90 reference fixed point. NMIJ then reported the expected thermometer output signal for each calibration temperature.

The participants provided the pilot with a report in the form of an Excel spreadsheet giving the calibration results and associated uncertainties, along with a Word document describing the equipment used and appropriate details of the measurement method.

Important note: due to the situation at the current time it has been necessary to exclude the results of VNIIM from any published comparison report. Therefore, for this interim Final report the VNIIM data have been removed from the data analysis and presentation of results. It is the intention that an addendum to this final comparison report will be published at a future date, to include the VNIIM results.

7 STABILITY OF THE TRANSFER THERMOMETERS

The stability of the transfer thermometers was measured using the transfer Cu fixed-point source. Participants were requested to check the transfer thermometers, using the fixed point, soon after receipt of the instruments at their institute, and also at the end of their measurements before the thermometers were transported to the next institute. The reported values, for each set of measurements with each thermometer, were the average of the output signals obtained during the central half of two freezing plateaux, corrected for the dark reading (background) of the thermometer.

Table 7 and Table 8 and Figure 3 and Figure 4 show the drift of the transfer thermometers over the course of the comparison, based on the results of the transfer Cu fixed-point check measurements. The drift has been presented in the form of equivalent temperature differences, ΔT, from the initial NPL measurements. The differences have been calculated using Equation 1:

$$\Delta T = \frac{\Delta S}{S} \; \frac{\lambda T^2}{c_2} \qquad (1)$$

where ΔS is the difference in thermometer output signal, S, between the participant measurements and the original pilot measurements, λ is the nominal thermometer wavelength (650 nm), c_2 is the second radiation constant (0.014388 m K) and T is the copper fixed point temperature (1357.77 K).

Both thermometers drifted over the duration of the comparison, equivalent to a maximum of around 0.7 °C for the LP3 and around 0.85 °C for the Chino thermometer. The cause of the drift is not completely clear. NPL has seen an upward drift in the signal of its own LP3, albeit mainly at 900 nm rather than 650 nm. Potentially this is a filter or gain effect. However, the drift seen with the transfer

LP3 during the comparison appears to be no larger than would be expected from the manufacturer's specification. NMIJ noticed, prior to sending the Chino thermometer to NPL at the start of the comparison, that it had drifted from its previous calibration. Potentially there was some initial instability after manufacture, which resolved over time, leading to the smaller drift from about October 2015.

Table 7 - the drift of the LP3 transfer thermometer

Date	Laboratory	I_{ph} at Cu check / A	Equivalent temperature difference from start/ °C	Average difference from start*/ °C
04-Sep-14	NPL	2.16887E-10	0.00	0.00
03-Oct-14	NPL	2.16785E-10	-0.04	
04-Dec-14	NMIJ	2.17081E-10	0.07	0.15
26-Jan-15	NMIJ	2.17349E-10	0.18	
18-Feb-15	NMIJ	2.17388E-10	0.19	
01-Apr-15	NIM	2.17234E-10	0.13	0.14
24-Apr-15	NIM	2.17359E-10	0.18	
11-May-15	NIM	2.17198E-10	0.12	
29-May-15	KRISS	2.17571E-10	0.26	0.30
11-Jul-15	KRISS	2.17758E-10	0.33	
31-Jul-15	NPL	2.17089E-10	0.08	0.13
08-Sep-15	NPL	2.17374E-10	0.19	
10-Oct-15	NRC	2.17583E-10	0.27	0.29
30-Oct-15	NRC	2.17626E-10	0.28	
19-Nov-15	NRC	2.17751E-10	0.33	
27-Jan-16	NIST	2.17383E-10	0.19	0.16
06-Jun-16	NIST	2.17216E-10	0.13	
16-Sep-16	NPL	2.17119E-10	0.09	0.18
20-Oct-16	NPL	2.17601E-10	0.27	
08-Nov-17	NPL	2.18147E-10	0.48	0.50
08-Jan-18	NPL	2.18237E-10	0.52	
05-Mar-18	LNE-Cnam	2.18310E-10	0.55	0.54
18-Apr-18	LNE-Cnam	2.18280E-10	0.53	
16-May-18	PTB	2.18399E-10	0.58	0.58
18-Jul-18	CEM	2.18796E-10	0.73	0.68
25-Sep-18	CEM	2.18516E-10	0.63	
28-Jan-20†	NPL	2.18888E-10	0.66	0.66

* The average difference is calculated from the average of the participant values. The start point reference signal is taken to be the NPL September 2014 photocurrent value. (Note: The difference between the September and October 2014 NPL values was considered to be negligible; hence the average difference from the start was taken to be 0.00 °C.)

† For technical and other reasons during the final NPL measurements, the Cu point measurement was only carried out once, close in time to the thermometer calibration measurements, and using the NPL Cu fixed point rather than the transfer Cu cell. An appropriate correction was applied to take into account the measured difference in temperature between the NPL and the transfer Cu cells, using the average of the measurements which had been made throughout the comparison (see Table 9).

Table 8 - the drift of the Chino transfer thermometer

Date	Laboratory	Signal at Cu check/ V	Equivalent temperature difference from start/ °C	Average difference from start[‡] / °C
15-Aug-14	NPL	2.5103E-02	0.00	0.00
30-Sep-14	NPL	2.5186E-02	0.28	
05-Dec-14	NMIJ	2.5174E-02	0.23	0.19
28-Jan-15	NMIJ	2.5219E-02	0.38	
17-Feb-15	NMIJ	2.5214E-02	0.37	
01-Apr-15	NIM	2.5231E-02	0.42	0.38
24-Apr-15	NIM	2.5271E-02	0.56	
11-May-15	NIM	2.5273E-02	0.57	
29-May-15	KRISS	2.5250E-02	0.49	0.34
11-Jul-15	KRISS	2.5243E-02	0.46	
05-Aug-15	NPL	2.5263E-02	0.53	0.42
08-Sep-15	NPL	2.5281E-02	0.59	
10-Oct-15	NRC	2.5278E-02	0.58	0.48
30-Oct-15	NRC	2.5296E-02	0.64	
19-Nov-15	NRC	2.5298E-02	0.65	
27-Jan-16	NIST	2.5307E-02	0.68	0.54
06-Jun-16	NIST	2.5305E-02	0.67	
16-Sep-16	NPL	2.5290E-02	0.62	0.54
20-Oct-16	NPL	2.5322E-02	0.73	
08-Nov-17	NPL	2.5323E-02	0.73	0.62
08-Jan-18	NPL	2.5338E-02	0.78	
05-Mar-18	LNE-Cnam	2.5344E-02	0.80	0.64
18-Apr-18	LNE-Cnam	2.5332E-02	0.76	
17-May-18	PTB	2.5335E-02	0.77	0.63
18-Jul-18	CEM	2.5296E-02	0.64	0.57
25-Sep-18	CEM	2.5338E-02	0.78	
19-Feb-20[†]	NPL	2.5388E-02	0.84	0.70

[‡] The average difference is calculated from the average of the participant values. The start point reference signal is taken to be the average of the NPL August 2014 and September 2014 signals.

[†] For technical and other reasons during the final NPL measurements, the Cu point measurement was only carried out once, close in time to the thermometer calibration measurements, and using the NPL Cu fixed point rather than the transfer Cu cell. An appropriate correction was applied to take into account the measured difference in temperature between the NPL and the transfer Cu cells, using the average of the measurements which had been made throughout the comparison (see Table 9).

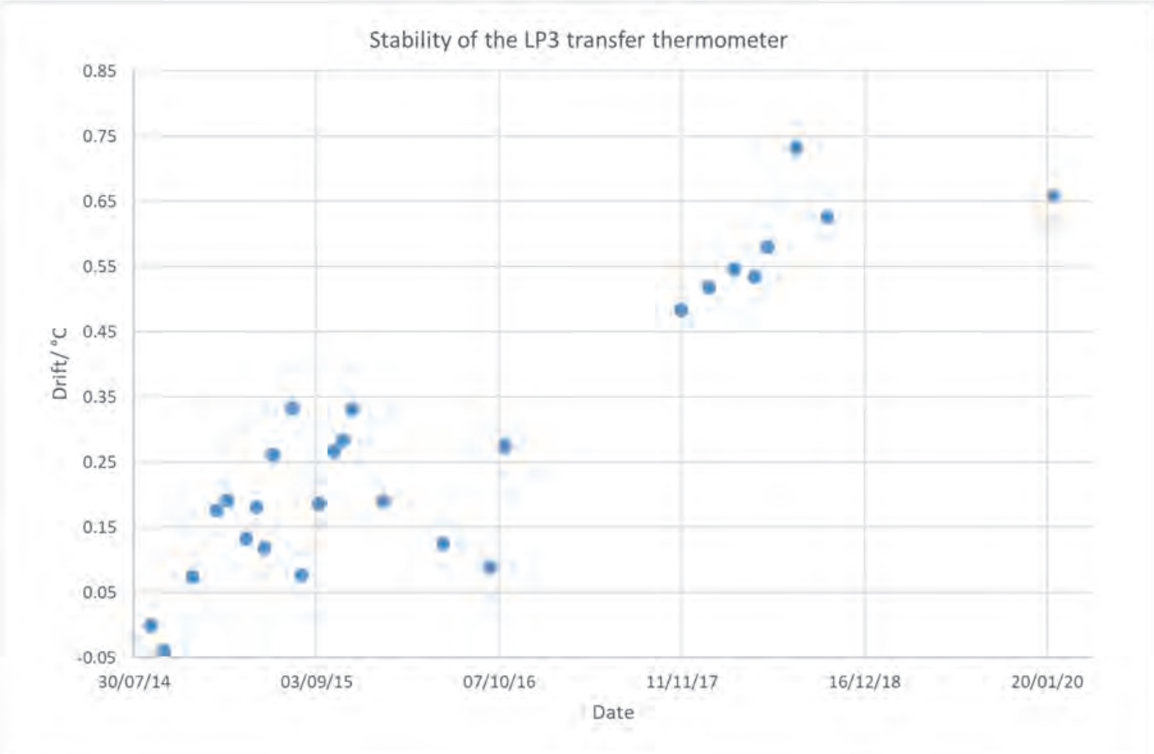


Figure 3 - the drift of the LP3 thermometer at the Cu point in terms of equivalent temperature difference from the start

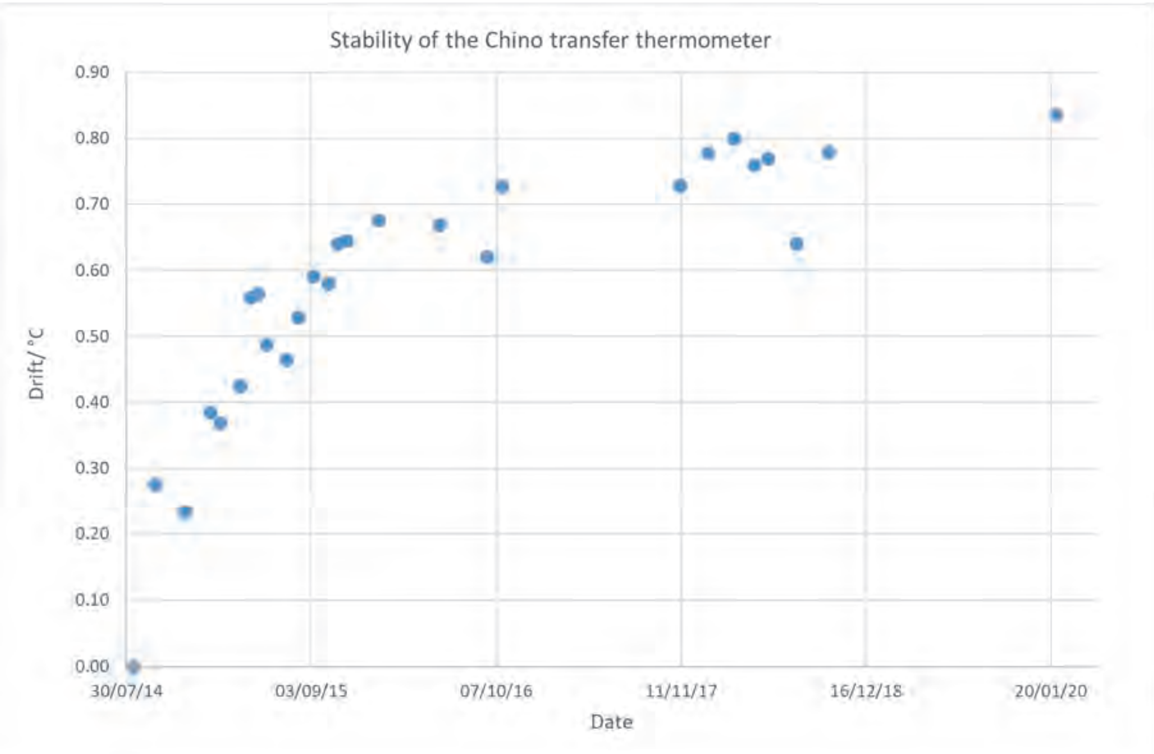


Figure 4 - the drift of the Chino thermometer at the Cu point in terms of equivalent temperature difference from the start

An additional component was included in each participant's overall uncertainty budget to allow for the uncertainty of the correction due to the thermometer drift during the measurements by that participant.

This additional component was the semi-range of the difference between the corrections calculated from, respectively, the Cu check at the start and the Cu check at the end of each participant's measurements, scaled according to the ratio of the squares of the temperatures, in kelvin (T_x^2/ T_{Cu}^2). NMIJ had already included a component for drift in the uncertainty budgets, so no additional component was required. For PTB, who had only carried out one Cu point check, the uncertainty was the semi-range of the difference between the average correction of LNE-Cnam and the average correction of CEM. For the NPL (Jan 2020) results the uncertainty component was the average of the semi-ranges of the corrections for the other NPL measurements. Note that the uncertainties due to the thermometer drift are, generally, a small component within the overall uncertainty of each participant's measurements.

To confirm the stability of the transfer Cu fixed-point source, NPL compared it to the NPL Cu fixed-point source via a calibrated radiation thermometer (the NPL LP3). The measurements were carried out at the start of the comparison and after each loop (except for the last loop (Jan 2020), as explained above). Table 9 shows the results of the comparisons. The temperature of the NPL Cu cell was assumed to be 1084.62 °C. The reported temperatures are from the average measurements made during the central half of each freezing plateaux of the transfer cell.

Table 9 - the results of the comparison of the transfer Cu cell with the NPL Cu cell

Date	$T_{\text{transfer Cu freeze}}$/ °C
August 2014	1084.47
July/ August 2015	1084.52
Sept 2016	1084.52
Nov 2017	1084.52
Average $t_{\text{NRC Cu freeze}}$**/ °C**	**1084.51**

8 RESULTS OF THE AUXILIARY MEASUREMENTS

The results of the various auxiliary measurements related to the transfer thermometers are given in the Sections below. Note that not all participants performed all the measurements.

8.1 SIZE-OF-SOURCE EFFECT MEASUREMENTS

The results of the size-of-source effect measurements carried out by the pilot laboratory for the LP3 and Chino thermometer are given in Figure 5 and Figure 6 respectively. The measurements were carried out by the indirect method, using an integrating sphere with the central obscuration provided by a small blackbody of nominally 3 mm diameter.

It can be seen that the September 2014 results for the LP3 are noticeably higher than the October 2016 results. However, the difference in the corrections from 3 mm diameter to 25 mm diameter, using each set of the results, is equivalent to only around 75 mK at 3000 °C (i.e., the difference between an SSE value of 0.00074 in September 2014 (SSE at 25 mm diameter) and 0.00057 in October 2016 (SSE at 25 mm diameter)).

Since the specific SSE set-up for each of the participants (e.g., maximum (reference) aperture diameter) were not the same (meaning, for example, that any ratio measurements (SSE at aperture diameter *i*/ SSE at maximum aperture diameter) would not be equivalent), plus the SSE results obtained by each participant were only being used to correct the calibration results if required (see Section 8.1.1), the SSE results from different participants are not compared.

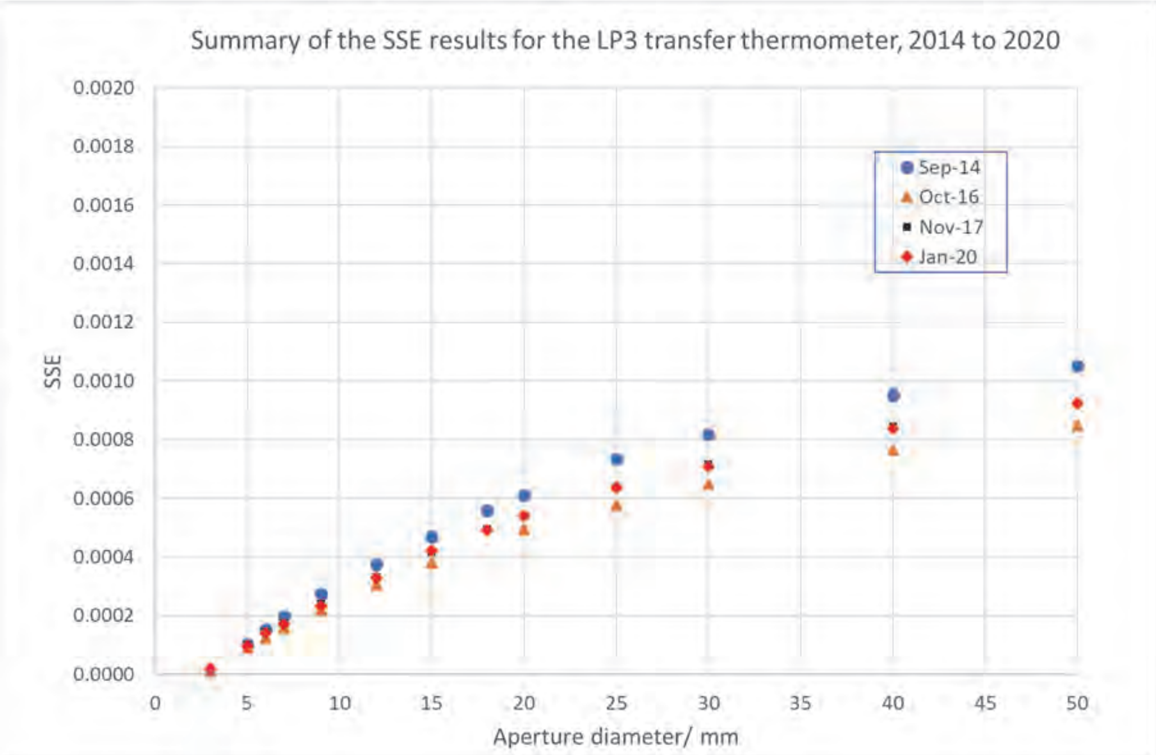


Figure 5 - NPL SSE results for the LP3 transfer thermometer

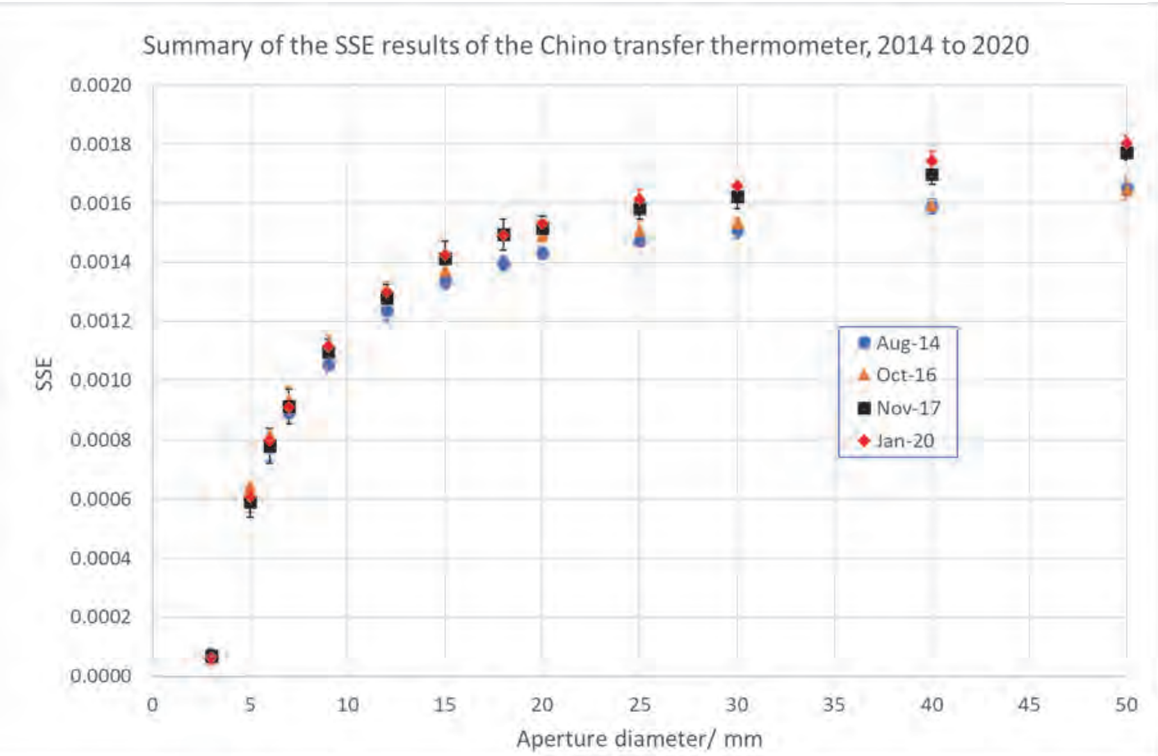


Figure 6 - NPL SSE results for the Chino transfer thermometer

8.1.1 Correction of the participant data to the reference aperture size

Table 10 gives a summary of the aperture sizes of the high temperature blackbodies (HTBBs) used by the participants for the calibration of the two transfer thermometers. Where the aperture size was different to 25 mm (the reference aperture for the comparison) a correction was applied to the thermometer results by the participant, using the SSE data for the radiation thermometer. Each participant determined the approach for taking into consideration the thermal profile of the blackbody source; for example, by determining the effective diameter of the source or including a component for non-uniformity in the uncertainty budget. The raw participant results presented in Table 118 to Table 130 for the LP3 and Table 131 to Table 143 for the Chino thermometer (refer to Section 9) are the corrected results.

Table 10: the aperture diameters of the participants' HTBBs

Participant	HTBB aperture size/ mm
NPL	25
NMIJ	8 (effective diameter 13.5)
NIM	38
KRISS	25
NRC	25
NIST	25
PTB	20
LNE-Cnam	5.2 up to 2400 °C, 3 mm above 2400 °C
CEM	10 from 960 °C to 2200 °C, 12 from 2000 °C to 2600 °C

8.2 GAIN AND RANGE RATIO MEASUREMENTS

The results of the range (for the LP3) and gain (for the Chino thermometer) ratio measurements are given Table 11 and Table 12 respectively. Note that not all participants measured these.

Table 11 - the range ratios of the LP3 transfer thermometer

Participant	LP3 range ratio, R2/R1
NPL (Sept 2014)	1.000432
NMIJ	1.000478
NIM	1.000420
KRISS	1.000411
NPL (Aug 2015)	---
NRC	1.000570
NIST	1.000208
NPL (Oct 2016)	1.000635
NPL (Jan 2018)	---
LNE-Cnam	---
PTB	1.000713
CEM	0.998219
NPL (Jan 2020)	1.000530

Notes: The CEM value is significantly different from the other values for reasons which are not known. For the data analysis the average of the range ratio values from the other participants was used to correct the CEM results. Similarly, the average of the range ratio values from the other participants was used to correct the LNE-Cnam results, the NPL (Aug 2015) results and the NPL (Jan 2018) results, where no range ratio was measured at the time (see Sections 9.1 and 9.2).

Table 12 - the gain ratios of the Chino transfer thermometer.

Participant	**Chino gain ratio L range/ M range**	**Chino gain ratio M range/ H range**
NPL (Sept 2014)	10.04446	9.99137
NMIJ	10.04626	9.99190
NIM	10.04793	9.99145
KRISS	10.04624	9.99275
NPL (Aug 2015)	10.04712	9.99104
NRC	10.04903	9.99105
NIST	---	---
NPL (Oct 2016)	10.04757	9.98705†
NPL (Jan 2018)	10.05062	9.99225
LNE-Cnam	10.05060	9.99163
PTB	---	---
CEM	10.05118	9.99153
NPL (Jan 2020)	10.05073	9.99219

†Note that the NPL Oct 2016 M/H ratio is noticeably smaller than the others, likely due to furnace drift during the measurements. This value was ignored when calculating the gain ratio uncertainty component (see Section 10.4.2).

8.3 LP3 NEUTRAL DENSITY (ND) FILTER TRANSMISSION

The results of the LP3 neutral density filter transmission measurements are given in Table 13.

Table 13 - the measurements of the LP3 ND filter transmission

Participant	**ND filter transmission**
NPL (Sept 2014)	0.12329
NMIJ	0.12334
NIM	0.12338
KRISS	0.12353
NPL (Aug 2015)	---
NRC	0.12356
NIST	0.12361
NPL (Oct 2016)	0.12384
NPL (Jan 2018)	0.12402
LNE-Cnam	0.12400
PTB	0.12409
CEM	0.12414
NPL (Jan 2020)	0.12435

It can be seen that the transmission of the neutral filter is gradually drifting over the course of the comparison. For the data analysis the average of the KRISS and NRC transmission values was used to correct the NPL (Aug 2015) results (see Section 9.1).

8.4 LP3 SPECTRAL RESPONSE MEASUREMENTS

The spectral response of the transfer LP3 thermometer was measured by the pilot three times: at the start of the comparison (September 2014), part way through the comparison (October 2016) and at the end of the comparison (November 2019).

The measurements were carried out using a scanning monochromator with a tungsten ribbon lamp as the radiance source. The calibration of the monochromator was checked regularly during the measurement process using a neon emission line source, using a number of emission lines across the wavelength range of the scan, with the monochromator wavelength being corrected accordingly.

On each occasion a series of runs was carried out both with the 650 nm filter in place and without the filter (using a ‘blank’ position of the filter wheel). The spectral response was determined from the ratio of the LP3 ‘filter in’ and ‘filter out’ scan signals (with background deducted) at each wavelength step.

Next, for each of the runs, the effective wavelength at the Cu fixed-point temperature was determined using NPL-written software, and assuming a spectral response for the silicon detector.

The resultant calculated values for the effective wavelength at the copper point for each of the three calibrations are given in Table 14, along with the estimated k = 2 uncertainties. The λ_{eff} values are each the average of at least three measurements. The uncertainties are comprised of:

- The correction of the monochromator wavelength (including differences between repeat emission line scans at the beginning and end of the day and the interpolation of the wavelength corrections between emission lines).
- The software calculation (integration) uncertainty.
- Uncertainty due to the assumption of the detector response.
- The repeatability of the calibration (the standard deviation of the results of a minimum of three runs during each measurement set).

Table 14 - the average calculated values of the effective wavelength (at the Cu point) for the transfer LP3

Date	**Average λ_{eff} (Cu point)/ nm**	***U* (*k* = 2)/ nm**
Sept 2014	651.655	0.16
Oct 2016	651.683	0.13
Nov 2019	651.810	0.10

The November 2019 result is higher than the previous values. This might be a result of drift in the response of the filter, but the difference is similar in magnitude to the measurement uncertainties.

8.5 CHINO THERMOMETER SPECTRAL RESPONSE MEASUREMENTS

The spectral response of the Chino thermometer was measured by NMIJ prior to the start of the comparison (in June 2014). The results are shown in the Figure 7 below. The calculated effective wavelength at the Cu point, λ_{eff} (Cu point), is 651.841 nm.

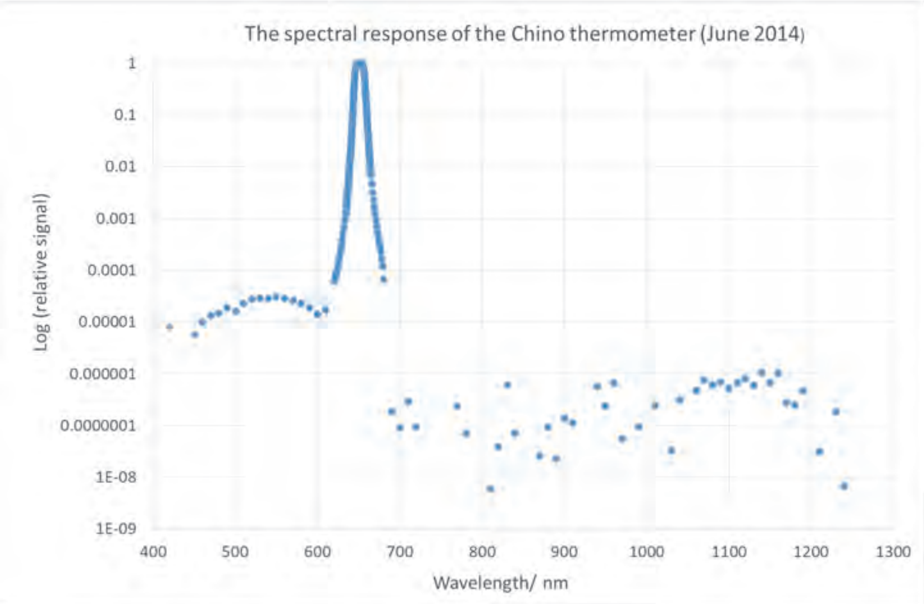


Figure 7 - the spectral response of the Chino thermometer

8.6 TRANSFER THERMOMETER LINEARITY MEASUREMENTS

The linearity of the two transfer thermometers was measured at NPL using the NPL high temperature (Thermo Gauge) blackbody source. A radiance doubling method was used, using an aperture system. The aperture system consists of two semi-circular segments, which are removed in turn to perform a series of measurements of the thermometer signal with segment 1 removed, or segment 2 removed or both segments removed. The non-linearity, *NL*, is then calculated using Equation 2.

$$NL = \frac{S_1 + S_2}{S_{1+2}} \qquad (2)$$

where S_1 is the thermometer signal with only segment 1 removed, S_2 is the thermometer signal with segment 1 replaced and only segment 2 removed, and S_{1+2} is the thermometer signal with both segment 1 and segment 2 removed. (Note that all thermometer signals were corrected for the background (dark reading)).

The measurements were carried out at a number of different blackbody temperatures (signal levels) and with the appropriate gain/ range settings. The results of the measurements (non-linearity ratio versus S_{1+2} signal) are given in the Figure 8 and Figure 9 for the LP3 and Chino thermometer respectively.

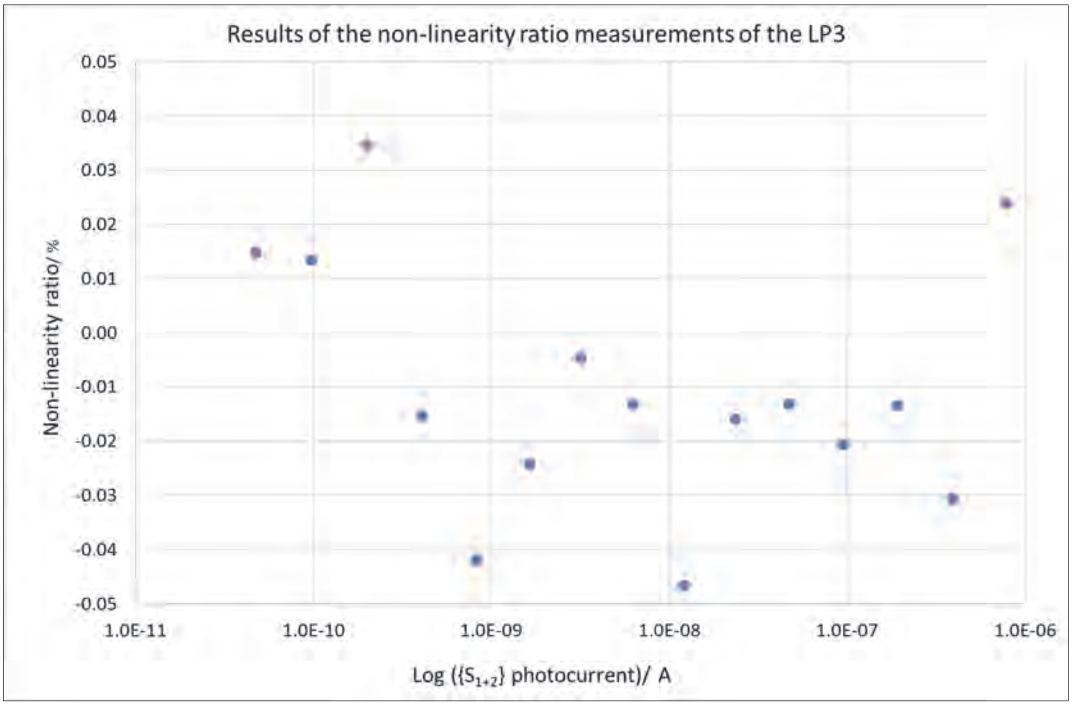


Figure 8 - the results of the non-linearity measurements with the LP3

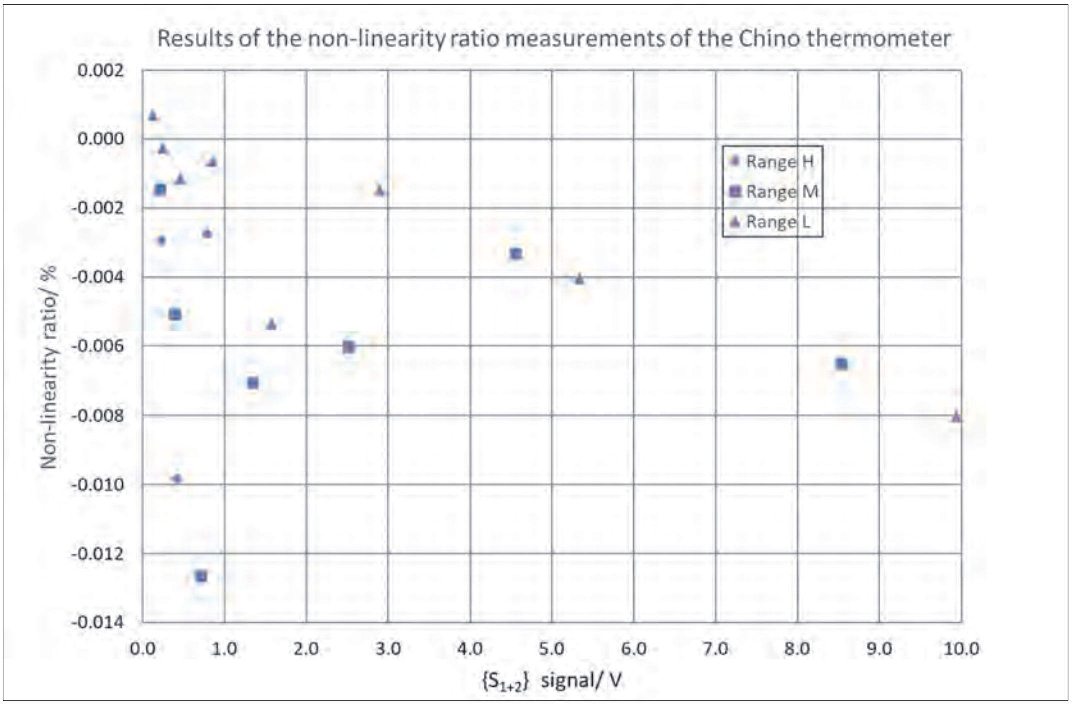


Figure 9 - the results of the non-linearity measurements with the Chino thermometer

The non-linearity correction factors were determined by setting the correction to 1.000 for the lowest S_{1+2} signal and then, for each S_{1+2} signal, multiplying each of the preceding linearity values together [2]. The factors for the LP3 and Chino thermometer are given in, respectively, Figure 10 and Figure 11. (Note that the results are given for information only; no corrections for non-linearity were applied to the thermometer results).

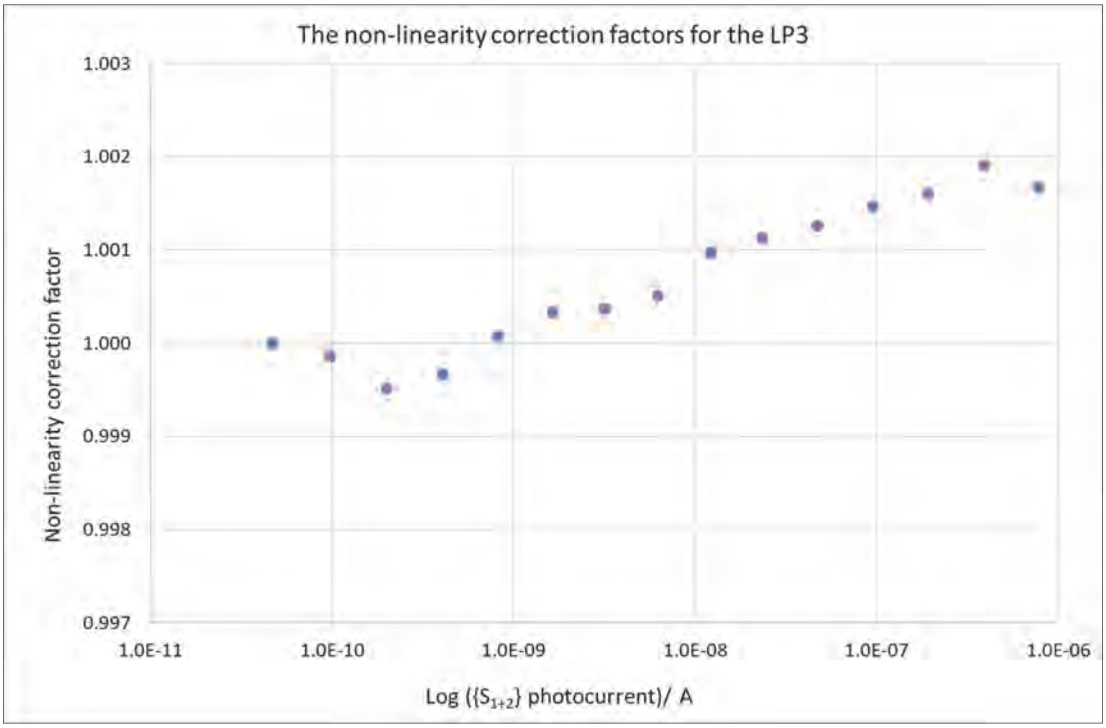


Figure 10 - the non-linearity correction factors for the LP3

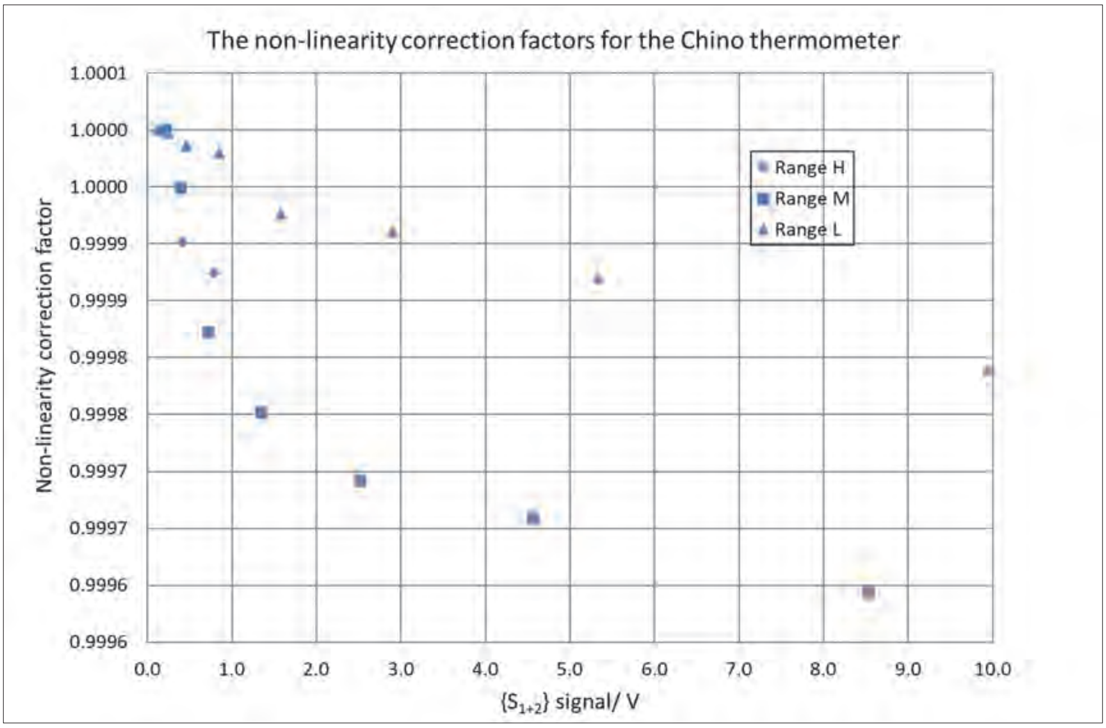


Figure 11 - the non-linearity correction factor for the Chino thermometer

9 RESULTS OF THE CALIBRATIONS OF THE TWO TRANSFER THERMOMETERS

9.1 RESULTS OF THE CALIBRATIONS BY THE PILOT

For each of the two transfer thermometers the result (background (dark reading)-corrected signal versus the ITS-90 temperature) at each nominal comparison temperature was first normalised [corrected] to the actual comparison temperature, t_{nom}, (e.g. if the result was at t_{90} = 1699.9 °C then the thermometer output was corrected to give the equivalent output at t_{nom} = 1700 °C) using the sensitivity of the thermometer using Equation 3.

$$\Delta S = \Delta T \frac{c_2}{\lambda T^2} S \qquad (3)$$

where Δ*S* is correction to be applied to the thermometer output signal *S*, Δ*T* is the difference between the blackbody temperature *T* (= t_{90} in K) and the nominal comparison temperature T_{nom} (= t_{nom} in K), c_2 is the second radiation constant and *λ* is the (nominal) thermometer wavelength.

The results of all the calibrations of the LP3 thermometer by the pilot over the duration of the comparison were then compared to the results at the start (the September 2014 calibration), in terms of equivalent temperature difference from the start. The equivalent temperature differences, at each t_{nom}, were calculated using Equation 1. The temperature differences at each t_{nom} are shown in Figure 12.

The thermometer results at each t_{nom} were then corrected using the measurements with the transfer Cu fixed-point blackbody, to take into account the observed drift at the Cu point, in °C (refer to Table 7). The Cu drift was first scaled according to t_{nom} using Equation 4 and the resultant values for each t_{nom} were used to correct the thermometer results (i.e., the differences from the September 2014 calibration).

$$correction = drift\ at\ Cu\ \times \frac{(T_{nom})^2}{(T_{Cu})^2} \qquad (4)$$

where *correction* = correction at t_{nom} in °C, T_{nom} (K) = t_{nom} (°C) + 273.15 and T_{Cu} = 1357.77 K

Figure 13 shows all the NPL results at each t_{nom}, corrected to take into account the drift at the Cu point.

It can be seen that there are ‘step changes’ in the NPL results of the transfer LP3 thermometer, in particular corresponding to where the ND filter was used (above 2400 °C). The calibration results were therefore corrected using the measured ND filter transmission data and also the range ratio data so as to correspond to no neutral filter and range R2. The corrected results (corrected to range R2 and no ND filter) are given in Figure 14 (results only) and Figure 15 (results with error bars showing the *k* = 2 measurement uncertainties).

A comparison of Figure 13 and Figure 14 shows an improvement in the results (better agreement between the results of the different NPL calibrations). Therefore, for the analysis of the results of all the participants (see Section 9.2), the LP3 results were corrected for range ratio and ND filter transmission.

However, even after the various corrections have been applied it can be seen that the January 2020 results for the range from 960 °C to 1800 °C are noticeably offset from the other results, for reasons which are not clear. One possibility is that there is some aspect of the LP3 drift which is not being satisfactorily corrected using the Cu point drift – the change in the LP3 effective wavelength between the 2016 and 2019 measurements has been noted above. Above 1800 °C there is more variation in all the results, although within the *k* = 2 measurement uncertainties.

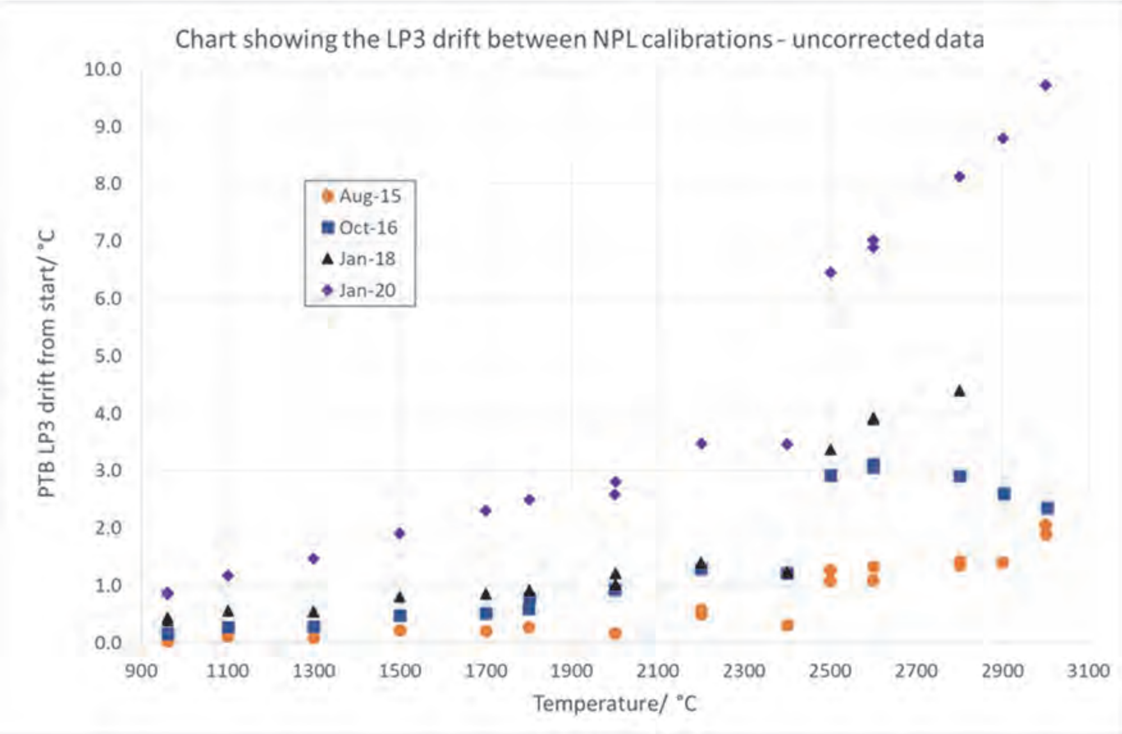


Figure 12 - the results of the NPL calibrations of the LP3 thermometer at each t_{nom}, in terms of equivalent temperature difference from the start (September 2014) – raw (uncorrected) data

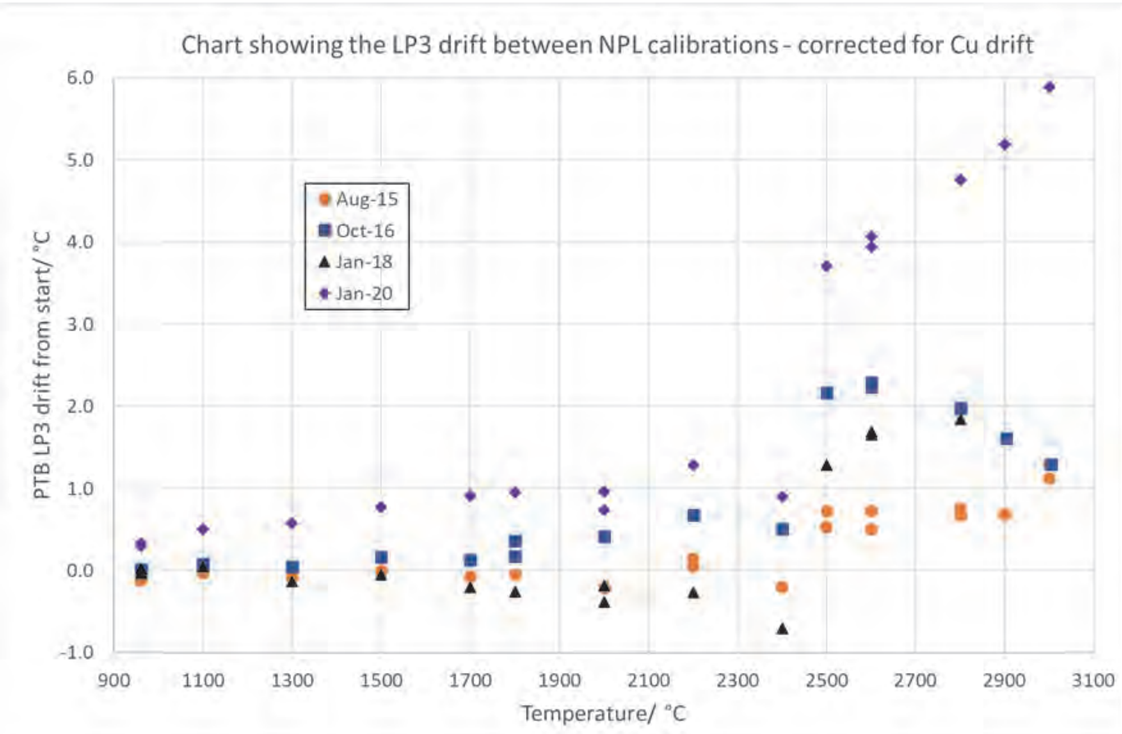


Figure 13 - the results of the NPL calibrations of the LP3 thermometer in terms of equivalent temperature difference from the start (September 2014) - corrected for Cu point drift

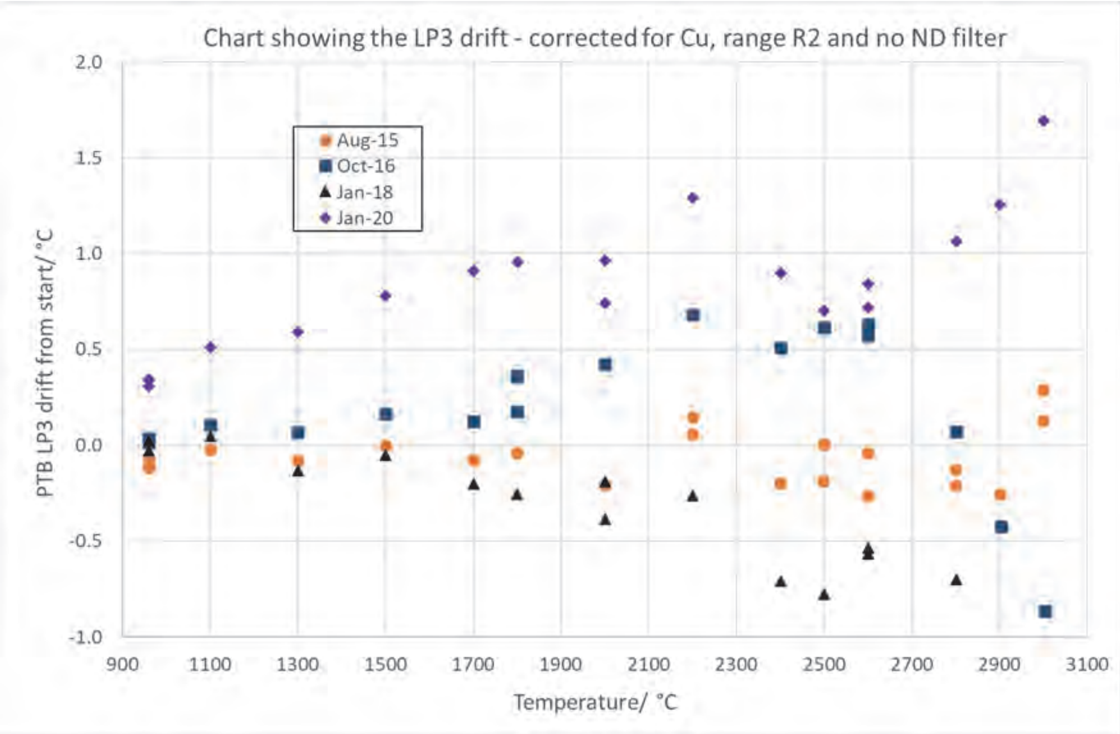


Figure 14 - the results of the NPL calibrations of the LP3 thermometer in terms of equivalent temperature difference from the start (September 2014) after correcting for Cu drift, range and ND filter transmission

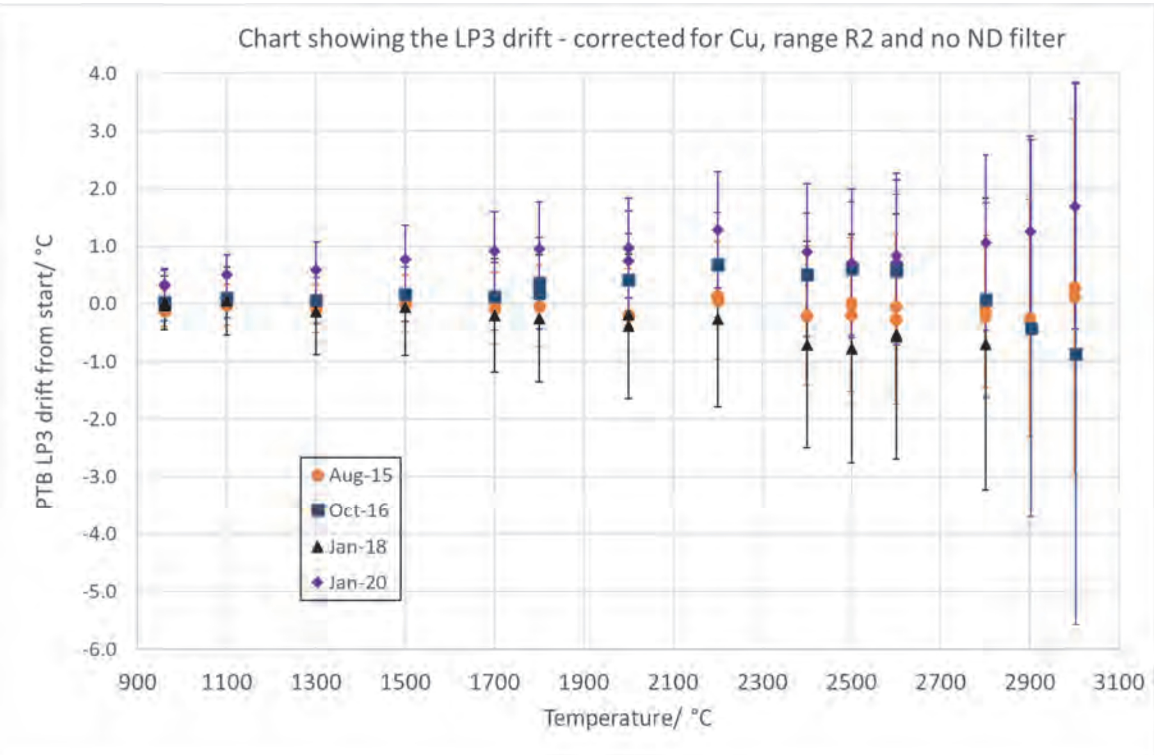


Figure 15 - the results of the NPL calibrations of the LP3 thermometer in terms of equivalent temperature difference from the start (September 2014). Error bars correspond to the k = 2 measurement uncertainties

Figure 16 and Figure 17 show the results of all the pilot calibrations of the Chino thermometer over the duration of the comparison, in terms of equivalent temperature difference from the start (September 2014 calibration). The equivalent temperature differences, at each t_{nom}, have been calculated using Equation 1. Figure 16 shows the 'raw' results (i.e., the results only corrected to t_{nom}); Figure 17 shows the results additionally corrected to take into account the drift at the Cu point (from Table 8), in the same way as described for the LP3 above. The 2900 °C and 3000 °C August 2015 measurements show an offset from the rest, likely due to issues with the temperature non-uniformity of the furnace.

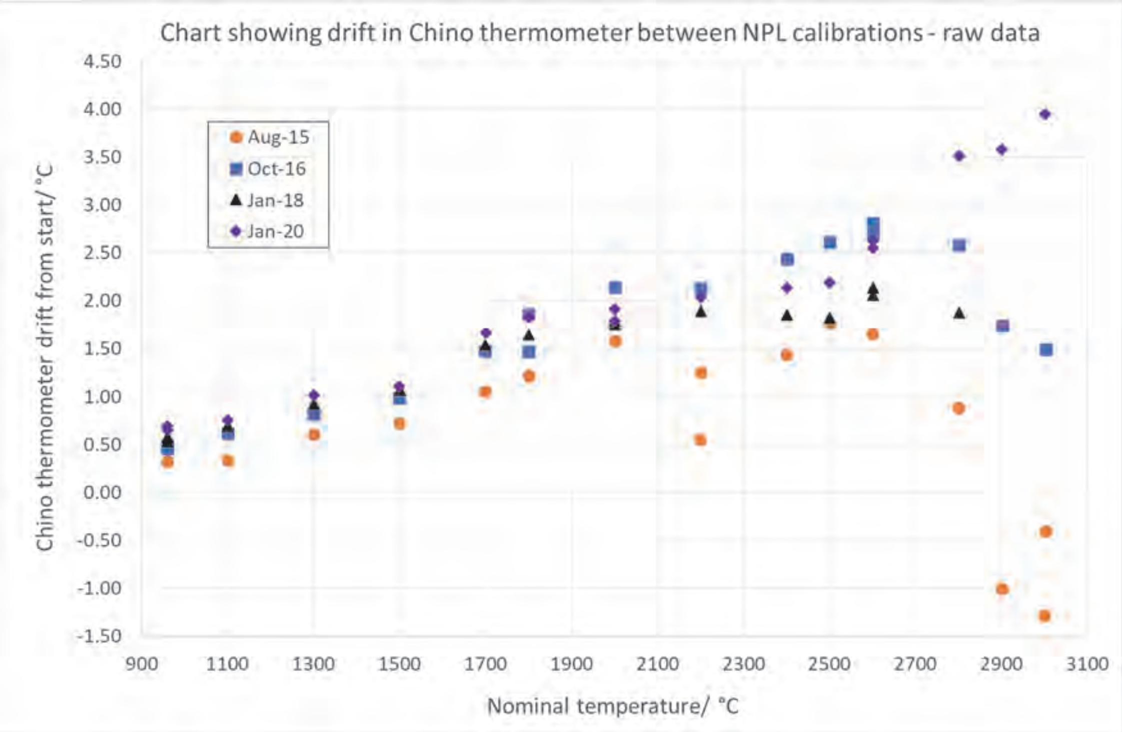


Figure 16 - the results of the NPL calibrations of the Chino thermometer at each t_{nom}, in terms of equivalent temperature difference from the start (September 2014) – raw (uncorrected) data

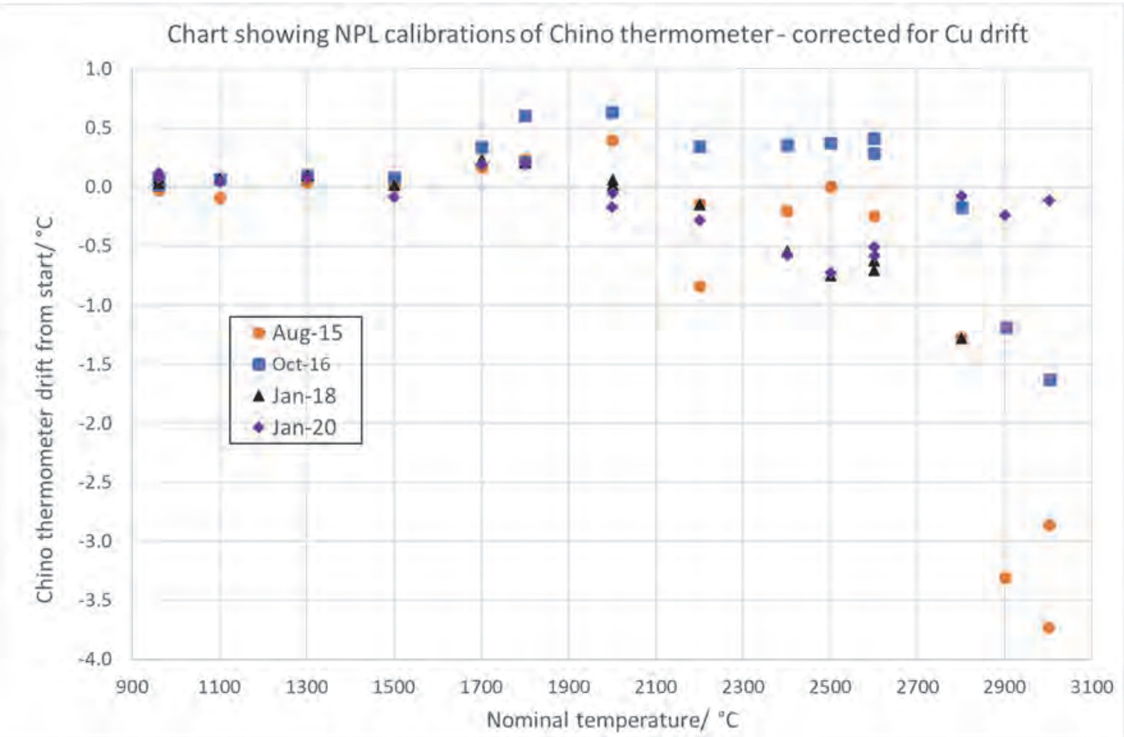


Figure 17 - the results of the NPL calibrations of the Chino thermometer in terms of equivalent temperature difference from the start (September 2014) - corrected for drift at the Cu point

There were no obvious step changes in the results of the Chino thermometer. However, the results of the NPL calibration were corrected to a common gain (gain ‘L’) so that the resulting graphs could be compared. These corrected results are shown in Figure 18 (results only) and Figure 19 (results with error bars showing the k = 2 measurement uncertainties).

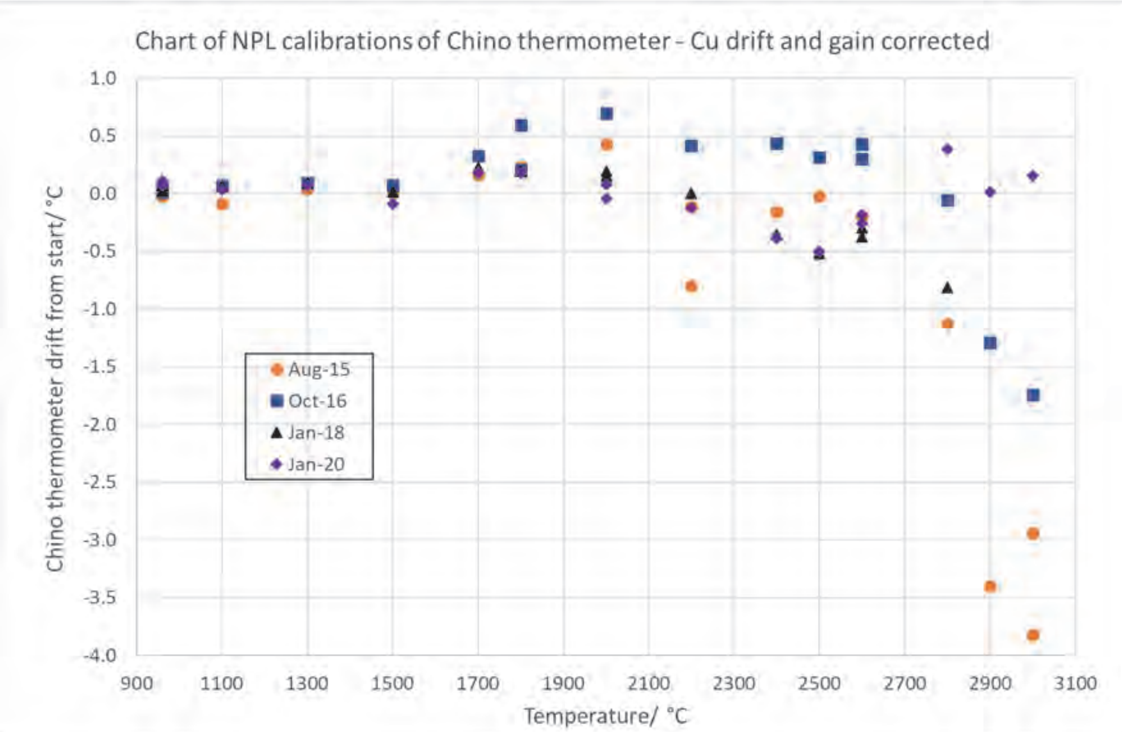


Figure 18 - the results of the NPL calibrations of the Chino thermometer in terms of equivalent temperature difference from the start (September 2014) – corrected for Cu drift and to the ‘L’ gain

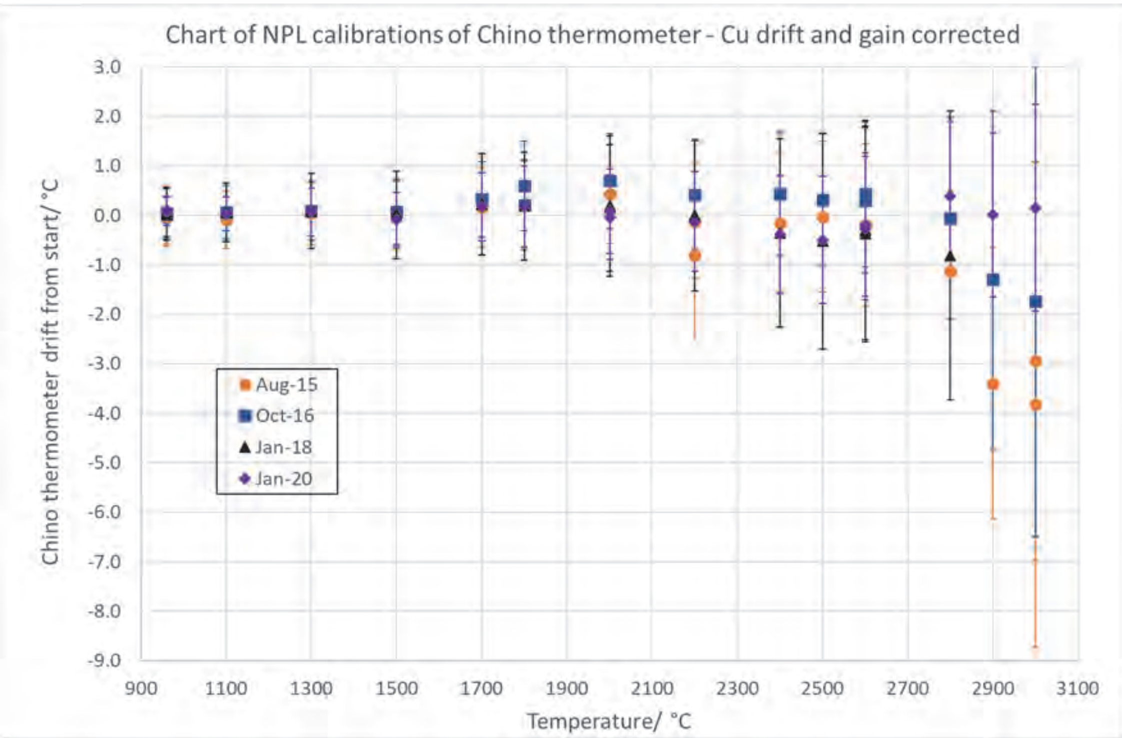


Figure 19 – the corrected results of the NPL calibrations of the Chino thermometer, with error bars showing the k = 2 measurement uncertainties

It can be seen that there is no significant difference in the observed drift between NPL calibrations whether or not the results are corrected to a common gain (Figure 17 and Figure 18). Therefore, for the analysis of the results of all the participants, only corrections to t_{nom} and for the Cu point drift were applied.

9.2 RESULTS OF THE CALIBRATIONS BY THE OTHER PARTICIPANTS

9.2.1 The calibration of the LP3 thermometer

The full results of the participant measurements with the LP3 thermometer are given in Table 118 to Table 130 in Appendix 2 along with the associated estimated uncertainties (k = 2). The results were obtained using the range and ND filter settings specified in the protocol (reproduced in Table 15 below for ease of reference) unless otherwise stated in the notes under the Tables in Appendix 2.

Table 15 – summary of the required range and ND filter settings for the LP3 measurements

Nominal temperature/ °C	Range setting	ND filter
960	R1	No
1100	R1	No
1300	R1	No
1500	R2	No
1700	R2	No
1800	R2	No
2000	R2	No
2200	R2	No
2400	R2	No
2500	R2	Yes
2600	R2	Yes
2800	R2	Yes
2900	R2	Yes
3000	R2	Yes

Table 118 to Table 130 present the 'raw' measurement data (blackbody temperature, t_{90}, and corresponding photocurrent, I_{ph}) (columns 2 and 3); I_{ph} corrected to the nominal calibration temperature, t_{nom}, (e.g. if the temperature of the participant's blackbody was 1699.8 °C then I_{ph} was corrected to correspond to a temperature of 1700 °C using Equation 1 above) (column 4); and I_{ph} corrected to correspond to range R2 and no ND filter using the range ratio and ND filter transmission measurements made by that participant (column 5). Where a participant did not measure the range ratio or ND filter transmission, the values were estimated from the results of the other participants (see notes under Table 11 and Table 13). Table 118 to Table 130 also present I_{ph} corrected to allow for the drift of the thermometer at the copper point from Table 7 using Equations 3 and 4 above (column 7), as well as both the participant measurement uncertainty, U_{lab}, and the uncertainty including a component for the thermometer drift during the participant's measurements (refer to the notes accompanying the Tables for details of the drift uncertainty component).

In cases where obvious outliers were evident participants were invited to check their data for typographical or arithmetical errors, without being given any specific information about the nature of the data anomaly. The values given in the Tables in Appendix 2 are the final values given by the participants, before circulation of the Draft A report.

The results of the calibrations, both raw and corrected, are given graphically in Figure 20 to Figure 26. The results are presented in terms of relative temperature differences from the first NPL calibration (NPL September 2014), calculated using the differences in signal values and using Equation 1.

Notes

1) The PTB results above 2500 °C show a tendency to be lower than those of the other participants. Following the circulation of the Draft A report this was determined as partly due to the correction for the neutral density filter in the PTB reference thermometer. Applying the appropriate correction would increase the PTB results by about 0.5 °C over the range from 2500 °C and 2900 °C.

2) The NPL Jan 2020 data were higher than the other data. There was no obvious reason for this.

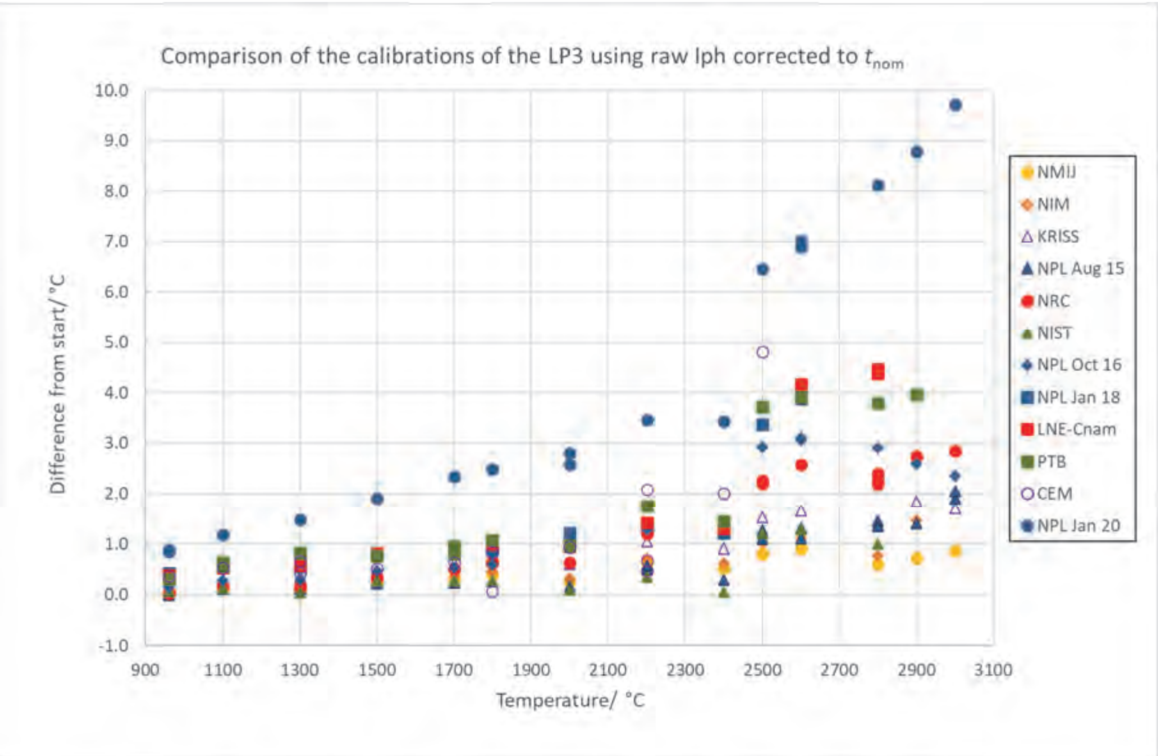


Figure 20 - results of the calibrations by all the participants, in terms of relative temperature difference from the start (NPL September 2014 calibration), corrected to t_{nom}

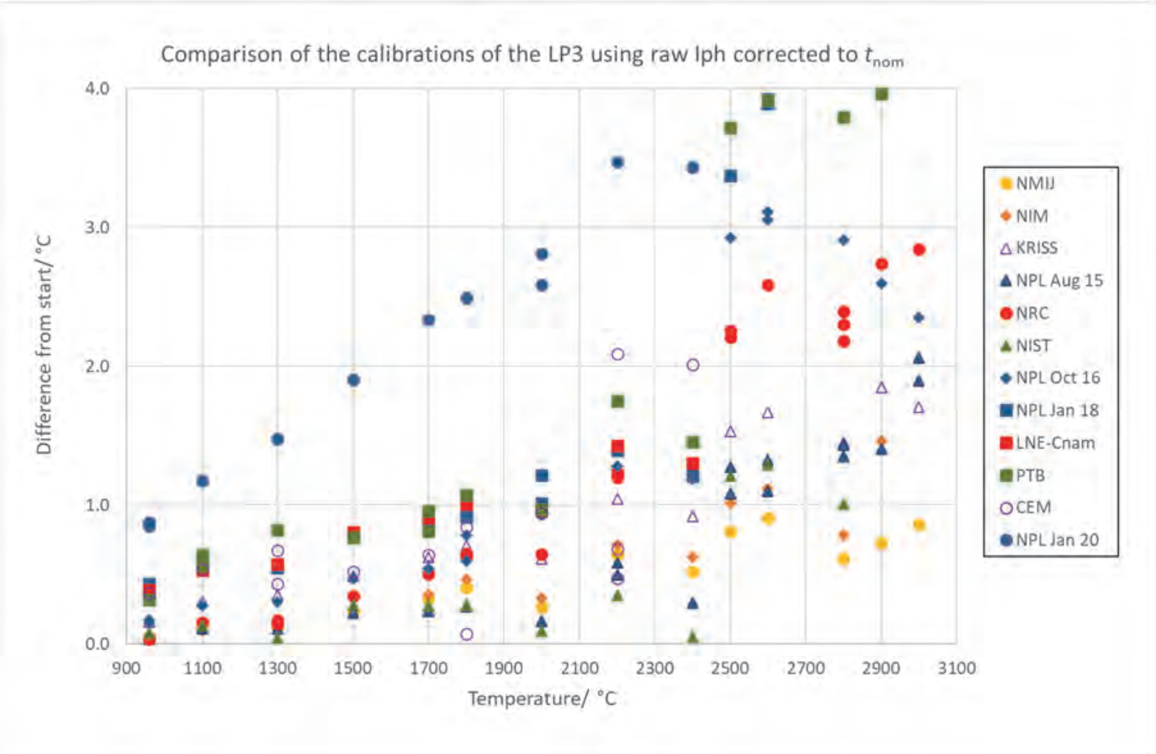


Figure 21 - results of the calibrations by all the participants, in terms of relative temperature difference from the start (NPL September 2014 calibration), corrected to t_{nom} (zoomed in)

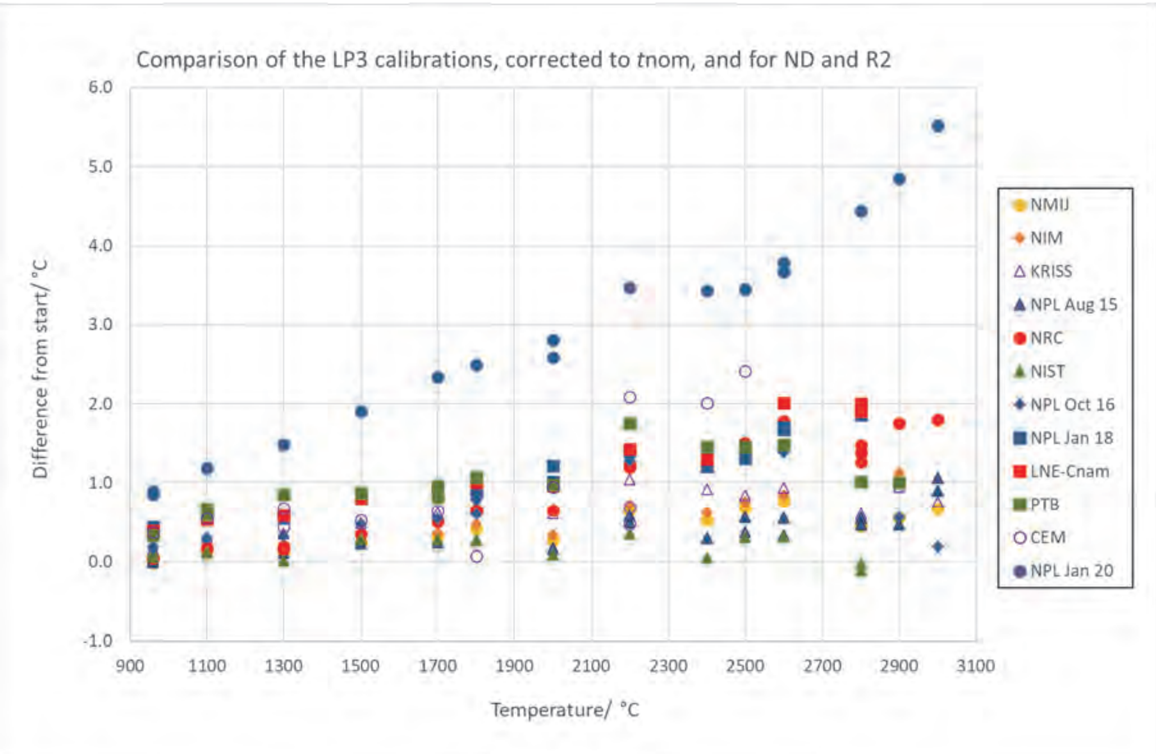


Figure 22 - results of the calibrations by all the participants, in terms of relative temperature difference from the start (NPL September 2014 calibration), corrected to t_{nom} and also to range R2 and no ND filter

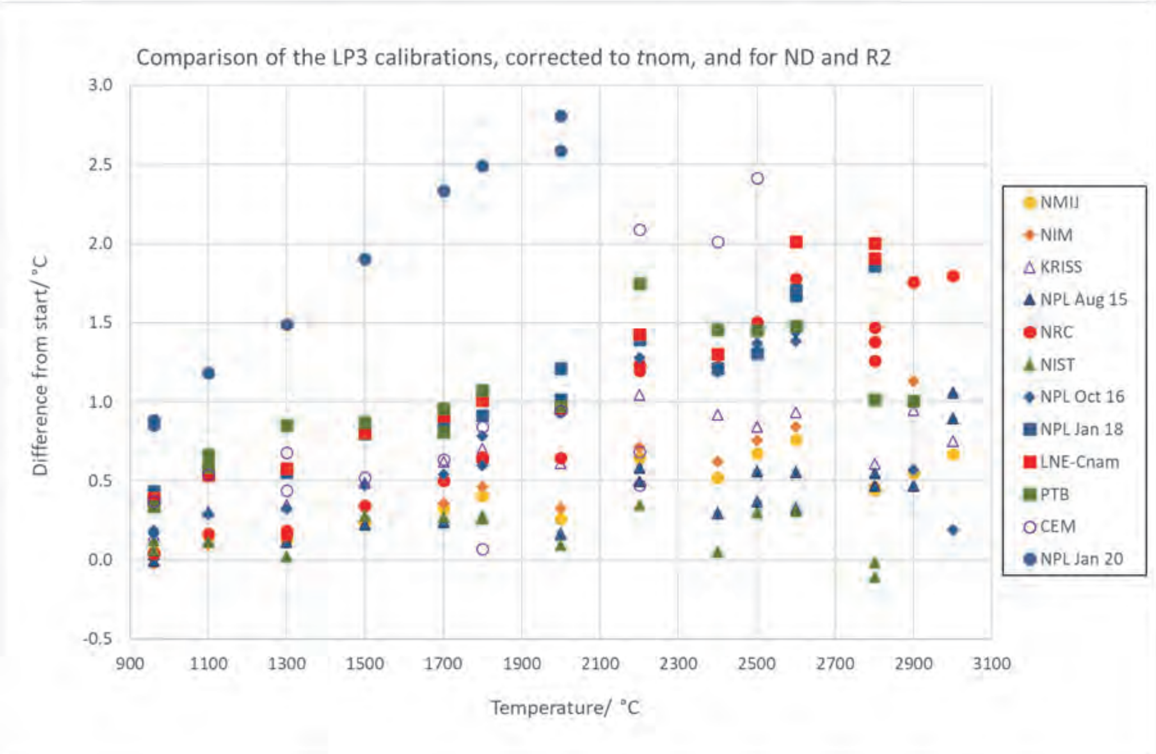


Figure 23 - results of the calibrations by all the participants, in terms of relative temperature difference from the start (NPL September 2014 calibration), corrected to t_{nom} and also to range R2 and no ND filter (zoomed in)

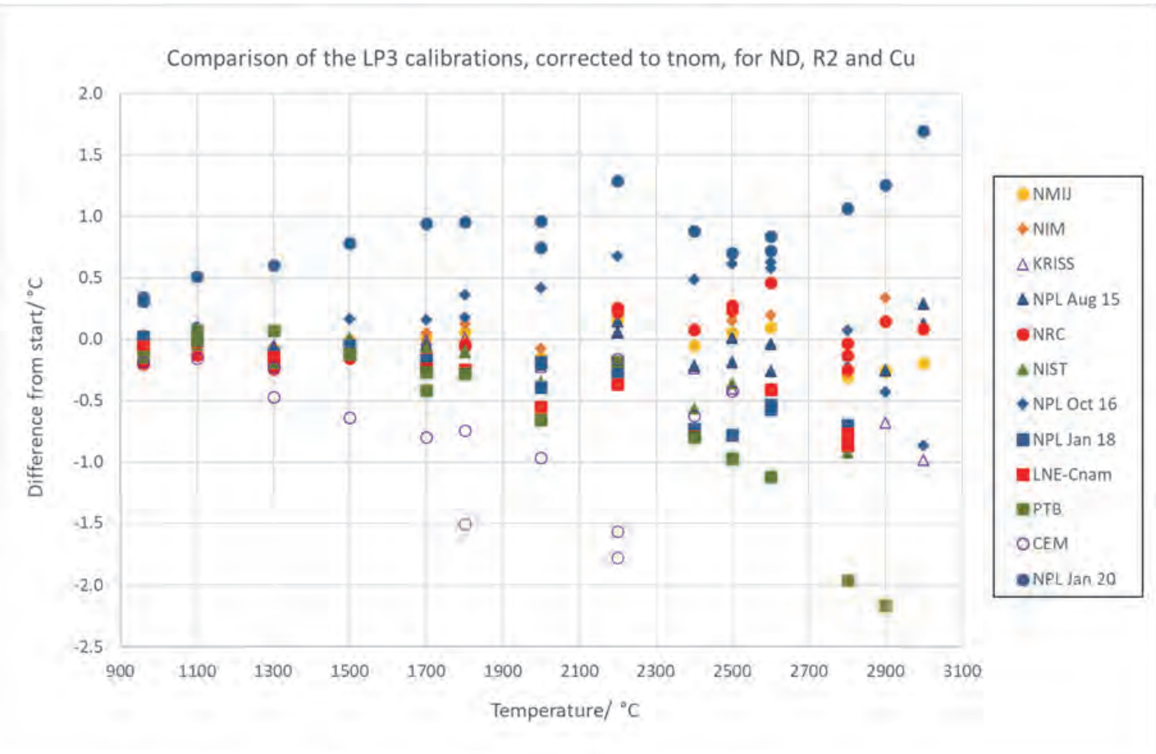


Figure 24 - results of the calibrations by all the participants, in terms of relative temperature difference from the start (NPL September 2014 calibration), corrected to t_{nom} and for range, ND filter and drift at the Cu point

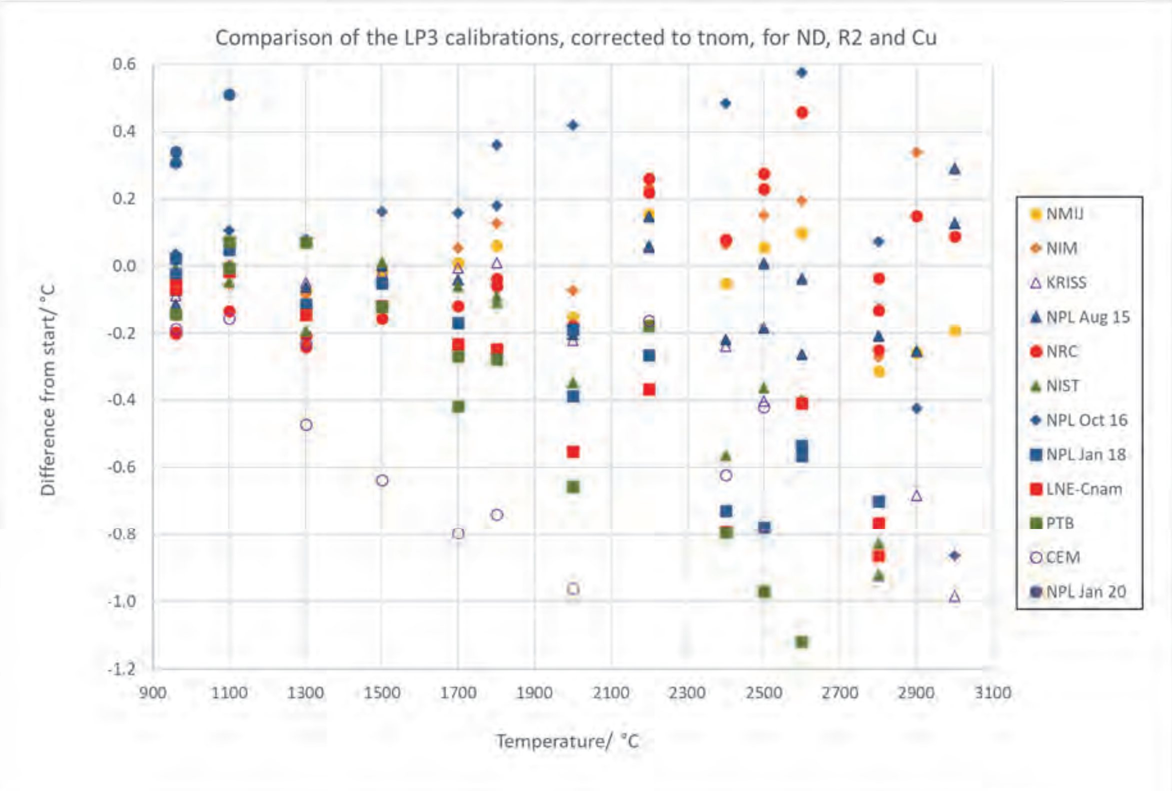


Figure 25 - results of the calibrations by all the participants, in terms of relative temperature difference from the start (NPL September 2014 calibration), corrected to t_{nom} and for range, ND filter and drift at the Cu point (zoomed in)

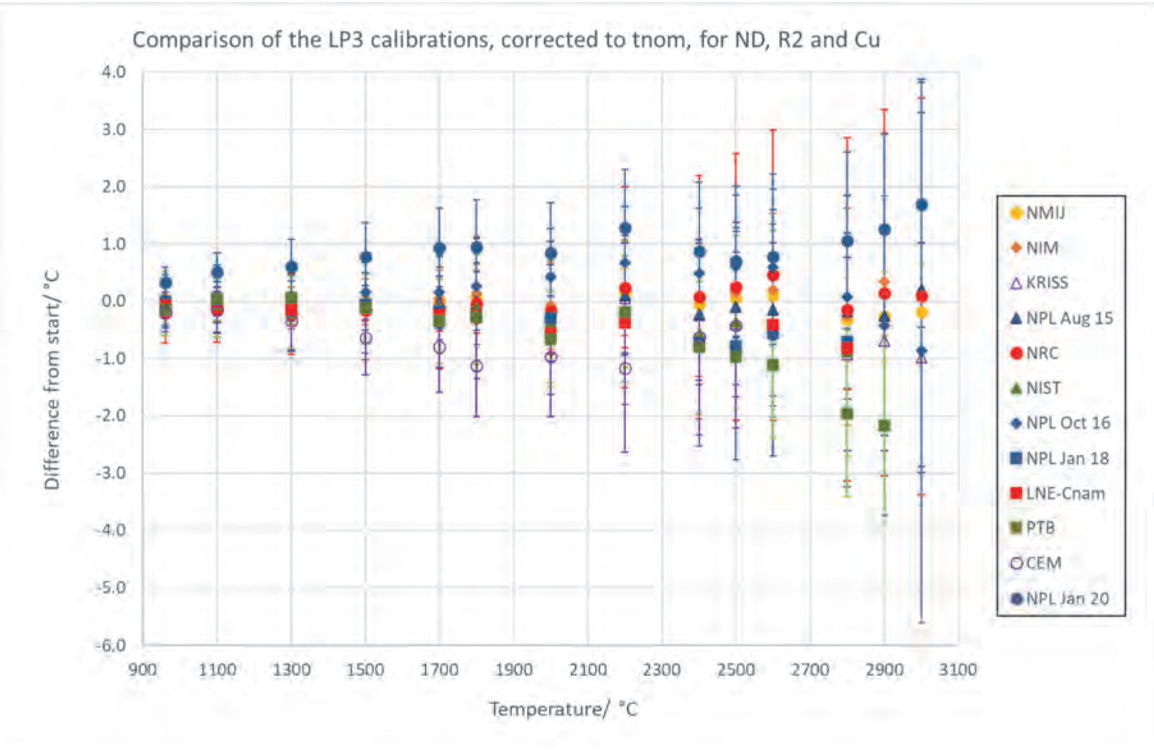


Figure 26 - fully corrected results of the calibrations by all participants, in terms of relative temperature difference from the start (NPL September 2014 calibration), with error bars showing the k = 2 participant uncertainties, which include the component for thermometer drift during the participant's measurements

9.2.2 The calibration of the Chino thermometer

The results of the participant measurements with the Chino thermometer are given in Table 131 to Table 143 in Appendix 3 along with the associated estimated uncertainties (k = 2). The results were obtained using the gain settings specified in the protocol (reproduced in Table 16 below for ease of reference) unless otherwise stated in the notes under the Tables in Appendix 3.

Table 16 – summary of the required gain settings for the Chino thermometer measurements

Nominal temperature/ °C	Gain setting
960	L
1100	L
1300	L
1500	L
1700	L
1800	L
2000	M
2200	M
2400	M
2500	H
2600	H
2800	H
2900	H
3000	H

Table 131 to Table 143 in Appendix 3 include the ‘raw’ measurement data (blackbody temperature, t_{90}, and corresponding signal, V) (columns 2 and 3); the signal corrected to the nominal calibration temperature (e.g. if the temperature of the participant’s blackbody was 1699.8 °C then the signal was corrected to correspond to a temperature of 1700 °C using Equation 1 above) (column 4). Table 131 to Table 143 also present the signal corrected to allow for the drift of the thermometer at the copper point from Table 8 and using Equations 3 and 4 above (column 6), along with both the participant measurement uncertainty, U_{lab}, and the uncertainty including a component for the thermometer drift during the participant’s measurements (refer to the notes accompanying the Tables for full details of the drift component). No corrections were applied for the thermometer’s gain ratio values (see comment in Section 9.1).

In cases where obvious outliers were evident participants were invited to check their data for typographical or arithmetical errors, without being given any specific information about the nature of the data anomaly. The values given in the Tables in Appendix 3 are the final values given by the participants before circulation of the Draft A report.

The results of the calibration, both raw and corrected results, are given graphically in Figure 27 to Figure 32. These are presented in terms of relative temperature differences from the first NPL calibration (NPL August/ September 2014), calculated using the differences in signal values and using Equation 1. It can be seen that there is more variation in the reported values for the Chino thermometer than for the LP3.

Notes:

1) As noted above, the PTB results above 2500 °C show a tendency to be lower than those of the other participants, especially for the Chino thermometer. Following the circulation of the Draft A report this was determined as partly due to the correction for the neutral density filter in the PTB reference thermometer. Applying the appropriate correction would increase the PTB results by about 0.5 °C over the range from 2500 °C and 2900 °C.

2) The NIM results at 2500 °C and above were higher than those of the other participants, although within the combined measurement uncertainties. The reason for this is not known. Further, the NIM results with the LP3 and the HTFP cells confirm NIM's high temperature measurement capability.

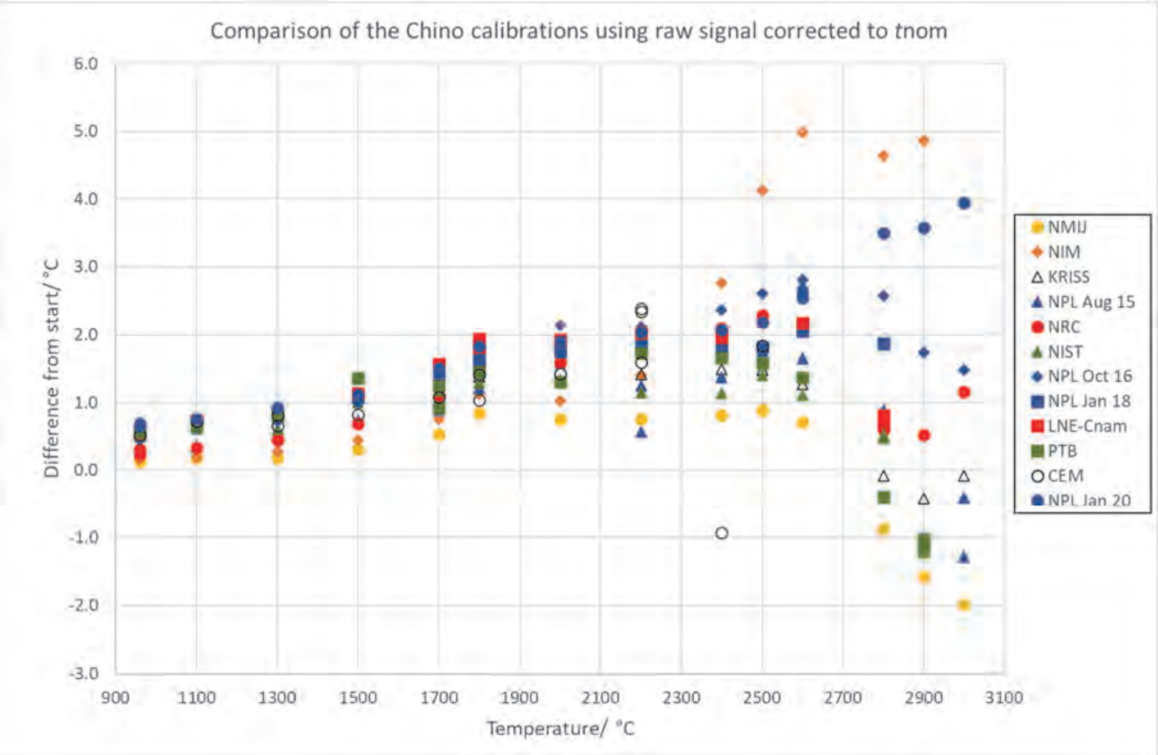


Figure 27 - results of the calibrations by all the participants, in terms of relative temperature difference from the start (NPL September 2014 calibration), corrected to t_{nom}

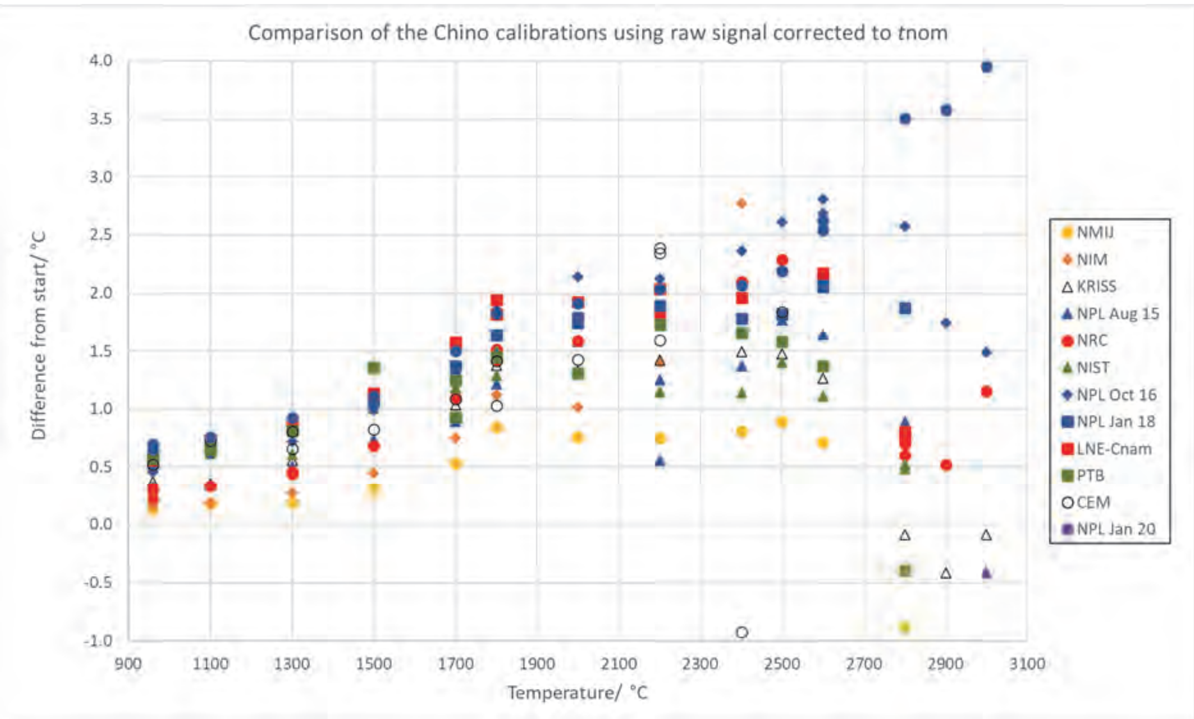


Figure 28 - results of the calibrations by all the participants, in terms of relative temperature difference from the start (NPL September 2014 calibration), corrected to t_{nom} (zoomed in)

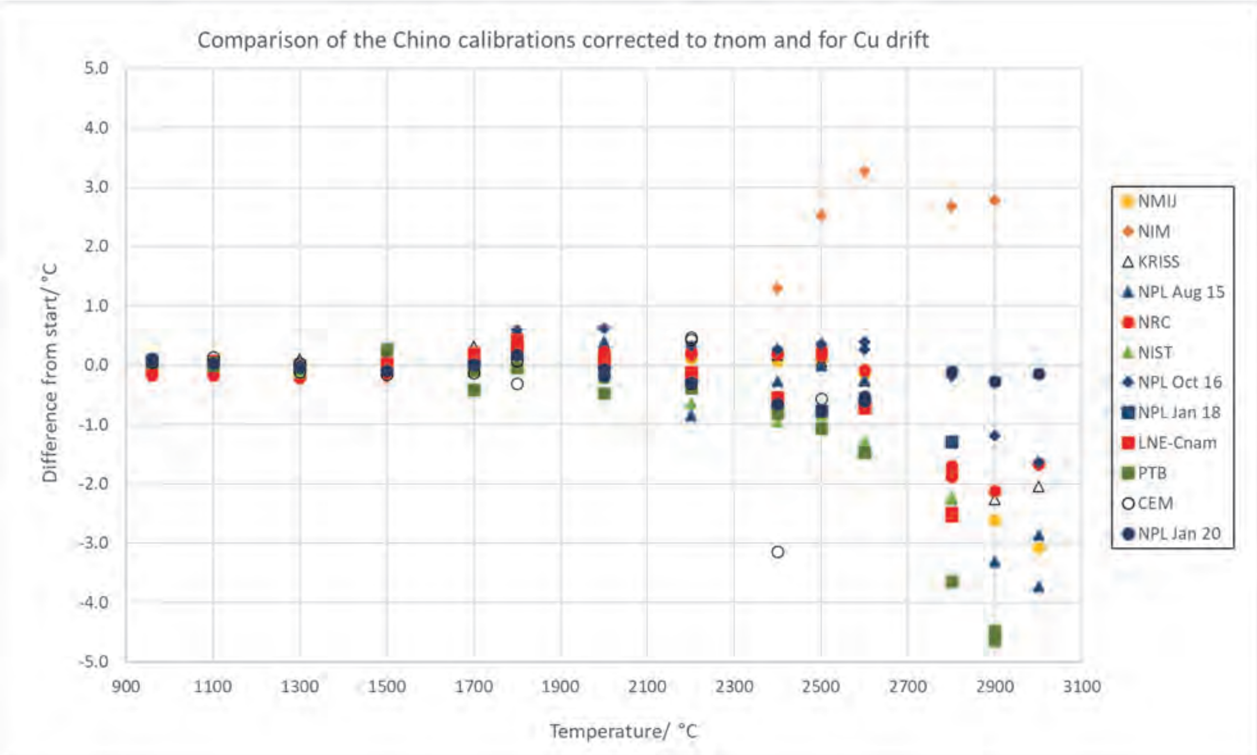


Figure 29 - results of the calibrations by all the participants, in terms of relative temperature difference from the start (NPL September 2014 calibration), corrected for drift at the Cu point

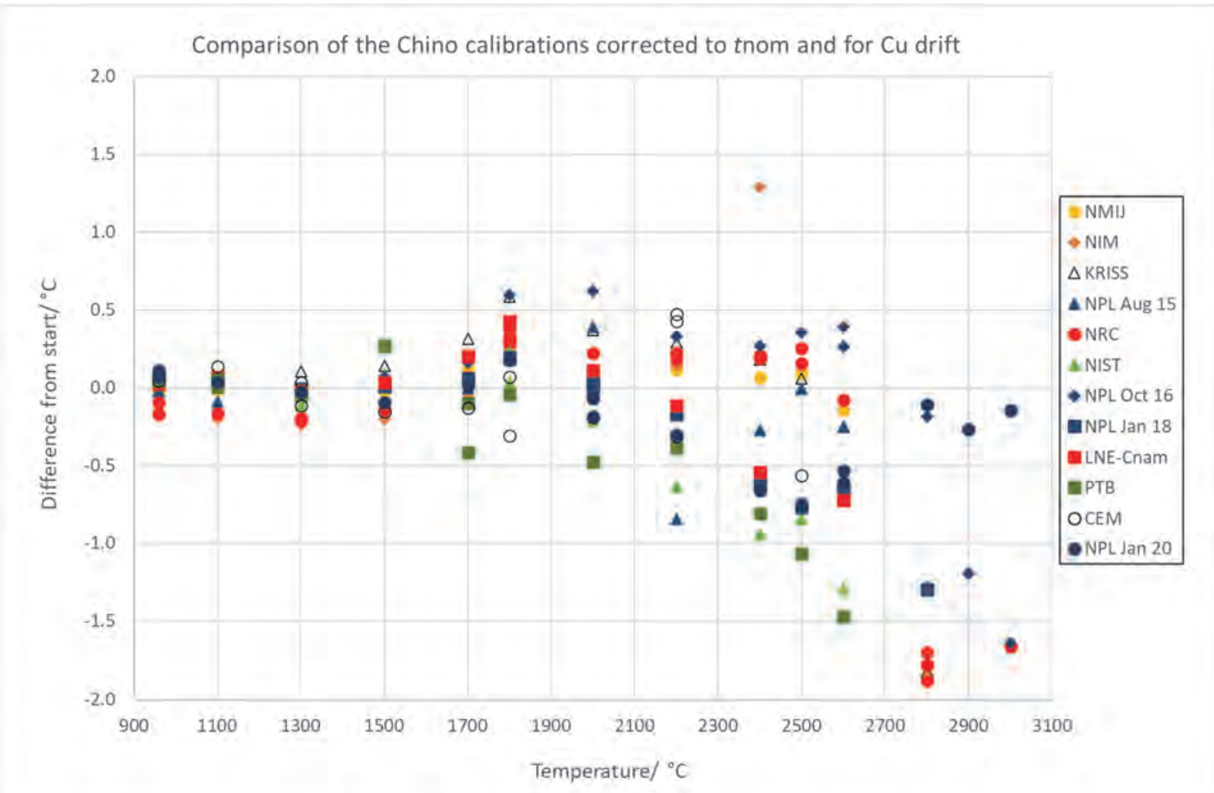


Figure 30 - results of the calibrations by all the participants, in terms of relative temperature difference from the start (NPL September 2014 calibration), corrected for drift at the Cu point (zoomed in)

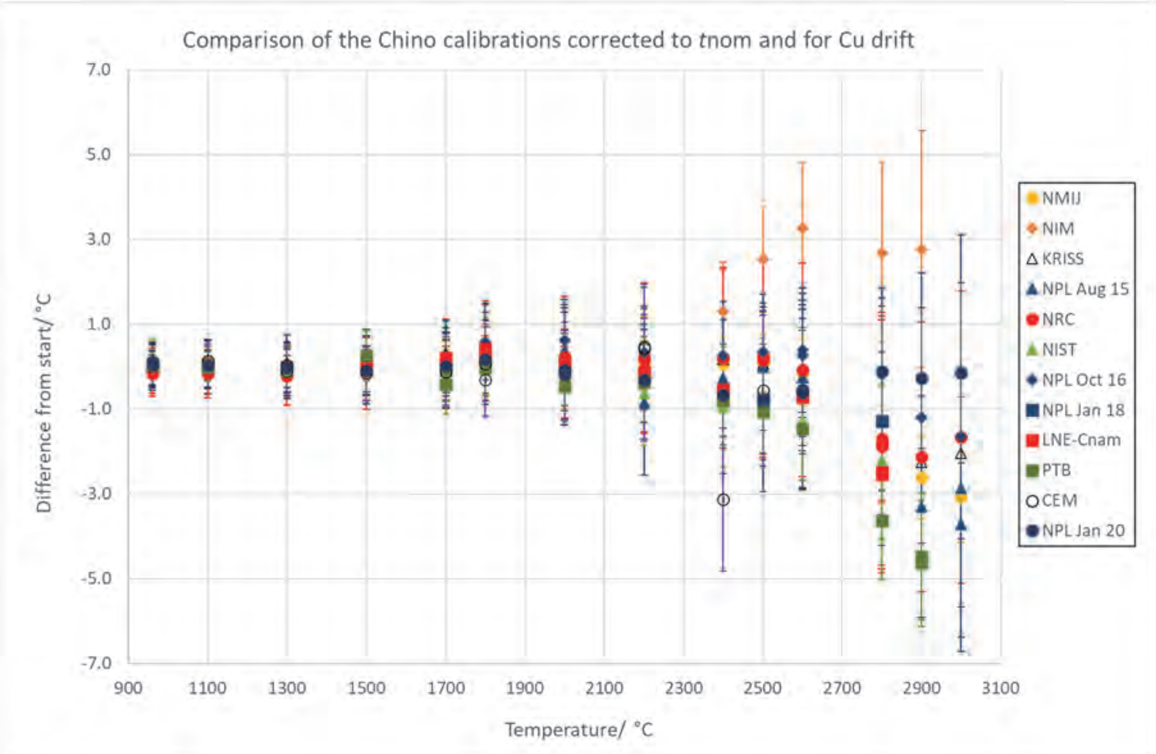


Figure 31 - corrected results of the calibrations by all the participants with error bars showing the *k* = 2 participant uncertainties, which include the component for thermometer drift during the participant's measurements

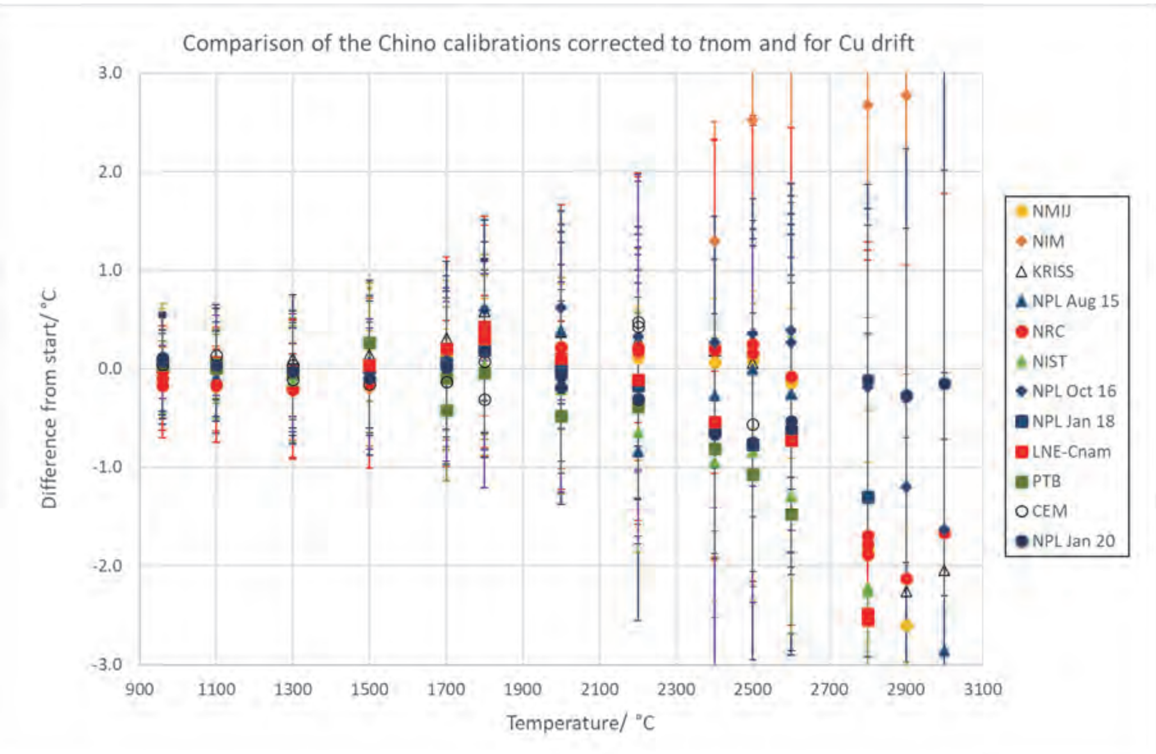


Figure 32 - corrected results of the calibrations by all the participants with error bars showing the *k* = 2 participant uncertainties, which include the component for thermometer drift during the participant's measurements (zoomed in)

10 FULL ANALYSIS OF THE THERMOMETER CALIBRATION RESULTS

10.1 PREPARING THE DATA

The data was prepared and analysed as follows. A diagram depicting the method, in the form of a flow chart, is given in Figure 33 to aid understanding of the steps.

For each of the two transfer thermometers the result (background corrected output versus the ITS-90 temperature) at each nominal comparison temperature was first normalised [corrected] to the common comparison temperature, t_{nom}, as described in Sections 9.2.1 and 9.2.2 above.

The thermometer output signal was then corrected to take into account the drift at the Cu point, as described in Section 9.1 above. For the LP3 thermometer the results were further corrected to range R2 and no ND filter, using the results of the range ratio and ND filter transmission measurements carried out by the participant. Where a participant did not perform these measurements, the values were estimated from the results of other participants, as described earlier.

For each transfer thermometer the results of all the pilot laboratory measurements over the entire period of the comparison were averaged for each t_{nom}, after correction of the results to allow for drift of the thermometer (including drift in range ratio and ND filter transmission for the LP3), to give one pilot result for each thermometer for each t_{nom}. The final uncertainty associated with the pilot results includes the standard deviation of the pilot measurements.

Where a participant had more than one result for a particular t_{nom}, as a result of carrying out repeat measurements, then the results were averaged to give one result for that t_{nom} for that participant, for each thermometer. The average result was used in the subsequent analysis.

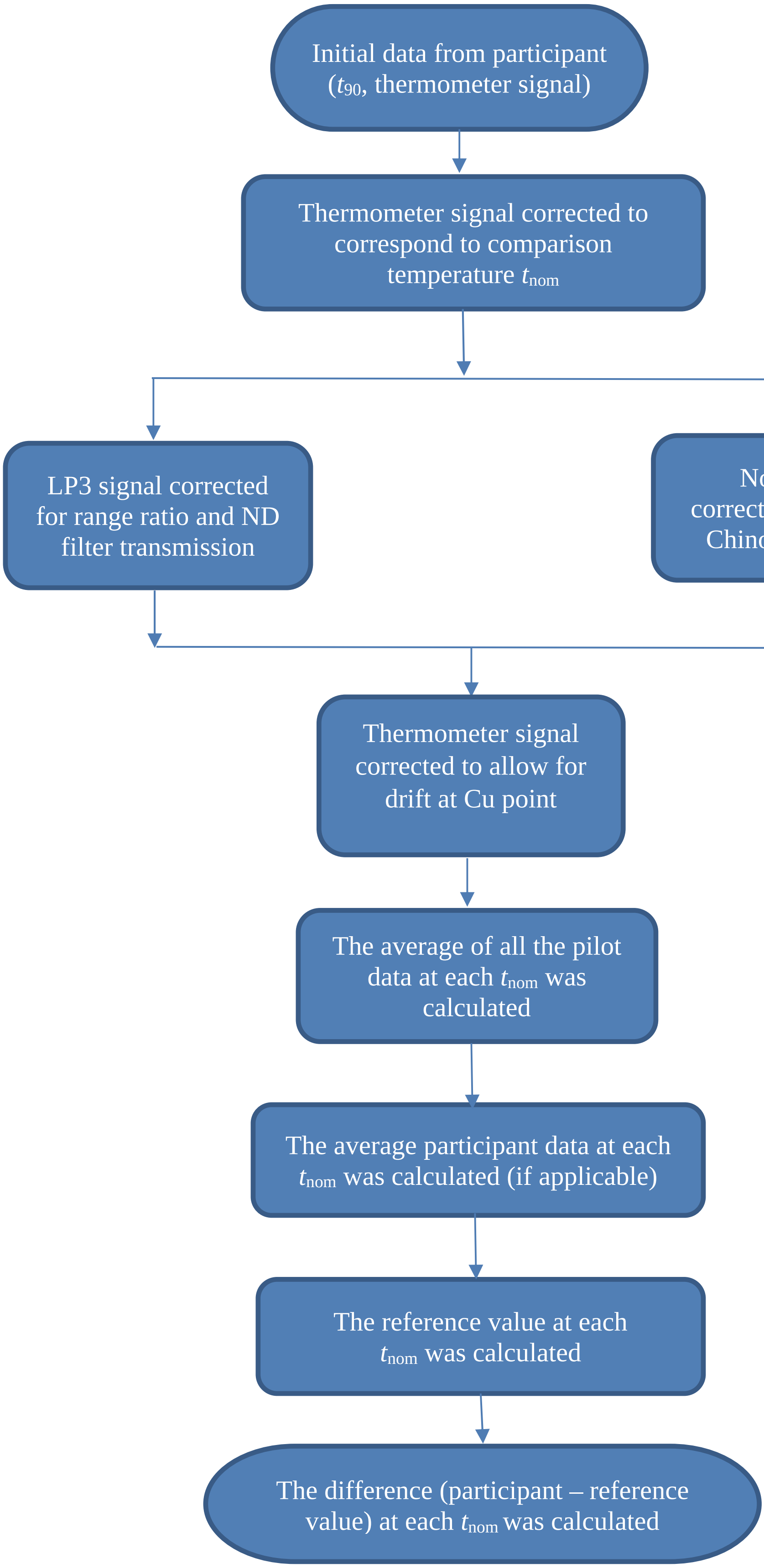


Figure 33 - flowchart for data analysis

10.2 ANALYSIS OF THE DATA

Initially the full analysis of the thermometer calibration results was carried out according to the method described in the protocol (namely using the weighted mean with cut off) according to [3] as described in Appendix 4. However, due to the presence of some outlying data, especially with the Chino thermometer, and after further discussion amongst the participants, it was decided that a better method would be to use the median as the reference value. The data was therefore re-analysed using the median value, and the results of the analysis are presented in the following sections.

When calibrating the transfer thermometers, the participants were requested to use their usual method. This included using their usual reference fixed point for calibrating their reference standard thermometer (if applicable). NPL, NMIJ, KRISS, NRC, CEM and LNE-Cnam used a copper fixed point as the reference; NIM used a silver point; NIST and PTB used a gold point. Strictly, use of different reference fixed points results in differences in the ITS-90 scale (see [4]). However, the purpose of the comparison was to compare each participant's ITS-90 scale realisation above the silver point. The text of the ITS-90 specifies that the reference fixed point can be any one of the silver, gold or copper points, and the T_{90} values are believed to be sufficiently self-consistent that using one over the other would not result in any significant difference in the measured values of T_{90}. Further, the differences in the ITS-90 scales are small (maximum of about 60 mK at 3000 °C, [4]). This is compared to the overall measurement uncertainties (typically a few °C at 3000 °C). For this reason, no correction was made to any of the results to adjust them to any particular reference fixed point.

10.3 ANALYSIS USING THE MEDIAN

For each transfer thermometer a reference value was calculated for each t_{nom} using the median of all the participant results, including the average pilot results, at that t_{nom}. The following data was not included in the median value:

- One of the PTB 2900 °C LP3 values, which was excluded from PTB's data – see comment below Table 129 in Appendix 2.

The uncertainty in the median value, *u* (median), was calculated using the 'median of absolute deviations' (or 'MAD') method [5], as shown in Equation 5:

$$u(median) \cong \frac{1.858}{\sqrt{(n-1)}} MAD \qquad (5)$$

where *n* is the number of results and

$$MAD = median\{|x_i - med|\} \qquad (6)$$

where x_i is the result of laboratory *i* and *med* is the median value (i.e., the thermometer reference value).

The median values and associated uncertainties are given in Table 19.

10.4 ADDITIONAL REFERENCE VALUE UNCERTAINTY COMPONENTS

The following additional uncertainty components, related to the stability of the transfer thermometers, were combined with the uncertainty of the median values (from Equation 5) to give the overall uncertainty in the reference value at each temperature for each thermometer. The calculated values for each of the uncertainty components, the total comparison uncertainties and the total reference value uncertainties (comparison uncertainty plus the uncertainty in the median) are given in Table 17 for the LP3 and Table 18 for the Chino thermometer.

10.4.1 Short term stability of the transfer thermometers

A component for the drift of the thermometers during each participant's measurements, estimated from the difference in corrections at the copper point at the start and at the end of the participant's measurements, had already been included in each participant's uncertainties (see Sections 7, 9.2.1 and 9.2.2 above). An additional uncertainty component was calculated to allow for the short-term stability of the thermometers. This was based on the maximum observed drift of the thermometers at the copper point during any participant measurements.

The maximum drifts were both observed during NPL measurements: during the 2016 NPL measurements for the LP3 and during the 2014 NPL measurements for the Chino thermometer, being 0.19 °C and 0.28 °C respectively. The short-term stability was calculated from the semi-range of the drift, taken as a Type B uncertainty, i.e., divided by the square root of 3. The equivalent uncertainty component at the other comparison temperatures was calculated from the ratio of the squares of the temperatures (t_{nom} and copper point) according to Equation 4.

10.4.2 Drift in the gain or range ratio values

The 960 °C, 1100 °C and 1300 °C results with the LP3 had been corrected to range R2 using measured values as described in Section 9.2.1; the results with the Chino thermometer had not been corrected for gain. For both thermometers uncertainty components to allow for any drift in the range or gain ratios were determined as follows.

For the LP3 the semi-range of the difference between the highest measured range ratio value and the lowest measured range ratio value was used to determine the range ratio correction uncertainty, treated as a type B uncertainty (i.e., divided by the square root of 3). The resulting uncertainty in the correction from R1 to R2, in terms of equivalent temperature, was estimated to be 0.01 °C, 0.01 °C and 0.02 °C at 960 °C, 1100 °C and 1300 °C respectively.

For the Chino thermometer the semi-range of the difference between the highest measured gain ratio value and the lowest measured gain ratio value, for both the L/M and M/H gain ratios, was used to estimate the uncertainty in correcting all values to the M range (ignoring the NPL October 2016 value, which was very low, likely due to furnace drift during the measurements). The maximum uncertainty (i.e., the maximum effect on the correction to the M range, which occurred when correcting between the L and M range) was used as the uncertainty across all temperatures, treated as a Type B uncertainty (divided by the square root of 3). The resulting estimated uncertainty, in terms of equivalent temperature, was taken to be 0.06 °C at all temperatures.

10.4.3 Drift in the LP3 ND filter transmission

The 2500 °C to 3000 °C results with the LP3 had been corrected for the effect of the ND filter using the measured values, as described in Section 9.2.1. It can be seen from Table 13 that the ND filter transmission drifted during the comparison. The results in Table 13 are plotted both in Figure 34 (ND transmission versus measurement number) and in Figure 35 (ND transmission versus nominal measurement date (approximate mid-point of the dates on which the participant measured the transfer Cu point)). Both graphs show an approximately linear drift. The uncertainty in the correction for the ND filter was determined from the root mean square of the residuals of the linear fit to the data shown in Figure 34. The resulting uncertainties in the correction ND filter, in terms of equivalent temperature, are shown in Table 17.

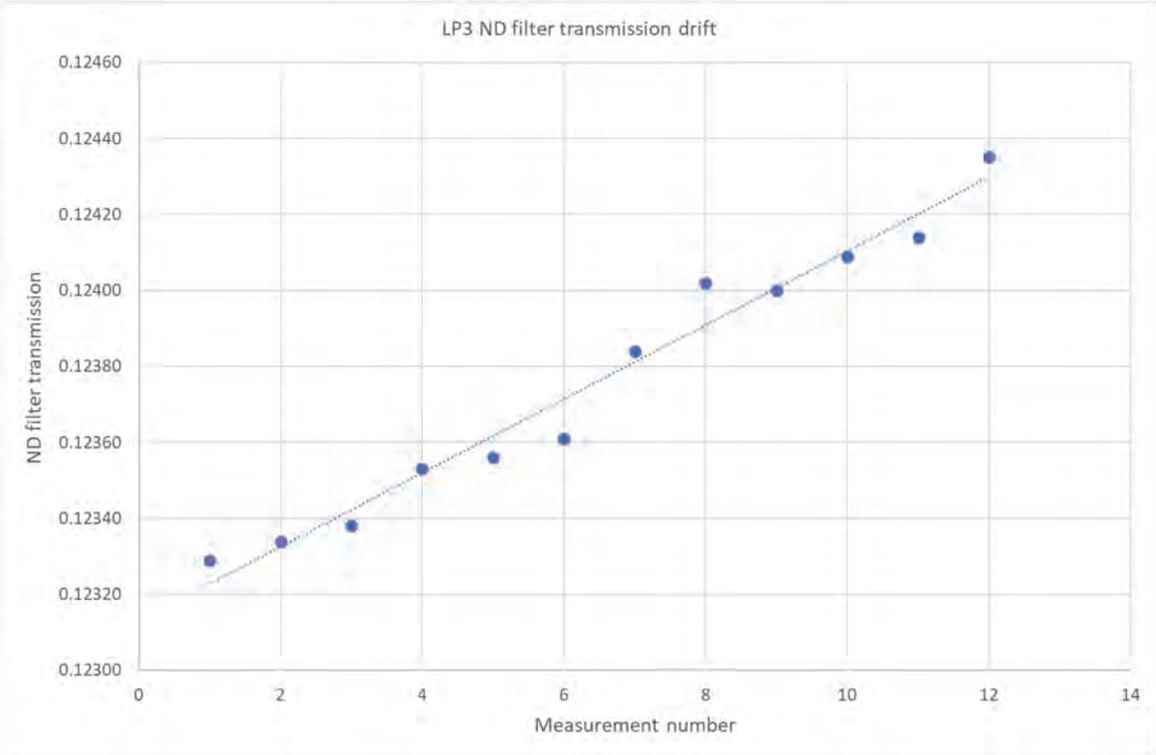


Figure 34 - drift in the LP3 ND filter transmission in terms of transmission versus measurement number

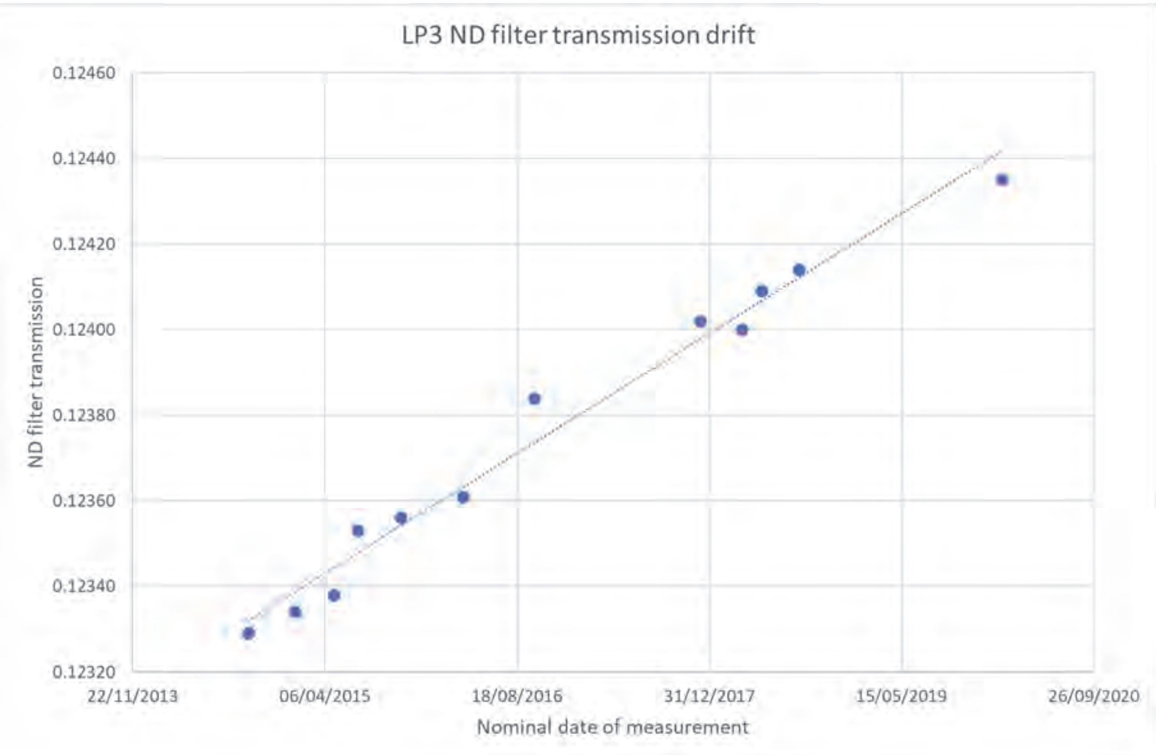


Figure 35 - drift in the LP3 ND filter transmission in terms of transmission versus nominal measurement date

Table 17 - the uncertainty components for the reference value for the LP3

t_{nom} / °C	u_{drift} / °C	$u_{range\ ratio}$ / °C	$u_{ND\ filter}$ / °C	$u_{comparison}$ / °C	u_{median} / °C	Totals	
						$u_{ref\ value}$ (*k* = 1)/ °C	$U_{ref\ value}$ (*k* = 2)/ °C
960	0.04	0.01	-	**0.04**	0.04	**0.06**	**0.11**
1100	0.05	0.01	-	**0.05**	0.02	**0.06**	**0.11**
1300	0.07	0.02	-	**0.07**	0.07	**0.10**	**0.20**
1500	0.09	-	-	**0.09**	0.07	**0.11**	**0.22**
1700	0.11	-	-	**0.11**	0.08	**0.13**	**0.26**
1800	0.12	-	-	**0.12**	0.11	**0.16**	**0.33**
2000	0.14	-	-	**0.14**	0.10	**0.17**	**0.34**
2200	0.17	-	-	**0.17**	0.15	**0.22**	**0.45**
2400	0.19	-	-	**0.19**	0.21	**0.28**	**0.57**
2500	0.21	-	0.16	**0.26**	0.19	**0.32**	**0.64**
2600	0.22	-	0.17	**0.28**	0.19	**0.34**	**0.68**
2800	0.26	-	0.19	**0.32**	0.23	**0.39**	**0.79**
2900	0.27	-	0.20	**0.34**	0.25	**0.42**	**0.85**
3000	0.29	-	0.22	**0.36**	0.24	**0.43**	**0.87**

Table 18 - the uncertainty components for the reference value for the Chino thermometer

t_{nom}/ °C	u_{drift} / °C	$u_{gain\ ratio}$ / °C	$u_{comparison}$ / °C	u_{median} / °C	Totals	
					$u_{ref\ value}$ (*k* = 1)/ °C	$U_{ref\ value}$ (*k* = 2)/ °C
960	0.07	0.06	**0.09**	0.03	**0.10**	**0.19**
1100	0.08	0.06	**0.10**	0.04	**0.11**	**0.22**
1300	0.11	0.06	**0.12**	0.02	**0.13**	**0.25**
1500	0.14	0.06	**0.15**	0.09	**0.18**	**0.35**
1700	0.17	0.06	**0.18**	0.06	**0.19**	**0.38**
1800	0.19	0.06	**0.20**	0.08	**0.21**	**0.43**
2000	0.22	0.06	**0.23**	0.10	**0.25**	**0.51**
2200	0.27	0.06	**0.27**	0.12	**0.30**	**0.59**
2400	0.31	0.06	**0.32**	0.30	**0.44**	**0.87**
2500	0.33	0.06	**0.34**	0.27	**0.43**	**0.87**
2600	0.36	0.06	**0.36**	0.23	**0.43**	**0.86**
2800	0.41	0.06	**0.41**	0.39	**0.57**	**1.13**
2900	0.44	0.06	**0.44**	0.59	**0.74**	**1.47**
3000	0.46	0.06	**0.47**	0.42	**0.63**	**1.26**

10.5 THE MEDIAN VALUE RESULTS FOR THE LP3 THERMOMETER

Table 19 presents the reference value data for the LP3; namely the median value for each temperature calibration point, using the participant calibration results, and the uncertainty of the median value. The summaries of the participant calibration results with associated uncertainties are given in Table 20 to Table 33, along with the calculated differences from the median values and the total uncertainties, U_{total}. U_{total} includes the participant uncertainties, the uncertainties associated with the comparison (thermometer drift for example) and the uncertainty of the median. The results, i.e., differences from the median and associated uncertainties, are presented graphically in Figure 36 and Figure 37 for all data and in Figure 38 to Figure 57 for the individual participant data.

10.6 THE MEDIAN VALUE RESULTS FOR THE CHINO THERMOMETERTHE MEDIAN VALUE RESULTS FOR THE CHINO THERMOMETER

Table 34

Table 34 presents the reference value data for the Chino thermometer; namely the median value for each temperature calibration point, using the participant calibration results, and the uncertainty of the median. The summaries of the participant calibration results with associated uncertainties are given in Table 35 to Table 48, along with the calculated difference from the median values and the total uncertainties, U_{total}. U_{total} includes the participant uncertainties, the uncertainties associated with the comparison (thermometer drift for example) and the uncertainty of the median. The results, i.e., differences from the median and associated uncertainties, are presented graphically in Figure 58 and Figure 59 for all data and in Figure 60 to Figure 79 for the individual participant data.

10.7 DETERMINING THE DEGREES OF EQUIVALENCE AND QDE_{95} VALUES

The degrees of equivalence (DOEs) for each participant for each thermometer and for each t_{nom} were calculated using the difference between the result of that participant and the reference value (median of results) for that particular thermometer at that t_{nom} and the uncertainty of the difference, which is the participant uncertainty (including a component for thermometer drift) combined with the uncertainty of the reference value ($u_{\text{ref value}}$ in Table 17 and Table 18). The degrees of equivalence between each pair of participants were also determined. All the differences were calculated in terms of equivalent temperature difference. The results are presented in Section 10.12 for the LP3 and Section 10.13 for the Chino thermometer.

The final result for each participant is therefore, for each thermometer, both the difference from the reference value (median of results) for that thermometer and difference from the other participants, along with the overall combined expanded (k = 2) uncertainty of the comparison at that temperature, U_{total}. U_{total} is the participant uncertainty, $U_{\text{laboratory}}$, which includes the component for thermometer drift during the participant's measurements, combined with $U_{\text{ref value}}$, the uncertainty in the reference value including the uncertainty in the median and the other associated uncertainties of the comparison, due to thermometer drift.

In addition, the quantified demonstrated equivalence (QDE_{95}) values for each pair of labs (i,j) were calculated, for each thermometer at each comparison temperature, from Equation 7 (see, for example, [6]):

$$QDE_{95(i,j)} \cong |\Delta t|_{(i,j)} + \left\{1.645 + 0.3295 exp\left(\frac{-4.05|\Delta t|_{(i,j)}}{u_{(i,j)}}\right)\right\} u_{(i,j)} \qquad (7)$$

where $|\Delta t|_{(i,j)}$ is the absolute difference between the temperature values of the two laboratories and $u_{(i,j)}$ is the combined k = 1 uncertainty.

10.8 THE MEDIAN VALUE RESULTS FOR THE LP3

Table 19 - determining the median values for the LP3

t_{nom}/ °C	Median value/ A	Median deviation/ A	u_{median}/ A	u_{median}/ °C
960	4.19878E-11	3.38714E-14	2.2250E-14	0.04
1100	2.60581E-10	1.05377E-13	6.9222E-14	0.02
1300	2.01294E-09	1.91765E-12	1.2597E-12	0.07
1500	9.80505E-09	7.14534E-12	4.6938E-12	0.07
1700	3.46361E-08	2.25430E-11	1.4809E-11	0.08
1800	5.94185E-08	5.33166E-11	3.5024E-11	0.11
2000	1.51734E-07	9.74582E-11	6.4020E-11	0.10
2200	3.32893E-07	2.74213E-10	1.8013E-10	0.15
2400	6.49278E-07	6.39241E-10	4.1992E-10	0.21
2500	8.74685E-07	6.76212E-10	4.7488E-10	0.19
2600	1.15413E-06	8.48610E-10	5.9594E-10	0.19
2800	1.90405E-06	1.46868E-09	1.0314E-09	0.23
2900	2.39099E-06	1.59107E-09	1.3221E-09	0.25
3000	2.95777E-06	1.34524E-09	1.4431E-09	0.24

Table 20 – summary of NPL 2014 LP3 results and difference from the median

t_{nom}/ °C	Average corrected Iph/ A	$U_{laboratory}$/ °C	Difference {Iph – median}/ A	Difference from median/ °C	$U_{ref\ value}$/ °C	U_{total}/ °C
960	4.20423E-11	0.21	5.4531E-14	0.09	0.11	0.24
1100	2.60645E-10	0.28	6.4095E-14	0.02	0.11	0.31
1300	2.01449E-09	0.34	1.5511E-12	0.09	0.20	0.39
1500	9.80653E-09	0.42	1.4779E-12	0.02	0.22	0.47
1700	3.46482E-08	0.56	1.2090E-11	0.06	0.26	0.62
1800	5.94331E-08	0.63	1.4579E-11	0.05	0.33	0.71
2000	1.51880E-07	0.75	1.4608E-10	0.22	0.34	0.82
2200	3.32830E-07	0.93	-6.2304E-11	-0.05	0.45	1.03
2400	6.49764E-07	1.12	4.8634E-10	0.24	0.57	1.25
2500	8.75072E-07	1.22	3.8677E-10	0.15	0.64	1.38
2600	1.15460E-06	1.35	4.6351E-10	0.15	0.68	1.51
2800	1.90660E-06	1.52	2.5508E-09	0.57	0.79	1.71
2900	2.39132E-06	1.49	3.2997E-10	0.06	0.85	1.72
3000	2.95811E-06	1.49	3.4087E-10	0.06	0.87	1.73

Table 21 – summary of NMIJ LP3 results and difference from the median

t_{nom}/ °C	Average corrected Iph/ A	$U_{laboratory}$ (inc. drift)/ °C	Difference {Iph – median}/ A	Difference from median/ °C	$U_{ref\ value}$/ °C	U_{total}/ °C
960	4.20018E-11	0.07	1.3978E-14	0.02	0.11	0.13
1100	2.60644E-10	0.09	6.2879E-14	0.02	0.11	0.14
1300	2.01316E-09	0.12	2.1716E-13	0.01	0.20	0.23
1500	9.80554E-09	0.17	4.8585E-13	0.01	0.22	0.27
1700	3.46502E-08	0.23	1.4061E-11	0.07	0.26	0.34
1800	5.94519E-08	0.26	3.3405E-11	0.11	0.33	0.42
2000	1.51782E-07	0.33	4.7279E-11	0.07	0.34	0.48
2200	3.33016E-07	0.41	1.2363E-10	0.10	0.45	0.61
2400	6.49658E-07	0.51	3.8001E-10	0.19	0.57	0.76
2500	8.75211E-07	0.56	5.2600E-10	0.21	0.64	0.86
2600	1.15490E-06	0.61	7.6839E-10	0.25	0.68	0.92
2800	1.90520E-06	0.72	1.1491E-09	0.26	0.79	1.08
2900	2.38995E-06	0.78	-1.0342E-09	-0.20	0.85	1.16
3000	2.95693E-06	0.84	-8.3640E-10	-0.14	0.87	1.22

Table 22 – summary of NIM LP3 results and difference from the median

t_{nom}/ °C	Average corrected Iph/ A	$U_{laboratory}$ (inc. drift)/ °C	Difference {Iph – median}/ A	Difference from median/ °C	$U_{ref\ value}$/ °C	U_{total}/ °C
960	4.195292E-11	0.28	-3.4865E-14	-0.06	0.11	0.30
1100	2.604755E-10	0.30	-1.0538E-13	-0.03	0.11	0.32
1300	2.012943E-09	0.34	0.0000E+00	0.00	0.20	0.39
1500	9.806294E-09	0.40	1.2441E-12	0.02	0.22	0.46
1700	3.465865E-08	0.49	2.2543E-11	0.11	0.26	0.55
1800	5.947180E-08	0.53	5.3317E-11	0.17	0.33	0.62
2000	1.518318E-07	0.75	9.7458E-11	0.15	0.34	0.83
2200	3.331113E-07	0.83	2.1851E-10	0.18	0.45	0.95
2400	6.498899E-07	0.95	6.1211E-10	0.30	0.57	1.10
2500	8.754525E-07	1.00	7.6718E-10	0.30	0.64	1.19
2600	1.155199E-06	1.33	1.0656E-09	0.34	0.68	1.50
2800	1.905392E-06	1.90	1.3382E-09	0.30	0.79	2.07
2900	2.393087E-06	2.61	2.1020E-09	0.40	0.85	2.74

Table 23 – summary of KRISS LP3 results and difference from the median

t_{nom}/ °C	Average corrected Iph / A	$U_{laboratory}$ (inc. drift)/ °C	Difference {Iph – median}/ A	Difference from median/ °C	$U_{ref\ value}$/ °C	U_{total}/ °C
960	4.19878E-11	0.15	0.0000E+00	0.00	0.11	0.18
1100	2.60648E-10	0.10	6.7307E-14	0.02	0.11	0.15
1300	2.01358E-09	0.16	6.3596E-13	0.04	0.20	0.26
1500	9.80505E-09	0.29	0.0000E+00	0.00	0.22	0.37
1700	3.46465E-08	0.44	1.0387E-11	0.05	0.26	0.51
1800	5.94351E-08	0.51	1.6571E-11	0.05	0.33	0.60
2000	1.51734E-07	0.69	0.0000E+00	0.00	0.34	0.77
2200	3.32893E-07	0.96	0.0000E+00	0.00	0.45	1.06
2400	6.49278E-07	1.14	0.0000E+00	0.00	0.57	1.27
2500	8.74053E-07	1.27	-6.3184E-10	-0.25	0.64	1.43
2600	1.15334E-06	1.42	-7.9590E-10	-0.26	0.68	1.58
2800	1.90247E-06	1.69	-1.5846E-09	-0.36	0.79	1.87
2900	2.38771E-06	1.93	-3.2740E-09	-0.62	0.85	2.11
3000	2.95208E-06	2.01	-5.6862E-09	-0.93	0.87	2.19

Table 24 – summary of NPL 2015 LP3 results and difference from the median

t_{nom}/ °C	Average corrected Iph/ A	$U_{laboratory}$ (inc. drift)/ °C	Difference {Iph – median}/ A	Difference from median/ °C	$U_{ref\ value}$/ °C	U_{total}/ °C
960	4.19844E-11	0.33	-3.3924E-15	-0.01	0.11	0.35
1100	2.60591E-10	0.36	1.0619E-14	0.00	0.11	0.38
1300	2.01336E-09	0.43	4.1539E-13	0.02	0.20	0.47
1500	9.80651E-09	0.51	1.4566E-12	0.02	0.22	0.55
1700	3.46400E-08	0.63	3.9334E-12	0.02	0.26	0.68
1800	5.94207E-08	0.72	2.1821E-12	0.01	0.33	0.79
2000	1.51747E-07	0.84	1.2603E-11	0.02	0.34	0.91
2200	3.32954E-07	1.05	6.1573E-11	0.05	0.45	1.14
2400	6.49324E-07	1.24	4.5876E-11	0.02	0.57	1.36
2500	8.74848E-07	1.37	1.6242E-10	0.06	0.64	1.52
2600	1.15413E-06	1.50	-4.4534E-12	0.00	0.68	1.65
2800	1.90585E-06	1.36	1.8007E-09	0.40	0.79	1.58
2900	2.38998E-06	2.09	-1.0064E-09	-0.19	0.85	2.26
3000	2.95938E-06	3.09	1.6078E-09	0.26	0.87	3.22

Table 25 – summary of NRC LP3 results and difference from the median

t_{nom}/ °C	Average corrected Iph/ A	$U_{laboratory}$ (inc. drift)/ °C	Difference {Iph – median}/ A	Difference from median/ °C	$U_{ref\ value}$/ °C	U_{total}/ °C
960	4.192024E-11	0.53	-6.7544E-14	-0.11	0.11	0.54
1100	2.602356E-10	0.58	-3.4523E-13	-0.11	0.11	0.59
1300	2.010432E-09	0.70	-2.5107E-12	-0.14	0.20	0.73
1500	9.795616E-09	0.86	-9.4347E-12	-0.14	0.22	0.89
1700	3.462431E-08	1.06	-1.1806E-11	-0.06	0.26	1.09
1800	5.941848E-08	1.17	0.0000E+00	0.00	0.33	1.22
2000	1.517628E-07	1.44	2.8462E-11	0.04	0.34	1.48
2200	3.331135E-07	1.75	2.2071E-10	0.18	0.45	1.81
2400	6.499145E-07	2.13	6.3675E-10	0.32	0.57	2.20
2500	8.756975E-07	2.33	1.0122E-09	0.40	0.64	2.42
2600	1.155997E-06	2.54	1.8637E-09	0.60	0.68	2.63
2800	1.905962E-06	3.00	1.9085E-09	0.43	0.79	3.10
2900	2.392065E-06	3.20	1.0801E-09	0.21	0.85	3.31
3000	2.958604E-06	3.46	8.3640E-10	0.14	0.87	3.57

Table 26 – summary of NIST LP3 results and difference from the median

t_{nom}/ °C	Average corrected Iph/ A	$U_{laboratory}$ (inc. drift)/ °C	Difference {Iph – median}/ A	Difference from median/ °C	$U_{ref\ value}$/ °C	U_{total}/ °C
960	4.201880E-11	0.56	3.1014E-14	0.05	0.11	0.57
1100	2.604985E-10	0.58	-8.2321E-14	-0.03	0.11	0.59
1300	2.011025E-09	0.64	-1.9176E-12	-0.11	0.20	0.67
1500	9.807327E-09	0.74	2.2765E-12	0.03	0.22	0.77
1700	3.463611E-08	0.85	0.0000E+00	0.00	0.26	0.89
1800	5.940238E-08	0.92	-1.6104E-11	-0.05	0.33	0.98
2000	1.516540E-07	1.07	-8.0399E-11	-0.12	0.34	1.12
2200	3.326185E-07	1.23	-2.7421E-10	-0.23	0.45	1.31
2400	6.486287E-07	1.42	-6.4910E-10	-0.32	0.57	1.53
2500	8.741593E-07	1.52	-5.2600E-10	-0.21	0.64	1.65
2600	1.153365E-06	1.62	-7.6839E-10	-0.25	0.68	1.76
2800	1.902701E-06	1.84	-1.3528E-09	-0.30	0.79	2.01

Table 27 – summary of NPL 2016 LP3 results and difference from the median

t_{nom}/ °C	Average corrected Iph/ A	$U_{laboratory}$ (inc. drift)/ °C	Difference {Iph – median}/ A	Difference from median/ °C	$U_{ref\ value}$/ °C	U_{total}/ °C
960	4.205789E-11	0.33	7.0113E-14	0.11	0.11	0.34
1100	2.609640E-10	0.36	3.8316E-13	0.13	0.11	0.38
1300	2.015903E-09	0.42	2.9599E-12	0.16	0.20	0.46
1500	9.817708E-09	0.51	1.2657E-11	0.18	0.22	0.55
1700	3.467889E-08	0.63	4.2774E-11	0.22	0.26	0.68
1800	5.951530E-08	0.83	9.6821E-11	0.32	0.33	0.89
2000	1.521521E-07	0.85	4.1770E-10	0.64	0.34	0.91
2200	3.336445E-07	0.98	7.5171E-10	0.62	0.45	1.08
2400	6.507354E-07	1.15	1.4576E-09	0.72	0.57	1.28
2500	8.766061E-07	1.24	1.9208E-09	0.76	0.64	1.41
2600	1.156449E-06	1.36	2.3163E-09	0.75	0.68	1.53
2800	1.906921E-06	1.78	2.8671E-09	0.64	0.79	1.95
2900	2.389075E-06	3.34	-1.9100E-09	-0.36	0.85	3.45
3000	2.952821E-06	4.75	-4.9468E-09	-0.81	0.87	4.83

Table 28 – summary of NPL 2018 LP3 results and difference from the median

t_{nom}/ °C	Average corrected Iph/ A	$U_{laboratory}$ (inc. drift)/ °C	Difference {Iph – median}/ A	Difference from median/ °C	$U_{ref\ value}$/ °C	U_{total}/ °C
960	4.204103E-11	0.47	5.3245E-14	0.09	0.11	0.48
1100	2.607875E-10	0.59	2.0660E-13	0.07	0.11	0.60
1300	2.012370E-09	0.76	-5.7241E-13	-0.03	0.20	0.78
1500	9.802582E-09	0.84	-2.4678E-12	-0.04	0.22	0.87
1700	3.461393E-08	0.99	-2.2183E-11	-0.11	0.26	1.02
1800	5.935389E-08	1.10	-6.4593E-11	-0.21	0.33	1.15
2000	1.516890E-07	1.34	-4.5421E-11	-0.07	0.34	1.38
2200	3.325026E-07	1.53	-3.9012E-10	-0.32	0.45	1.60
2400	6.482843E-07	1.80	-9.9345E-10	-0.49	0.57	1.88
2500	8.730915E-07	1.99	-1.5938E-09	-0.63	0.64	2.10
2600	1.152861E-06	2.15	-1.2722E-09	-0.41	0.68	2.26
2800	1.903420E-06	2.54	-6.3379E-10	-0.14	0.79	2.66

Table 29 – summary of LNE-Cnam LP3 results and difference from the median

t_{nom}/ °C	Average corrected Iph/ A	$U_{laboratory}$ (inc. drift)/ °C	Difference {Iph – median}/ A	Difference from median/ °C	$U_{ref\ value}$/ °C	U_{total}/ °C
960	4.200249E-11	0.10	1.4707E-14	0.02	0.11	0.15
1100	2.605809E-10	0.13	0.0000E+00	0.00	0.11	0.17
1300	2.011813E-09	0.17	-1.1298E-12	-0.06	0.20	0.26
1500	9.797905E-09	0.21	-7.1453E-12	-0.10	0.22	0.30
1700	3.460111E-08	0.28	-3.4997E-11	-0.18	0.26	0.38
1800	5.935483E-08	0.31	-6.3651E-11	-0.21	0.33	0.45
2000	1.515169E-07	0.37	-2.1745E-10	-0.33	0.34	0.50
2200	3.323779E-07	0.44	-5.1488E-10	-0.43	0.45	0.62
2400	6.481529E-07	0.51	-1.1249E-09	-0.56	0.57	0.77
2500	-	-	-	-	-	
2600	1.153293E-06	0.64	-8.4006E-10	-0.27	0.68	0.94
2800	1.902905E-06	0.72	-1.1491E-09	-0.26	0.79	1.07

Table 30 – summary of PTB LP3 results and difference from the median

t_{nom}/ °C	Average corrected Iph / A	$U_{laboratory}$ (inc. drift)/ °C	Difference {Iph – median}/ A	Difference from median/ °C	$U_{ref\ value}$/ °C	U_{total}/ °C
960	4.19539E-11	0.25	-3.3871E-14	-0.06	0.11	0.27
1100	2.60735E-10	0.36	1.5369E-13	0.05	0.11	0.38
1300	2.01568E-09	0.47	2.7364E-12	0.15	0.20	0.51
1500	9.79782E-09	0.60	-7.2332E-12	-0.10	0.22	0.64
1700	3.45794E-08	0.74	-5.6759E-11	-0.29	0.26	0.78
1800	5.93455E-08	0.82	-7.2949E-11	-0.24	0.33	0.88
2000	1.51449E-07	0.84	-2.8515E-10	-0.44	0.34	0.91
2200	3.32601E-07	0.97	-2.9216E-10	-0.24	0.45	1.07
2400	6.48145E-07	1.15	-1.1331E-09	-0.56	0.57	1.28
2500	8.72603E-07	1.24	-2.0824E-09	-0.83	0.64	1.41
2600	1.15110E-06	1.27	-3.0294E-09	-0.98	0.68	1.45
2800	1.89782E-06	1.45	-6.2358E-09	-1.40	0.79	1.66
2900†	2.37990E-06	1.55	-1.1086E-08	-2.11	0.85	1.78

† Only one 2900 °C measurement result was included in the median (see note below Table 129 in Appendix 2).

Table 31 – summary of CEM LP3 results and difference from the median

t_{nom}/ °C	Average corrected Iph/ A	$U_{laboratory}$ (inc. drift)/ °C	Difference {Iph – median}/ A	Difference from median/ °C	$U_{ref\ value}$/ °C	U_{total}/ °C
960	4.192621E-11	0.34	-6.1576E-14	-0.10	0.11	0.36
1100	2.601557E-10	0.40	-4.2517E-13	-0.14	0.11	0.42
1300	2.008095E-09	0.51	-4.8479E-12	-0.27	0.20	0.55
1500	9.762228E-09	0.65	-4.2822E-11	-0.62	0.22	0.69
1700	3.449039E-08	0.80	-1.4572E-10	-0.74	0.26	0.84
1800	5.908776E-08	0.89	-3.3072E-10	-1.08	0.33	0.94
2000	1.512499E-07	1.06	-4.8445E-10	-0.75	0.34	1.11
2200	3.314114E-07	1.46	-1.4813E-09	-1.23	0.45	1.53
2400	6.484778E-07	1.70	-7.9998E-10	-0.40	0.57	1.80
2500	8.739647E-07	1.79	-7.2058E-10	-0.29	0.64	1.91

Table 32 – summary of NPL 2020 LP3 results and difference from the median

t_{nom}/ °C	Average corrected Iph/ A	$U_{laboratory}$ (inc. drift)/ °C	Difference {Iph – median}/ A	Difference from median/ °C	$U_{ref\ value}$/ °C	U_{total}/ °C
960	4.223714E-11	0.28	2.4936E-13	0.41	0.11	0.30
1100	2.621771E-10	0.34	1.5962E-12	0.52	0.11	0.36
1300	2.025157E-09	0.49	1.2214E-11	0.68	0.20	0.52
1500	9.859289E-09	0.60	5.4239E-11	0.79	0.22	0.63
1700	3.483031E-08	0.69	1.9420E-10	0.99	0.26	0.74
1800	5.971986E-08	0.82	3.0138E-10	0.98	0.33	0.88
2000	1.524210E-07	0.88	6.8665E-10	1.06	0.34	0.94
2200	3.343491E-07	1.02	1.4564E-09	1.21	0.45	1.11
2400	6.514776E-07	1.20	2.1998E-09	1.09	0.57	1.33
2500	8.767742E-07	1.31	2.0889E-09	0.83	0.64	1.46
2600	1.156916E-06	1.45	2.7826E-09	0.90	0.68	1.60
2800	1.911196E-06	1.54	7.1425E-09	1.60	0.79	1.74
2900	2.397709E-06	1.67	6.7235E-09	1.28	0.85	1.88
3000	2.968182E-06	2.14	1.0414E-08	1.70	0.87	2.31

Table 33 – summary of the average of all the NPL calibrations of the LP3 and difference from the median

t_{nom} / °C	Average corrected Iph / A	Iph standard deviation / A	Average U_{NPL} (inc. drift) / A	Average U_{NPL} inc. drift & {std deviation/ $\sqrt{n}$} / A	Average U_{NPL} inc. drift & stdev)/ °C	Difference {average Iph – median}/ A	Difference from median/ °C	$U_{ref\ value}$ / °C	U_{total} / °C
960	4.207255E-11	9.6156E-14	1.9684E-13	2.1481E-13	0.35	8.4771E-14	0.14	0.11	0.37
1100	2.610330E-10	6.5565E-13	1.1838E-12	1.3211E-12	0.43	4.5214E-13	0.15	0.11	0.45
1300	2.016256E-09	5.1466E-12	8.7454E-12	9.8829E-12	0.55	3.3136E-12	0.18	0.20	0.58
1500	9.818523E-09	2.3478E-11	3.9667E-11	4.4883E-11	0.65	1.3473E-11	0.20	0.22	0.68
1700	3.468227E-08	8.5937E-11	1.3800E-10	1.5796E-10	0.80	4.6162E-11	0.23	0.26	0.84
1800	5.948855E-08	1.4146E-10	2.5122E-10	2.8129E-10	0.92	7.0073E-11	0.23	0.33	0.97
2000	1.519779E-07	3.0537E-10	6.0541E-10	6.6417E-10	1.02	2.4352E-10	0.37	0.34	1.08
2200	3.332562E-07	7.3917E-10	1.3294E-09	1.4847E-09	1.23	3.6344E-10	0.30	0.45	1.31
2400	6.499170E-07	1.2396E-09	2.6147E-09	2.8401E-09	1.41	6.3924E-10	0.32	0.57	1.52
2500	8.752783E-07	1.5009E-09	3.5903E-09	3.8331E-09	1.52	5.9301E-10	0.24	0.64	1.66
2600	1.154990E-06	1.6784E-09	4.8328E-09	5.0606E-09	1.63	8.5716E-10	0.28	0.68	1.77
2800	1.906799E-06	2.8151E-09	7.7996E-09	8.1960E-09	1.83	2.7455E-09	0.62	0.79	2.00
2900	2.392019E-06	3.9029E-09	1.1302E-08	1.1957E-08	2.27	1.0342E-09	0.20	0.85	2.43
3000	2.959621E-06	6.3739E-09	1.7533E-08	1.8656E-08	3.05	1.8541E-09	0.30	0.87	3.17

10.9 THE MEDIAN VALUE RESULTS FOR THE CHINO THERMOMETER

Table 34 - determining the median values for the Chino thermometer

t_{nom}/ °C	Median value/ V	Median deviation/ V	u_{median}/ V	u_{median}/ °C
960	0.004871	0.000004	0.000002	0.03
1100	0.030199	0.000020	0.000013	0.04
1300	0.233136	0.000051	0.000033	0.02
1500	1.135095	0.001147	0.000754	0.09
1700	4.008140	0.002190	0.001439	0.06
1800	6.874136	0.004515	0.002966	0.08
2000	1.747312	0.001151	0.000756	0.10
2200	3.835241	0.002450	0.001609	0.12
2400	7.473960	0.010585	0.006953	0.30
2500	1.008179	0.001115	0.000783	0.27
2600	1.330654	0.001147	0.000805	0.23
2800	2.195758	0.002824	0.001983	0.39
2900	2.756808	0.004306	0.003578	0.59
3000	3.416361	0.002759	0.002959	0.42

Table 35 – summary of NPL 2014 Chino thermometer results and difference from the median

t_{nom}/ °C	Average corrected signal/ V	$U_{laboratory}$/ °C	Difference {signal – median}/ V	Difference from median/ °C	$U_{ref\ value}$/ °C	U_{total}/ °C
960	0.004869	0.46	-0.000002	-0.03	0.19	0.50
1100	0.030194	0.50	-0.000005	-0.01	0.22	0.55
1300	0.233220	0.56	0.000084	0.04	0.25	0.62
1500	1.135099	0.66	0.000004	0.00	0.35	0.75
1700	4.007070	0.88	-0.001070	-0.05	0.38	0.96
1800	6.865701	0.89	-0.008435	-0.24	0.43	0.99
2000	1.746495	1.10	-0.000816	-0.11	0.51	1.21
2200	3.833636	1.22	-0.001605	-0.12	0.59	1.36
2400	7.479915	1.39	0.005955	0.26	0.87	1.64
2500	1.008424	1.51	0.000246	0.08	0.87	1.74
2600	1.331524	1.65	0.000870	0.24	0.86	1.86
2800	2.205235	1.70	0.009477	1.84	1.13	2.04
2900	2.770156	1.76	0.013348	2.20	1.47	2.30
3000	3.429509	1.92	0.013148	1.86	1.26	2.30

Table 36 – summary of NMIJ Chino thermometer results and difference from median

t_{nom}/ °C	Average corrected signal/ V	$U_{laboratory}$ (inc. drift)/ °C	Difference {signal – median}/ V	Difference from median/ °C	$U_{ref\ value}$/ °C	U_{total}/ °C
960	0.004867	0.09	-0.000004	-0.06	0.19	0.21
1100	0.030190	0.10	-0.000009	-0.02	0.22	0.24
1300	0.233086	0.14	-0.000051	-0.02	0.25	0.29
1500	1.134986	0.20	-0.000108	-0.01	0.35	0.41
1700	4.010009	0.27	0.001870	0.08	0.38	0.47
1800	6.879800	0.32	0.005663	0.16	0.43	0.53
2000	1.748152	0.41	0.000840	0.11	0.51	0.65
2200	3.835241	0.51	0.000000	0.00	0.59	0.78
2400	7.481484	0.63	0.007523	0.32	0.87	1.08
2500	1.008692	0.70	0.000513	0.18	0.87	1.11
2600	1.331014	0.76	0.000360	0.10	0.86	1.15
2800	2.195663	0.91	-0.000095	-0.02	1.13	1.45
2900	2.754281	0.98	-0.002527	-0.42	1.47	1.77
3000	3.407657	1.06	-0.008703	-1.23	1.26	1.65

Table 37 – summary of NIM Chino thermometer results and difference from the median

t_{nom}/ °C	Average corrected signal/ V	$U_{laboratory}$ (inc. drift)/ °C	Difference {signal – median}/ V	Difference from median / °C	$U_{ref\ value}$/ °C	U_{total}/ °C
960	0.004859	0.36	-0.000012	-0.17	0.19	0.41
1100	0.030123	0.43	-0.000076	-0.21	0.22	0.48
1300	0.232733	0.49	-0.000403	-0.19	0.25	0.55
1500	1.133486	0.58	-0.001608	-0.20	0.35	0.68
1700	4.005949	0.68	-0.002190	-0.10	0.38	0.78
1800	6.874136	0.71	0.000000	0.00	0.43	0.83
2000	1.746161	0.97	-0.001151	-0.15	0.51	1.10
2200	3.835637	1.07	0.000397	0.03	0.59	1.22
2400	7.509864	1.21	0.035904	1.55	0.87	1.50
2500	1.015756	1.29	0.007578	2.61	0.87	1.55
2600	1.343191	1.58	0.012537	3.51	0.86	1.80
2800	2.219083	2.16	0.023325	4.53	1.13	2.44
2900	2.787050	2.83	0.030242	4.99	1.47	3.19

As noted previously the difference of the NIM results from the median above 2400 °C could not be explained. No error in the data could be found. Further, the NIM results with the LP3 thermometer and the HTFP cells confirm the capability of NIM in high temperature radiation thermometer measurements.

Table 38 – summary of KRISS Chino thermometer results and difference from the median

t_{nom}/ °C	Average corrected signal/ V	$U_{laboratory}$ (inc. drift)/ °C	Difference {signal – median}/ V	Difference from median/ °C	$U_{ref\ value}$/ °C	U_{total}/ °C
960	0.004876	0.14	0.000005	0.07	0.19	0.24
1100	0.030196	0.10	-0.000003	-0.01	0.22	0.24
1300	0.233438	0.16	0.000301	0.14	0.25	0.30
1500	1.136242	0.27	0.001147	0.14	0.35	0.44
1700	4.014277	0.50	0.006138	0.27	0.38	0.63
1800	6.886391	0.50	0.012255	0.35	0.43	0.66
2000	1.749278	0.69	0.001966	0.26	0.51	0.85
2200	3.837690	0.94	0.002450	0.18	0.59	1.11
2400	7.484104	1.13	0.010144	0.44	0.87	1.43
2500	1.008606	1.26	0.000427	0.15	0.87	1.53
2600	1.330620	1.39	-0.000034	-0.01	0.86	1.63
2800	2.195853	1.68	0.000095	0.02	1.13	2.02
2900	2.756414	1.91	-0.000394	-0.07	1.47	2.42
3000	3.415004	2.00	-0.001357	-0.19	1.26	2.37

Table 39 – summary of NPL 2015 Chino thermometer results and difference from median

t_{nom}/ °C	Average corrected signal/ V	$U_{laboratory}$ (inc. drift)/ °C	Difference {signal – median}/ V	Difference from median/ °C	$U_{ref\ value}$/ °C	U_{total}/ °C
960	0.004868	0.54	-0.000004	-0.05	0.19	0.57
1100	0.030163	0.56	-0.000036	-0.10	0.22	0.60
1300	0.233100	0.62	-0.000037	-0.02	0.25	0.67
1500	1.135153	0.69	0.000059	0.01	0.35	0.77
1700	4.007030	0.79	-0.001109	-0.05	0.38	0.88
1800	6.873782	0.87	-0.000354	-0.01	0.43	0.97
2000	1.749424	1.00	0.002112	0.28	0.51	1.12
2200	3.826725	1.44	-0.008515	-0.61	0.59	1.55
2400	7.473572	1.38	-0.000388	-0.02	0.87	1.63
2500	1.008413	1.51	0.000235	0.08	0.87	1.74
2600	1.330626	1.62	-0.000028	-0.01	0.86	1.83
2800	2.198612	1.64	0.002854	0.55	1.13	1.99
2900	2.750022	2.61	-0.006786	-1.12	1.47	3.00
3000	3.406198	2.91	-0.010162	-1.44	1.26	3.17

Table 40 – summary of NRC Chino thermometer results and difference from median

t_{nom}/ °C	Average corrected signal/ V	$U_{laboratory}$ (inc. drift)/ °C	Difference {signal – median}/ V	Difference from median / °C	$U_{ref\ value}$/ °C	U_{total}/ °C
960	0.004860	0.53	-0.000011	-0.16	0.19	0.56
1100	0.030136	0.58	-0.000063	-0.18	0.22	0.62
1300	0.232796	0.70	-0.000340	-0.16	0.25	0.75
1500	1.133935	0.86	-0.001160	-0.15	0.35	0.93
1700	4.008684	1.06	0.000545	0.02	0.38	1.13
1800	6.877912	1.17	0.003776	0.11	0.43	1.25
2000	1.748160	1.44	0.000848	0.11	0.51	1.53
2200	3.836444	1.76	0.001203	0.09	0.59	1.86
2400	7.484545	2.13	0.010585	0.46	0.87	2.30
2500	1.009021	2.32	0.000842	0.29	0.87	2.47
2600	1.331247	2.53	0.000593	0.17	0.86	2.67
2800	2.195996	2.99	0.000238	0.05	1.13	3.19
2900	2.757202	3.19	0.000394	0.07	1.47	3.51
3000	3.417717	3.45	0.001357	0.19	1.26	3.67

Table 41 – summary of NIST Chino thermometer results and difference from the median

t_{nom}/ °C	Average corrected signal/ V	$U_{laboratory}$ (inc. drift)/ °C	Difference {signal – median}/ V	Difference from median/ °C	$U_{ref\ value}$/ °C	U_{total}/ °C
960	0.004875	0.56	0.000004	0.05	0.19	0.59
1100	0.030220	0.58	0.000020	0.06	0.22	0.62
1300	0.232984	0.64	-0.000152	-0.07	0.25	0.68
1500	1.135770	0.73	0.000675	0.08	0.35	0.81
1700	4.008135	0.85	-0.000004	0.00	0.38	0.93
1800	6.870674	0.92	-0.003463	-0.10	0.43	1.01
2000	1.744942	1.06	-0.002370	-0.32	0.51	1.18
2200	3.824819	1.23	-0.010422	-0.75	0.59	1.36
2400	7.458087	1.41	-0.015873	-0.69	0.87	1.66
2500	1.005982	1.51	-0.002196	-0.76	0.87	1.74
2600	1.326912	1.61	-0.003742	-1.05	0.86	1.83
2800	2.193646	1.83	-0.002112	-0.41	1.13	2.15

Table 42 – summary of NPL 2016 Chino thermometer results and difference from median

t_{nom}/ °C	Average corrected signal/ V	$U_{laboratory}$ (inc. drift)/ °C	Difference {signal – median}/ V	Difference from median/ °C	$U_{ref\ value}$/ °C	U_{total}/ °C
960	0.004871	0.52	0.000000	0.00	0.19	0.56
1100	0.030217	0.55	0.000018	0.05	0.22	0.59
1300	0.233211	0.60	0.000075	0.04	0.25	0.65
1500	1.135661	0.67	0.000567	0.07	0.35	0.76
1700	4.010817	0.78	0.002678	0.12	0.38	0.87
1800	6.879807	0.92	0.005671	0.16	0.43	1.01
2000	1.751156	0.98	0.003844	0.51	0.51	1.10
2200	3.838216	1.11	0.002975	0.21	0.59	1.26
2400	7.486176	1.28	0.012216	0.53	0.87	1.55
2500	1.009463	1.37	0.001284	0.44	0.87	1.62
2600	1.332701	1.49	0.002047	0.57	0.86	1.72
2800	2.204268	2.06	0.008510	1.65	1.13	2.35
2900	2.762874	3.43	0.006066	1.00	1.47	3.73
3000	3.417901	4.76	0.001541	0.22	1.26	4.92

Table 43 – summary of NPL 2018 Chino thermometer results and difference from the median

t_{nom}/ °C	Average corrected signal/ V	$U_{laboratory}$ (inc. drift)/ °C	Difference {signal – median}/ V	Difference from median/ °C	$U_{ref\ value}$/ °C	U_{total}/ °C
960	0.004872	0.51	0.000001	0.02	0.19	0.55
1100	0.030215	0.59	0.000016	0.05	0.22	0.63
1300	0.233207	0.76	0.000071	0.03	0.25	0.80
1500	1.135188	0.89	0.000094	0.01	0.35	0.96
1700	4.008400	1.03	0.000260	0.01	0.38	1.09
1800	6.872483	1.09	-0.001653	-0.05	0.43	1.17
2000	1.746693	1.35	-0.000619	-0.08	0.51	1.44
2200	3.831306	1.54	-0.003935	-0.28	0.59	1.65
2400	7.465481	1.90	-0.008480	-0.37	0.87	2.09
2500	1.006199	2.18	-0.001980	-0.68	0.87	2.35
2600	1.329095	2.20	-0.001559	-0.44	0.86	2.36
2800	2.198532	2.92	0.002774	0.54	1.13	3.13

Table 44 – summary of LNE-Cnam Chino thermometer results and difference from the median

t_{nom}/ °C	Average corrected signal/ V	$U_{laboratory}$ (inc. drift)/ °C	Difference {signal – median}/ V	Difference from median/ °C	$U_{ref\ value}$/ °C	U_{total}/ °C
960	0.004871	0.10	0.000000	0.00	0.19	0.22
1100	0.030219	0.13	0.000020	0.06	0.22	0.25
1300	0.233171	0.17	0.000035	0.02	0.25	0.30
1500	1.135364	0.21	0.000269	0.03	0.35	0.41
1700	4.011732	0.28	0.003593	0.16	0.38	0.48
1800	6.878651	0.31	0.004515	0.13	0.43	0.53
2000	1.747312	0.37	0.000000	0.00	0.51	0.63
2200	3.832084	0.44	-0.003157	-0.23	0.59	0.74
2400	7.467360	0.52	-0.006600	-0.29	0.87	1.01
2500	-	-	-	-	-	
2600	1.328954	0.59	-0.001700	-0.48	0.86	1.04
2800	2.192222	0.67	-0.003537	-0.69	1.13	1.31

Table 45 – summary of PTB Chino thermometer results and difference from the median

t_{nom}/ °C	Average corrected signal/ V	$U_{laboratory}$ (inc. drift)/ °C	Difference {signal – median}/ V	Difference from median/ °C	$U_{ref\ value}$/ °C	U_{total}/ °C
960	0.004872	0.24	0.000001	0.02	0.19	0.31
1100	0.030203	0.35	0.000004	0.01	0.22	0.41
1300	0.233136	0.47	0.000000	0.00	0.25	0.54
1500	1.137261	0.60	0.002167	0.27	0.35	0.70
1700	4.001250	0.72	-0.006890	-0.30	0.38	0.82
1800	6.864309	0.67	-0.009828	-0.28	0.43	0.80
2000	1.742937	0.79	-0.004374	-0.58	0.51	0.94
2200	3.828337	0.95	-0.006904	-0.50	0.59	1.12
2400	7.461211	1.12	-0.012749	-0.55	0.87	1.42
2500	1.005326	1.14	-0.002853	-0.98	0.87	1.44
2600	1.326265	1.22	-0.004389	-1.23	0.86	1.49
2800	2.186457	1.41	-0.009301	-1.81	1.13	1.81
2900	2.742404	1.51	-0.014404	-2.38	1.47	2.11

Table 46 – summary of CEM Chino thermometer results and difference from the median

t_{nom}/ °C	Average corrected signal/ V	$U_{laboratory}$ (inc. drift)/ °C	Difference {signal – median}/ V	Difference from median/ °C	$U_{ref\ value}$/ °C	U_{total}/ °C
960	0.004872	0.35	0.000001	0.02	0.19	0.40
1100	0.030243	0.41	0.000044	0.12	0.22	0.46
1300	0.233139	0.52	0.000003	0.00	0.25	0.58
1500	1.133876	0.66	-0.001218	-0.15	0.35	0.75
1700	4.004105	0.81	-0.004035	-0.18	0.38	0.90
1800	6.861510	0.89	-0.012627	-0.36	0.43	0.99
2000	1.745093	1.07	-0.002218	-0.30	0.51	1.18
2200	3.836372	1.48	0.001131	0.08	0.59	1.60
2400	7.407262	1.72	-0.066698	-2.88	0.87	1.93
2500	1.006790	1.81	-0.001389	-0.48	0.87	2.01

Table 47 – summary of NPL 2020 Chino thermometer results and difference from the median

t_{nom}/ °C	Average corrected signal/ V	$U_{laboratory}$ (inc. drift)/ °C	Difference {signal – median}/ V	Difference from median/ °C	$U_{ref\ value}$/ °C	U_{total}/ °C
960	0.004876	0.29	0.000004	0.06	0.19	0.34
1100	0.030206	0.35	0.000007	0.02	0.22	0.41
1300	0.233171	0.49	0.000034	0.02	0.25	0.55
1500	1.134371	0.57	-0.000723	-0.09	0.35	0.67
1700	4.007381	0.71	-0.000759	-0.03	0.38	0.80
1800	6.871978	0.83	-0.002158	-0.06	0.43	0.93
2000	1.745544	0.87	-0.001768	-0.24	0.51	1.01
2200	3.829469	1.03	-0.005771	-0.42	0.59	1.19
2400	7.464658	1.22	-0.009302	-0.40	0.87	1.50
2500	1.006257	1.31	-0.001922	-0.66	0.87	1.58
2600	1.329496	1.48	-0.001159	-0.32	0.86	1.71
2800	2.204689	1.56	0.008931	1.74	1.13	1.93
2900	2.768519	1.70	0.011711	1.93	1.47	2.25
3000	3.428476	2.16	0.012115	1.72	1.26	2.50

Table 48 – average of all the NPL calibrations of the Chino thermometer and difference from the median

t_{nom}/ °C	Average corrected signal/ V	Signal standard deviation/ V	Average U_{NPL}/ V	Average U_{NPL} with {std deviation/ √n} /V	Average U_{NPL} inc. drift & stdev)/ °C	Difference {average signal – median} / V	Difference from median/ °C	$U_{ref\ value}$/ °C	U_{total}/ °C
960	0.004871	0.000003	0.000033	0.000033	0.47	0.000000	0.00	0.19	0.50
1100	0.030199	0.000022	0.000181	0.000182	0.51	0.000000	0.00	0.22	0.56
1300	0.233182	0.000050	0.001263	0.001264	0.61	0.000045	0.02	0.25	0.66
1500	1.135095	0.000463	0.005542	0.005557	0.70	0.000000	0.00	0.35	0.78
1700	4.008140	0.001596	0.019081	0.019134	0.84	0.000000	0.00	0.38	0.92
1800	6.872750	0.005030	0.032555	0.032864	0.93	-0.001386	-0.04	0.43	1.02
2000	1.747862	0.002340	0.007938	0.008209	1.10	0.000551	0.07	0.51	1.21
2200	3.831870	0.004357	0.017575	0.018002	1.30	-0.003370	-0.24	0.59	1.43
2400	7.473960	0.009264	0.033194	0.034213	1.48	0.000000	0.00	0.87	1.72
2500	1.007751	0.001454	0.004577	0.004758	1.64	-0.000427	-0.15	0.87	1.86
2600	1.330688	0.001476	0.006024	0.006167	1.73	0.000034	0.01	0.86	1.93
2800	2.202267	0.003391	0.010206	0.010647	2.06	0.006509	1.26	1.13	2.35
2900	2.762893	0.009130	0.014420	0.017067	2.81	0.006085	1.00	1.47	3.17
3000	3.420521	0.010894	0.020755	0.023440	3.32	0.004160	0.59	1.26	3.55

10.10 GRAPHICAL RESULTS WITH THE LP3 THERMOMETER

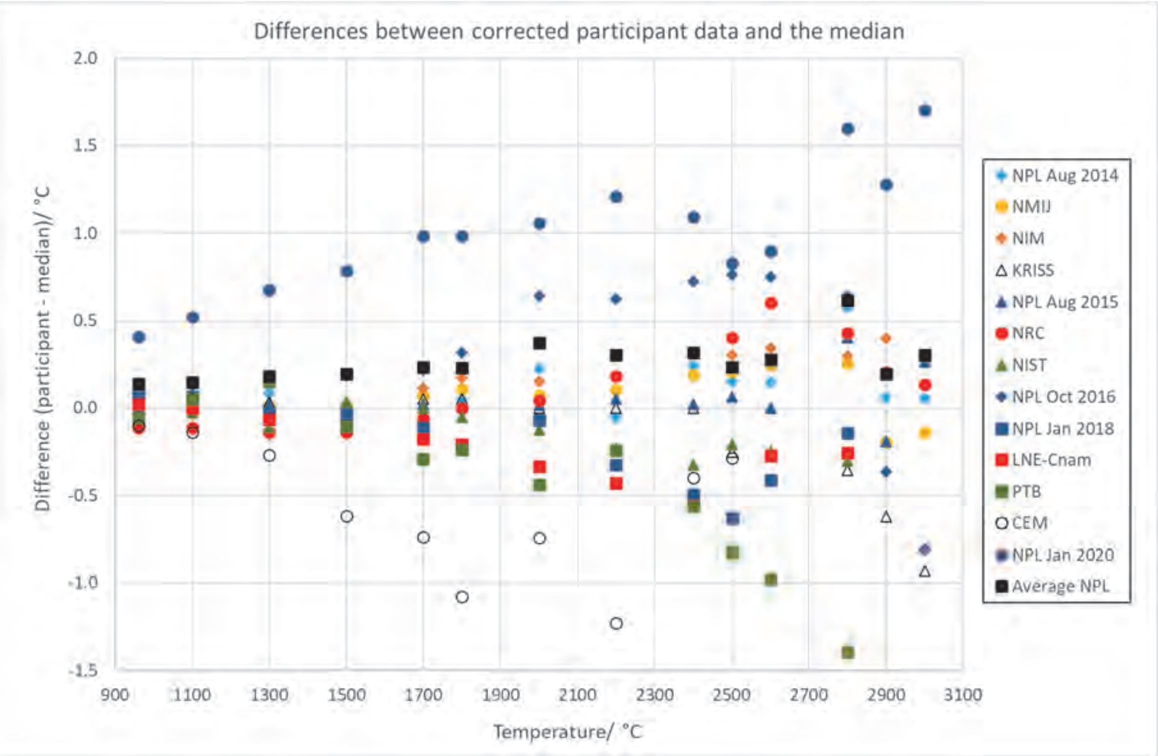


Figure 36 - Results of the comparison with the LP3, showing differences of each participant from the median value

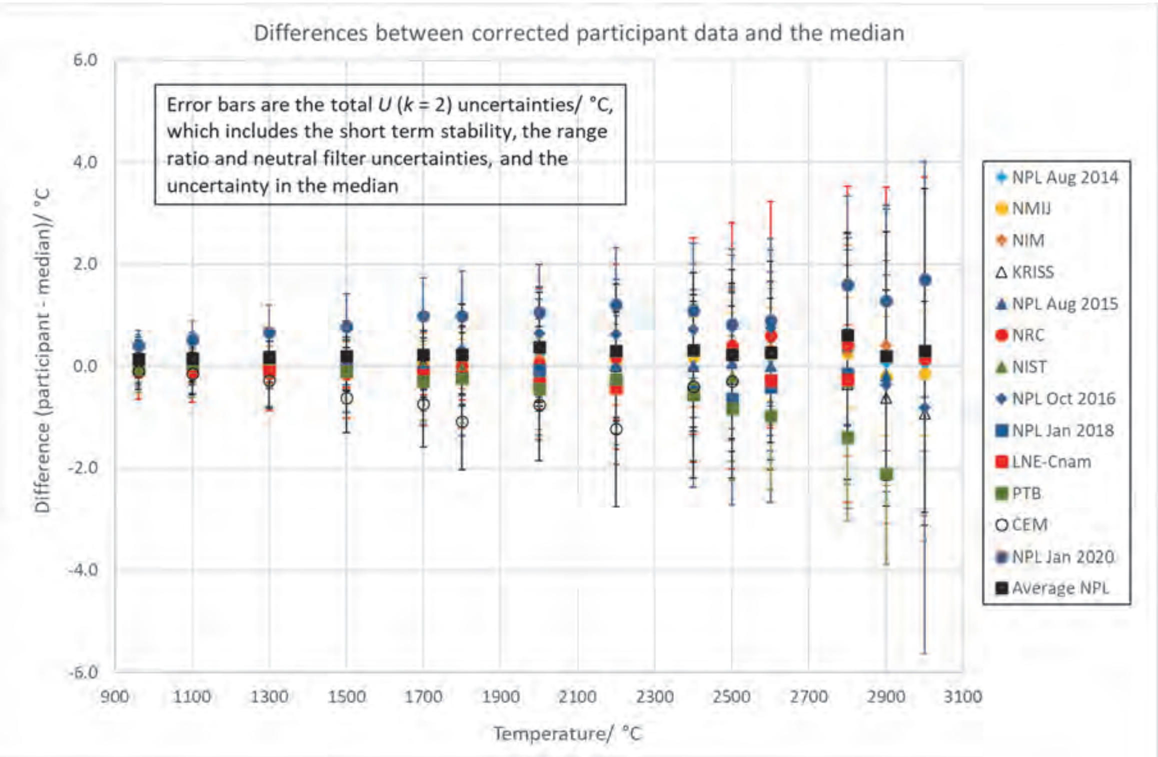


Figure 37 - Results of the comparison with the LP3, showing differences of each participant from the median value and the total, k = 2 uncertainties

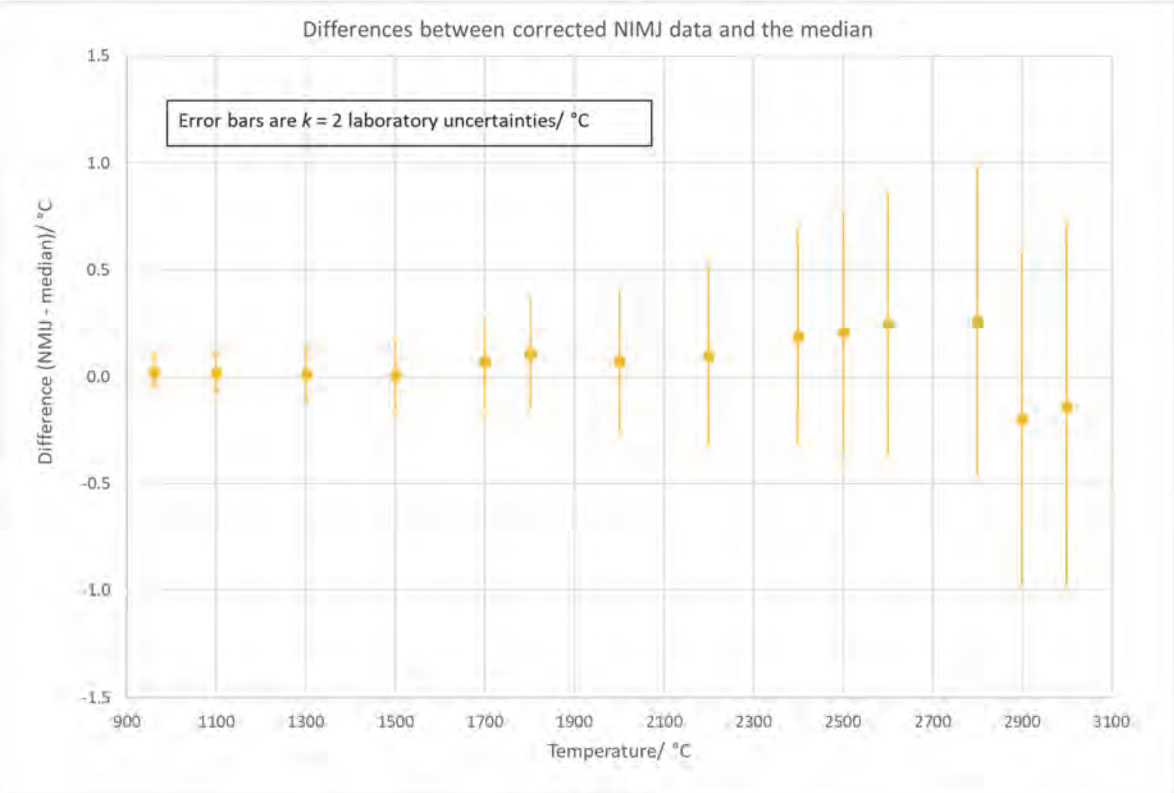


Figure 38 – difference between the NMIJ results with the LP3 and the median (*k* = 2 laboratory uncertainties)

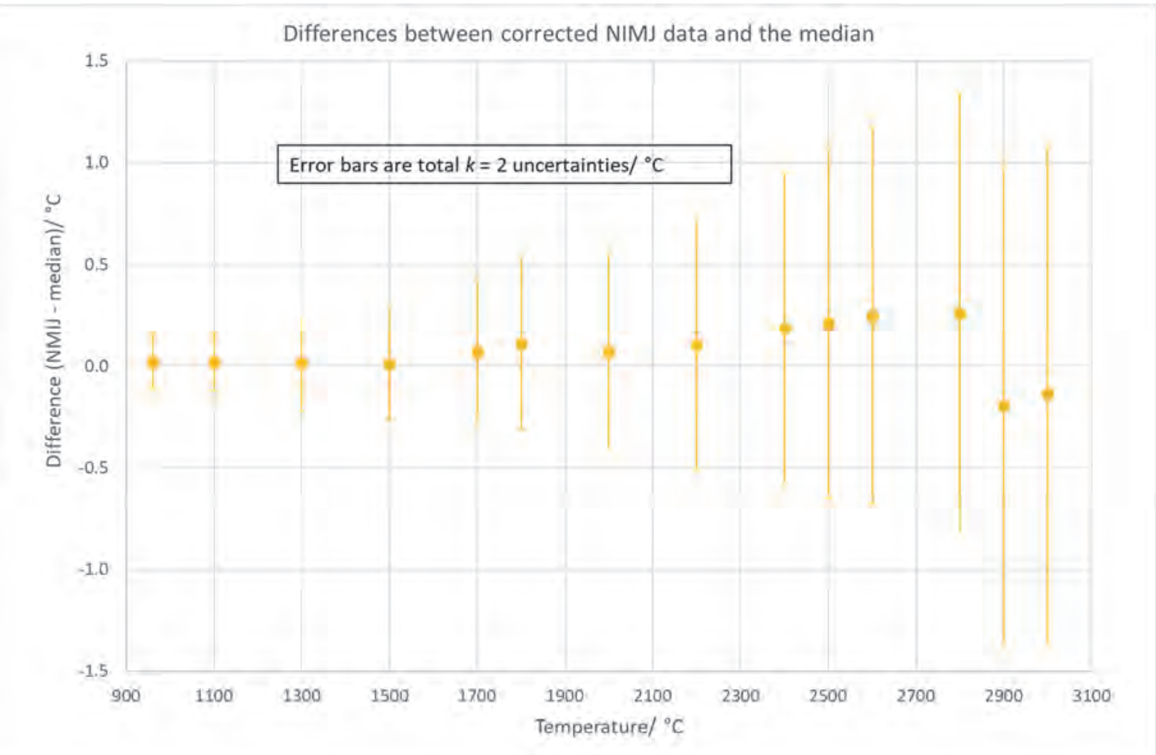


Figure 39 – difference between the NMIJ results with the LP3 and the median (*k* = 2 total uncertainties)

Figure 40 – difference between the NIM results with the LP3 and the median (*k* = 2 laboratory uncertainties)

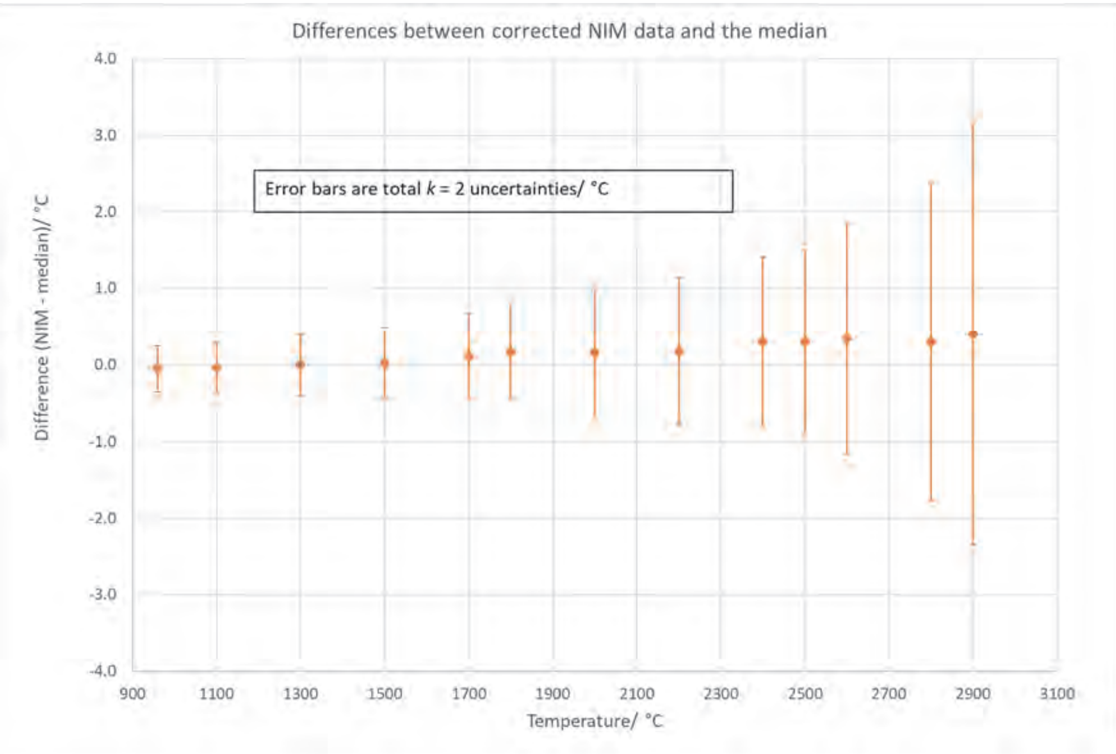


Figure 41 – difference between the NIM results with the LP3 and the median (*k* = 2 total uncertainties)

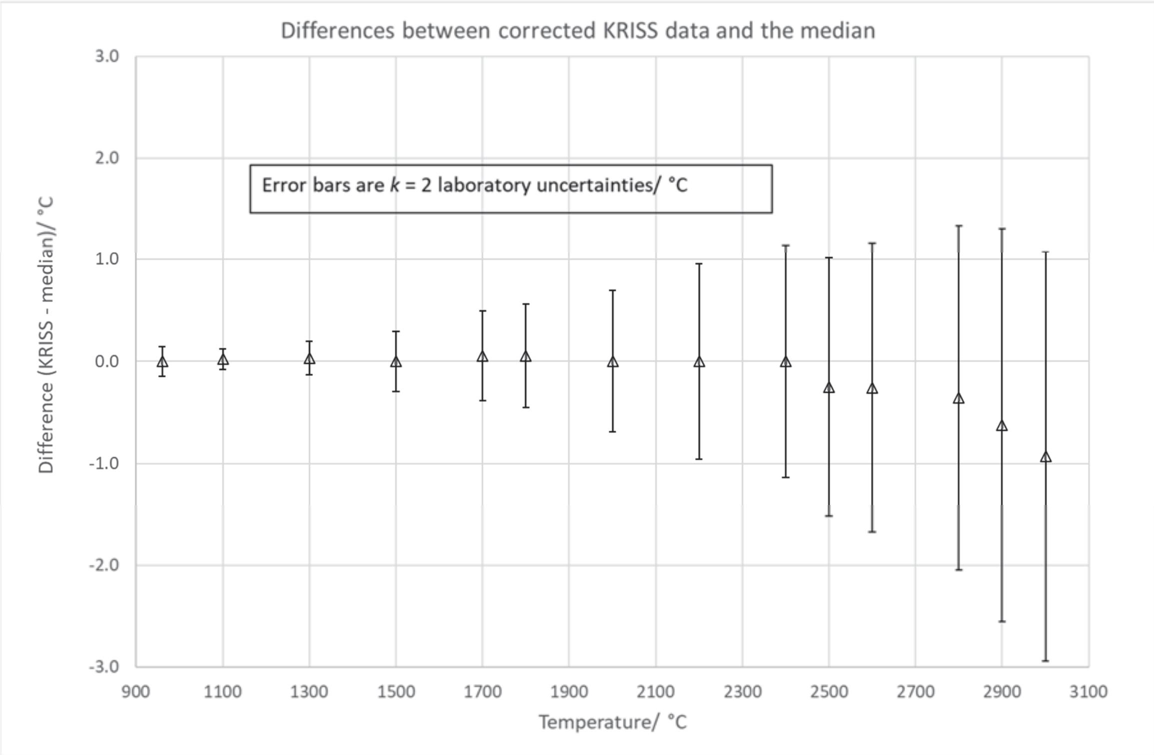


Figure 42 – difference between the KRISS results with the LP3 and the median (*k* = 2 laboratory uncertainties)

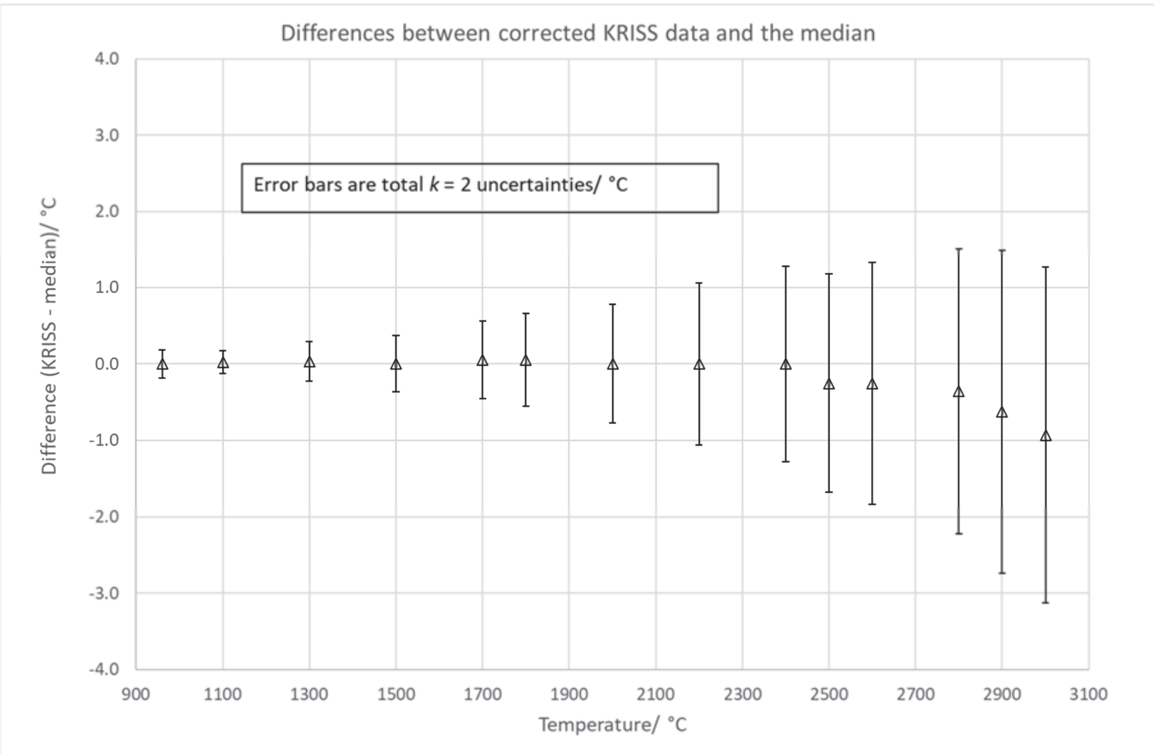


Figure 43 – difference between the KRISS results with the LP3 and the median (*k* = 2 total uncertainties)

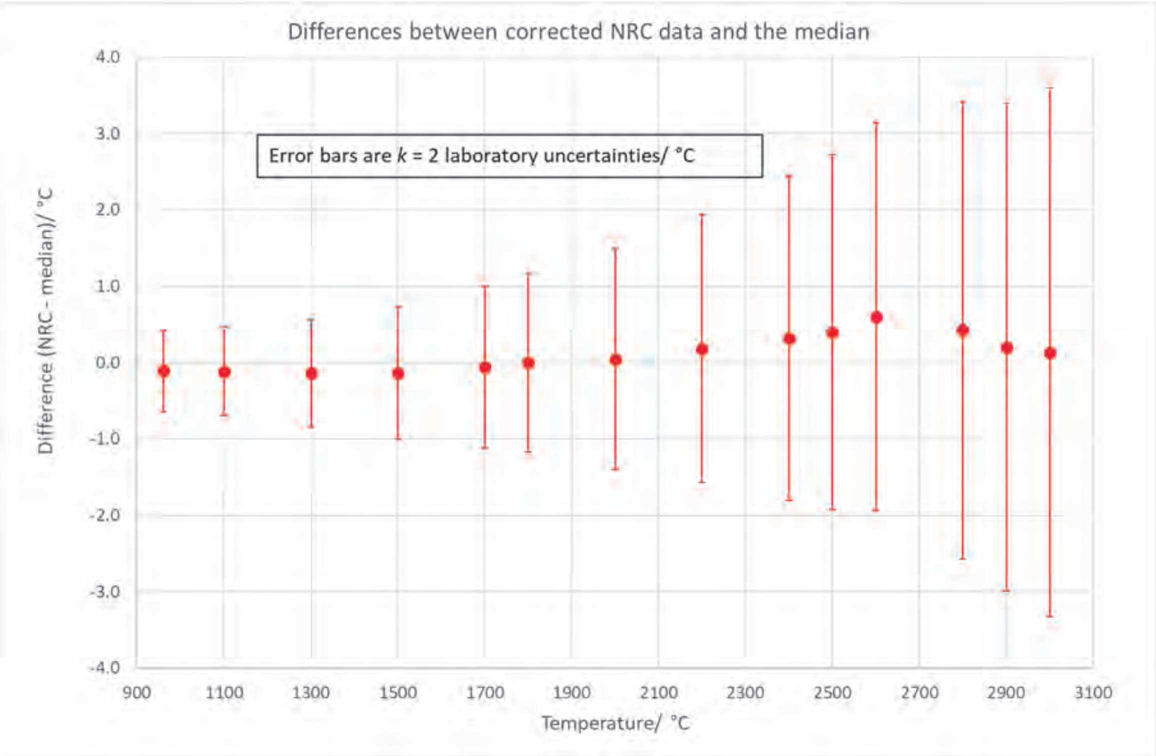


Figure 44 – difference between the NRC results with the LP3 and the median (*k* = 2 laboratory uncertainties)

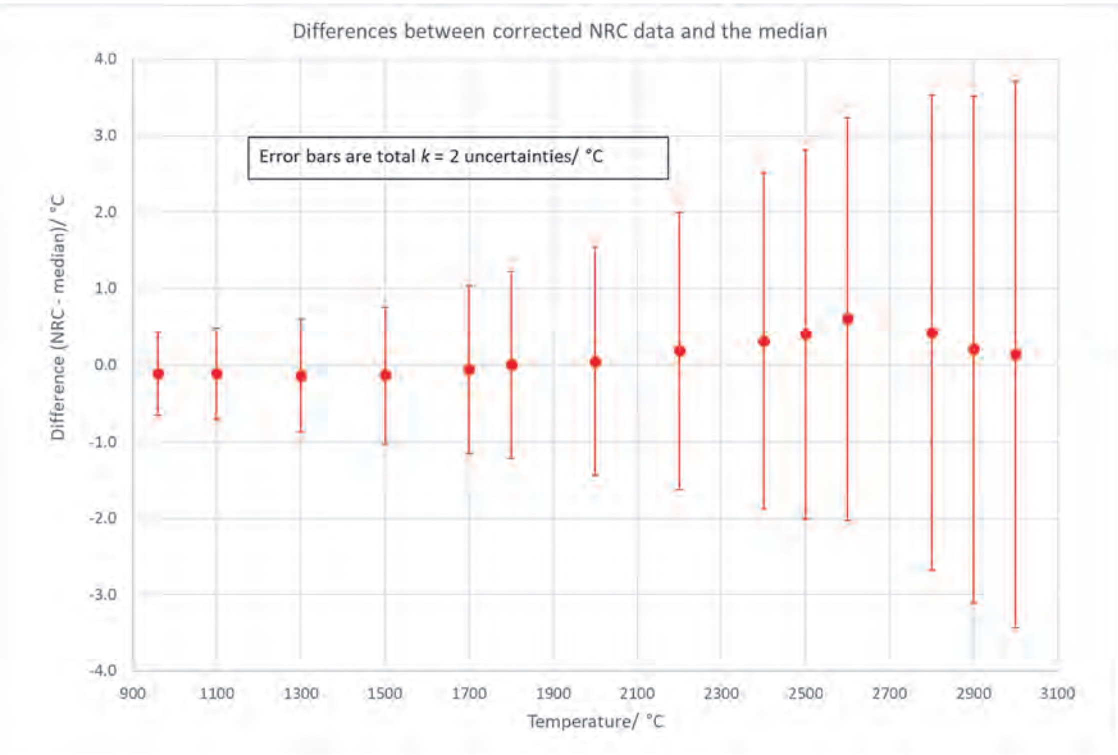


Figure 45 – difference between the NRC results with the LP3 and the median (*k* = 2 total uncertainties)

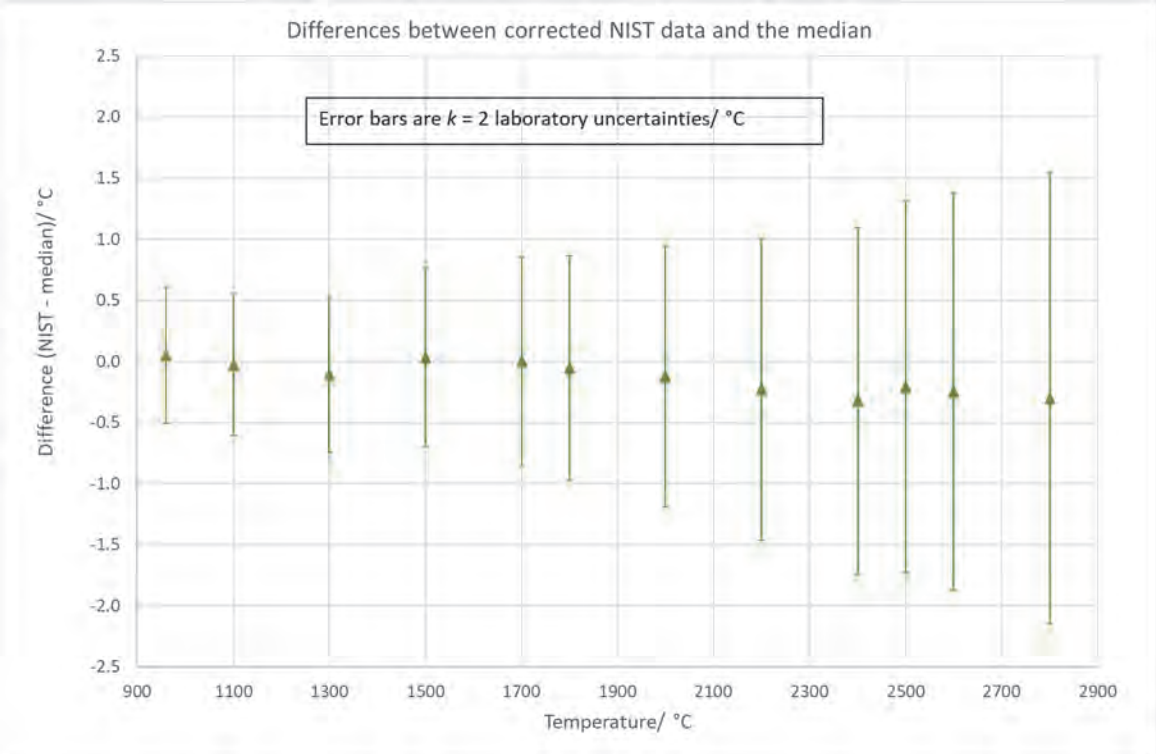


Figure 46 – difference between the NIST results with the LP3 and the median (*k* = 2 laboratory uncertainties)

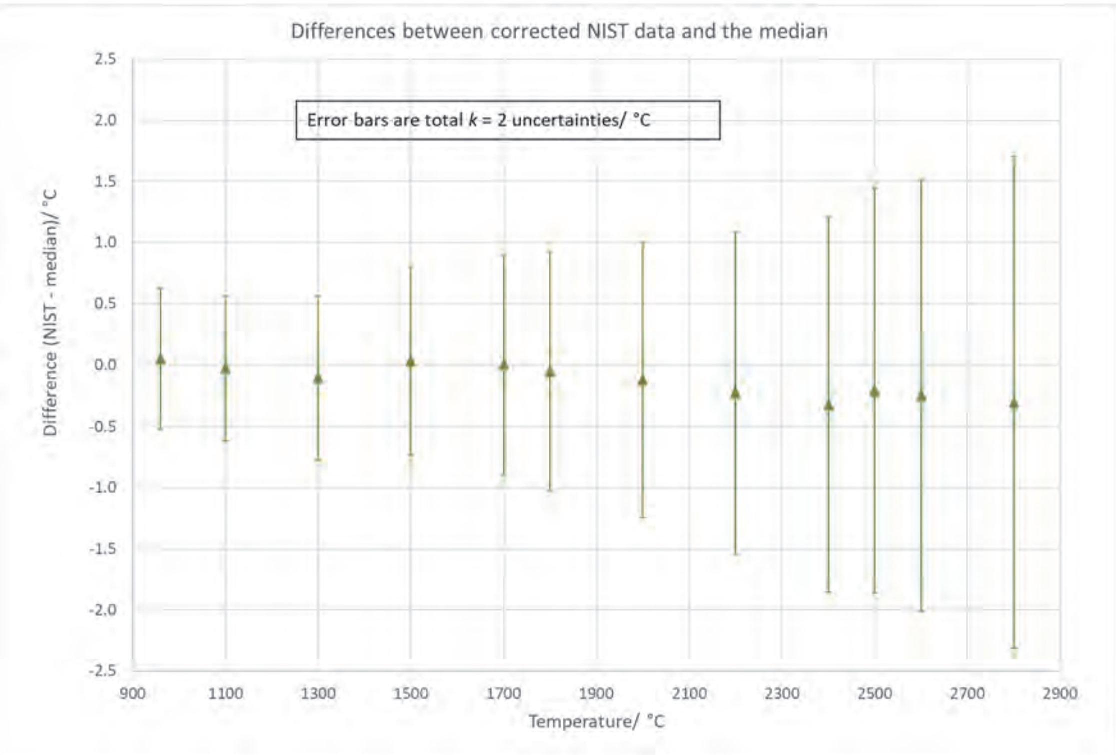


Figure 47 – difference between the NIST results with the LP3 and the median (*k* = 2 total uncertainties)

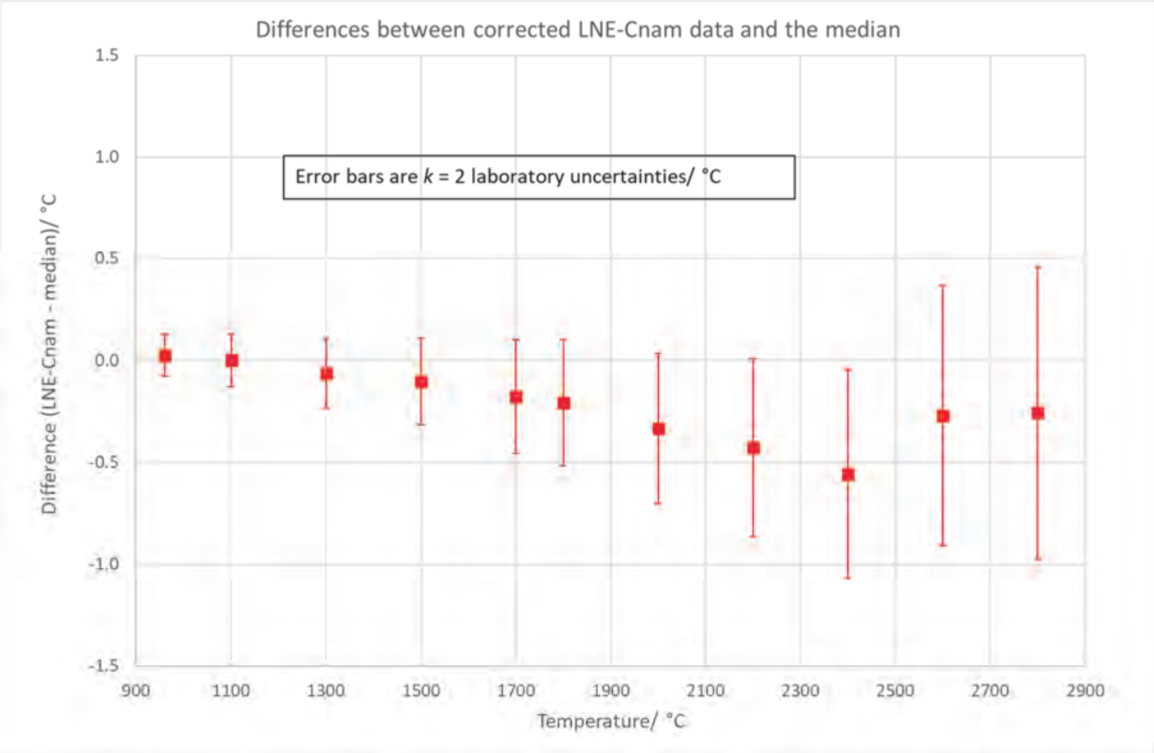


Figure 48 – difference between the LNE-Cnam results with the LP3 and the median (*k* = 2 laboratory uncertainties)

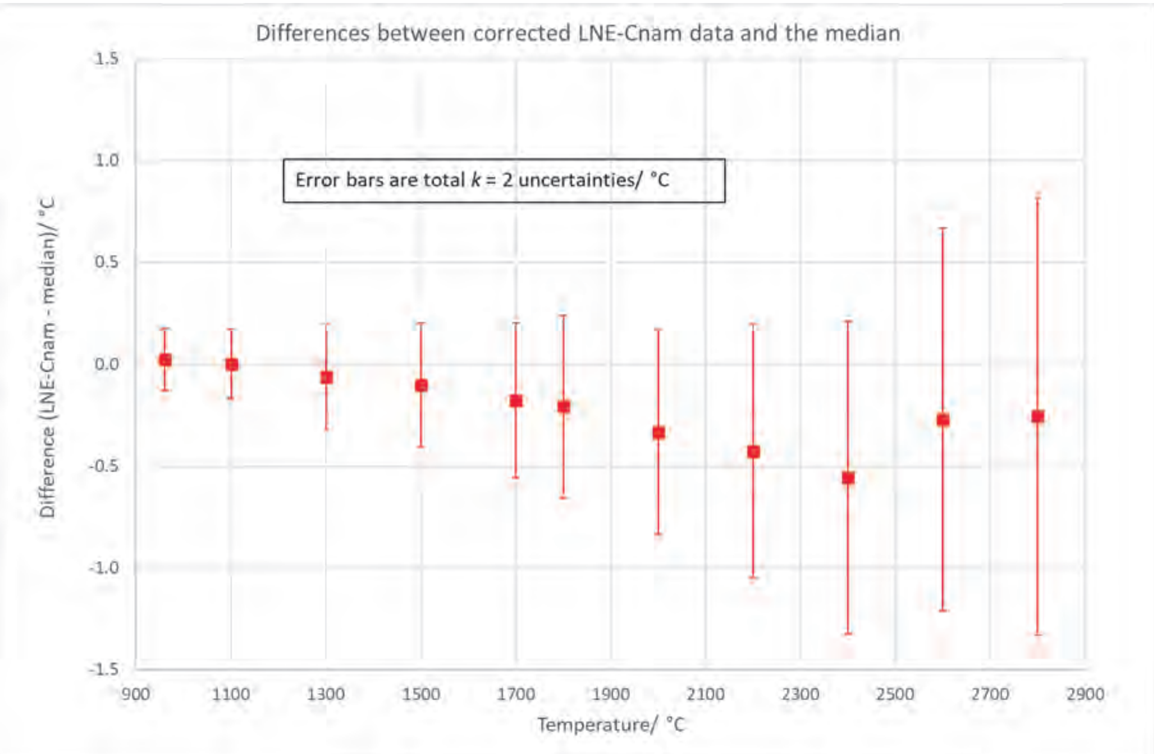


Figure 49 – difference between the LNE-Cnam results with the LP3 and the median (*k* = 2 total uncertainties)

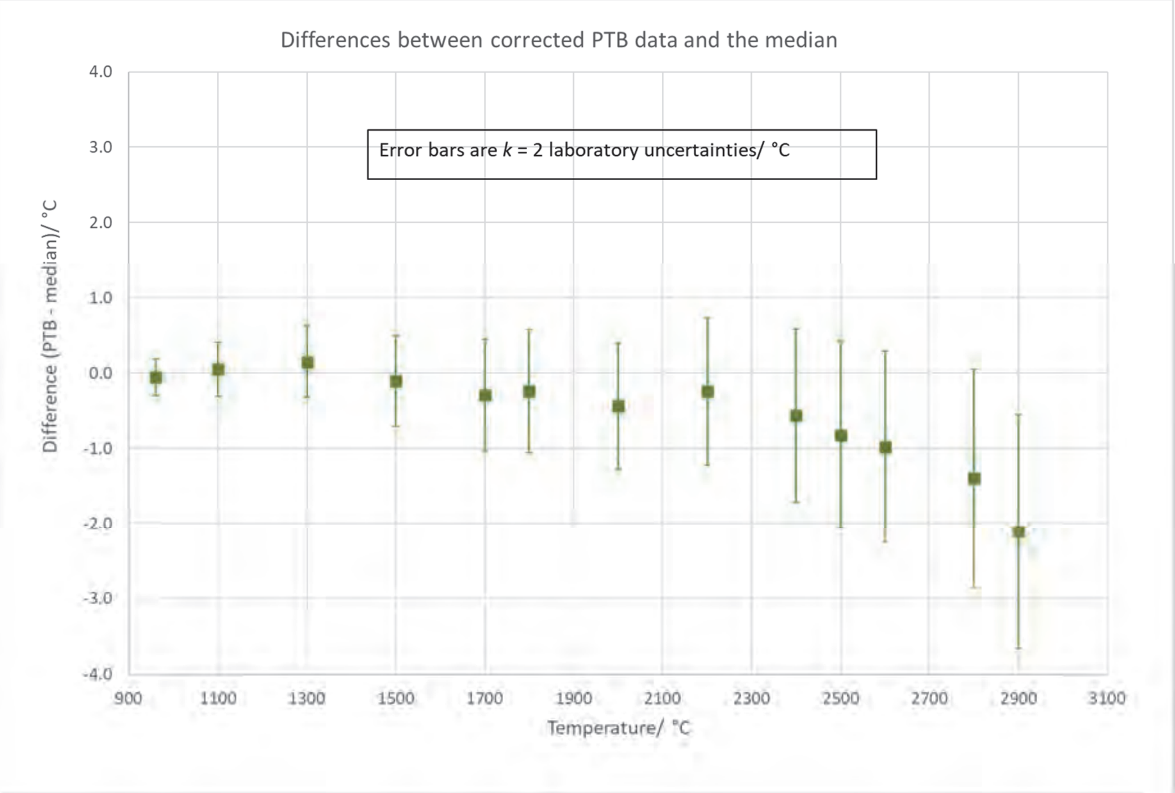


Figure 50 – difference between the PTB results with the LP3 and the median (k = 2 laboratory uncertainties)

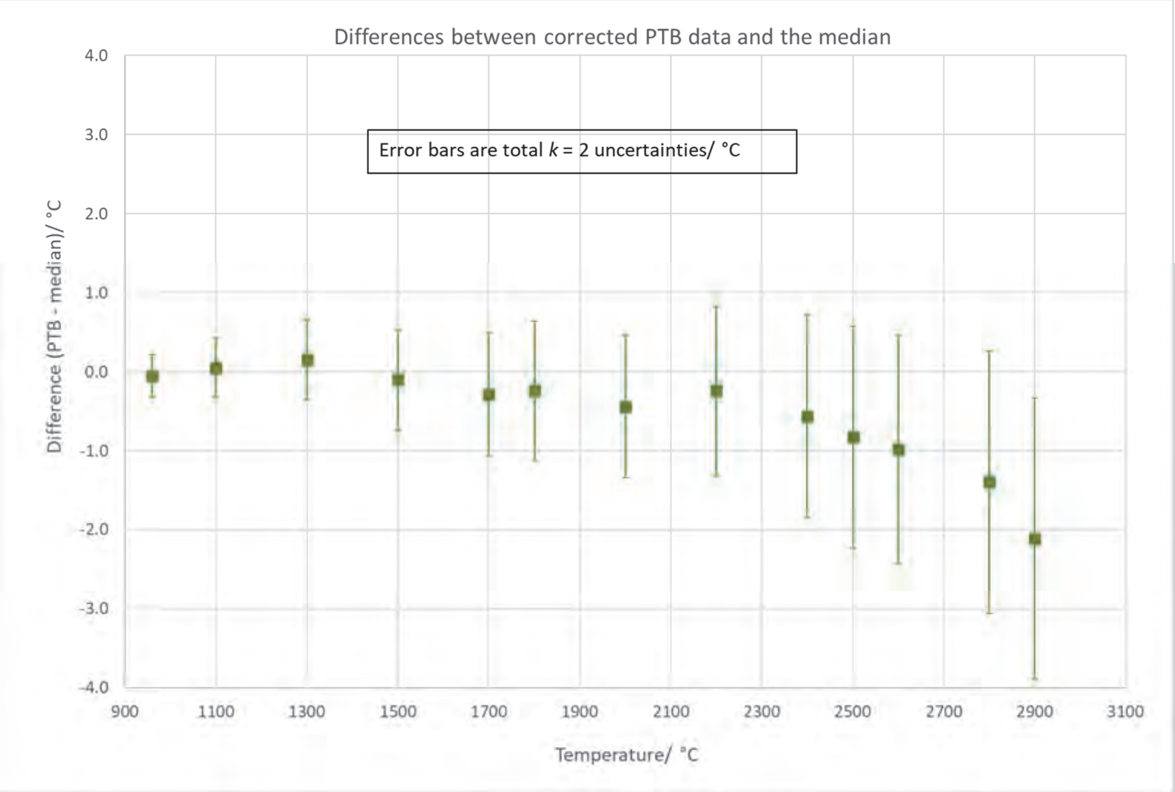


Figure 51 – difference between the PTB results with the LP3 and the median (k = 2 total uncertainties)

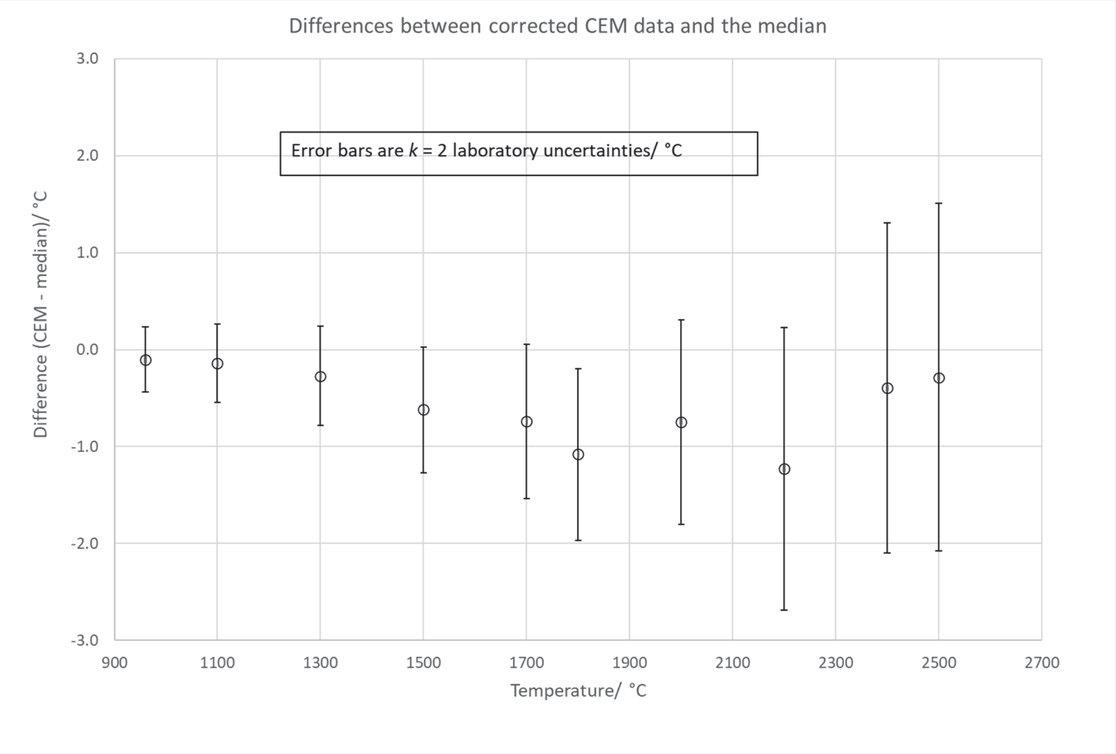


Figure 52 – difference between the CEM results with the LP3 and the median (*k* = 2 laboratory uncertainties)

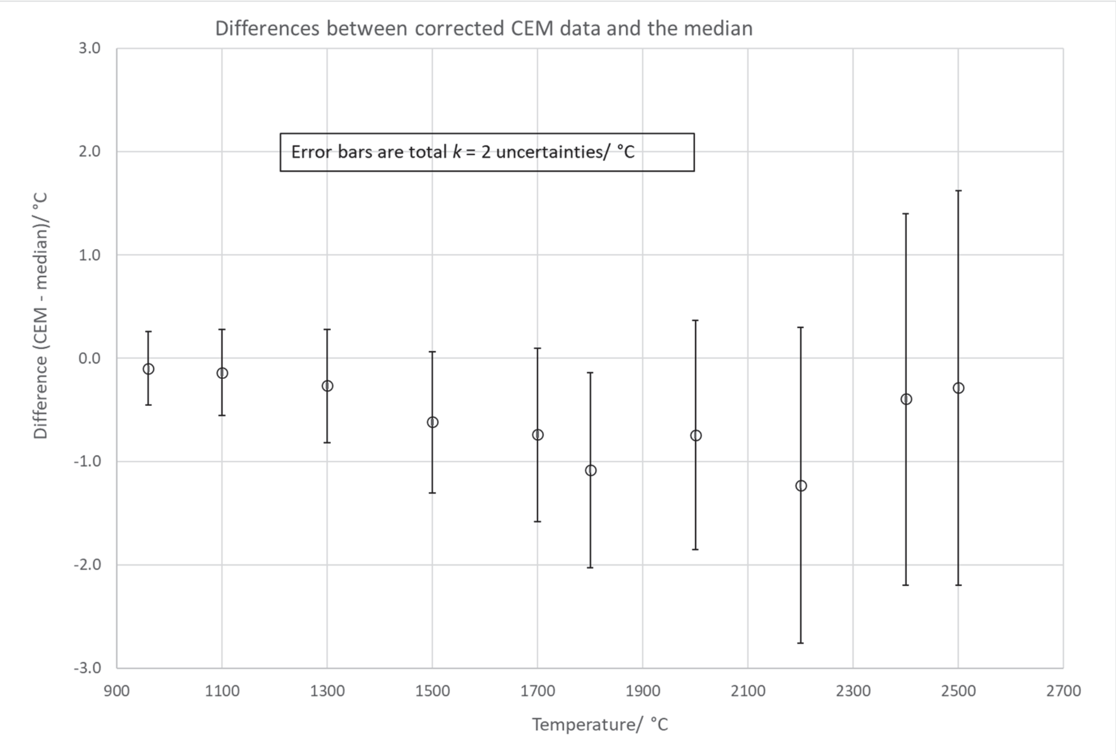


Figure 53 – difference between the CEM results with the LP3 and the median (*k* = 2 total uncertainties)

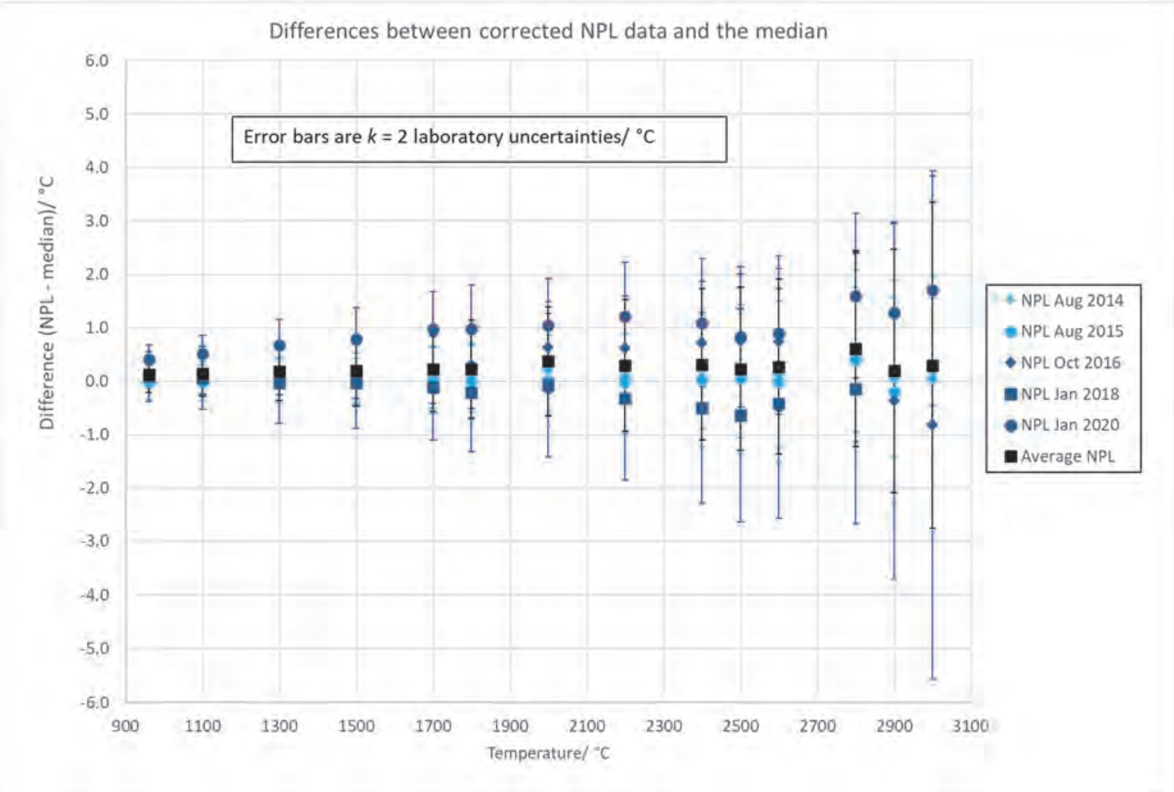


Figure 54 – difference between the NPL results with the LP3 and the median (*k* = 2 laboratory uncertainties)

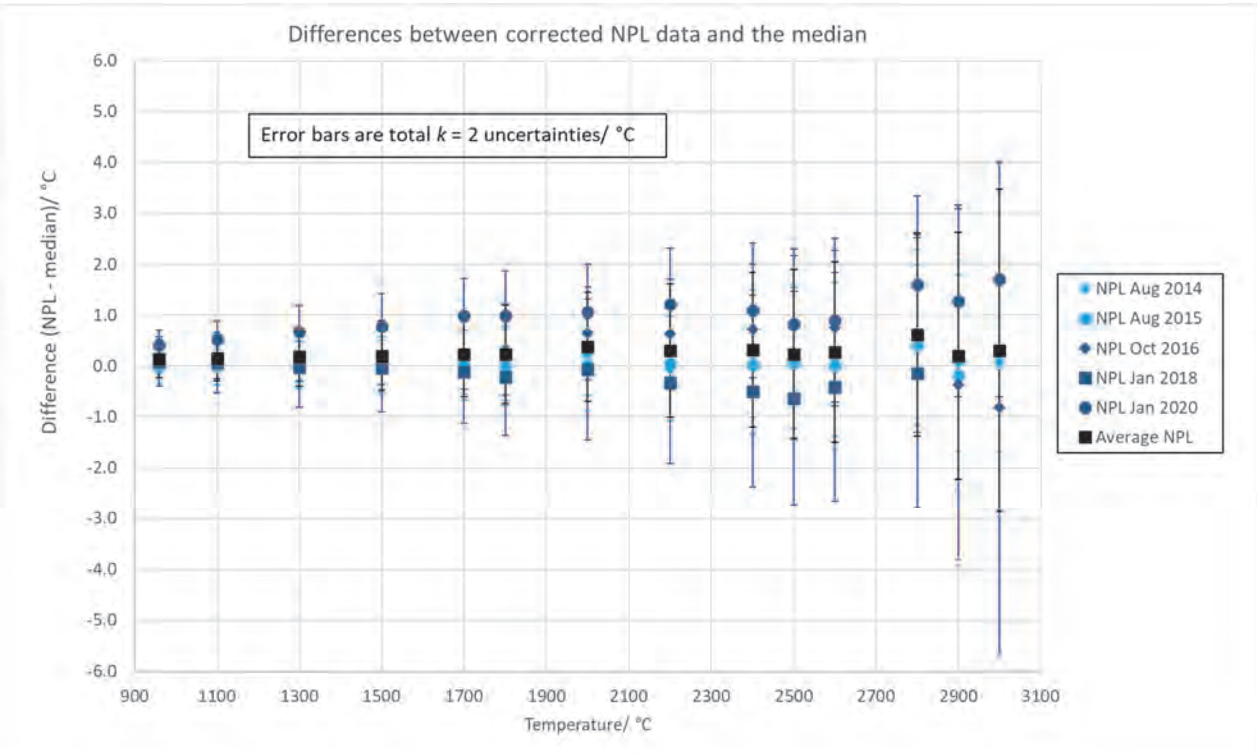


Figure 55 – difference between the NPL results with the LP3 and the median (*k* = 2 total uncertainties)

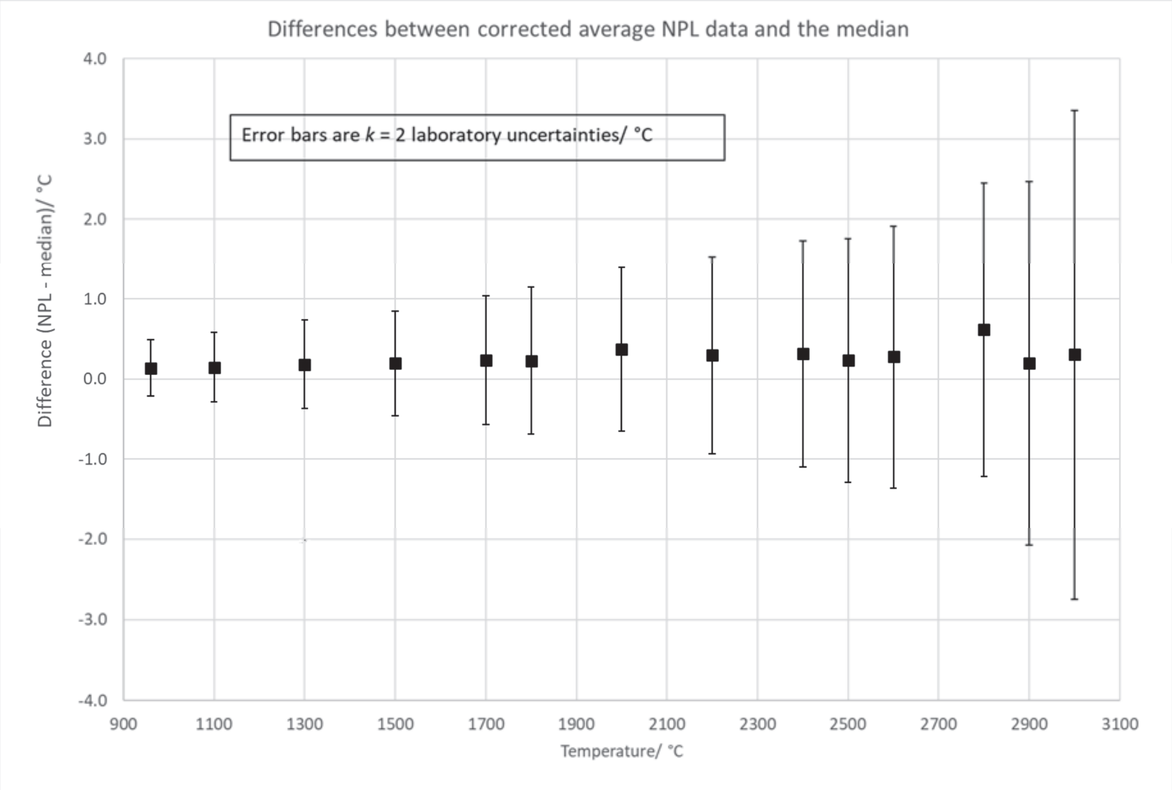


Figure 56 – difference between the average NPL results with the LP3 and the median (*k* = 2 laboratory uncertainties)

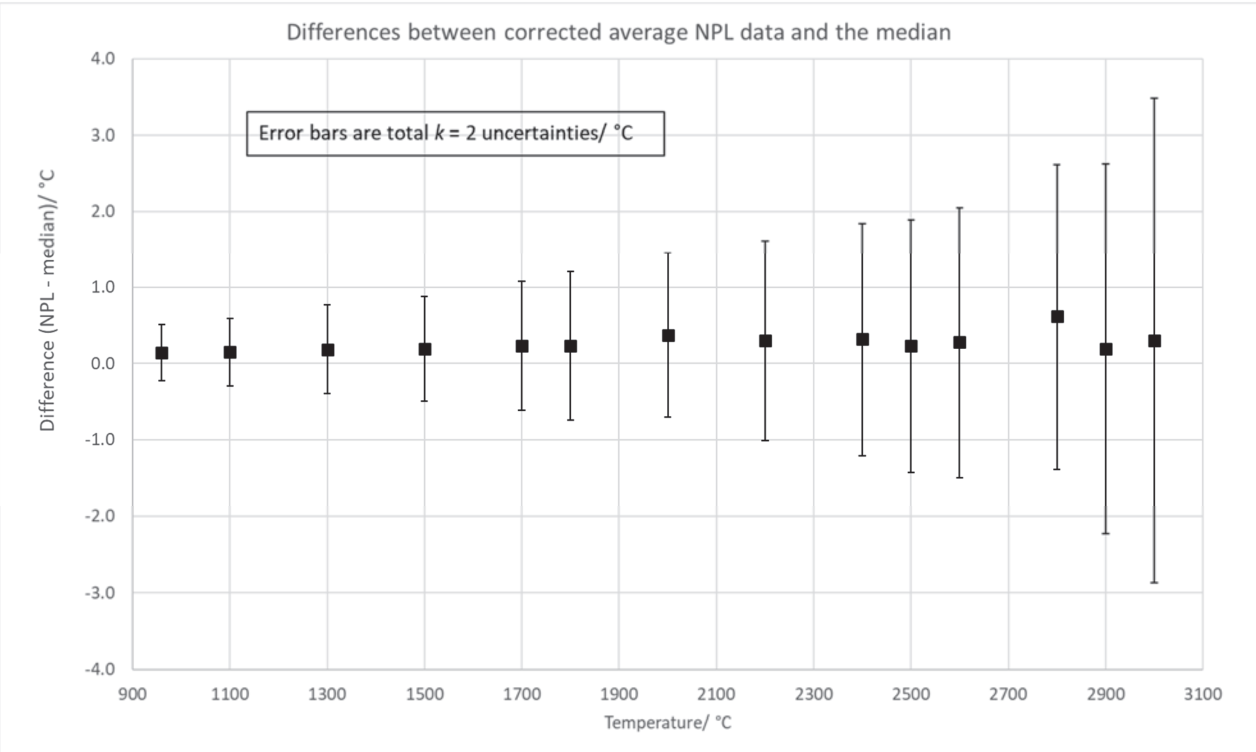


Figure 57 – difference between the average NPL results with the LP3 and the median (*k* = 2 total uncertainties)

10.11 GRAPHICAL RESULTS WITH THE CHINO THERMOMETER

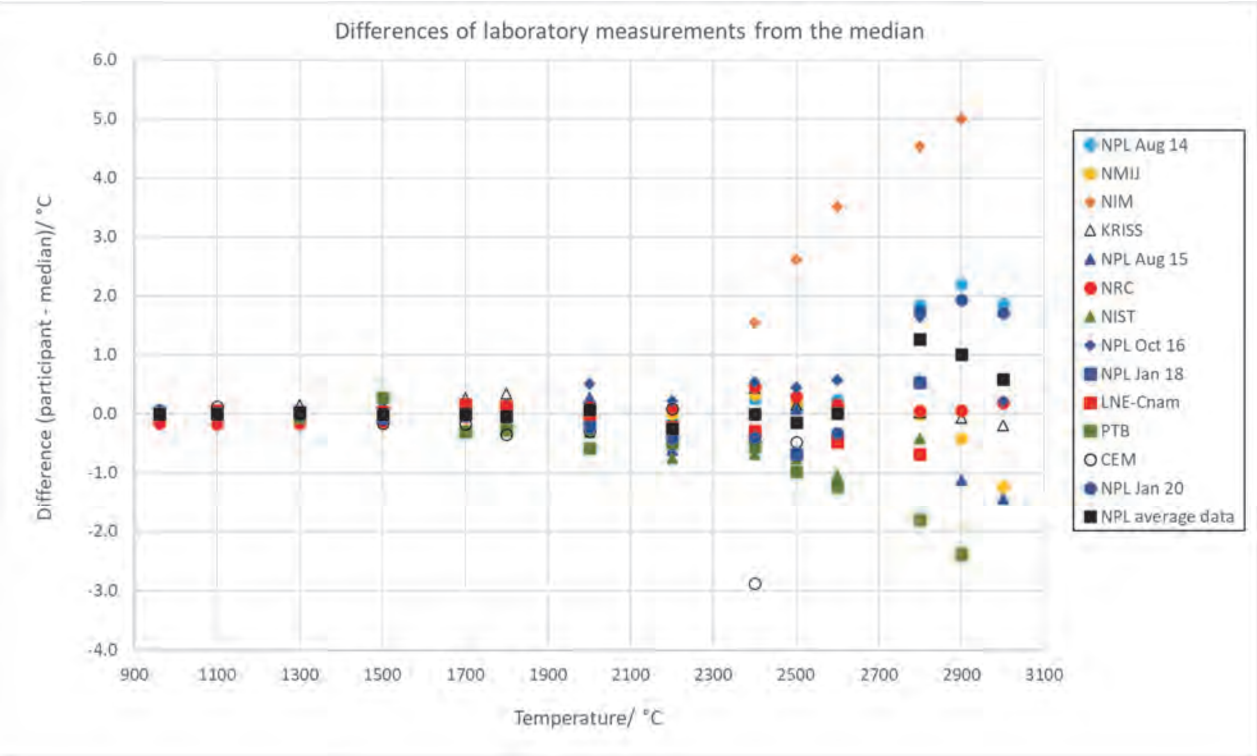


Figure 58 – Results of the comparison with the Chino thermometer, showing differences of each participant from the median value

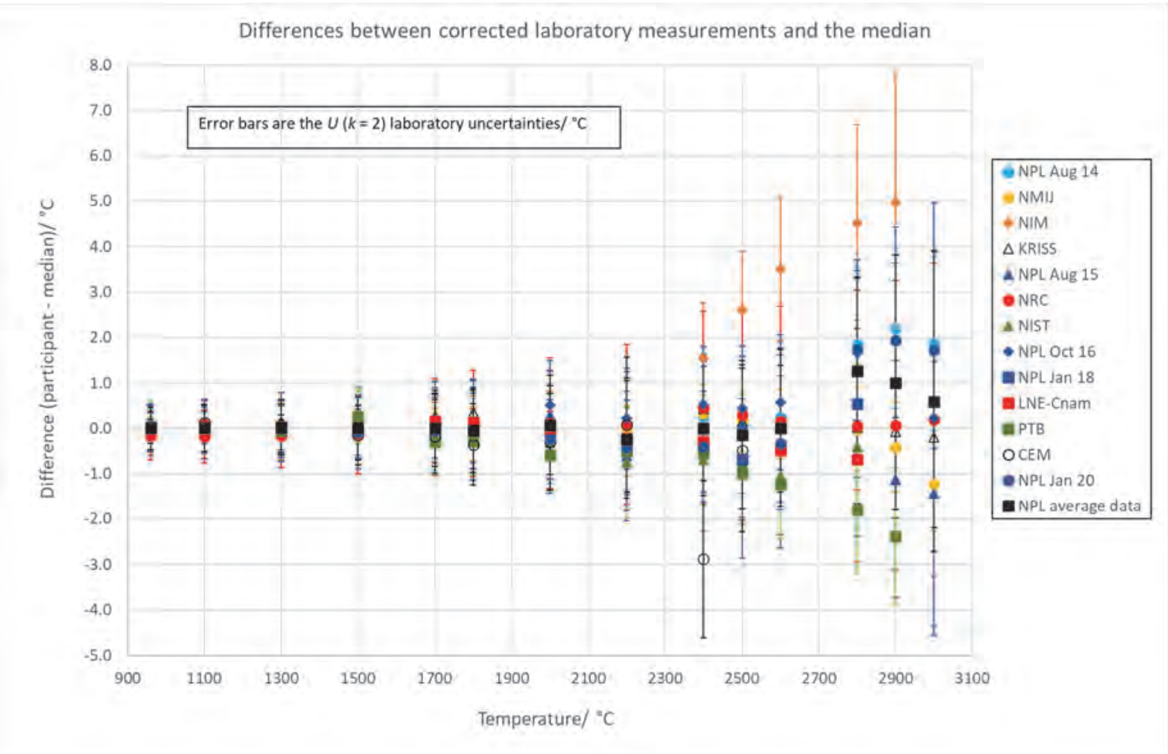


Figure 59 - Results of the comparison with the Chino thermometer, showing differences of each participant from the median value and the total, *k* = 2 uncertainties

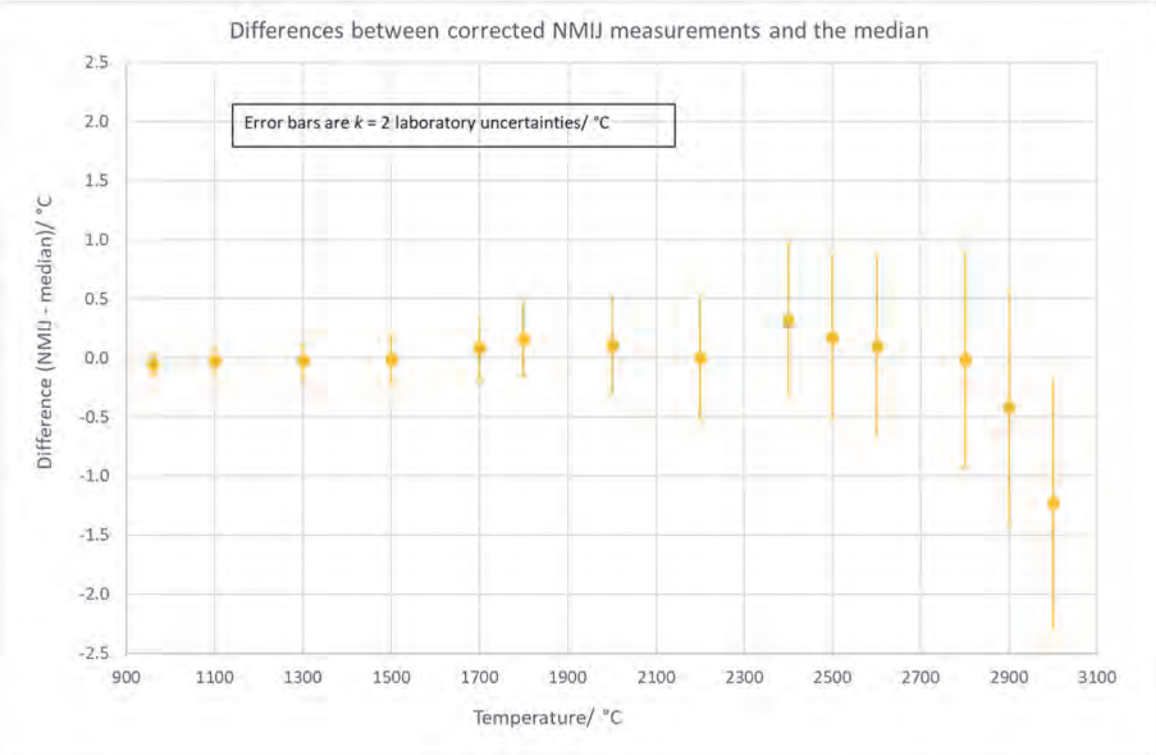


Figure 60 – difference between the NMIJ results with the Chino thermometer and the median (*k* = 2 laboratory uncertainties)

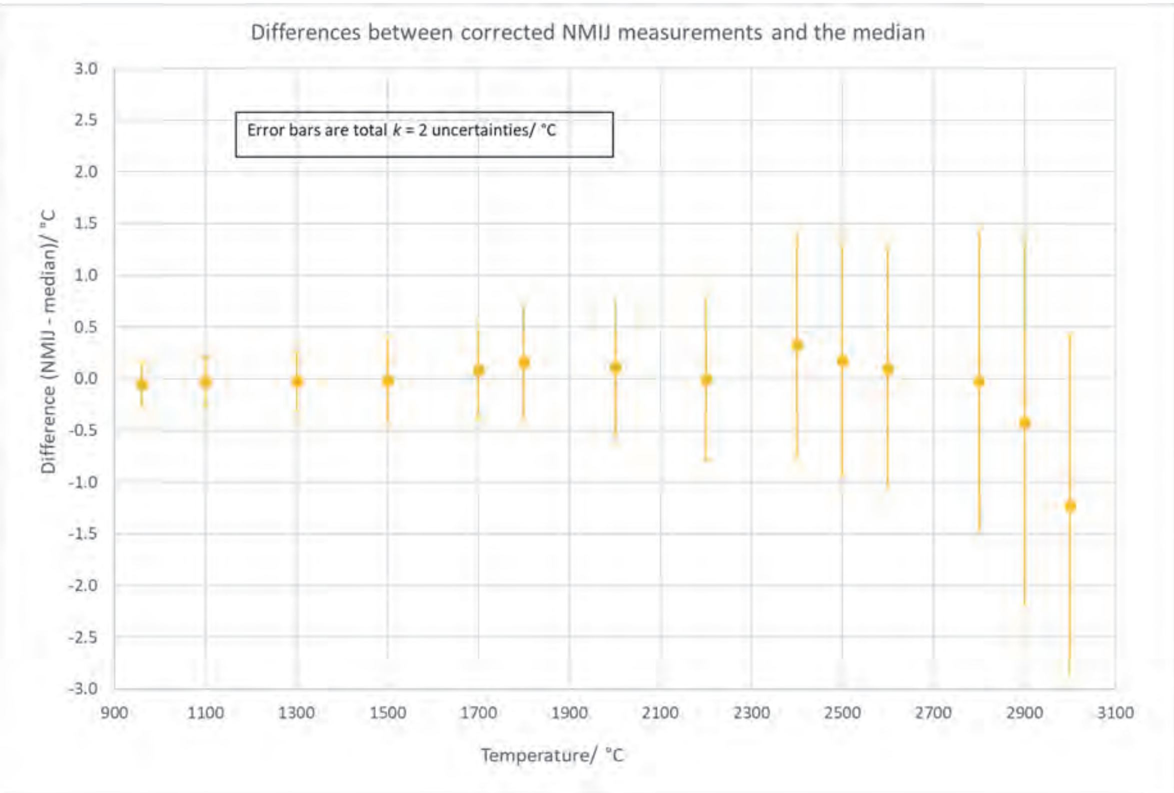


Figure 61 – difference between the NMIJ results with the Chino thermometer and the median (*k* = 2 total uncertainties)

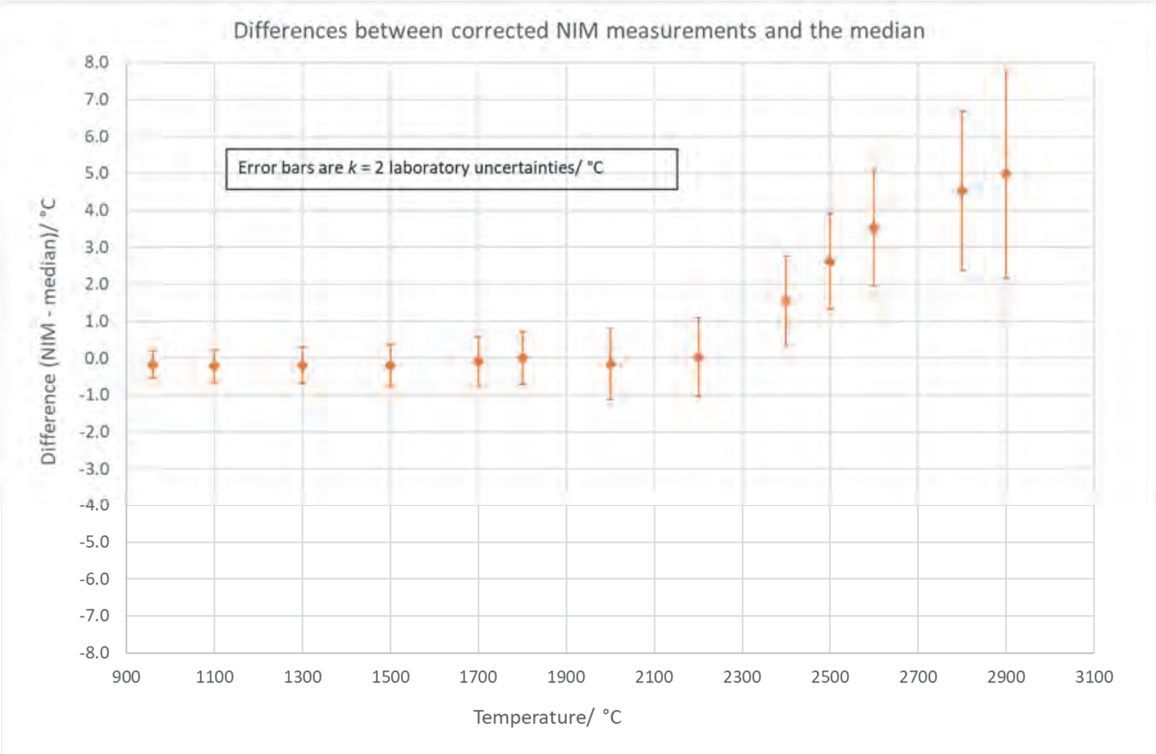


Figure 62 – difference between the NIM results with the Chino thermometer and the median (k = 2 laboratory uncertainties)

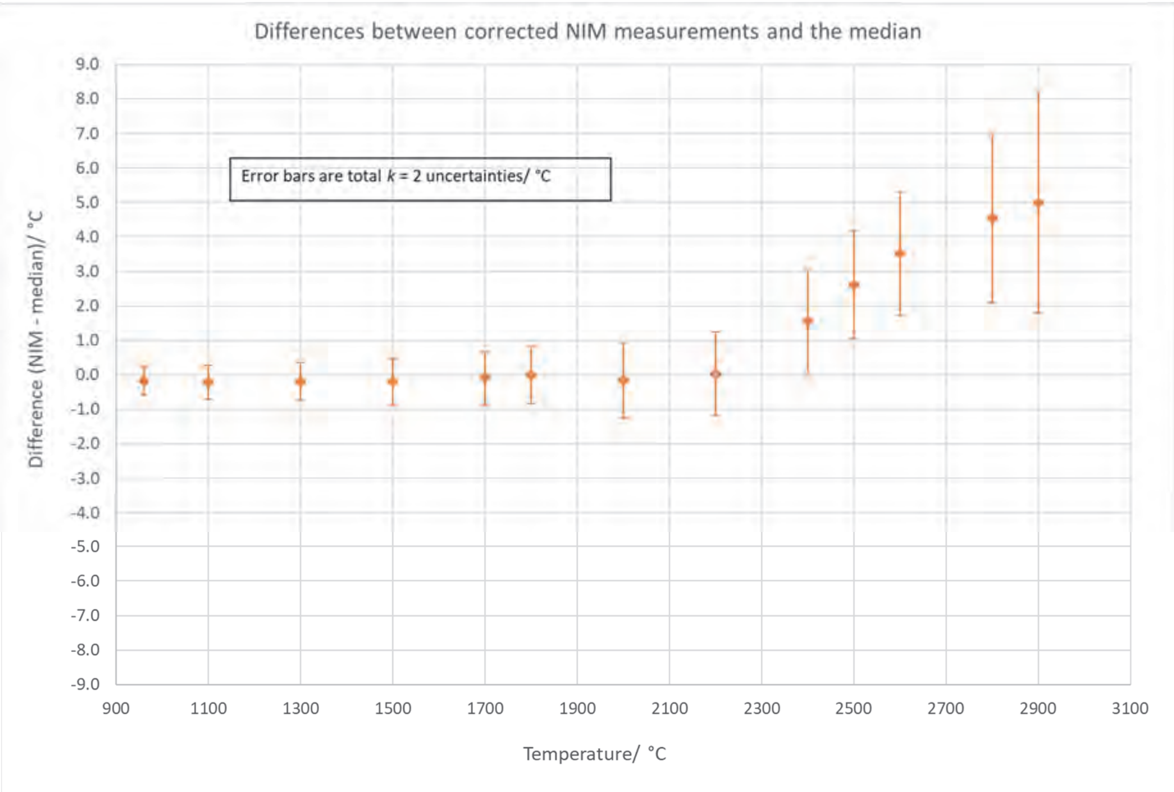


Figure 63 – difference between the NIM results with the Chino thermometer and the median (k = 2 total uncertainties)

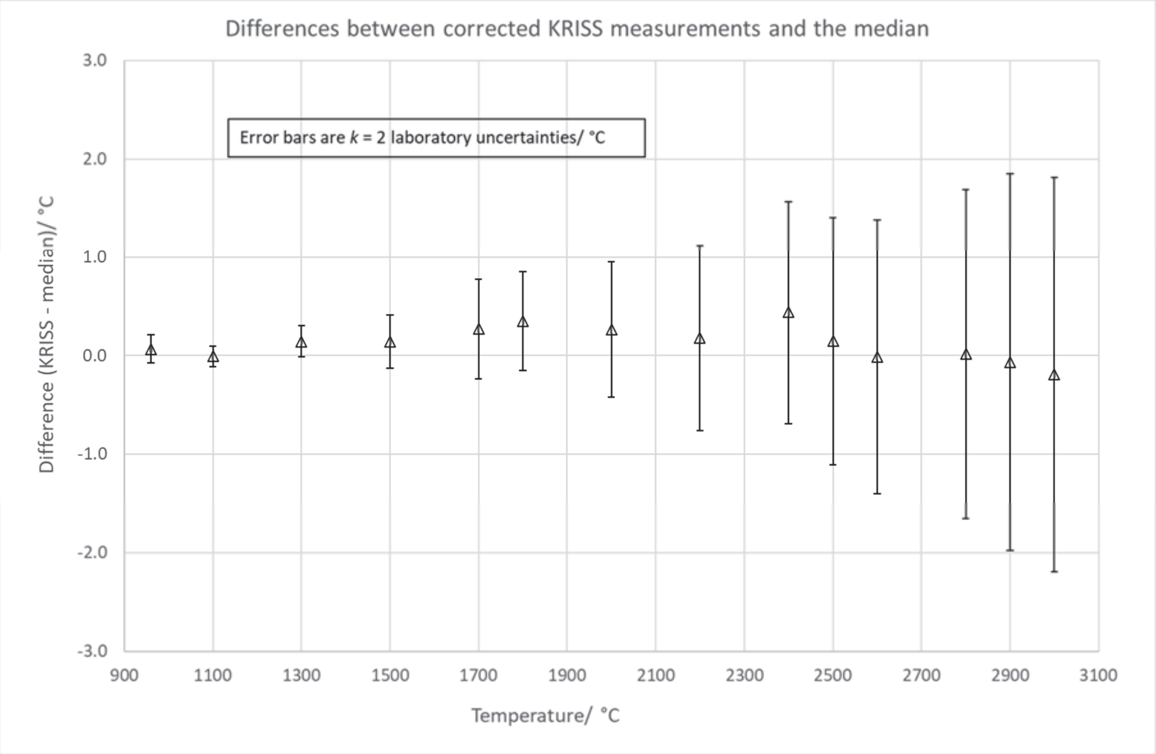


Figure 64 - difference between the KRISS results with the Chino thermometer and the median (*k* = 2 laboratory uncertainties)

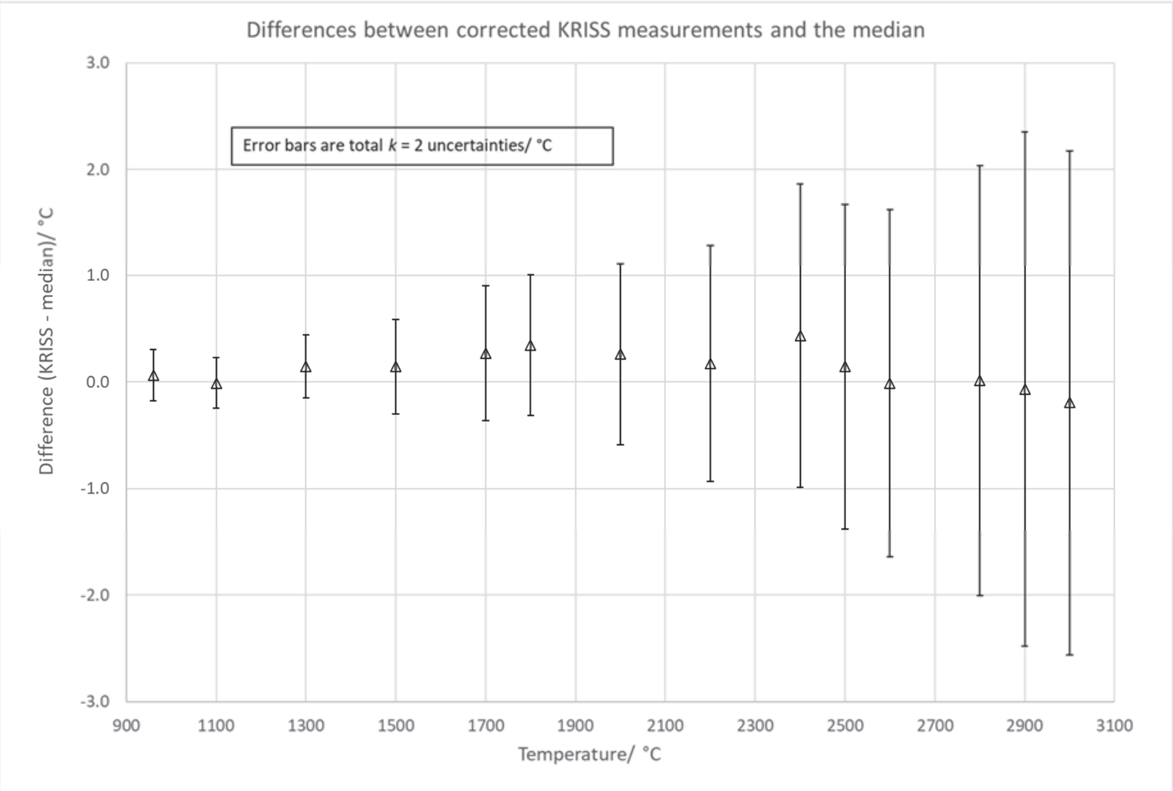


Figure 65 - difference between the KRISS results with the Chino thermometer and the median (*k* = 2 total uncertainties)

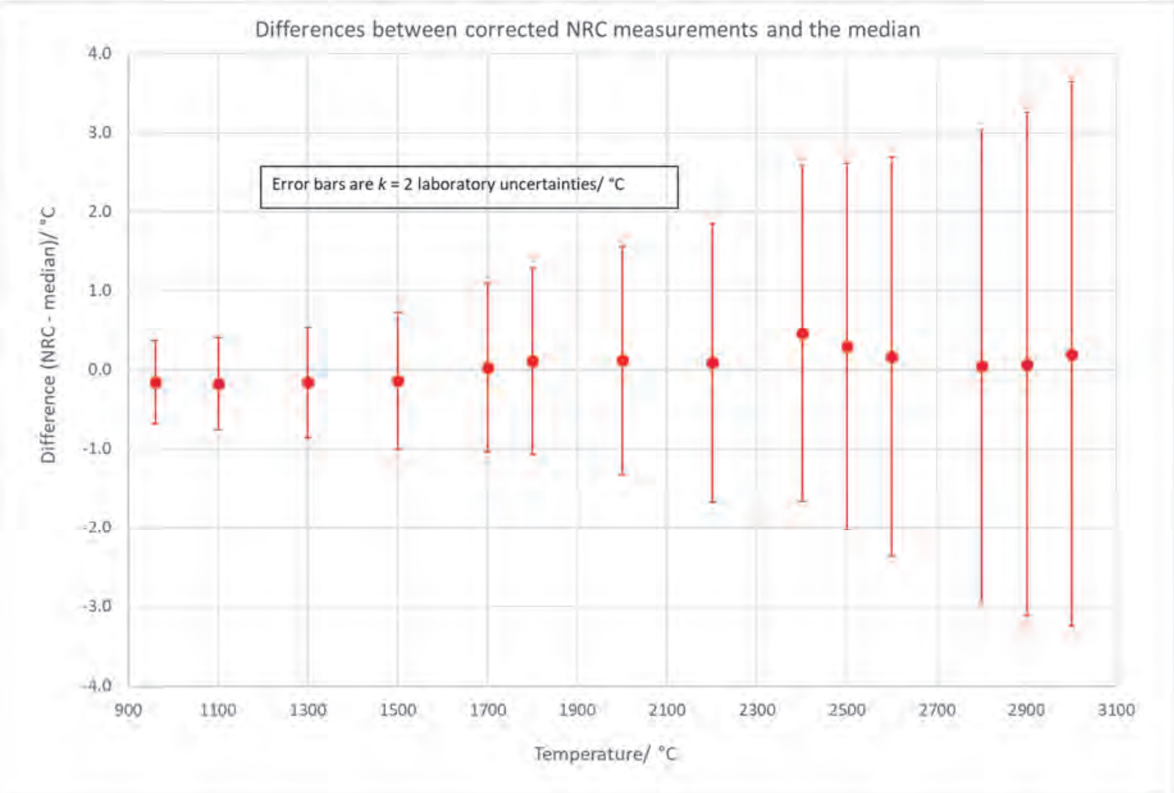


Figure 66 - difference between the NRC results with the Chino thermometer and the median (*k* = 2 laboratory uncertainties)

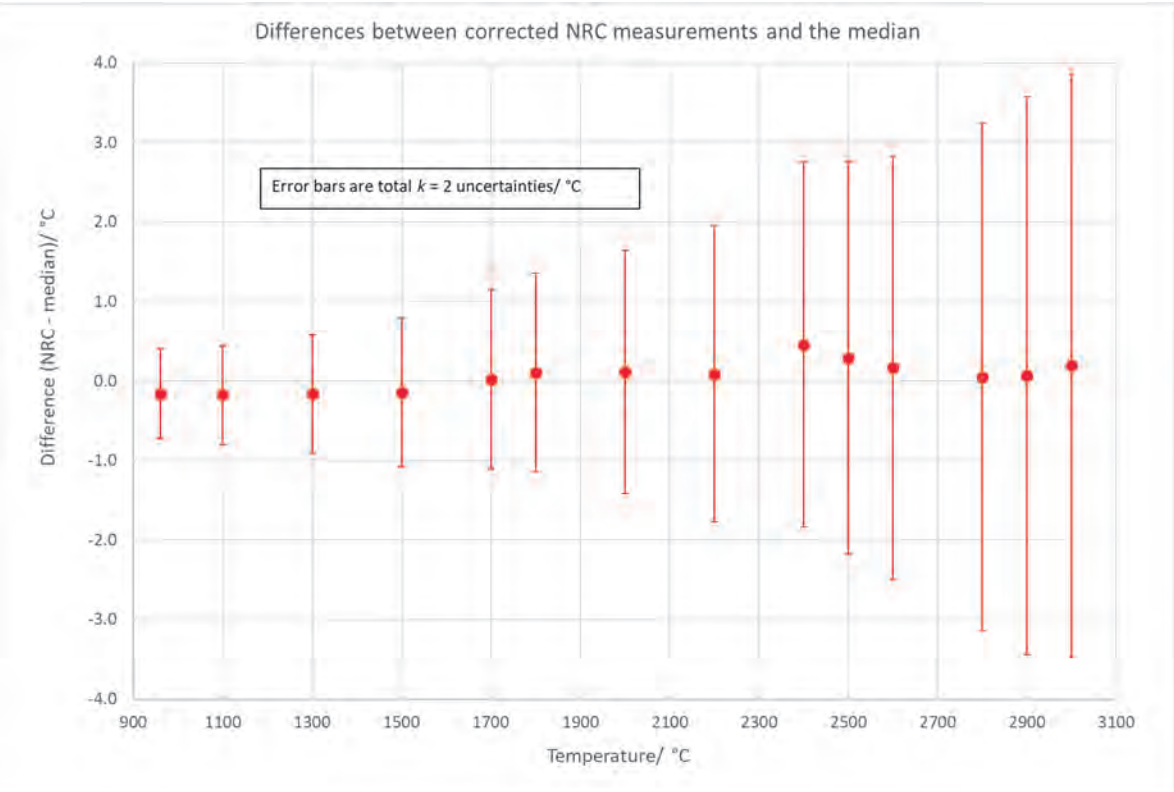


Figure 67 - difference between the NRC results with the Chino thermometer and the median (*k* = 2 total uncertainties)

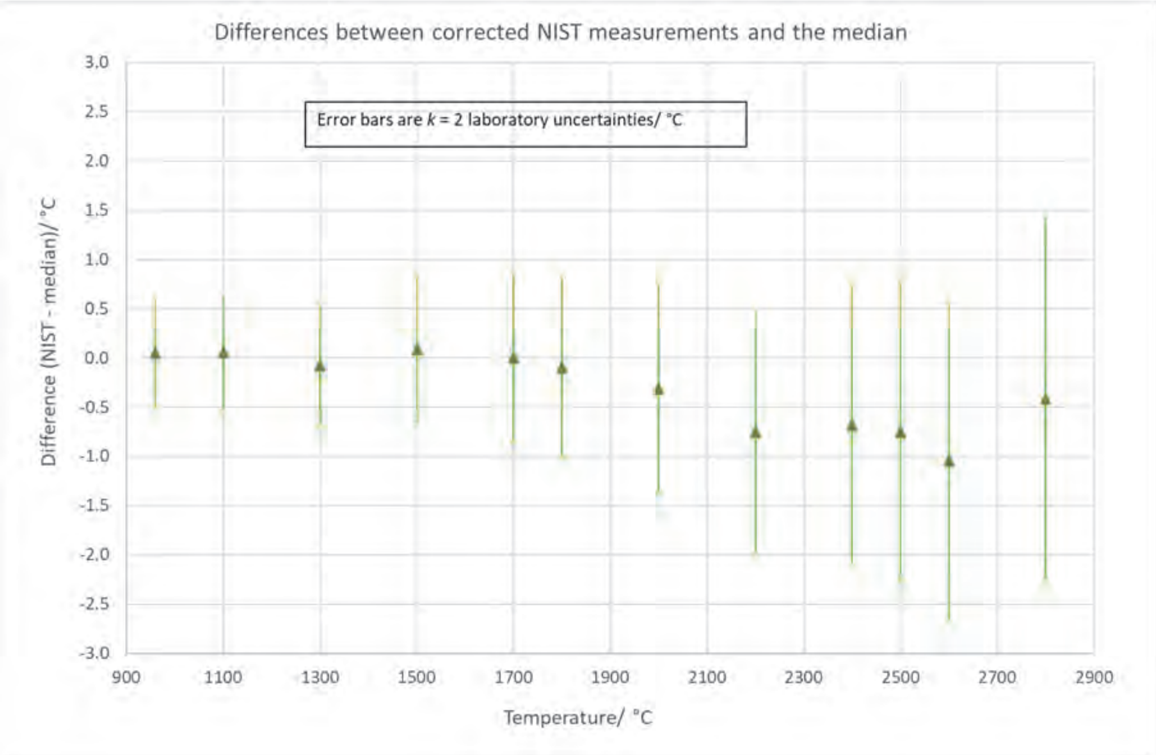


Figure 68 - difference between the NIST results with the Chino thermometer and the median (k = 2 laboratory uncertainties)

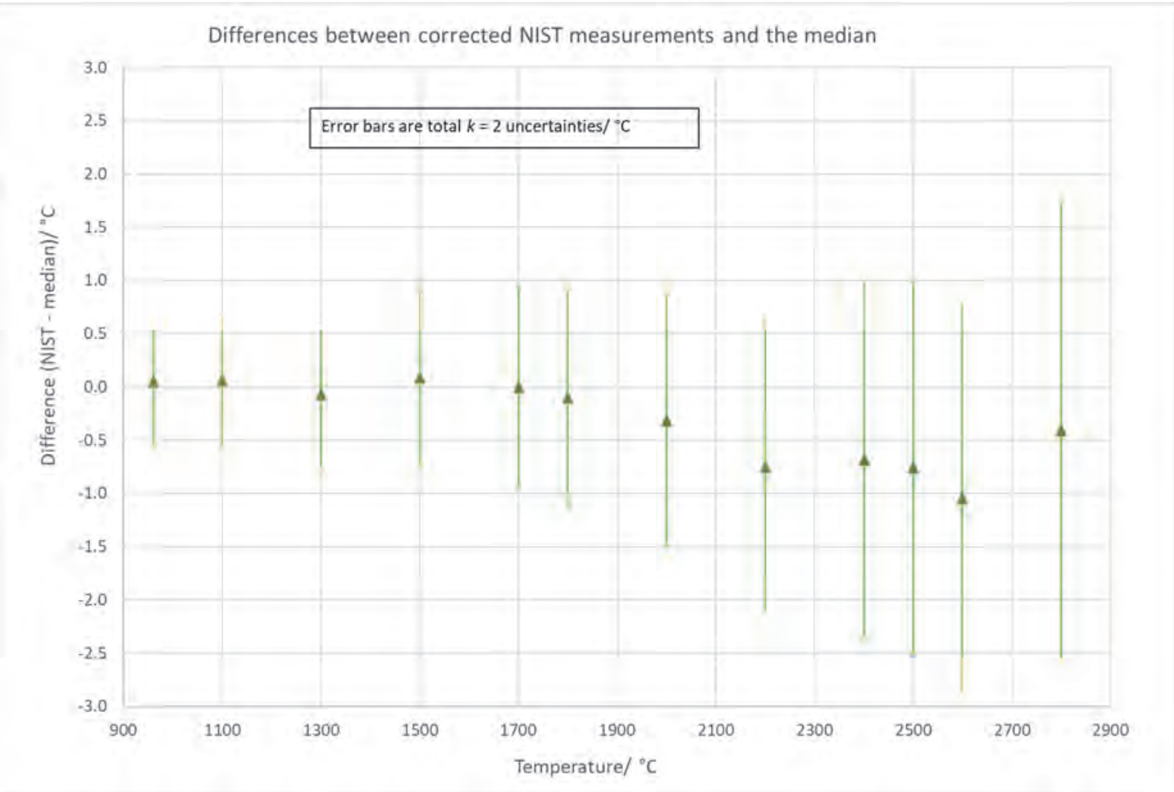


Figure 69 - difference between the NIST results with the Chino thermometer and the median (k = 2 total uncertainties)

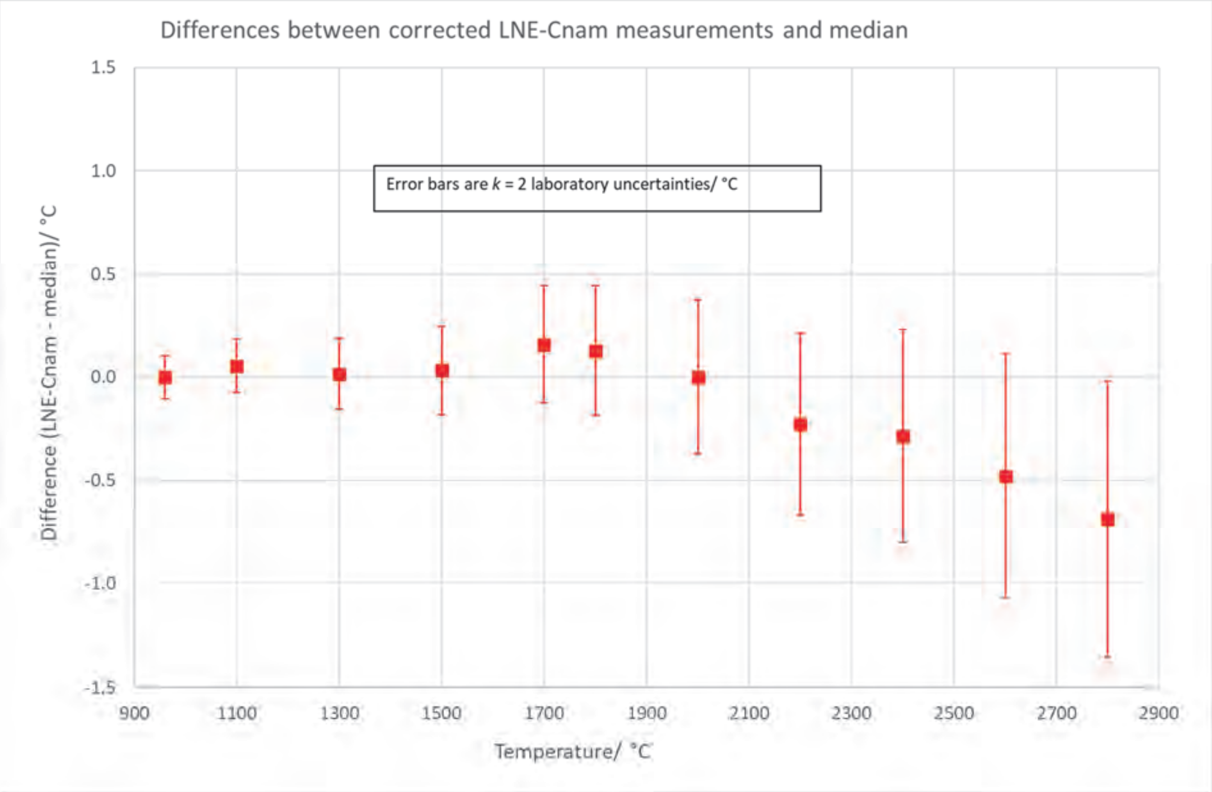


Figure 70 - difference between the LNE-Cnam results with the Chino thermometer and the median (k = 2 laboratory uncertainties)

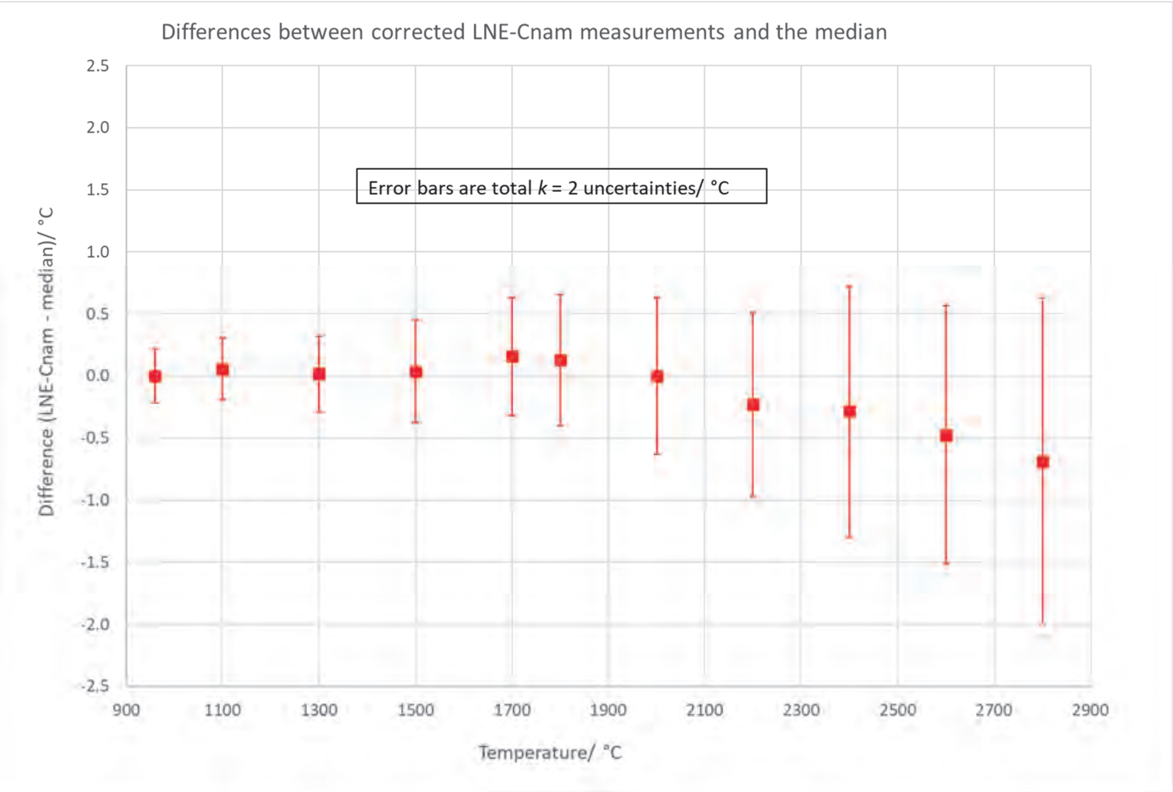


Figure 71 - difference between the LNE-Cnam results with the Chino thermometer and the median (k = 2 total uncertainties)

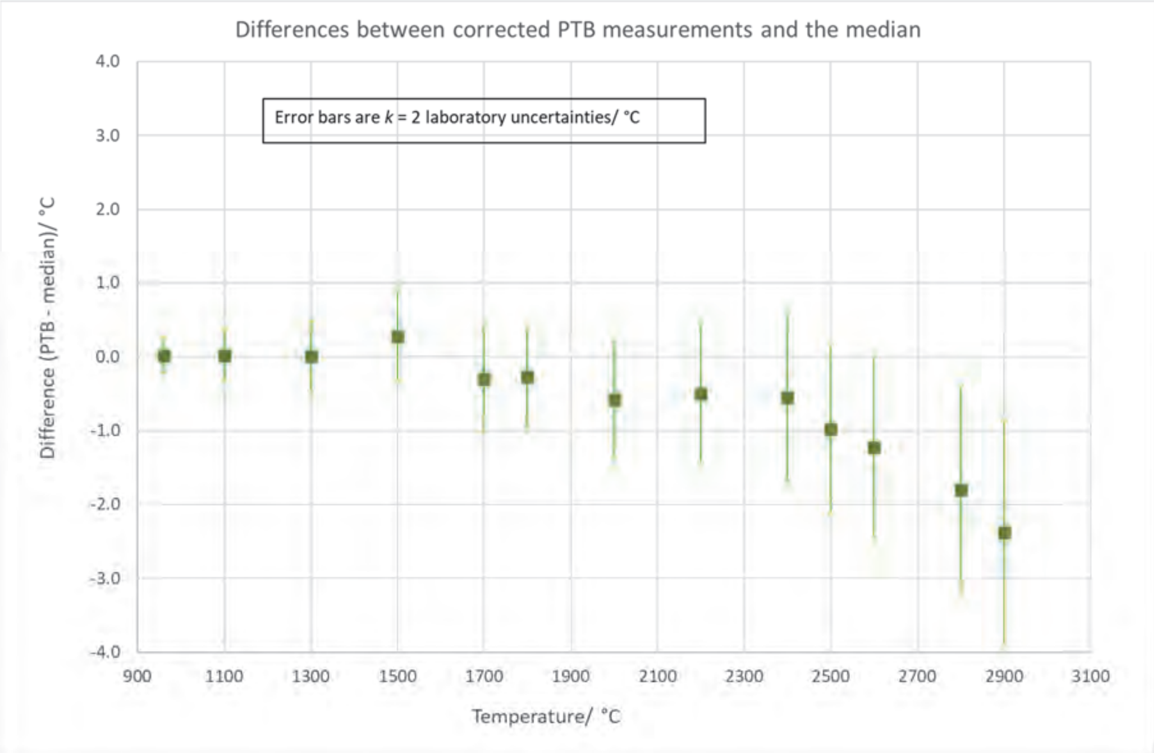


Figure 72 - difference between the PTB results with the Chino thermometer and the median (*k* = 2 laboratory uncertainties)

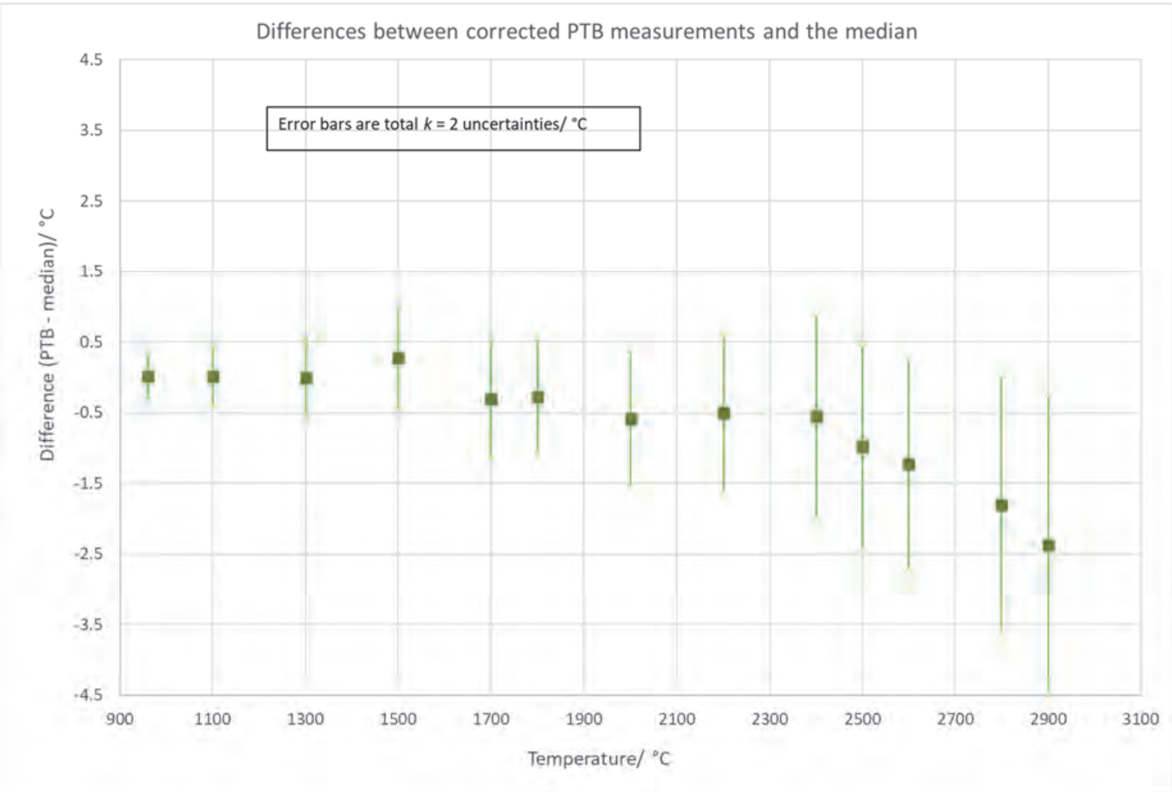


Figure 73 - difference between the PTB results with the Chino thermometer and the median (*k* = 2 total uncertainties)

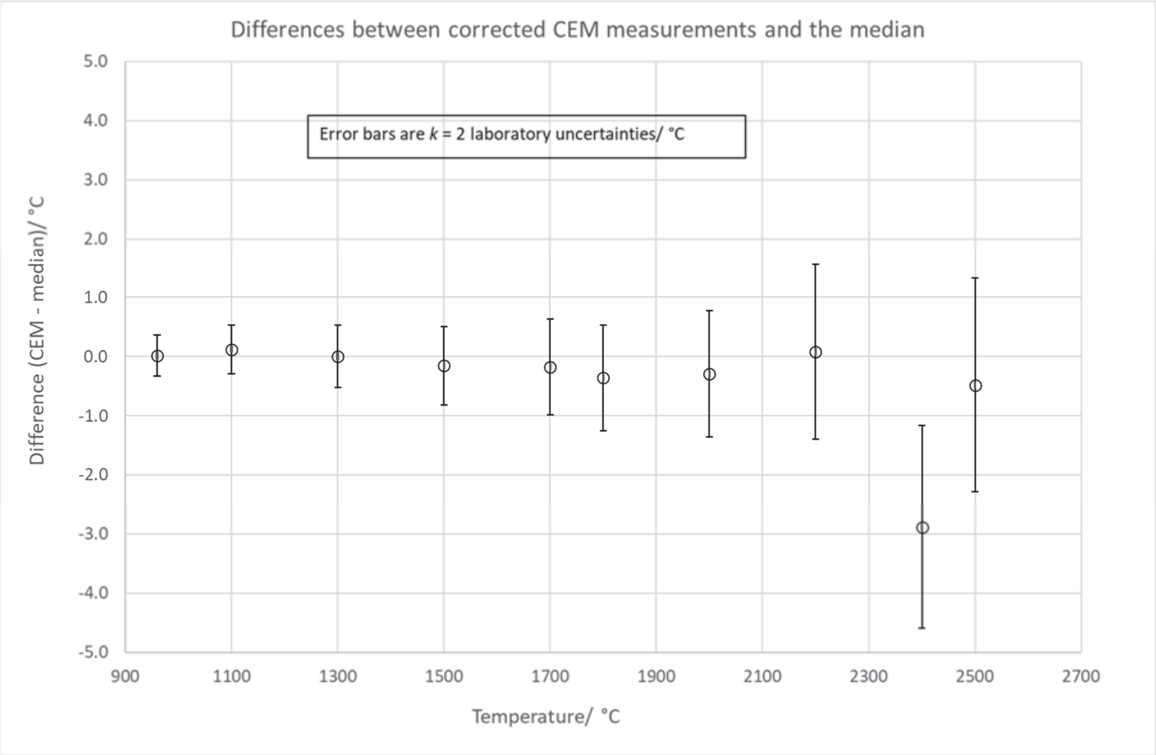


Figure 74 - difference between the CEM results with the Chino thermometer and the median (*k* = 2 laboratory uncertainties)

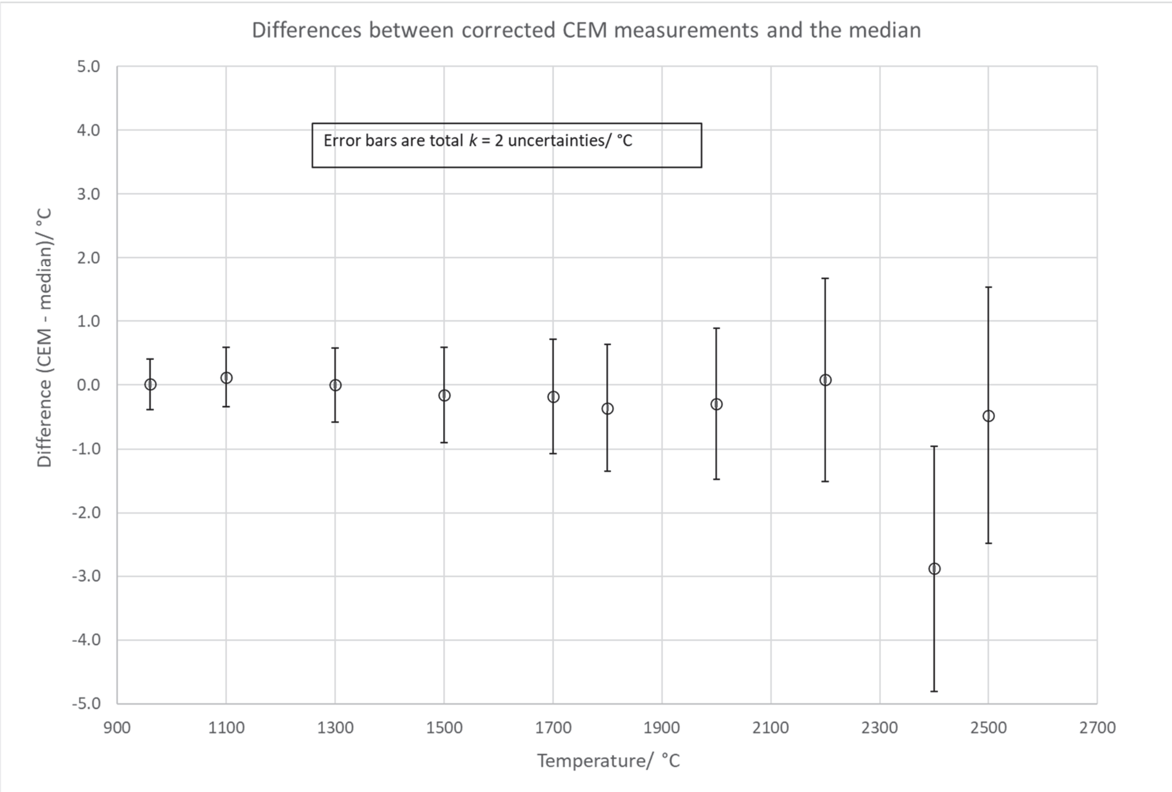


Figure 75 - difference between the CEM results with the Chino thermometer and the median (*k* = 2 total uncertainties)

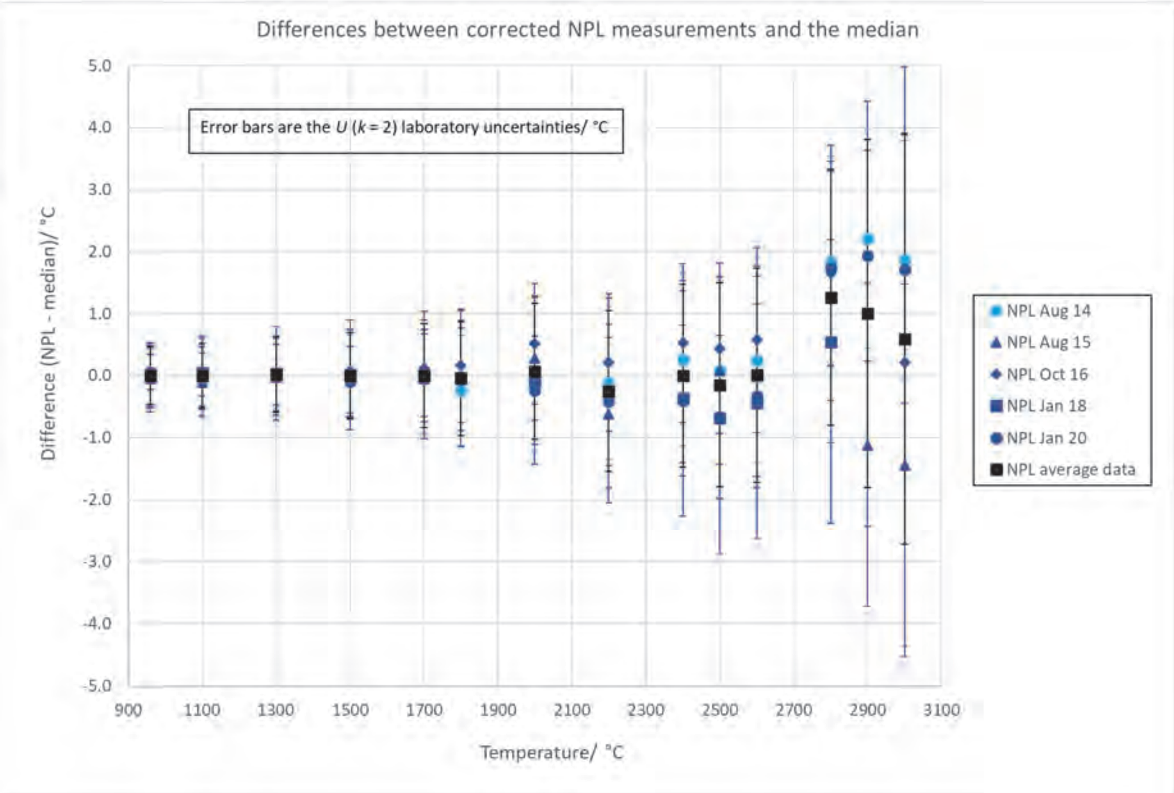


Figure 76 - difference between the NPL results with the Chino thermometer and the median (*k* = 2 laboratory uncertainties)

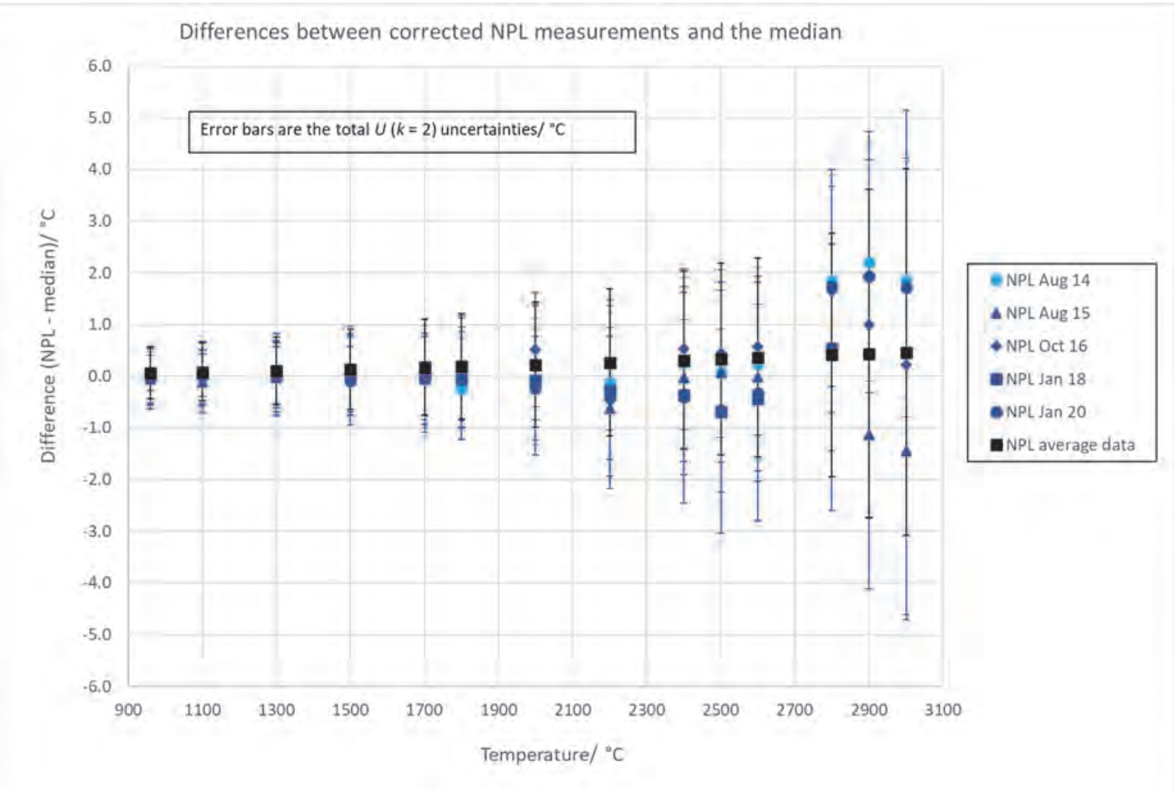


Figure 77 - difference between the NPL results with the Chino thermometer and the median (*k* = 2 total uncertainties)

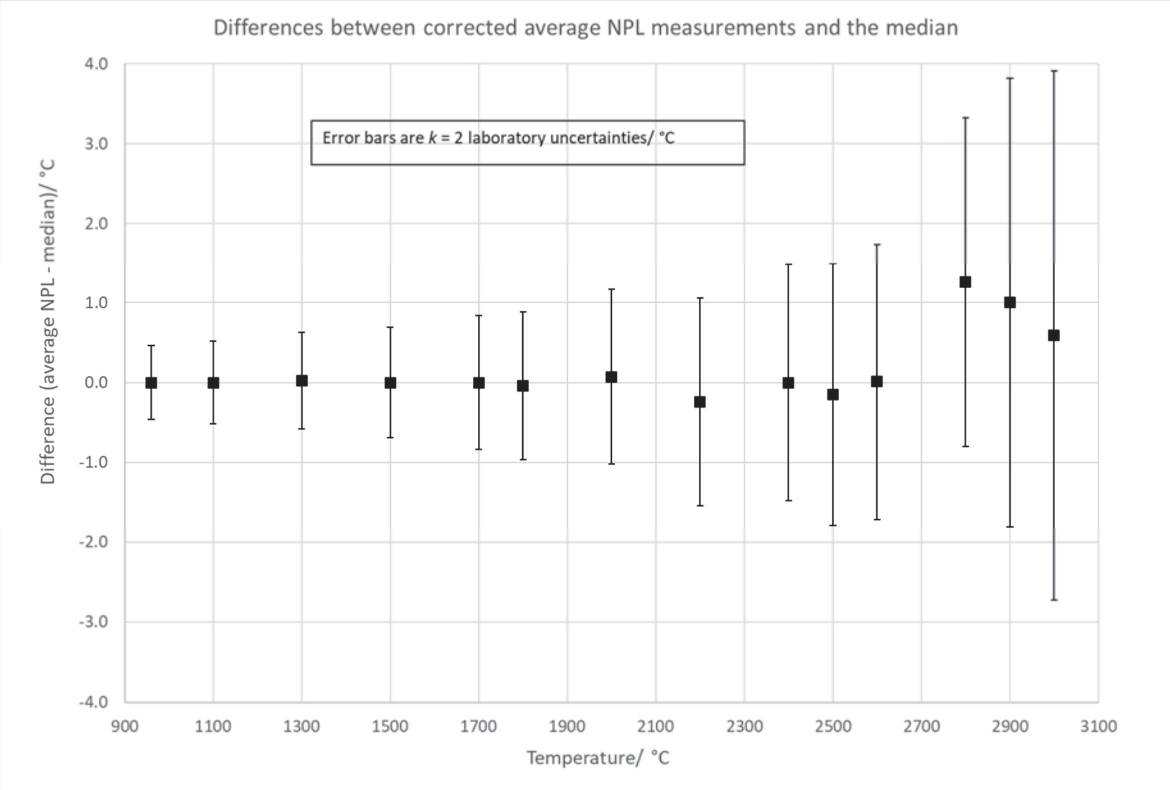


Figure 78 - difference between the average NPL results with the Chino thermometer and the median (*k* = 2 laboratory uncertainties)

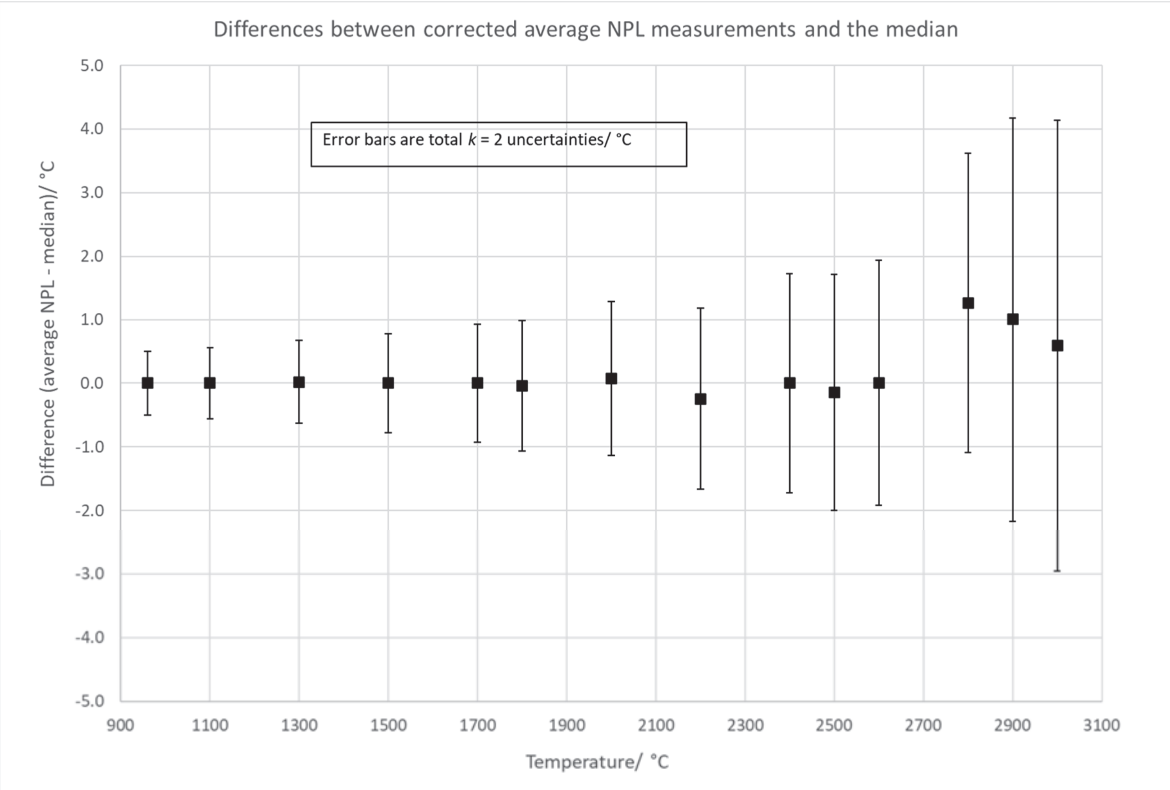


Figure 79 - difference between the average NPL results with the Chino thermometer and the median (*k* = 2 total uncertainties)

10.12 QDE_{95} AND DOE TABLES AND CHARTS – LP3 THERMOMETER

The Tables and Charts showing Degree of Equivalence (DOE) and QDE_{95} values, as described in Section 10.7, are given in this Section for the LP3 thermometer.

Table 49 - DOE and QDE_{95} table of results for the LP3 at 960 °C (all units are in °C) and chart with differences from the median

	NMIJ	NIM	KRISS	NRC	NIST	LNE-Cnam	PTB	CEM	Average NPL
NMIJ	-	0.08 ± 0.33	0.02 ± 0.23	0.13 ± 0.56	-0.03 ± 0.59	0.00 ± 0.20	0.08 ± 0.30	0.12 ± 0.38	-0.12 ± 0.39
NIM	*0.36*	-	-0.06 ± 0.35	0.05 ± 0.62	-0.11 ± 0.64	-0.08 ± 0.33	0.00 ± 0.40	0.04 ± 0.47	-0.20 ± 0.47
KRISS	*0.23*	*0.36*	-	0.11 ± 0.57	-0.05 ± 0.60	-0.02 ± 0.24	0.06 ± 0.33	0.10 ± 0.40	-0.14 ± 0.41
NRC	*0.61*	*0.61*	*0.60*	-	-0.16 ± 0.79	-0.13 ± 0.56	-0.06 ± 0.61	-0.01 ± 0.65	-0.25 ± 0.66
NIST	*0.58*	*0.67*	*0.59*	*0.83*	-	0.03 ± 0.59	0.11 ± 0.63	0.15 ± 0.67	-0.09 ± 0.68
LNE-Cnam	*0.20*	*0.36*	*0.24*	*0.61*	*0.58*	-	0.08 ± 0.31	0.12 ± 0.39	-0.11 ± 0.40
PTB	*0.33*	*0.40*	*0.34*	*0.60*	*0.65*	*0.34*	-	0.05 ± 0.45	-0.19 ± 0.46
CEM	*0.44*	*0.46*	*0.44*	*0.64*	*0.72*	*0.45*	*0.45*	-	-0.24 ± 0.51
Average NPL	*0.44*	*0.59*	*0.48*	*0.79*	*0.69*	*0.45*	*0.57*	*0.66*	-

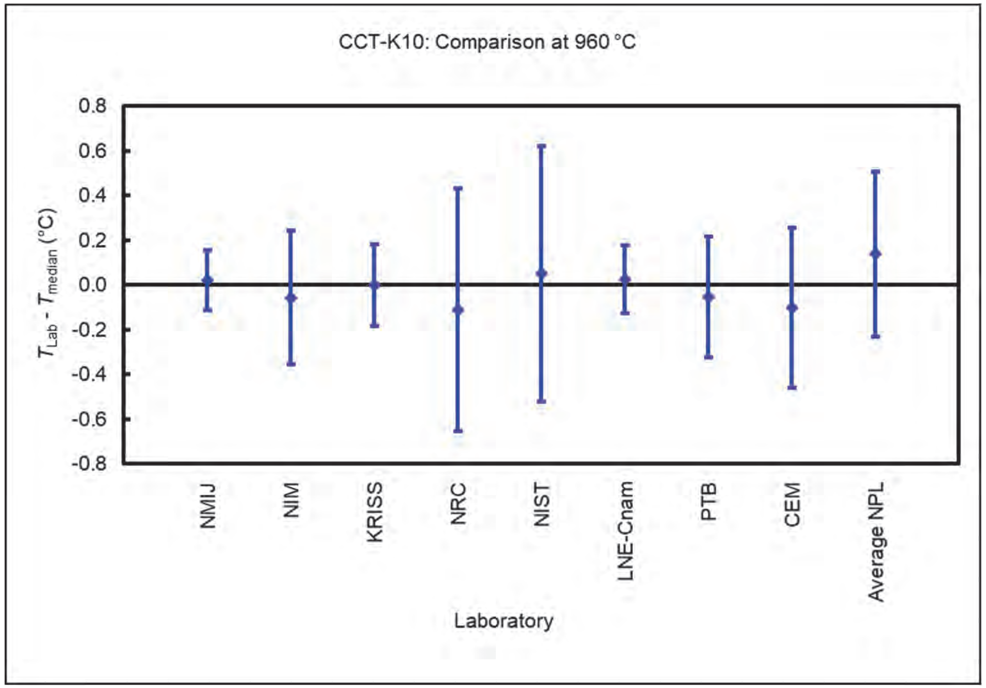


Table 50 - DOE and QDE_{95} table of results for the LP3 at 1100 °C (all units are in °C) and chart with differences from the median

	NMIJ	NIM	KRISS	NRC	NIST	LNE-Cnam	PTB	CEM	Average NPL
NMIJ	-	0.06 ± 0.35	0.00 ± 0.21	0.13 ± 0.61	0.05 ± 0.61	0.02 ± 0.22	-0.03 ± 0.40	0.16 ± 0.44	-0.13 ± 0.47
NIM	*0.36*	-	-0.06 ± 0.35	0.08 ± 0.67	-0.01 ± 0.67	-0.03 ± 0.36	-0.08 ± 0.49	0.10 ± 0.53	-0.18 ± 0.55
KRISS	*0.20*	*0.36*	-	0.13 ± 0.61	0.05 ± 0.61	0.02 ± 0.23	-0.03 ± 0.41	0.16 ± 0.45	-0.13 ± 0.47
NRC	*0.65*	*0.68*	*0.65*	-	-0.09 ± 0.84	-0.11 ± 0.62	-0.16 ± 0.70	0.03 ± 0.73	-0.26 ± 0.74
NIST	*0.60*	*0.66*	*0.60*	*0.83*	-	-0.03 ± 0.61	-0.08 ± 0.70	0.11 ± 0.72	-0.17 ± 0.74
LNE-Cnam	*0.22*	*0.36*	*0.23*	*0.64*	*0.60*	-	-0.05 ± 0.41	0.14 ± 0.45	-0.15 ± 0.48
PTB	*0.40*	*0.51*	*0.40*	*0.76*	*0.70*	*0.42*	-	0.19 ± 0.56	-0.10 ± 0.58
CEM	*0.53*	*0.56*	*0.53*	*0.71*	*0.74*	*0.52*	*0.66*	-	-0.29 ± 0.61
Average NPL	*0.52*	*0.64*	*0.52*	*0.88*	*0.80*	*0.55*	*0.60*	*0.79*	-

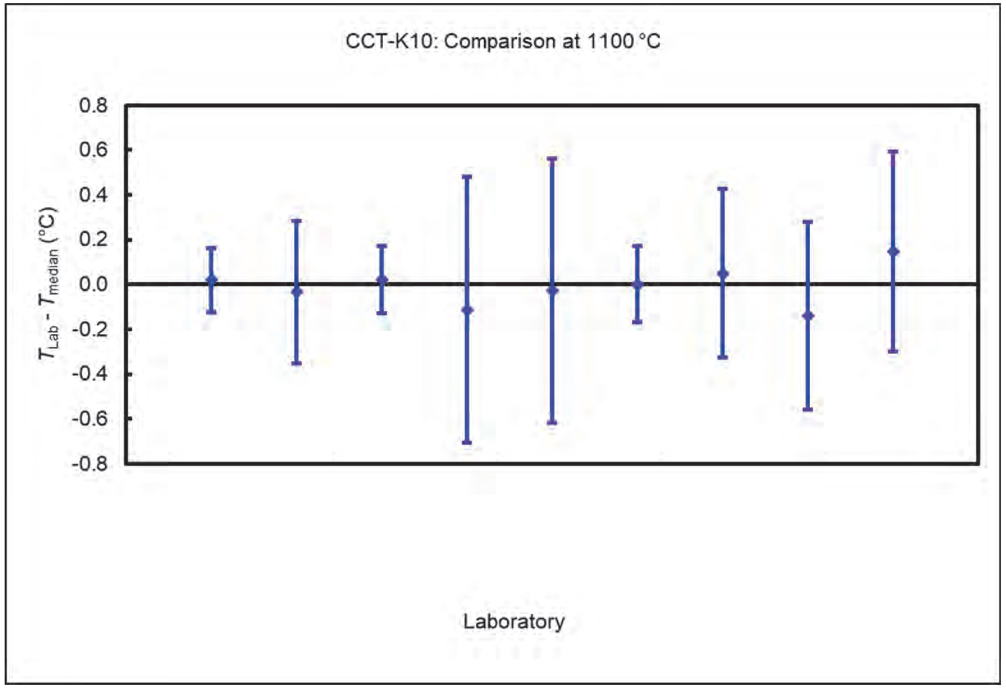


Table 51 - DOE and QDE$_{95}$ table of results for the LP3 at 1300 °C (all units are in °C) and chart with differences from the median

	NMIJ	NIM	KRISS	NRC	NIST	LNE-Cnam	PTB	CEM	Average NPL
NMIJ	-	0.01 ± 0.46	-0.02 ± 0.35	0.15 ± 0.76	0.12 ± 0.71	0.07 ± 0.35	-0.14 ± 0.56	0.28 ± 0.60	-0.17 ± 0.63
NIM	*0.45*	-	-0.04 ± 0.47	0.14 ± 0.83	0.11 ± 0.77	0.06 ± 0.47	-0.15 ± 0.64	0.27 ± 0.68	-0.18 ± 0.70
KRISS	*0.34*	*0.46*	-	0.17 ± 0.77	0.14 ± 0.72	0.10 ± 0.37	-0.12 ± 0.57	0.30 ± 0.61	-0.15 ± 0.64
NRC	*0.81*	*0.86*	*0.83*	-	-0.03 ± 0.99	-0.08 ± 0.77	-0.29 ± 0.89	0.13 ± 0.91	-0.32 ± 0.93
NIST	*0.73*	*0.79*	*0.75*	*0.97*	-	-0.04 ± 0.72	-0.26 ± 0.84	0.16 ± 0.87	-0.29 ± 0.89
LNE-Cnam	*0.37*	*0.48*	*0.41*	*0.77*	*0.71*	-	-0.21 ± 0.57	0.21 ± 0.61	-0.25 ± 0.64
PTB	*0.61*	*0.70*	*0.60*	*1.03*	*0.96*	*0.69*	-	0.42 ± 0.75	-0.03 ± 0.77
CEM	*0.77*	*0.83*	*0.81*	*0.93*	*0.91*	*0.71*	*1.04*	-	-0.45 ± 0.80
Average NPL	*0.70*	*0.78*	*0.69*	*1.10*	*1.03*	*0.78*	*0.76*	*1.11*	-

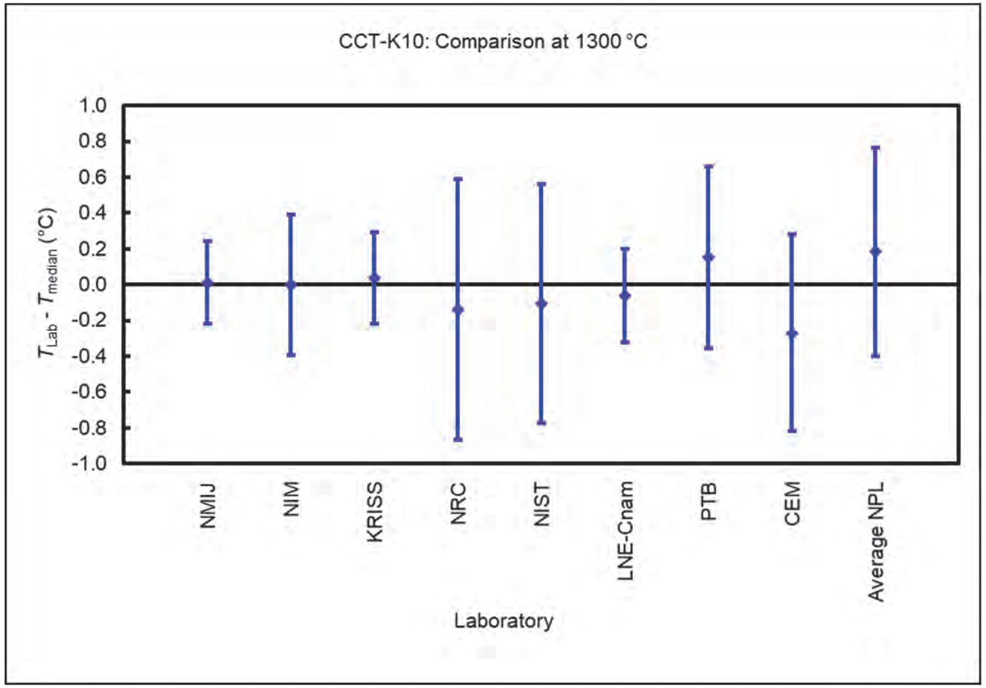


Table 52 - DOE and QDE_{95} table of results for the LP3 at 1500 °C (all units are in °C) and chart with differences from the median

	NMIJ	NIM	KRISS	NRC	NIST	LNE-Cnam	PTB	CEM	Average NPL
NMIJ	-	-0.01 ± 0.53	0.01 ± 0.46	0.14 ± 0.93	-0.03 ± 0.81	0.11 ± 0.41	0.11 ± 0.69	0.63 ± 0.74	-0.19 ± 0.74
NIM	*0.53*	-	0.02 ± 0.59	0.15 ± 1.00	-0.01 ± 0.89	0.12 ± 0.55	0.12 ± 0.79	0.64 ± 0.83	-0.18 ± 0.82
KRISS	*0.45*	*0.58*	-	0.14 ± 0.96	-0.03 ± 0.85	0.10 ± 0.48	0.10 ± 0.74	0.62 ± 0.78	-0.20 ± 0.78
NRC	*0.95*	*1.03*	*0.98*	-	-0.17 ± 1.17	-0.03 ± 0.94	-0.03 ± 1.09	0.48 ± 1.12	-0.33 ± 1.12
NIST	*0.80*	*0.88*	*0.83*	*1.20*	-	0.14 ± 0.82	0.14 ± 1.00	0.65 ± 1.03	-0.16 ± 1.03
LNE-Cnam	*0.46*	*0.59*	*0.51*	*0.92*	*0.85*	-	0.00 ± 0.71	0.52 ± 0.75	-0.30 ± 0.75
PTB	*0.71*	*0.81*	*0.75*	*1.07*	*1.01*	*0.70*	-	0.52 ± 0.94	-0.30 ± 0.94
CEM	*1.24*	*1.32*	*1.26*	*1.41*	*1.50*	*1.13*	*1.29*	-	-0.82 ± 0.97
Average NPL	*0.81*	*0.88*	*0.85*	*1.27*	*1.06*	*0.92*	*1.08*	*1.61*	-

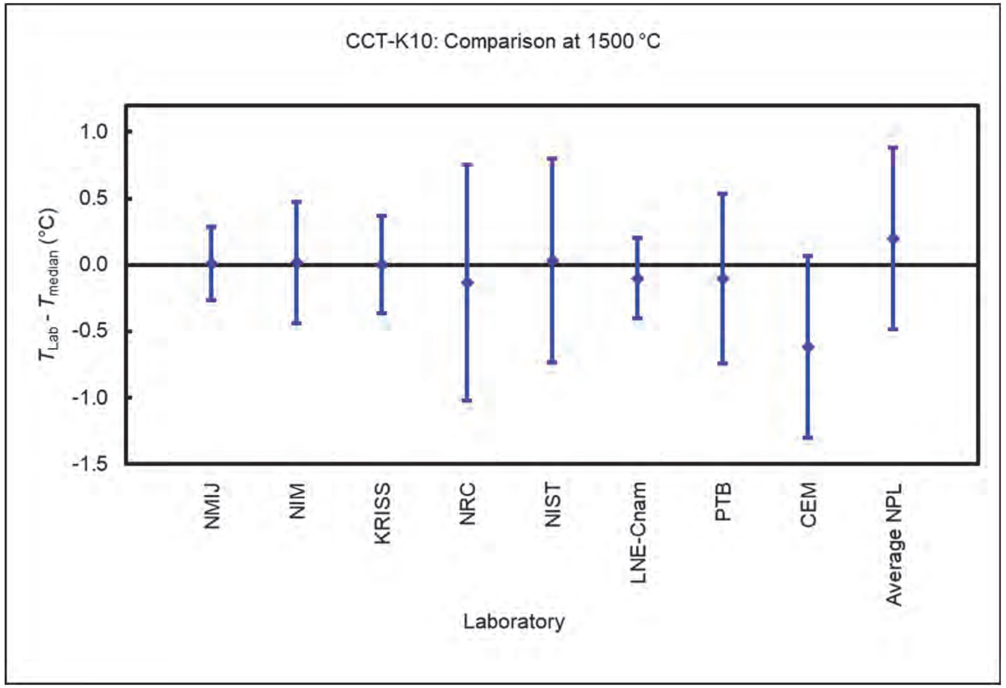


Table 53 - DOE and QDE95 table of results for the LP3 at 1700 °C (all units are in °C) and chart with differences from the median

	NMIJ	NIM	KRISS	NRC	NIST	LNE-Cnam	PTB	CEM	Average NPL
NMIJ	-	-0.04 ± 0.65	0.02 ± 0.61	0.13 ± 1.15	0.07 ± 0.96	0.25 ± 0.51	0.36 ± 0.85	0.81 ± 0.91	-0.16 ± 0.91
NIM	*0.64*	-	0.06 ± 0.75	0.17 ± 1.22	0.11 ± 1.05	0.29 ± 0.67	0.40 ± 0.96	0.85 ± 1.00	-0.12 ± 1.01
KRISS	*0.60*	*0.74*	-	0.11 ± 1.21	0.05 ± 1.03	0.23 ± 0.64	0.34 ± 0.93	0.79 ± 0.98	-0.18 ± 0.98
NRC	*1.15*	*1.25*	*1.20*	-	-0.06 ± 1.41	0.12 ± 1.16	0.23 ± 1.34	0.68 ± 1.38	-0.29 ± 1.38
NIST	*0.94*	*1.05*	*1.01*	*1.39*	-	0.18 ± 0.97	0.29 ± 1.19	0.74 ± 1.22	-0.23 ± 1.23
LNE-Cnam	*0.67*	*0.85*	*0.76*	*1.15*	*1.01*	-	0.11 ± 0.87	0.56 ± 0.92	-0.41 ± 0.92
PTB	*1.07*	*1.19*	*1.12*	*1.39*	*1.29*	*0.88*	-	0.45 ± 1.15	-0.52 ± 1.15
CEM	*1.56*	*1.68*	*1.60*	*1.82*	*1.75*	*1.32*	*1.40*	-	-0.97 ± 1.19
Average NPL	*0.95*	*1.01*	*1.03*	*1.47*	*1.29*	*1.18*	*1.47*	*1.95*	-

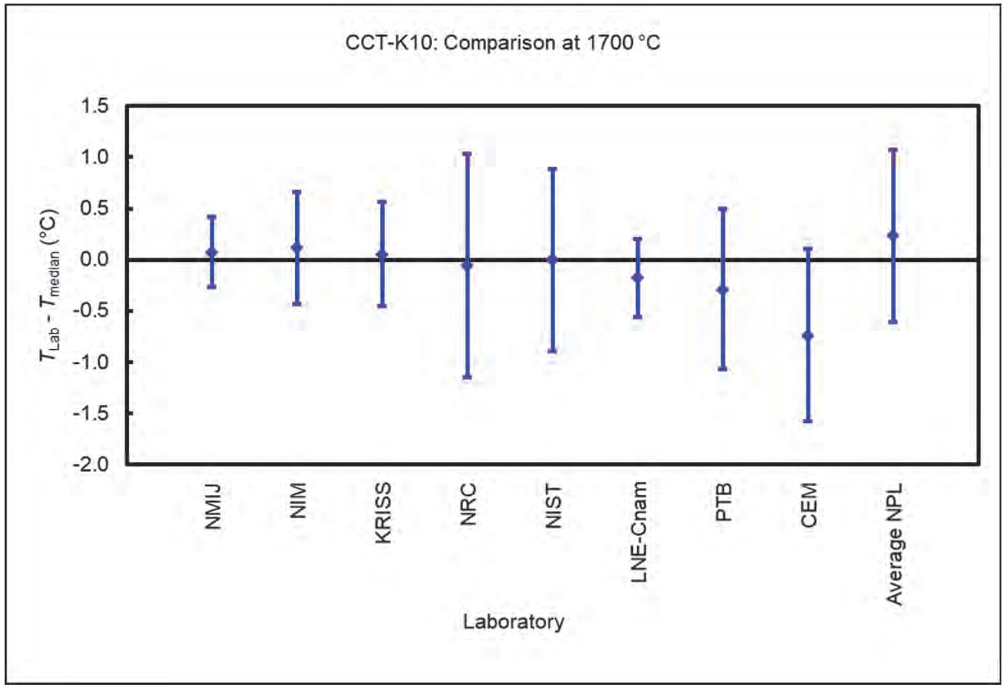


Table 54 - DOE and QDE_{95} table of results for the LP3 at 1800 °C (all units are in °C) and chart with differences from the median

	NMIJ	NIM	KRISS	NRC	NIST	LNE-Cnam	PTB	CEM	Average NPL
NMIJ	-	-0.07 ± 0.75	0.06 ± 0.73	0.11 ± 1.29	0.16 ± 1.06	0.32 ± 0.61	0.35 ± 0.97	1.19 ± 1.03	-0.12 ± 1.06
NIM	*0.74*	-	0.12 ± 0.87	0.17 ± 1.37	0.23 ± 1.16	0.38 ± 0.77	0.41 ± 1.08	1.25 ± 1.13	-0.05 ± 1.16
KRISS	*0.72*	*0.88*	-	0.05 ± 1.36	0.11 ± 1.15	0.26 ± 0.75	0.29 ± 1.07	1.13 ± 1.12	-0.17 ± 1.15
NRC	*1.27*	*1.38*	*1.33*	-	0.05 ± 1.56	0.21 ± 1.30	0.24 ± 1.50	1.08 ± 1.54	-0.23 ± 1.56
NIST	*1.09*	*1.22*	*1.14*	*1.53*	-	0.16 ± 1.07	0.19 ± 1.31	1.03 ± 1.36	-0.28 ± 1.38
LNE-Cnam	*0.82*	*1.01*	*0.89*	*1.33*	*1.09*	-	0.03 ± 0.99	0.87 ± 1.05	-0.44 ± 1.07
PTB	*1.16*	*1.31*	*1.19*	*1.54*	*1.34*	*0.97*	-	0.84 ± 1.29	-0.47 ± 1.31
CEM	*2.04*	*2.18*	*2.06*	*2.35*	*2.15*	*1.73*	*1.91*	-	-1.31 ± 1.36
Average NPL	*1.06*	*1.13*	*1.17*	*1.59*	*1.46*	*1.33*	*1.56*	*2.43*	-

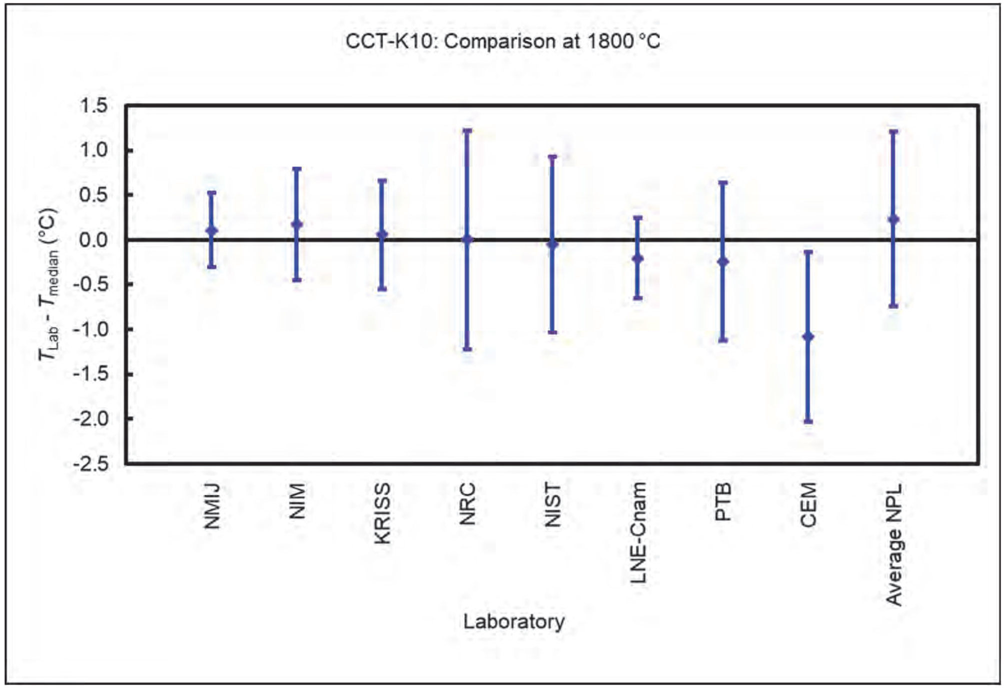


Table 55 - DOE and QDE$_{95}$ table of results for the LP3 at 2000 °C (all units are in °C) and chart with differences from the median

	NMIJ	NIM	KRISS	NRC	NIST	LNE-Cnam	PTB	CEM	Average NPL
NMIJ	-	-0.08 ± 0.96	0.07 ± 0.91	0.03 ± 1.56	0.20 ± 1.22	0.41 ± 0.69	0.51 ± 1.02	0.82 ± 1.21	-0.30 ± 1.18
NIM	*0.95*	-	0.15 ± 1.13	0.11 ± 1.70	0.27 ± 1.39	0.48 ± 0.97	0.59 ± 1.23	0.90 ± 1.38	-0.22 ± 1.36
KRISS	*0.90*	*1.15*	-	-0.04 ± 1.67	0.12 ± 1.36	0.33 ± 0.92	0.44 ± 1.19	0.75 ± 1.35	-0.37 ± 1.33
NRC	*1.53*	*1.67*	*1.64*	-	0.17 ± 1.86	0.38 ± 1.57	0.48 ± 1.74	0.79 ± 1.85	-0.33 ± 1.83
NIST	*1.25*	*1.47*	*1.35*	*1.85*	-	0.21 ± 1.23	0.32 ± 1.44	0.62 ± 1.58	-0.50 ± 1.55
LNE-Cnam	*0.98*	*1.28*	*1.10*	*1.70*	*1.27*	-	0.10 ± 1.04	0.41 ± 1.22	-0.71 ± 1.19
PTB	*1.36*	*1.60*	*1.43*	*1.94*	*1.54*	*1.03*	-	0.31 ± 1.43	-0.81 ± 1.41
CEM	*1.81*	*2.04*	*1.86*	*2.32*	*1.93*	*1.43*	*1.53*	-	-1.12 ± 1.55
Average NPL	*1.29*	*1.40*	*1.49*	*1.91*	*1.80*	*1.69*	*1.97*	*2.39*	-

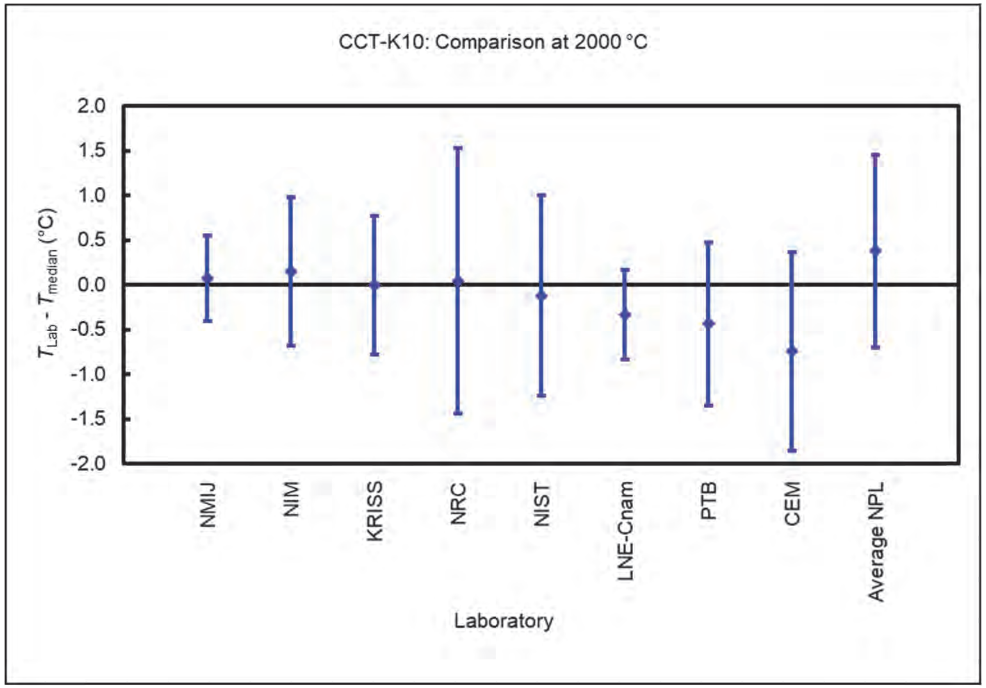


Table 56 - DOE and QDE95 table of results for the LP3 at 2200 °C (all units are in °C) and chart with differences from the median

	NMIJ	NIM	KRISS	NRC	NIST	LNE-Cnam	PTB	CEM	Average NPL
NMIJ	-	-0.08 ± 1.12	0.10 ± 1.22	-0.08 ± 1.91	0.33 ± 1.45	0.53 ± 0.87	0.35 ± 1.23	1.33 ± 1.64	-0.20 ± 1.44
NIM	*1.11*	-	0.18 ± 1.42	0.00 ± 2.04	0.41 ± 1.62	0.61 ± 1.13	0.42 ± 1.43	1.41 ± 1.80	-0.12 ± 1.62
KRISS	*1.21*	*1.43*	-	-0.18 ± 2.10	0.23 ± 1.69	0.43 ± 1.23	0.24 ± 1.51	1.23 ± 1.86	-0.30 ± 1.68
NRC	*1.88*	*2.02*	*2.08*	-	0.41 ± 2.24	0.61 ± 1.91	0.43 ± 2.10	1.41 ± 2.37	-0.12 ± 2.23
NIST	*1.56*	*1.77*	*1.71*	*2.33*	-	0.20 ± 1.45	0.01 ± 1.69	1.00 ± 2.01	-0.53 ± 1.85
LNE-Cnam	*1.25*	*1.54*	*1.45*	*2.21*	*1.47*	-	-0.18 ± 1.24	0.80 ± 1.65	-0.73 ± 1.45
PTB	*1.38*	*1.62*	*1.55*	*2.22*	*1.67*	*1.27*	-	0.99 ± 1.87	-0.54 ± 1.69
CEM	*2.69*	*2.89*	*2.76*	*3.36*	*2.66*	*2.16*	*2.53*	-	-1.53 ± 2.01
Average NPL	*1.46*	*1.59*	*1.75*	*2.20*	*2.08*	*1.93*	*1.96*	*3.19*	-

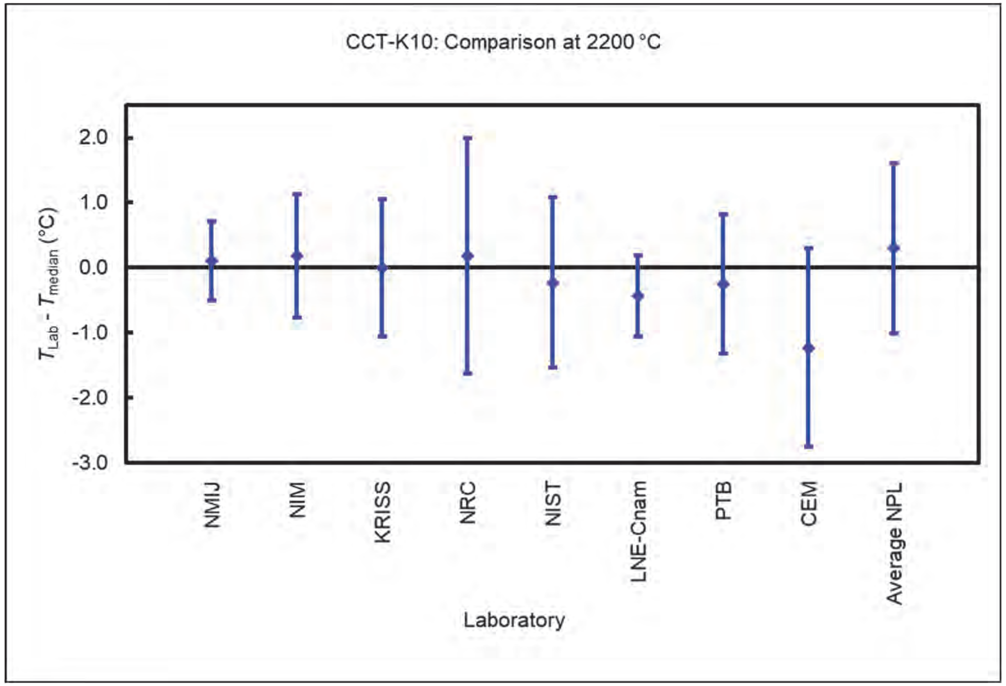


Table 57 - DOE and QDE_{95} table of results for the LP3 at 2400 °C (all units are in °C) and chart with differences from the median

	NMIJ	NIM	KRISS	NRC	NIST	LNE-Cnam	PTB	CEM	Average NPL
NMIJ	-	-0.12 ± 1.34	0.19 ± 1.49	-0.13 ± 2.33	0.51 ± 1.71	0.75 ± 1.08	0.75 ± 1.49	0.59 ± 1.95	-0.13 ± 1.70
NIM	*1.33*	-	0.30 ± 1.69	-0.01 ± 2.46	0.63 ± 1.89	0.86 ± 1.34	0.87 ± 1.69	0.70 ± 2.11	-0.01 ± 1.88
KRISS	*1.50*	*1.76*	-	-0.32 ± 2.54	0.32 ± 1.99	0.56 ± 1.49	0.56 ± 1.81	0.40 ± 2.20	-0.32 ± 1.98
NRC	*2.29*	*2.43*	*2.56*	-	0.64 ± 2.68	0.88 ± 2.33	0.88 ± 2.55	0.71 ± 2.84	0.00 ± 2.67
NIST	*1.94*	*2.20*	*2.05*	*2.91*	-	0.24 ± 1.71	0.24 ± 2.00	0.08 ± 2.36	-0.64 ± 2.16
LNE-Cnam	*1.64*	*1.97*	*1.79*	*2.81*	*1.74*	-	0.00 ± 1.50	-0.16 ± 1.95	-0.88 ± 1.70
PTB	*1.99*	*2.27*	*2.08*	*3.00*	*2.01*	*1.48*	-	-0.17 ± 2.21	-0.88 ± 1.99
CEM	*2.22*	*2.46*	*2.29*	*3.11*	*2.32*	*1.93*	*2.18*	-	-0.72 ± 2.35
Average NPL	*1.68*	*1.85*	*2.04*	*2.64*	*2.45*	*2.28*	*2.53*	*2.69*	-

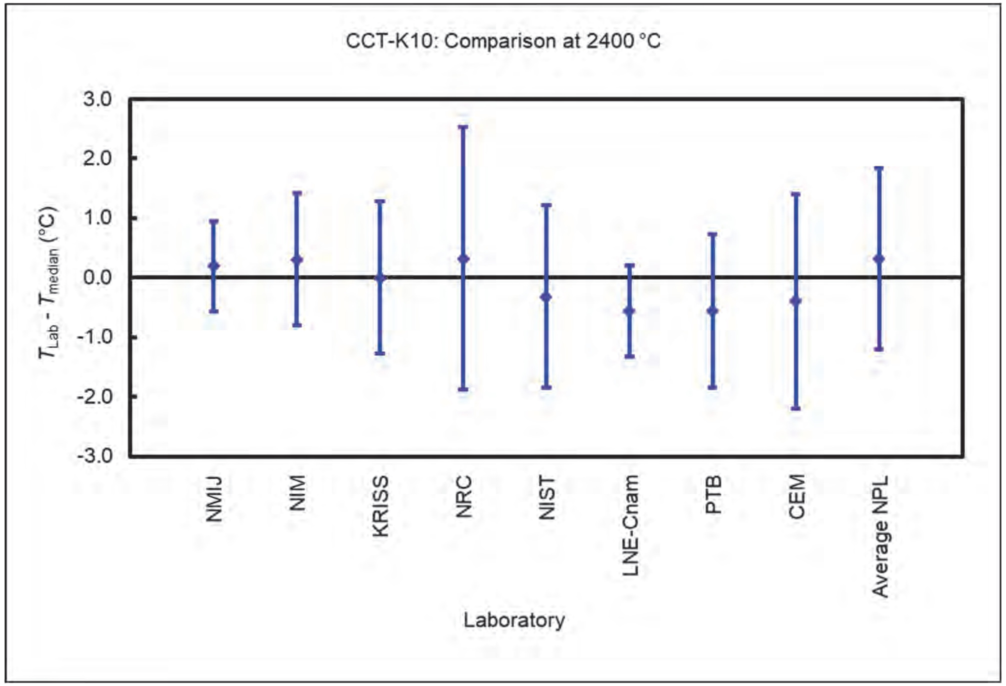


Table 58 - DOE and QDE_{95} table of results for the LP3 at 2500 °C (all units are in °C) and chart with differences from the median

	NMIJ	NIM	KRISS	NRC	NIST	PTB	CEM	Average NPL
NMIJ	-	-0.10 ± 1.46	0.46 ± 1.66	-0.19 ± 2.56	0.42 ± 1.86	1.04 ± 1.64	0.50 ± 2.09	-0.03 ± 1.86
NIM	*1.44*	-	0.56 ± 1.85	-0.10 ± 2.69	0.51 ± 2.03	1.13 ± 1.84	0.59 ± 2.25	0.07 ± 2.03
KRISS	*1.85*	*2.11*	-	-0.65 ± 2.80	-0.04 ± 2.18	0.58 ± 2.00	0.04 ± 2.38	-0.49 ± 2.18
NRC	*2.53*	*2.64*	*3.03*	-	0.61 ± 2.92	1.23 ± 2.79	0.69 ± 3.07	0.17 ± 2.92
NIST	*1.99*	*2.23*	*2.14*	*3.10*	-	0.62 ± 2.16	0.08 ± 2.52	-0.44 ± 2.33
PTB	*2.38*	*2.64*	*2.25*	*3.54*	*2.43*	-	-0.54 ± 2.36	-1.06 ± 2.16
CEM	*2.26*	*2.48*	*2.34*	*3.30*	*2.47*	*2.55*	-	-0.52 ± 2.52
Average NPL	*1.83*	*2.00*	*2.34*	*2.87*	*2.45*	*2.85*	*2.67*	-

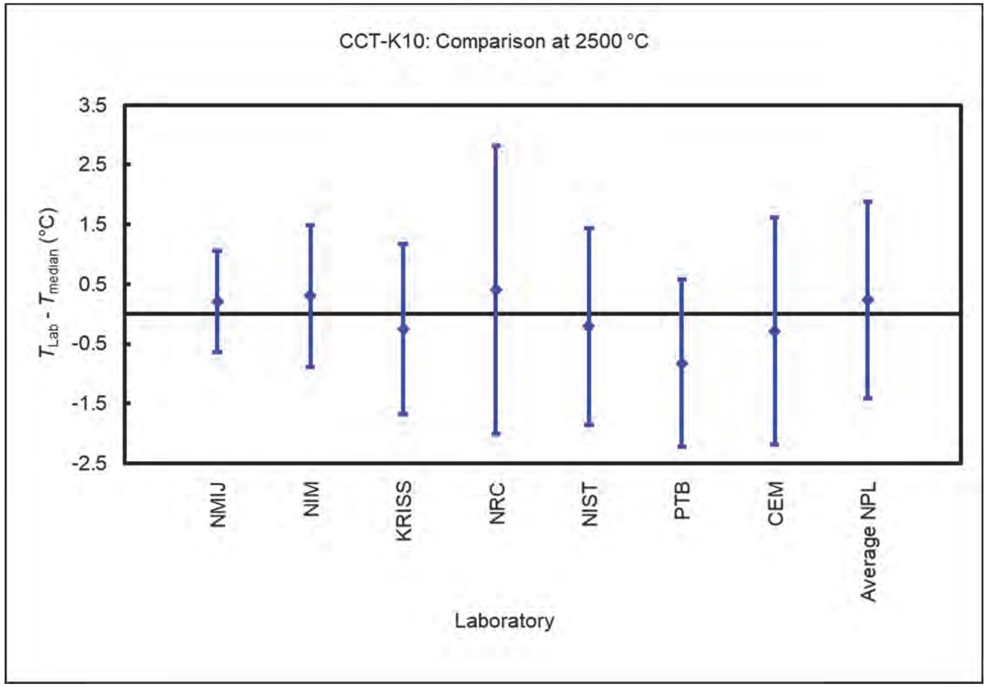


Table 59 - DOE and QDE$_{95}$ table of results for the LP3 at 2600 °C (all units are in °C) and chart with differences from the median

	NMIJ	NIM	KRISS	NRC	NIST	LNE-Cnam	PTB	Average NPL
NMIJ	-	-0.10 ± 1.75	0.51 ± 1.82	-0.35 ± 2.78	0.50 ± 1.98	0.52 ± 1.30	1.23 ± 1.71	-0.03 ± 1.99
NIM	*1.72*	-	0.60 ± 2.17	-0.26 ± 3.02	0.59 ± 2.31	0.62 ± 1.76	1.32 ± 2.08	0.07 ± 2.32
KRISS	*2.03*	*2.43*	-	-0.86 ± 3.06	-0.01 ± 2.36	0.01 ± 1.83	0.72 ± 2.13	-0.53 ± 2.37
NRC	*2.80*	*2.99*	*3.43*	-	0.85 ± 3.16	0.87 ± 2.78	1.58 ± 2.99	0.33 ± 3.17
NIST	*2.17*	*2.54*	*2.33*	*3.51*	-	0.02 ± 1.99	0.73 ± 2.27	-0.53 ± 2.49
LNE-Cnam	*1.60*	*2.08*	*1.80*	*3.20*	*1.96*	-	0.71 ± 1.72	-0.55 ± 2.00
PTB	*2.63*	*3.03*	*2.50*	*4.05*	*2.63*	*2.13*	-	-1.26 ± 2.28
Average NPL	*1.96*	*2.28*	*2.54*	*3.16*	*2.65*	*2.23*	*3.14*	-

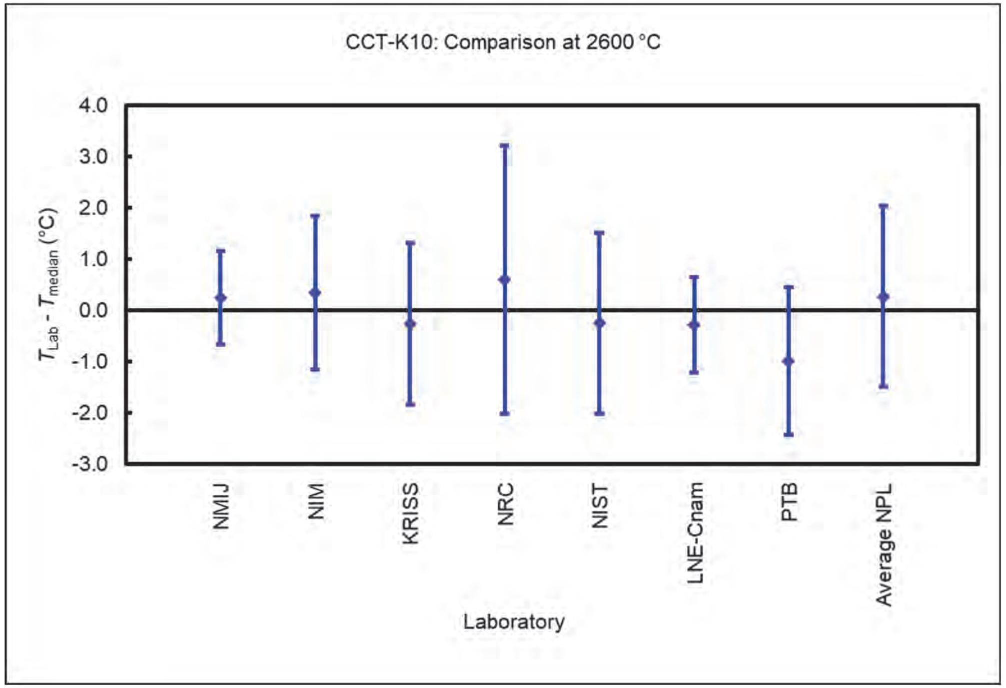


Table 60 - DOE and QDE_{95} table of results for the LP3 at 2800 °C (all units are in °C) and chart with differences from the median

	NMIJ	NIM	KRISS	NRC	NIST	LNE-Cnam	PTB	Average NPL
NMIJ	-	-0.04 ± 2.32	0.61 ± 2.15	-0.17 ± 3.28	0.56 ± 2.27	0.51 ± 1.51	1.65 ± 1.97	-0.36 ± 2.26
NIM	*2.28*	-	0.65 ± 2.78	-0.13 ± 3.72	0.60 ± 2.87	0.56 ± 2.32	1.70 ± 2.64	-0.32 ± 2.87
KRISS	*2.42*	*3.01*	-	-0.78 ± 3.62	-0.05 ± 2.74	-0.10 ± 2.15	1.04 ± 2.49	-0.97 ± 2.73
NRC	*3.22*	*3.65*	*3.86*	-	0.73 ± 3.69	0.69 ± 3.28	1.82 ± 3.51	-0.19 ± 3.69
NIST	*2.48*	*3.05*	*2.69*	*3.89*	-	-0.05 ± 2.27	1.09 ± 2.60	-0.92 ± 2.83
LNE-Cnam	*1.77*	*2.52*	*2.11*	*3.48*	*2.23*	-	1.14 ± 1.97	-0.87 ± 2.26
PTB	*3.27*	*3.87*	*3.11*	*4.72*	*3.24*	*2.76*	-	-2.01 ± 2.59
Average NPL	*2.32*	*2.87*	*3.24*	*3.62*	*3.28*	*2.75*	*4.14*	-

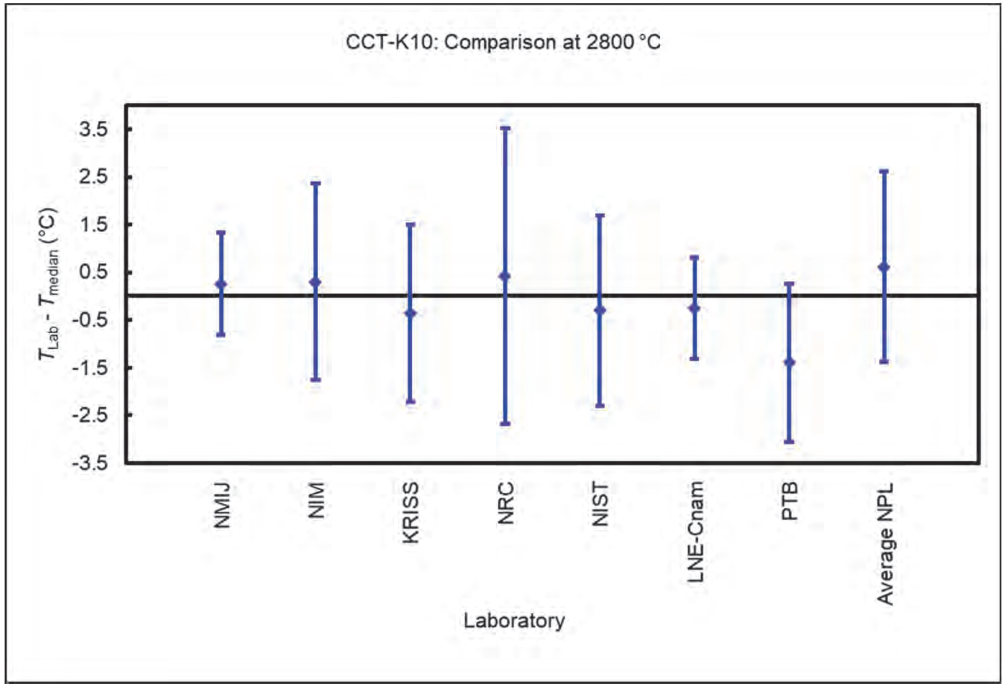


Table 61 - DOE and QDE$_{95}$ table of results for the LP3 at 2900 °C (all units are in °C) and chart with differences from the median

	NMIJ	NIM	KRISS	NRC	PTB	Average NPL
NMIJ	-	-0.60 ± 2.97	0.43 ± 2.40	-0.40 ± 3.50	1.91 ± 2.11	-0.39 ± 2.69
NIM	*3.14*	-	1.02 ± 3.46	0.19 ± 4.29	2.51 ± 3.26	0.20 ± 3.66
KRISS	*2.50*	*3.92*	-	-0.83 ± 3.92	1.49 ± 2.75	-0.82 ± 3.21
NRC	*3.51*	*4.22*	*4.17*	-	2.31 ± 3.75	0.01 ± 4.10
PTB	*3.65*	*5.19*	*3.76*	*5.40*	-	-2.31 ± 3.00
Average NPL	*2.74*	*3.60*	*3.53*	*4.05*	*4.78*	-

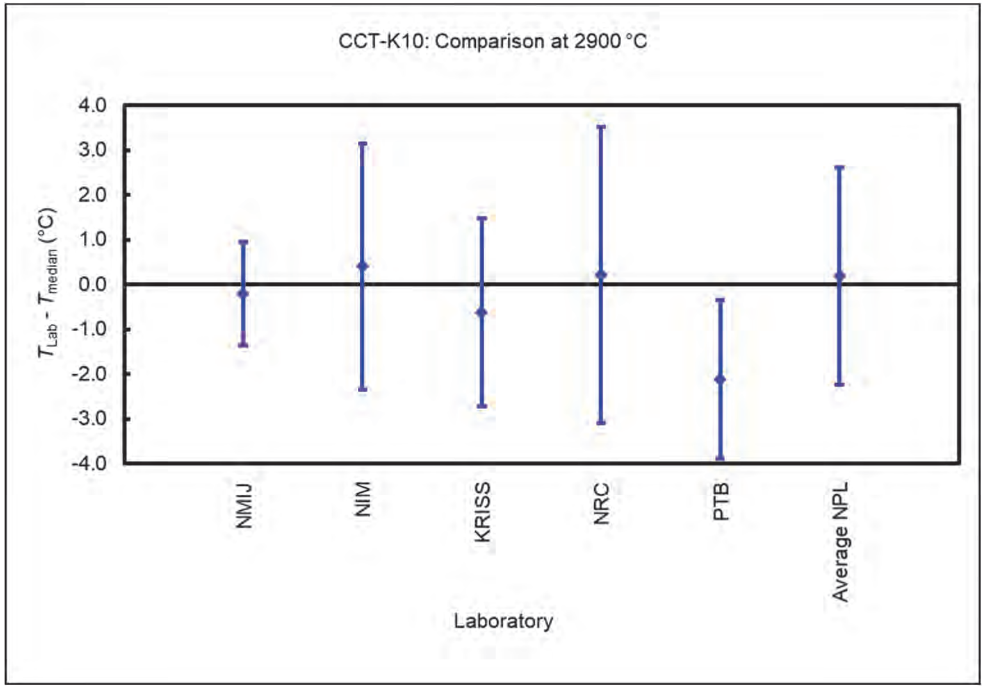
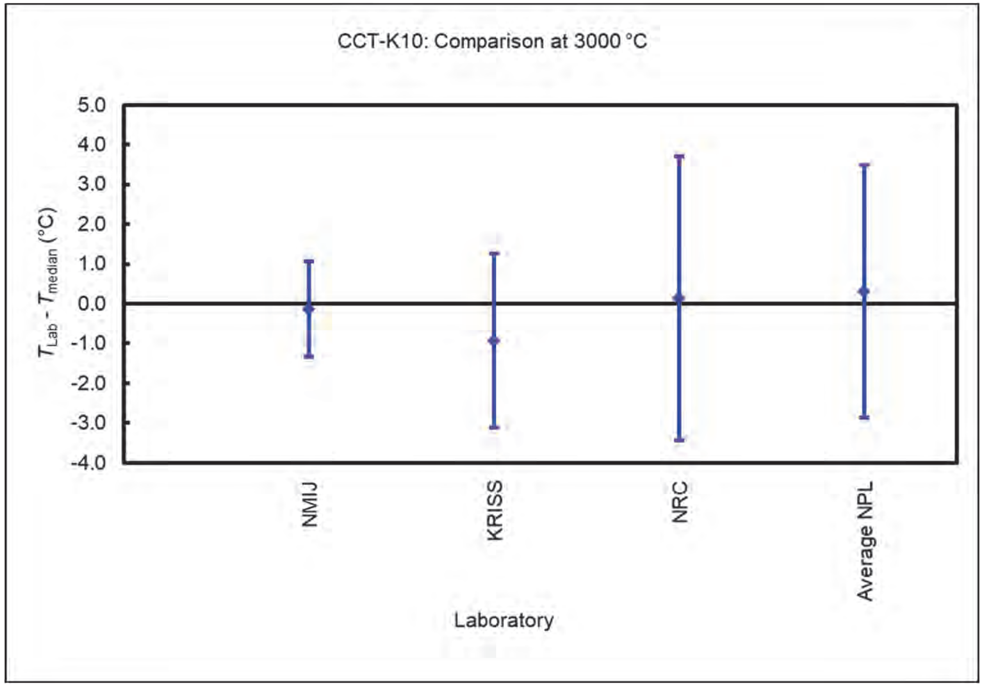


Table 62 - DOE and QDE_{95} table of results for the LP3 at 3000 °C (all units are in °C) and chart with differences from the median

	NMIJ	KRISS	NRC	Average NPL
NMIJ	-	0.79 ± 2.50	-0.27 ± 3.76	-0.44 ± 3.39
KRISS	*2.88*	-	-1.07 ± 4.18	-1.23 ± 3.85
NRC	*3.71*	*4.59*	-	-0.17 ± 4.77
Average NPL	*3.43*	*4.45*	*4.68*	-



10.13 QDE_{95} AND DOE TABLES AND CHARTS – CHINO THERMOMETER

The Tables and Charts showing Degree of Equivalence (DOE) and QDE_{95} values, as described in Section 10.6, are given in this Section for the Chino thermometer.

Table 63 - DOE and QDE_{95} table of results for the Chino thermometer at 960 °C (all units are in °C) and chart with differences from the median.

	NMIJ	NIM	KRISS	NRC	NIST	LNE-Cnam	PTB	CEM	Average NPL
NMIJ	-	0.12 ± 0.46	-0.12 ± 0.32	0.10 ± 0.60	-0.11 ± 0.63	-0.06 ± 0.31	-0.07 ± 0.37	-0.07 ± 0.45	-0.06 ± 0.55
NIM	*0.50*	-	-0.24 ± 0.47	-0.01 ± 0.70	-0.22 ± 0.72	-0.17 ± 0.46	-0.19 ± 0.51	-0.19 ± 0.57	-0.17 ± 0.65
KRISS	*0.39*	*0.63*	-	0.23 ± 0.61	0.02 ± 0.64	0.07 ± 0.33	0.05 ± 0.39	0.05 ± 0.46	0.07 ± 0.56
NRC	*0.63*	*0.69*	*0.74*	-	-0.21 ± 0.82	-0.16 ± 0.61	-0.18 ± 0.64	-0.18 ± 0.69	-0.16 ± 0.76
NIST	*0.65*	*0.82*	*0.63*	*0.90*	-	0.05 ± 0.63	0.03 ± 0.67	0.03 ± 0.71	0.05 ± 0.78
LNE-Cnam	*0.32*	*0.56*	*0.34*	*0.67*	*0.62*	-	-0.02 ± 0.38	-0.02 ± 0.45	0.00 ± 0.55
PTB	*0.39*	*0.61*	*0.39*	*0.72*	*0.66*	*0.37*	-	0.00 ± 0.50	0.02 ± 0.59
CEM	*0.46*	*0.66*	*0.46*	*0.76*	*0.70*	*0.44*	*0.50*	-	0.02 ± 0.64
Average NPL	*0.55*	*0.72*	*0.56*	*0.81*	*0.76*	*0.54*	*0.58*	*0.63*	-

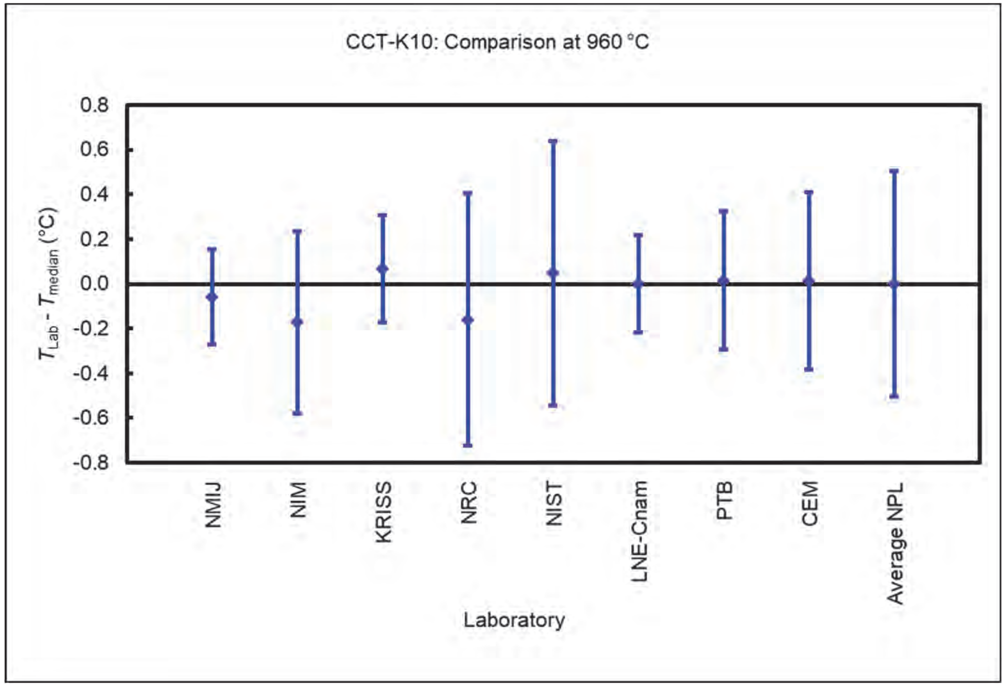


Table 64 - DOE and QDE_{95} table of results for the Chino thermometer at 1100 °C (all units are in °C) and chart with differences from the median.

	NMIJ	NIM	KRISS	NRC	NIST	LNE-Cnam	PTB	CEM	Average NPL
NMIJ	-	0.19 ± 0.54	-0.02 ± 0.34	0.15 ± 0.66	-0.08 ± 0.66	-0.08 ± 0.35	-0.04 ± 0.48	-0.15 ± 0.52	-0.02 ± 0.61
NIM	*0.64*	-	-0.20 ± 0.54	-0.04 ± 0.79	-0.27 ± 0.78	-0.27 ± 0.54	-0.23 ± 0.63	-0.34 ± 0.67	-0.21 ± 0.74
KRISS	*0.33*	*0.65*	-	0.17 ± 0.66	-0.07 ± 0.66	-0.06 ± 0.35	-0.02 ± 0.48	-0.13 ± 0.52	-0.01 ± 0.61
NRC	*0.72*	*0.77*	*0.73*	-	-0.23 ± 0.87	-0.23 ± 0.67	-0.19 ± 0.74	-0.30 ± 0.77	-0.18 ± 0.83
NIST	*0.67*	*0.92*	*0.66*	*0.97*	-	0.00 ± 0.67	0.05 ± 0.74	-0.07 ± 0.77	0.06 ± 0.83
LNE-Cnam	*0.37*	*0.72*	*0.36*	*0.79*	*0.66*	-	0.04 ± 0.48	-0.07 ± 0.53	0.06 ± 0.61
PTB	*0.47*	*0.75*	*0.47*	*0.82*	*0.73*	*0.48*	-	-0.11 ± 0.62	0.01 ± 0.69
CEM	*0.59*	*0.89*	*0.57*	*0.94*	*0.76*	*0.53*	*0.64*	-	0.12 ± 0.72
Average NPL	*0.60*	*0.83*	*0.60*	*0.89*	*0.82*	*0.61*	*0.68*	*0.75*	-

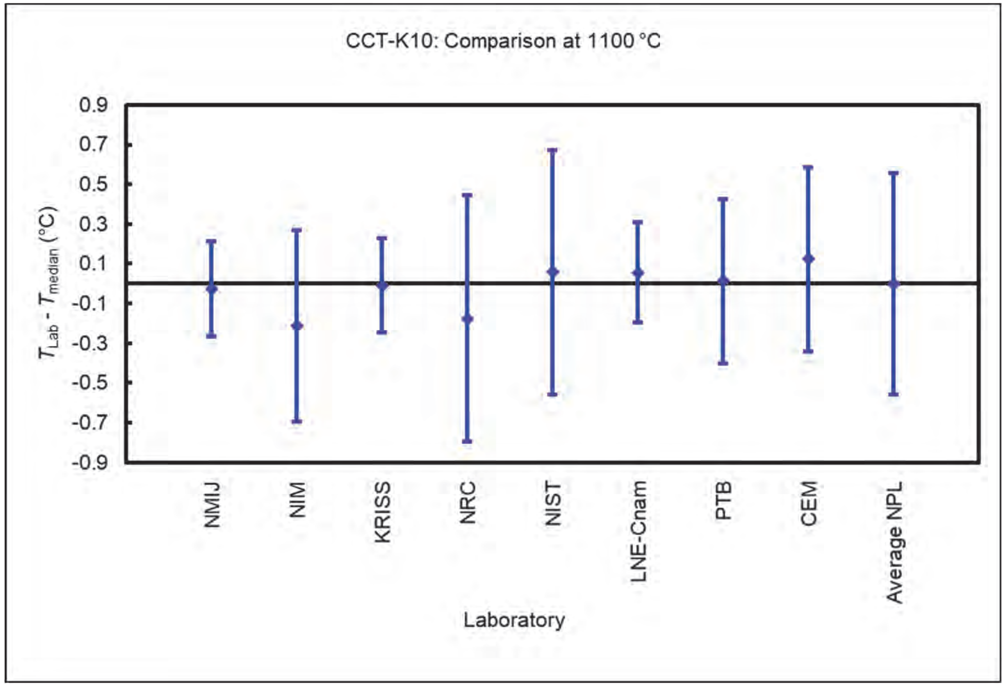


Table 65 - DOE and QDE_{95} table of results for the Chino thermometer at 1300 °C (all units are in °C) and chart with differences from the median.

	NMIJ	NIM	KRISS	NRC	NIST	LNE-Cnam	PTB	CEM	Average NPL
NMIJ	-	0.17 ± 0.62	-0.17 ± 0.41	0.14 ± 0.80	0.05 ± 0.74	-0.04 ± 0.42	-0.02 ± 0.61	-0.03 ± 0.65	-0.05 ± 0.72
NIM	*0.69*	-	-0.34 ± 0.62	-0.03 ± 0.93	-0.12 ± 0.88	-0.21 ± 0.63	-0.19 ± 0.77	-0.19 ± 0.80	-0.22 ± 0.86
KRISS	*0.51*	*0.85*	-	0.31 ± 0.80	0.22 ± 0.74	0.13 ± 0.42	0.14 ± 0.61	0.14 ± 0.65	0.12 ± 0.72
NRC	*0.83*	*0.91*	*0.97*	-	-0.09 ± 1.01	-0.18 ± 0.80	-0.16 ± 0.92	-0.16 ± 0.94	-0.18 ± 0.99
NIST	*0.73*	*0.89*	*0.84*	*1.00*	-	-0.09 ± 0.75	-0.07 ± 0.87	-0.07 ± 0.90	-0.09 ± 0.95
LNE-Cnam	*0.42*	*0.73*	*0.48*	*0.86*	*0.75*	-	0.02 ± 0.62	0.02 ± 0.66	-0.01 ± 0.72
PTB	*0.60*	*0.84*	*0.66*	*0.95*	*0.86*	*0.60*	-	0.00 ± 0.79	-0.02 ± 0.85
CEM	*0.64*	*0.87*	*0.70*	*0.98*	*0.89*	*0.64*	*0.78*	-	-0.02 ± 0.88
Average NPL	*0.71*	*0.94*	*0.74*	*1.04*	*0.94*	*0.71*	*0.83*	*0.86*	-

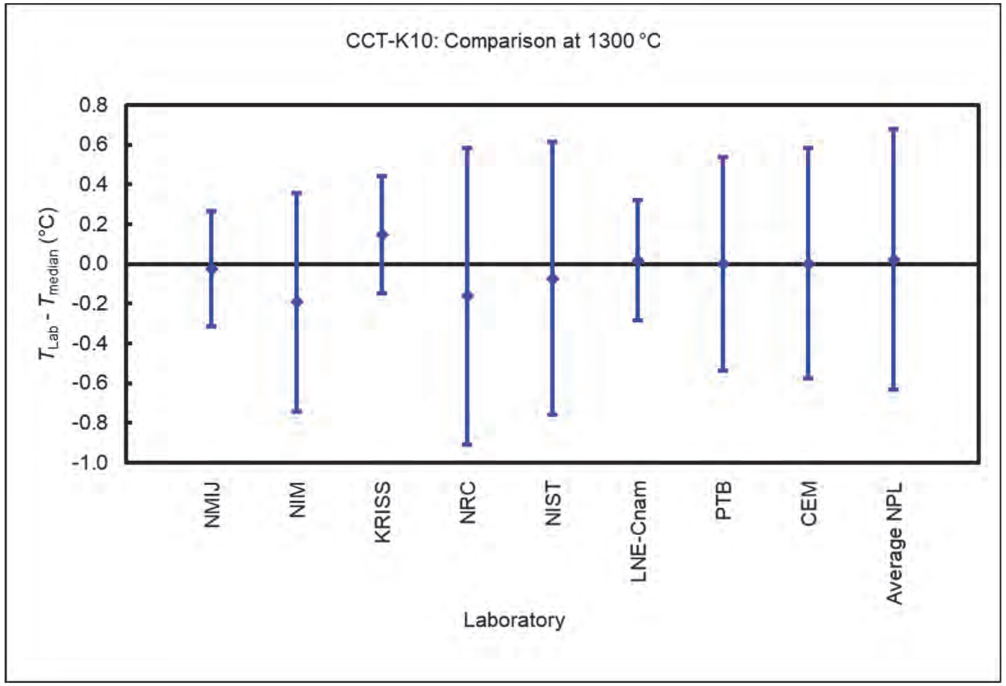


Table 66 - DOE and QDE_{95} table of results for the Chino thermometer at 1500 °C (all units are in °C) and chart with differences from the median.

	NMIJ	NIM	KRISS	NRC	NIST	LNE-Cnam	PTB	CEM	Average NPL
NMIJ	-	0.19 ± 0.79	-0.16 ± 0.60	0.13 ± 1.02	-0.10 ± 0.91	-0.05 ± 0.58	-0.28 ± 0.81	0.14 ± 0.85	-0.01 ± 0.88
NIM	*0.86*	-	-0.34 ± 0.81	-0.06 ± 1.15	-0.29 ± 1.06	-0.23 ± 0.80	-0.47 ± 0.98	-0.05 ± 1.01	-0.20 ± 1.04
KRISS	*0.67*	*1.02*	-	0.29 ± 1.03	0.06 ± 0.93	0.11 ± 0.61	-0.13 ± 0.83	0.30 ± 0.87	0.14 ± 0.90
NRC	*1.03*	*1.13*	*1.16*	-	-0.23 ± 1.24	-0.18 ± 1.02	-0.42 ± 1.16	0.01 ± 1.20	-0.15 ± 1.22
NIST	*0.91*	*1.18*	*0.91*	*1.29*	-	0.05 ± 0.91	-0.19 ± 1.07	0.24 ± 1.11	0.08 ± 1.13
LNE-Cnam	*0.57*	*0.90*	*0.63*	*1.06*	*0.90*	-	-0.24 ± 0.81	0.19 ± 0.86	0.03 ± 0.88
PTB	*0.96*	*1.28*	*0.85*	*1.38*	*1.11*	*0.92*	-	0.42 ± 1.02	0.27 ± 1.05
CEM	*0.88*	*0.99*	*1.02*	*1.18*	*1.18*	*0.91*	*1.27*	-	-0.15 ± 1.08
Average NPL	*0.87*	*1.09*	*0.92*	*1.22*	*1.11*	*0.87*	*1.15*	*1.10*	-

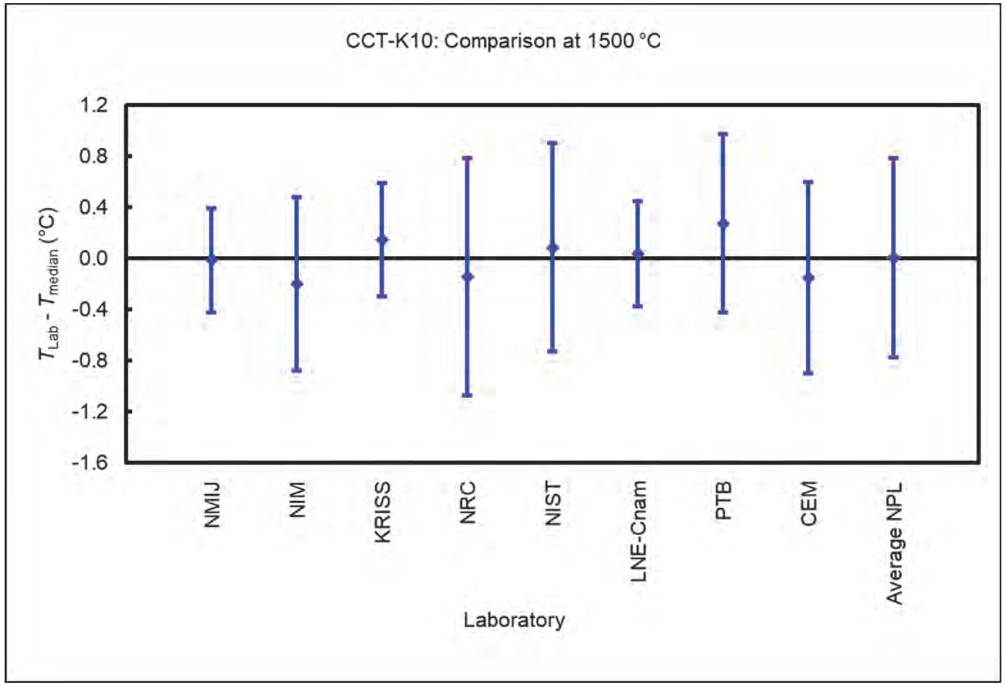


Table 67 - DOE and QDE_{95} table of results for the Chino thermometer at 1700 °C (all units are in °C) and chart with differences from the median.

	NMIJ	NIM	KRISS	NRC	NIST	LNE-Cnam	PTB	CEM	Average NPL
NMIJ	-	0.18 ± 0.91	-0.19 ± 0.79	0.06 ± 1.22	0.08 ± 1.04	-0.08 ± 0.67	0.38 ± 0.94	0.26 ± 1.01	0.08 ± 1.04
NIM	*0.96*	-	-0.37 ± 1.00	-0.12 ± 1.37	-0.10 ± 1.21	-0.25 ± 0.91	0.21 ± 1.13	0.08 ± 1.18	-0.10 ± 1.21
KRISS	*0.85*	*1.20*	-	0.25 ± 1.29	0.27 ± 1.13	0.11 ± 0.79	0.57 ± 1.03	0.45 ± 1.10	0.27 ± 1.12
NRC	*1.20*	*1.36*	*1.36*	-	0.02 ± 1.46	-0.13 ± 1.23	0.33 ± 1.39	0.20 ± 1.44	0.02 ± 1.46
NIST	*1.03*	*1.20*	*1.22*	*1.44*	-	-0.16 ± 1.05	0.30 ± 1.24	0.18 ± 1.29	0.00 ± 1.31
LNE-Cnam	*0.67*	*1.02*	*0.80*	*1.23*	*1.07*	-	0.46 ± 0.95	0.33 ± 1.01	0.16 ± 1.04
PTB	*1.17*	*1.18*	*1.42*	*1.51*	*1.35*	*1.24*	-	-0.13 ± 1.21	-0.30 ± 1.23
CEM	*1.11*	*1.17*	*1.35*	*1.46*	*1.31*	*1.18*	*1.21*	-	-0.18 ± 1.29
Average NPL	*1.02*	*1.19*	*1.22*	*1.43*	*1.29*	*1.06*	*1.34*	*1.30*	-

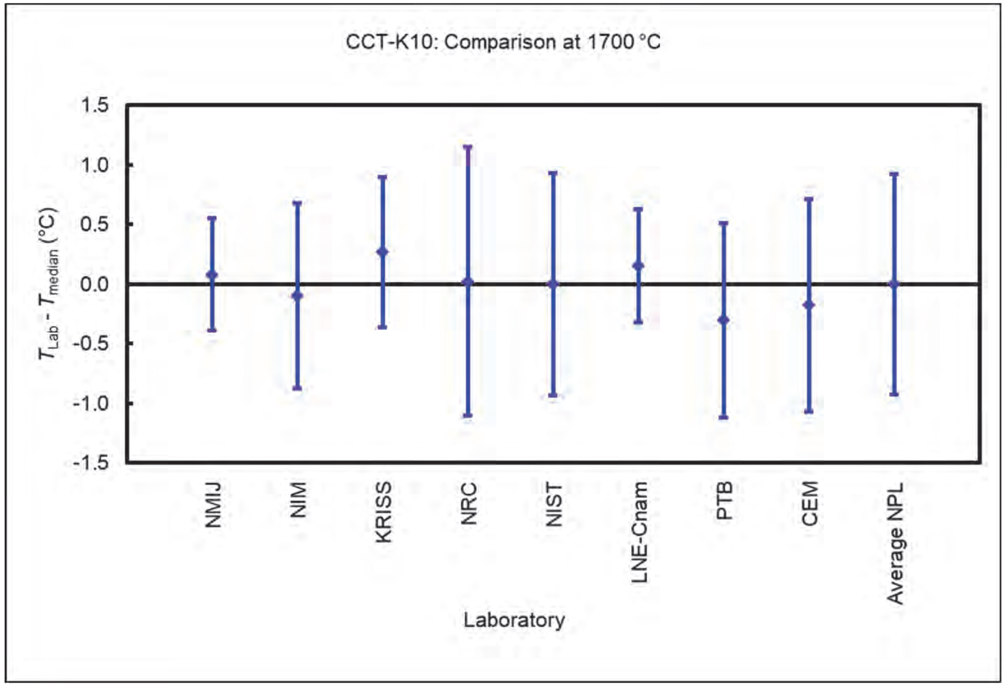


Table 68 - DOE and QDE$_{95}$ table of results for the Chino thermometer at 1800 °C (all units are in °C) and chart with differences from the median.

	NMIJ	NIM	KRISS	NRC	NIST	LNE-Cnam	PTB	CEM	Average NPL
NMIJ	-	0.16 ± 0.99	-0.19 ± 0.85	0.05 ± 1.36	0.26 ± 1.14	0.03 ± 0.75	0.44 ± 0.96	0.52 ± 1.12	0.20 ± 1.15
NIM	*1.02*	-	-0.35 ± 1.06	-0.11 ± 1.50	0.10 ± 1.31	-0.13 ± 0.99	0.28 ± 1.15	0.36 ± 1.29	0.04 ± 1.32
KRISS	*0.91*	*1.23*	-	0.24 ± 1.41	0.44 ± 1.21	0.22 ± 0.84	0.62 ± 1.03	0.70 ± 1.19	0.39 ± 1.22
NRC	*1.33*	*1.48*	*1.46*	-	0.20 ± 1.61	-0.02 ± 1.36	0.38 ± 1.48	0.46 ± 1.59	0.15 ± 1.61
NIST	*1.23*	*1.29*	*1.45*	*1.62*	-	-0.23 ± 1.14	0.18 ± 1.29	0.26 ± 1.41	-0.06 ± 1.44
LNE-Cnam	*0.74*	*1.00*	*0.93*	*1.33*	*1.20*	-	0.41 ± 0.96	0.48 ± 1.12	0.17 ± 1.15
PTB	*1.23*	*1.25*	*1.48*	*1.63*	*1.31*	*1.20*	-	0.08 ± 1.27	-0.24 ± 1.30
CEM	*1.45*	*1.44*	*1.68*	*1.80*	*1.48*	*1.41*	*1.25*	-	-0.32 ± 1.42
Average NPL	*1.19*	*1.29*	*1.40*	*1.60*	*1.41*	*1.17*	*1.35*	*1.53*	-

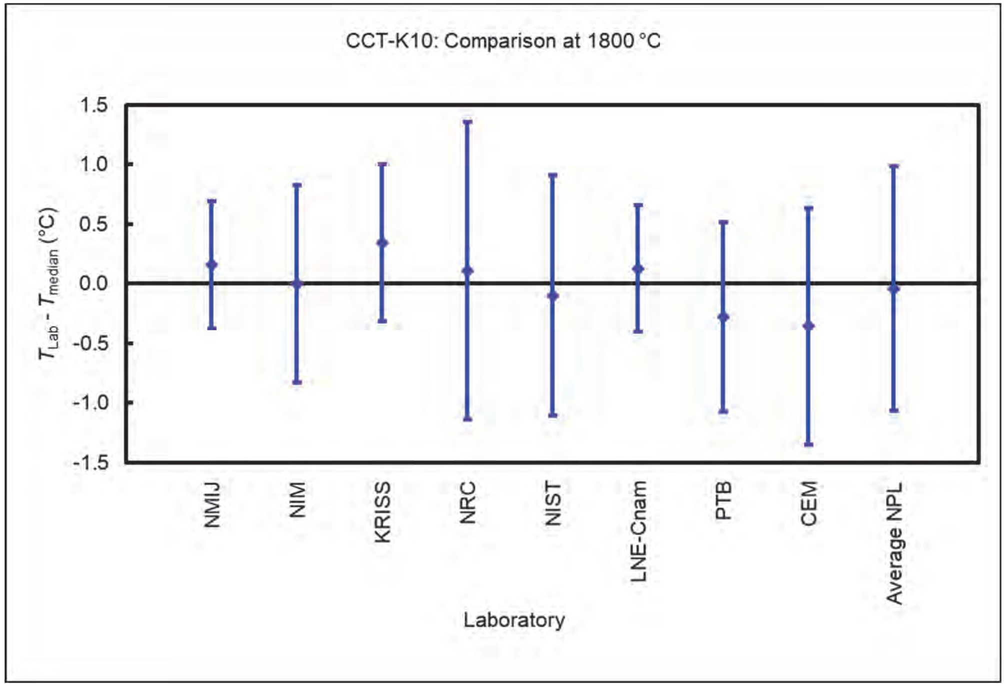


Table 69 - DOE and QDE_{95} table of results for the Chino thermometer at 2000 °C (all units are in °C) and chart with differences from the median.

	NMIJ	NIM	KRISS	NRC	NIST	LNE-Cnam	PTB	CEM	Average NPL
NMIJ	-	0.27 ± 1.27	-0.15 ± 1.07	0.00 ± 1.66	0.43 ± 1.35	0.11 ± 0.91	0.70 ± 1.15	0.41 ± 1.35	0.04 ± 1.37
NIM	*1.35*	-	-0.42 ± 1.39	-0.27 ± 1.88	0.16 ± 1.61	-0.15 ± 1.26	0.43 ± 1.44	0.14 ± 1.61	-0.23 ± 1.63
KRISS	*1.09*	*1.58*	-	0.15 ± 1.75	0.58 ± 1.45	0.26 ± 1.06	0.85 ± 1.27	0.56 ± 1.46	0.19 ± 1.48
NRC	*1.64*	*1.91*	*1.74*	-	0.43 ± 1.93	0.11 ± 1.65	0.70 ± 1.80	0.41 ± 1.93	0.04 ± 1.95
NIST	*1.55*	*1.60*	*1.78*	*2.07*	-	-0.32 ± 1.34	0.27 ± 1.51	-0.02 ± 1.67	-0.39 ± 1.69
LNE-Cnam	*0.91*	*1.27*	*1.16*	*1.63*	*1.45*	-	0.58 ± 1.13	0.30 ± 1.34	-0.07 ± 1.36
PTB	*1.64*	*1.64*	*1.89*	*2.19*	*1.57*	*1.52*	-	-0.29 ± 1.51	-0.66 ± 1.53
CEM	*1.54*	*1.60*	*1.77*	*2.06*	*1.64*	*1.43*	*1.58*	-	-0.37 ± 1.69
Average NPL	*1.35*	*1.66*	*1.49*	*1.92*	*1.82*	*1.34*	*1.93*	*1.81*	-

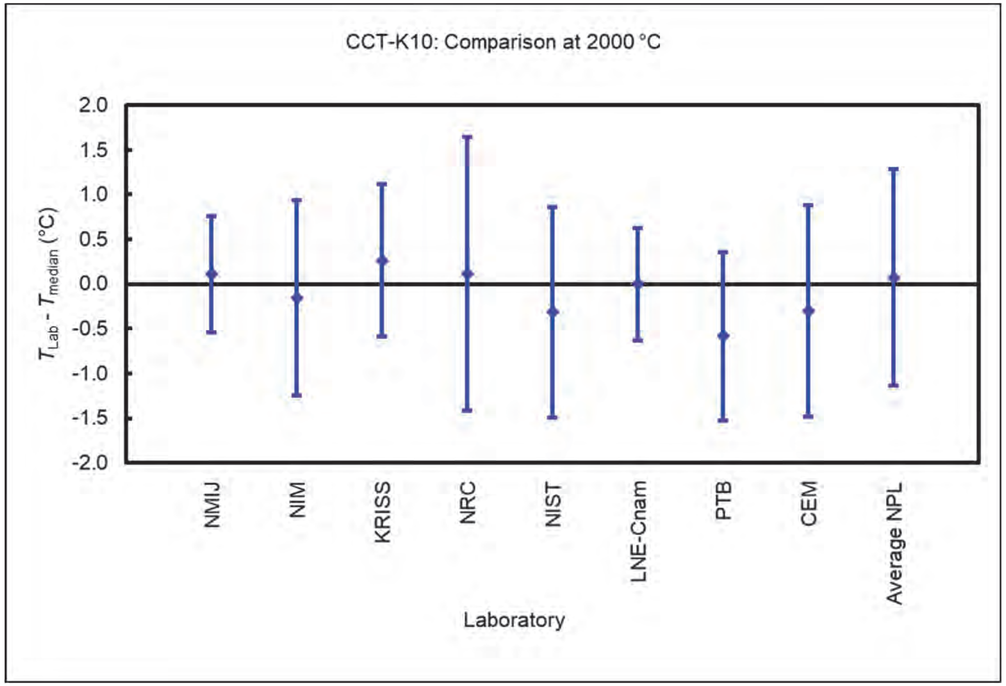


Table 70 - DOE and QDE_{95} table of results for the Chino thermometer at 2200 °C (all units are in °C) and chart with differences from the median.

	NMIJ	NIM	KRISS	NRC	NIST	LNE-Cnam	PTB	CEM	Average NPL
NMIJ	-	-0.03 ± 1.45	-0.18 ± 1.36	-0.09 ± 2.02	0.75 ± 1.57	0.23 ± 1.08	0.50 ± 1.37	-0.08 ± 1.78	0.24 ± 1.63
NIM	*1.43*	-	-0.15 ± 1.65	-0.06 ± 2.23	0.78 ± 1.83	0.26 ± 1.43	0.53 ± 1.66	-0.05 ± 2.01	0.27 ± 1.88
KRISS	*1.37*	*1.64*	-	0.09 ± 2.17	0.93 ± 1.76	0.40 ± 1.33	0.67 ± 1.58	0.09 ± 1.94	0.42 ± 1.81
NRC	*1.98*	*2.19*	*2.13*	-	0.84 ± 2.31	0.31 ± 2.00	0.58 ± 2.17	0.01 ± 2.45	0.33 ± 2.35
NIST	*2.05*	*2.30*	*2.38*	*2.76*	-	-0.52 ± 1.55	-0.25 ± 1.76	-0.83 ± 2.10	-0.51 ± 1.97
LNE-Cnam	*1.14*	*1.49*	*1.52*	*2.05*	*1.82*	-	0.27 ± 1.34	-0.31 ± 1.76	0.02 ± 1.61
PTB	*1.63*	*1.91*	*1.98*	*2.41*	*1.80*	*1.41*	-	-0.58 ± 1.95	-0.25 ± 1.81
CEM	*1.75*	*1.97*	*1.91*	*2.42*	*2.57*	*1.82*	*2.21*	-	0.32 ± 2.14
Average NPL	*1.66*	*1.91*	*1.95*	*2.38*	*2.17*	*1.58*	*1.84*	*2.19*	-

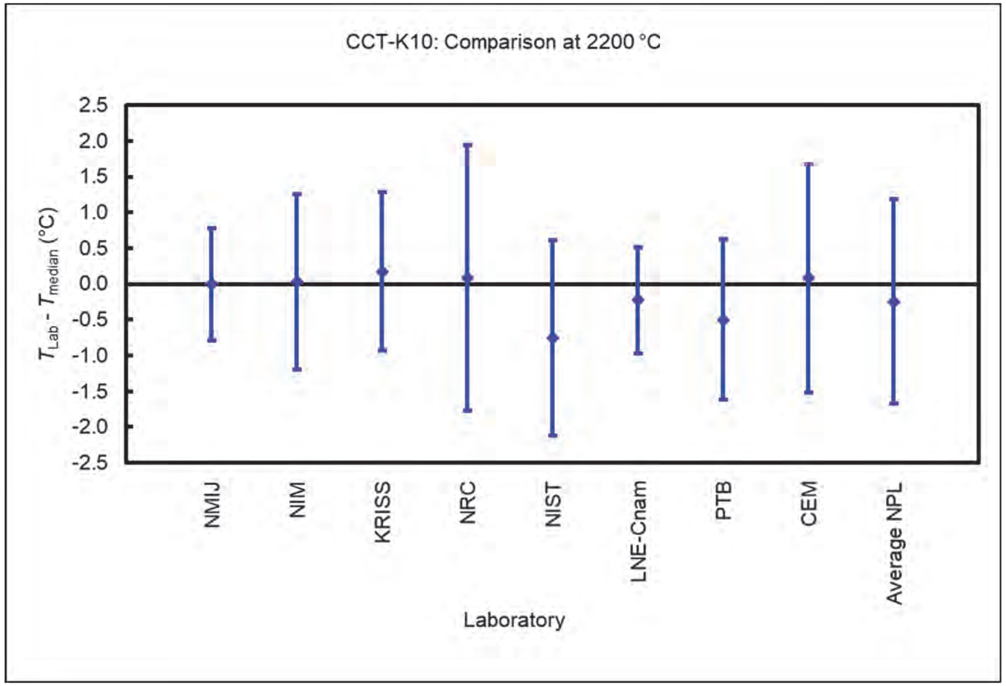


Table 71 - DOE and QDE_{95} table of results for the Chino thermometer at 2400 °C (all units are in °C) and chart with differences from the median.

	NMIJ	NIM	KRISS	NRC	NIST	LNE-Cnam	PTB	CEM	Average NPL
NMIJ	-	-1.23 ± 1.84	-0.11 ± 1.79	-0.13 ± 2.54	1.01 ± 1.98	0.61 ± 1.48	0.88 ± 1.78	3.21 ± 2.21	0.32 ± 2.03
NIM	*2.74*	-	1.11 ± 2.07	1.09 ± 2.74	2.24 ± 2.23	1.84 ± 1.81	2.10 ± 2.06	4.43 ± 2.44	1.55 ± 2.28
KRISS	*1.76*	*2.82*	-	-0.02 ± 2.70	1.12 ± 2.19	0.72 ± 1.75	0.99 ± 2.01	3.32 ± 2.40	0.44 ± 2.23
NRC	*2.49*	*3.37*	*2.66*	-	1.14 ± 2.83	0.74 ± 2.51	1.01 ± 2.70	3.34 ± 3.00	0.46 ± 2.87
NIST	*2.64*	*4.07*	*2.93*	*3.49*	-	-0.40 ± 1.95	-0.13 ± 2.19	2.20 ± 2.54	-0.69 ± 2.39
LNE-Cnam	*1.84*	*3.32*	*2.17*	*2.85*	*2.06*	-	0.27 ± 1.75	2.60 ± 2.18	-0.29 ± 1.99
PTB	*2.35*	*3.80*	*2.65*	*3.25*	*2.15*	*1.79*	-	2.33 ± 2.39	-0.55 ± 2.23
CEM	*5.02*	*6.44*	*5.29*	*5.80*	*4.29*	*4.39*	*4.30*	-	-2.88 ± 2.58
Average NPL	*2.08*	*3.42*	*2.35*	*2.95*	*2.69*	*2.03*	*2.43*	*5.00*	-

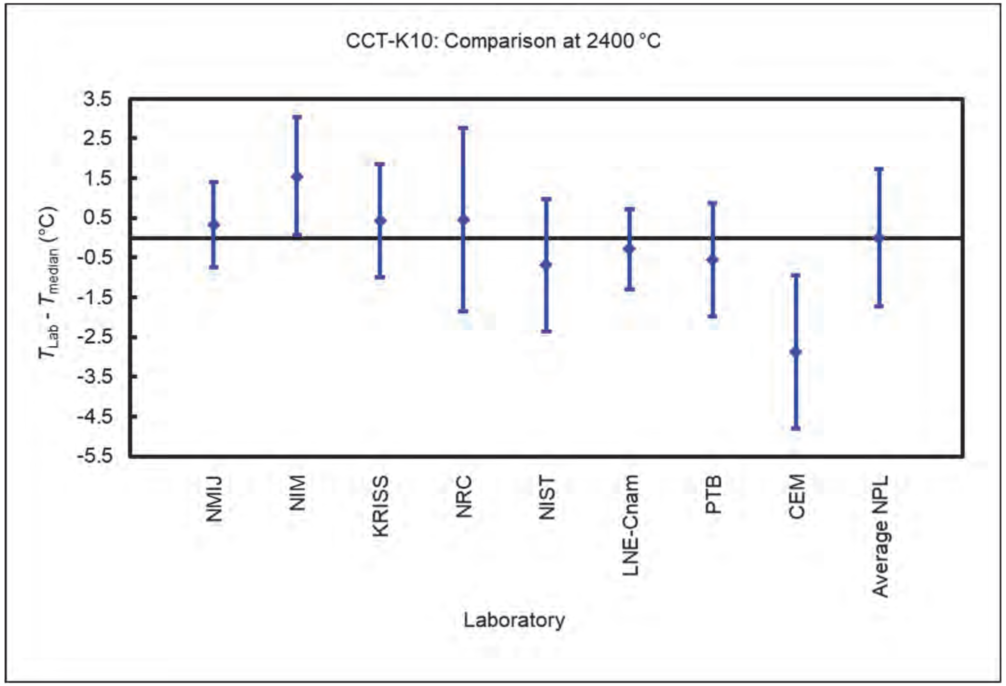


Table 72 - DOE and QDE_{95} table of results for the Chino thermometer at 2500 °C (all units are in °C) and chart with differences from the median.

	NMIJ	NIM	KRISS	NRC	NIST	PTB	CEM	Average NPL
NMIJ	-	-2.43 ± 1.91	0.03 ± 1.89	-0.11 ± 2.71	0.93 ± 2.07	1.16 ± 1.82	0.66 ± 2.30	0.32 ± 2.16
NIM	*4.00*	-	2.46 ± 2.18	2.32 ± 2.92	3.37 ± 2.33	3.59 ± 2.11	3.09 ± 2.54	2.76 ± 2.42
KRISS	*1.86*	*4.25*	-	-0.14 ± 2.91	0.90 ± 2.32	1.13 ± 2.09	0.63 ± 2.52	0.29 ± 2.40
NRC	*2.66*	*4.72*	*2.85*	-	1.05 ± 3.02	1.27 ± 2.86	0.77 ± 3.18	0.44 ± 3.09
NIST	*2.64*	*5.29*	*2.83*	*3.57*	-	0.23 ± 2.26	-0.28 ± 2.66	-0.61 ± 2.55
PTB	*2.66*	*5.33*	*2.86*	*3.64*	*2.25*	-	-0.50 ± 2.47	-0.84 ± 2.35
CEM	*2.58*	*5.18*	*2.76*	*3.46*	*2.65*	*2.61*	-	-0.33 ± 2.73
Average NPL	*2.21*	*4.75*	*2.42*	*3.14*	*2.76*	*2.79*	*2.75*	-

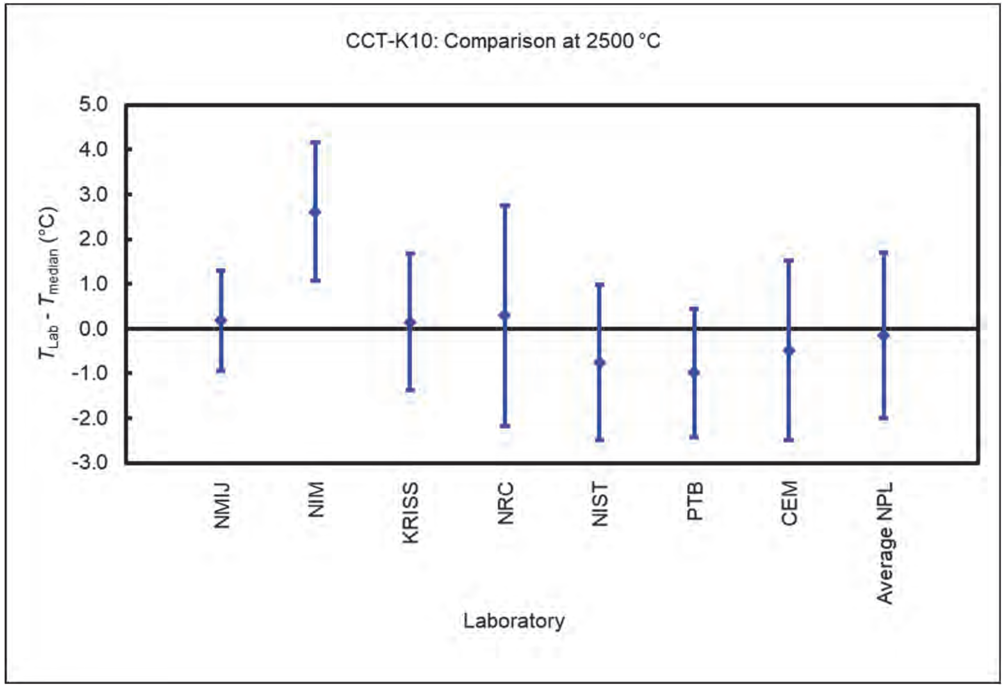


Table 73 - DOE and QDE$_{95}$ table of results for the Chino thermometer at 2600 °C (all units are in °C) and chart with differences from the median.

	NMIJ	NIM	KRISS	NRC	NIST	LNE-Cnam	PTB	Average NPL
NMIJ	-	-3.41 ± 2.13	0.11 ± 1.99	-0.07 ± 2.90	1.15 ± 2.16	0.58 ± 1.55	1.33 ± 1.88	0.09 ± 2.24
NIM	*5.17*	-	3.52 ± 2.43	3.35 ± 3.22	4.56 ± 2.56	3.99 ± 2.08	4.74 ± 2.33	3.50 ± 2.64
KRISS	*1.96*	*5.52*	-	-0.18 ± 3.13	1.04 ± 2.45	0.47 ± 1.93	1.22 ± 2.21	-0.02 ± 2.53
NRC	*2.85*	*5.99*	*3.07*	-	1.21 ± 3.23	0.64 ± 2.86	1.40 ± 3.05	0.16 ± 3.29
NIST	*2.93*	*6.67*	*3.07*	*3.90*	-	-0.57 ± 2.10	0.18 ± 2.36	-1.06 ± 2.66
LNE-Cnam	*1.86*	*5.70*	*2.10*	*3.07*	*2.34*	-	0.75 ± 1.82	-0.49 ± 2.19
PTB	*2.88*	*6.66*	*3.04*	*3.92*	*2.33*	*2.26*	-	-1.24 ± 2.44
Average NPL	*2.20*	*5.67*	*2.49*	*3.23*	*3.26*	*2.35*	*3.25*	-

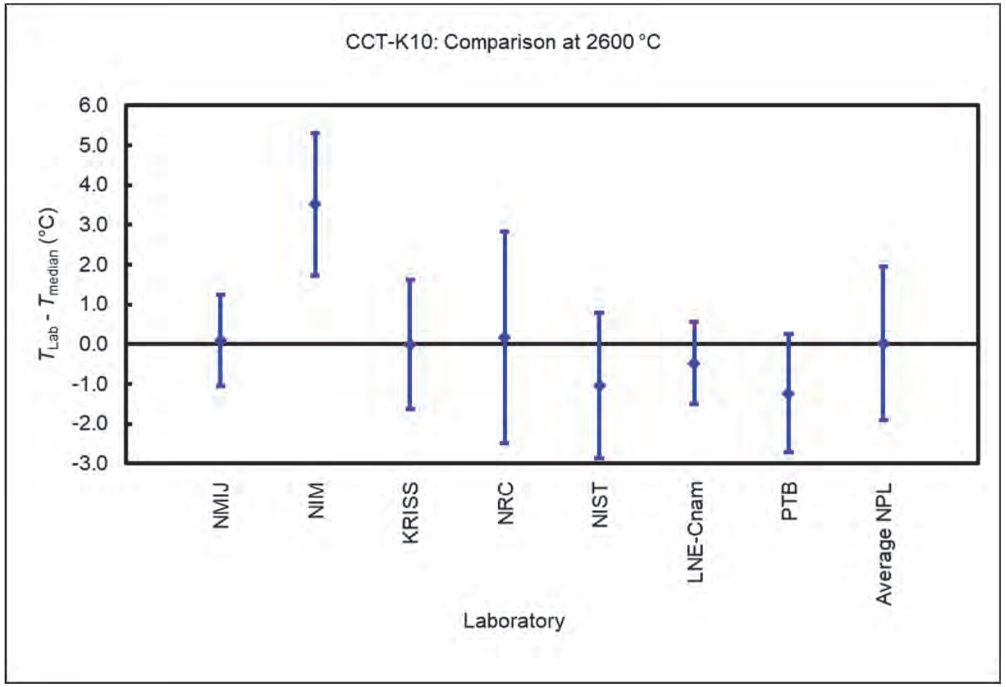


Table 74 - DOE and QDE_{95} table of results for the Chino thermometer at 2800 °C (all units are in °C) and chart with differences from the median.

	NMIJ	NIM	KRISS	NRC	NIST	LNE-Cnam	PTB	Average NPL
NMIJ	-	-4.55 ± 2.83	-0.04 ± 2.49	-0.06 ± 3.51	0.39 ± 2.60	0.67 ± 1.96	1.79 ± 2.32	-1.28 ± 2.76
NIM	*6.88*	-	4.51 ± 3.17	4.49 ± 4.02	4.94 ± 3.25	5.22 ± 2.77	6.34 ± 3.03	3.27 ± 3.39
KRISS	*2.45*	*7.12*	-	-0.03 ± 3.78	0.43 ± 2.95	0.71 ± 2.41	1.83 ± 2.71	-1.25 ± 3.10
NRC	*3.45*	*7.79*	*3.72*	-	0.46 ± 3.85	0.73 ± 3.45	1.85 ± 3.67	-1.22 ± 3.97
NIST	*2.65*	*7.62*	*3.01*	*3.87*	-	0.28 ± 2.52	1.40 ± 2.81	-1.68 ± 3.19
LNE-Cnam	*2.30*	*7.50*	*2.73*	*3.68*	*2.52*	-	1.12 ± 2.23	-1.95 ± 2.70
PTB	*3.69*	*8.83*	*4.06*	*4.88*	*3.72*	*2.96*	-	-3.07 ± 2.97
Average NPL	*3.57*	*6.05*	*3.82*	*4.54*	*4.31*	*4.17*	*5.51*	-

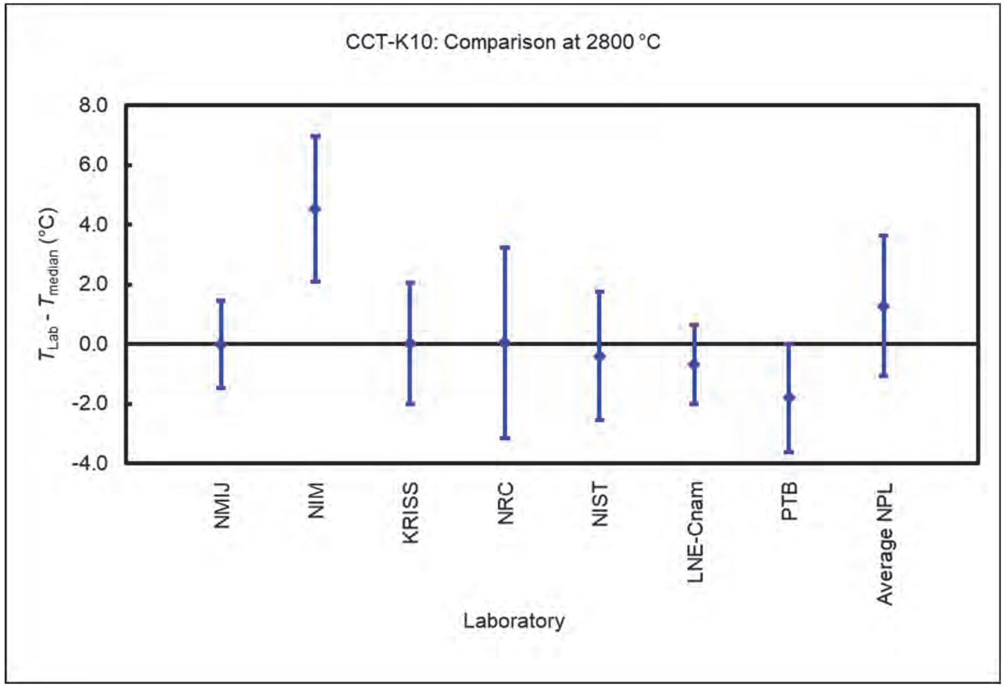


Table 75 - DOE and QDE_{95} table of results for the Chino thermometer at 2900 °C (all units are in °C) and chart with differences from the median.

	NMIJ	NIM	KRISS	NRC	PTB	Average NPL
NMIJ	-	-5.41 ± 3.65	-0.35 ± 3.00	-0.48 ± 3.93	1.96 ± 2.75	-1.42 ± 3.63
NIM	*8.41*	-	5.05 ± 4.00	4.92 ± 4.74	7.37 ± 3.82	3.99 ± 4.50
KRISS	*3.01*	*8.35*	-	-0.13 ± 4.26	2.31 ± 3.21	-1.07 ± 3.99
NRC	*3.96*	*8.83*	*4.18*	-	2.44 ± 4.10	-0.94 ± 4.73
PTB	*4.23*	*10.51*	*4.95*	*5.82*	-	-3.38 ± 3.81
Average NPL	*4.44*	*7.69*	*4.42*	*4.99*	*6.51*	-

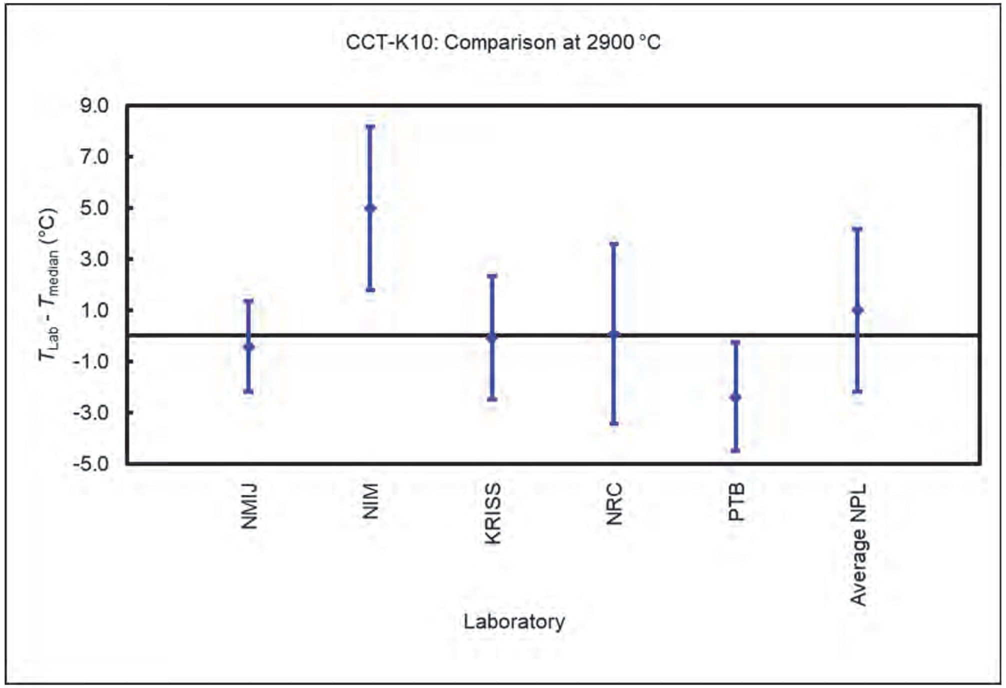
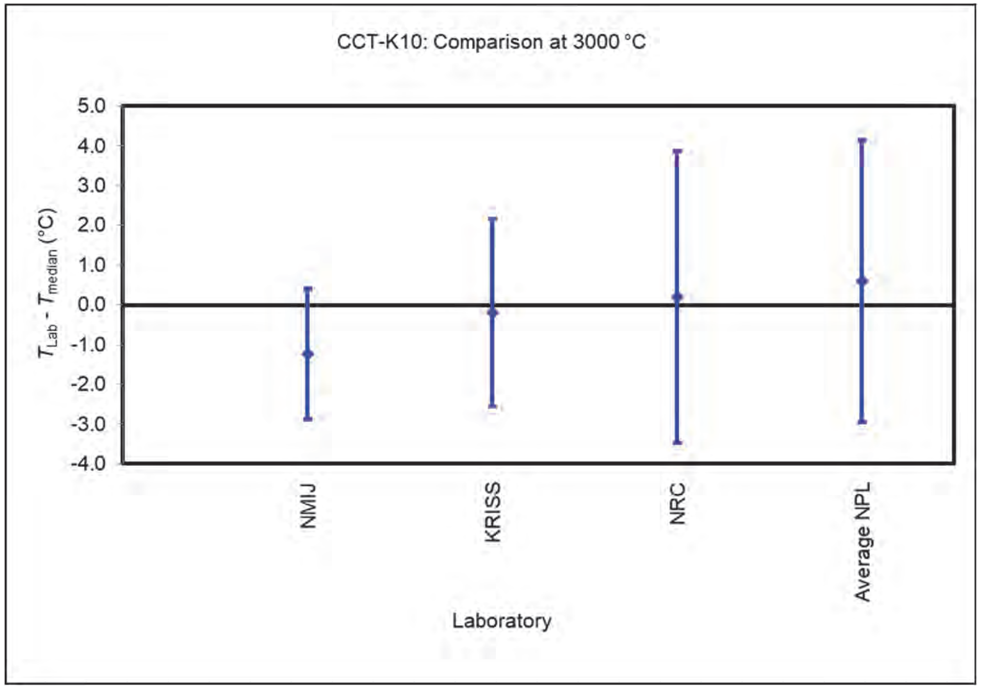


Table 76 - DOE and QDE_{95} table of results for the Chino thermometer at 3000 °C (all units are in °C) and chart with differences from the median.

	NMIJ	KRISS	NRC	Average NPL
NMIJ	-	-1.04 ± 2.88	-1.43 ± 4.02	-1.82 ± 3.91
KRISS	*3.44*	-	-0.38 ± 4.37	-0.78 ± 4.26
NRC	*4.77*	*4.33*	-	-0.40 ± 5.10
Average NPL	*5.05*	*4.45*	*5.04*	-



11 DIFFERENCES FROM THE KCRV – RADIATION THERMOMETERS

11.1 CALCULATING THE DIFFERENCES

The final step for the comparison using the transfer radiation thermometers is to calculate, for each participant, one difference from a Key Comparison Reference Value at each comparison temperature.

Using two transfer thermometers for a comparison is preferred to using just one, as it helps with difficulties which can arise should the one thermometer perform poorly, for example due to drift. However, it leads to the situation where there are two reference values (one for each thermometer) meaning that each participant has two ‘difference from the median’ values, one for each thermometer.

It was necessary to decide how to determine the ‘definitive’ KCRV for the CCT-K10 for the measurements with the transfer thermometers – use the average of the differences from each of the two medians or select the results of one thermometer over the other. Both thermometers exhibited drift over the duration of the comparison. The Chino thermometer drifted significantly at the start but then became more stable. For the LP3 the drift was less significant at the beginning of the comparison but then increased towards the end. Therefore, there was no significant difference in the overall performance of the thermometers over the course of the comparison, although there seemed to be more variation in some of the participant results with the Chino thermometer for reasons which are not clear.

The decision about how to calculate the KCRV was taken after discussion with the other participants. Since neither thermometer performed particularly worse or better than the other, it was decided that the results from both thermometers would be used.

Therefore, for each participant at each temperature the {participant - KCRV} difference has been calculated by taking the average (simple mean) of the differences of the LP3 and Chino thermometers from, respectively, the LP3 and Chino reference values (medians). The uncertainty of the {participant – KCRV} difference at each temperature was taken to be, for that participant, the largest total uncertainty (laboratory uncertainty combined with the uncertainty in the reference value); i.e., the larger of the total uncertainty for the LP3 and the total uncertainty for the Chino thermometer. Where data for one of the thermometers had been withdrawn from the comparison, the uncertainty was simply the total uncertainty related to the remaining thermometer.

The results of the calculations of the difference from the KCRV for each participant are presented in Table 77 to Table 85. The results for each participant are presented graphically in Figure 80 to Figure 97. The DOE and QDE_{95} values (see Section 10.6 and Equation 7) are presented in Section 11.2 Table 86 to Table 99 and in the accompanying graphs.

Table 77 – calculating the difference from the KCRV for the NMIJ results

t_{nom} / °C	LP3			Chino thermometer			Average difference from the median (KCRV)/ °C	Maximum U or used U	
	Difference from the median/ °C	U_{lab} / °C	U_{total} / °C	Difference from the median/ °C	U_{lab} / °C	U_{total} / °C		U_{lab} / °C	U_{total} / °C
960	0.02	0.07	0.13	-0.06	0.09	0.21	-0.02	0.09	0.21
1100	0.02	0.09	0.14	-0.02	0.10	0.24	0.00	0.10	0.24
1300	0.01	0.12	0.23	-0.02	0.14	0.29	-0.01	0.14	0.29
1500	0.01	0.17	0.27	-0.01	0.20	0.41	0.00	0.20	0.41
1700	0.07	0.23	0.34	0.08	0.27	0.47	0.08	0.27	0.47
1800	0.11	0.26	0.42	0.16	0.32	0.53	0.13	0.32	0.53
2000	0.07	0.33	0.48	0.11	0.41	0.65	0.09	0.41	0.65
2200	0.10	0.41	0.61	0.00	0.51	0.78	0.05	0.51	0.78
2400	0.19	0.51	0.76	0.32	0.63	1.08	0.26	0.63	1.08
2500	0.21	0.56	0.86	0.18	0.70	1.11	0.19	0.70	1.11
2600	0.25	0.61	0.92	0.10	0.76	1.15	0.17	0.76	1.15
2800	0.26	0.72	1.08	-0.02	0.91	1.45	0.12	0.91	1.45
2900	-0.20	0.78	1.16	-0.42	0.98	1.77	-0.31	0.98	1.77
3000	-0.14	0.84	1.22	-1.23	1.06	1.65	-0.68	1.06	1.65

Table 78 – calculating the difference from the KCRV for the NIM results

t_{nom} / °C	LP3			Chino thermometer			Average difference from the median (KCRV)/ °C	Maximum *U* or used *U*	
	Difference from the median/ °C	U_{lab} / °C	U_{total} / °C	Difference from the median/ °C	U_{lab} / °C	U_{total} / °C		U_{lab} / °C	U_{total} / °C
960	-0.06	0.28	0.30	-0.17	0.36	0.41	-0.11	0.36	0.41
1100	-0.03	0.30	0.32	-0.21	0.43	0.48	-0.12	0.43	0.48
1300	0.00	0.34	0.39	-0.19	0.49	0.55	-0.10	0.49	0.55
1500	0.02	0.40	0.46	-0.20	0.58	0.68	-0.09	0.58	0.68
1700	0.11	0.49	0.55	-0.10	0.68	0.78	0.01	0.68	0.78
1800	0.17	0.53	0.62	0.00	0.71	0.83	0.09	0.71	0.83
2000	0.15	0.75	0.83	-0.15	0.97	1.10	0.00	0.97	1.10
2200	0.18	0.83	0.95	0.03	1.07	1.22	0.10	1.07	1.22
2400	0.30	0.95	1.10	1.55	1.21	1.50	0.93	1.21	1.50
2500	0.30	1.00	1.19	2.61	1.29	1.55	1.46	1.29	1.55
2600	0.34	1.33	1.50	3.51	1.58	1.80	1.93	1.58	1.80
2800	0.30	1.90	2.07	4.53	2.16	2.44	2.42	2.16	2.44
2900	0.40	2.61	2.74	4.99	2.83	3.19	2.69	2.83	3.19

Table 79 – calculating the difference from the KCRV for the KRISS results

t_{nom} / °C	LP3			Chino thermometer			Average difference from the median (KCRV)/ °C	Maximum U or used U	
	Difference from the median/ °C	U_{lab} / °C	U_{total} / °C	Difference from the median/ °C	U_{lab} / °C	U_{total} / °C		U_{lab} / °C	U_{total} / °C
960	0.00	0.15	0.18	0.07	0.14	0.24	0.03	0.15	0.24
1100	0.02	0.10	0.15	-0.01	0.10	0.24	0.01	0.10	0.24
1300	0.04	0.16	0.26	0.14	0.16	0.30	0.09	0.16	0.30
1500	0.00	0.29	0.37	0.14	0.27	0.44	0.07	0.29	0.44
1700	0.05	0.44	0.51	0.27	0.50	0.63	0.16	0.50	0.63
1800	0.05	0.51	0.60	0.35	0.50	0.66	0.20	0.51	0.66
2000	0.00	0.69	0.77	0.26	0.69	0.85	0.13	0.69	0.85
2200	0.00	0.96	1.06	0.18	0.94	1.11	0.09	0.96	1.11
2400	0.00	1.14	1.27	0.44	1.13	1.43	0.22	1.14	1.43
2500	-0.25	1.27	1.43	0.15	1.26	1.53	-0.05	1.27	1.53
2600	-0.26	1.42	1.58	-0.01	1.39	1.63	-0.13	1.42	1.63
2800	-0.36	1.69	1.87	0.02	1.68	2.02	-0.17	1.69	2.02
2900	-0.62	1.93	2.11	-0.07	1.91	2.42	-0.34	1.93	2.42
3000	-0.93	2.01	2.19	-0.19	2.00	2.37	-0.56	2.01	2.37

Table 80 – calculating the difference from the KCRV for the NRC results

t_{nom} / °C	LP3			Chino thermometer			Average difference from the median (KCRV)/ °C	Maximum U or used U	
	Difference from the median/ °C	U_{lab} / °C	U_{total} / °C	Difference from the median/ °C	U_{lab} / °C	U_{total} / °C		U_{lab} / °C	U_{total} / °C
960	-0.11	0.53	0.54	-0.16	0.53	0.56	-0.14	0.53	0.56
1100	-0.11	0.58	0.59	-0.18	0.58	0.62	-0.14	0.58	0.62
1300	-0.14	0.70	0.73	-0.16	0.70	0.75	-0.15	0.70	0.75
1500	-0.14	0.86	0.89	-0.15	0.86	0.93	-0.14	0.86	0.93
1700	-0.06	1.06	1.09	0.02	1.06	1.13	-0.02	1.06	1.13
1800	0.00	1.17	1.22	0.11	1.17	1.25	0.05	1.17	1.25
2000	0.04	1.44	1.48	0.11	1.44	1.53	0.08	1.44	1.53
2200	0.18	1.75	1.81	0.09	1.76	1.86	0.13	1.76	1.86
2400	0.32	2.13	2.20	0.46	2.13	2.30	0.39	2.13	2.30
2500	0.40	2.33	2.42	0.29	2.32	2.47	0.35	2.33	2.47
2600	0.60	2.54	2.63	0.17	2.53	2.67	0.38	2.54	2.67
2800	0.43	3.00	3.10	0.05	2.99	3.19	0.24	3.00	3.19
2900	0.21	3.20	3.31	0.07	3.19	3.51	0.14	3.20	3.51
3000	0.14	3.46	3.57	0.19	3.45	3.67	0.16	3.46	3.67

Table 81 – calculating the difference from the KCRV for the NIST results

t_{nom} / °C	LP3			Chino thermometer			Average difference from the median (KCRV)/ °C	Maximum U or used U	
	Difference from the median/ °C	U_{lab} / °C	U_{total} / °C	Difference from the median/ °C	U_{lab} / °C	U_{total} / °C		U_{lab} / °C	U_{total} / °C
960	0.05	0.56	0.57	0.05	0.56	0.59	0.05	0.56	0.59
1100	-0.03	0.58	0.59	0.06	0.58	0.62	0.02	0.58	0.62
1300	-0.11	0.64	0.67	-0.07	0.64	0.68	-0.09	0.64	0.68
1500	0.03	0.74	0.77	0.08	0.73	0.81	0.06	0.74	0.81
1700	0.00	0.85	0.89	0.00	0.85	0.93	0.00	0.85	0.93
1800	-0.05	0.92	0.98	-0.10	0.92	1.01	-0.08	0.92	1.01
2000	-0.12	1.07	1.12	-0.32	1.06	1.18	-0.22	1.07	1.18
2200	-0.23	1.23	1.31	-0.75	1.23	1.36	-0.49	1.23	1.36
2400	-0.32	1.42	1.53	-0.69	1.41	1.66	-0.50	1.42	1.66
2500	-0.21	1.52	1.65	-0.76	1.51	1.74	-0.48	1.52	1.74
2600	-0.25	1.62	1.76	-1.05	1.61	1.83	-0.65	1.62	1.83
2800	-0.30	1.84	2.01	-0.41	1.83	2.15	-0.36	1.84	2.15

Table 82 – calculating the difference from the KCRV for the LNE-Cnam results

t_{nom} / °C	LP3			Chino thermometer			Average difference from the median (KCRV)/ °C	Maximum *U* or used *U*	
	Difference from the median/ °C	U_{lab} / °C	U_{total} / °C	Difference from the median/ °C	U_{lab} / °C	U_{total} / °C		U_{lab} / °C	U_{total} / °C
960	0.02	0.10	0.15	0.00	0.10	0.22	0.01	0.10	0.22
1100	0.00	0.13	0.17	0.06	0.13	0.25	0.03	0.13	0.25
1300	-0.06	0.17	0.26	0.02	0.17	0.30	-0.02	0.17	0.30
1500	-0.10	0.21	0.30	0.03	0.21	0.41	-0.03	0.21	0.41
1700	-0.18	0.28	0.38	0.16	0.28	0.48	-0.01	0.28	0.48
1800	-0.21	0.31	0.45	0.13	0.31	0.53	-0.04	0.31	0.53
2000	-0.33	0.37	0.50	0.00	0.37	0.63	-0.17	0.37	0.63
2200	-0.43	0.44	0.62	-0.23	0.44	0.74	-0.33	0.44	0.74
2400	-0.56	0.51	0.77	-0.29	0.52	1.01	-0.42	0.52	1.01
2500									
2600	-0.27	0.64	0.94	-0.48	0.59	1.04	-0.37	0.64	1.04
2800	-0.26	0.72	1.07	-0.69	0.67	1.31	-0.47	0.72	1.31

Table 83 – calculating the difference from the KCRV for the PTB results

t_{nom} / °C	LP3			Chino thermometer			Average difference from the median (KCRV)/ °C	Maximum *U* or used *U*	
	Difference from the median/ °C	U_{lab} / °C	U_{total} / °C	**Difference from the median/ °C**	U_{lab} / °C	U_{total} / °C		U_{lab} / °C	U_{total} / °C
960	-0.06	0.25	0.27	0.02	0.24	0.31	-0.02	0.25	0.31
1100	0.05	0.36	0.38	0.01	0.35	0.41	0.03	0.36	0.41
1300	0.15	0.47	0.51	0.00	0.47	0.54	0.08	0.47	0.54
1500	-0.10	0.60	0.64	0.27	0.60	0.70	0.08	0.60	0.70
1700	-0.29	0.74	0.78	-0.30	0.72	0.82	-0.30	0.74	0.82
1800	-0.24	0.82	0.88	-0.28	0.67	0.80	-0.26	0.82	0.88
2000	-0.44	0.84	0.91	-0.58	0.79	0.94	-0.51	0.84	0.94
2200	-0.24	0.97	1.07	-0.50	0.95	1.12	-0.37	0.97	1.12
2400	-0.56	1.15	1.28	-0.55	1.12	1.42	-0.56	1.15	1.42
2500	-0.83	1.24	1.41	-0.98	1.14	1.44	-0.91	1.24	1.44
2600	-0.98	1.27	1.45	-1.23	1.22	1.49	-1.10	1.27	1.49
2800	-1.40	1.45	1.66	-1.81	1.41	1.81	-1.60	1.45	1.81
2900	-2.11	1.55	1.78	-2.38	1.51	2.11	-2.24	1.55	2.11

Table 84 – calculating the difference from the KCRV for the CEM results

t_{nom} / °C	LP3			Chino thermometer			Average difference from the median (KCRV)/ °C	Maximum U or used U	
	Difference from the median/ °C	U_{lab} / °C	U_{total} / °C	Difference from the median/ °C	U_{lab} / °C	U_{total} / °C		U_{lab} / °C	U_{total} / °C
960	-0.10	0.34	0.36	0.02	0.35	0.40	-0.04	0.35	0.40
1100	-0.14	0.40	0.42	0.12	0.41	0.46	-0.01	0.41	0.46
1300	-0.27	0.51	0.55	0.00	0.52	0.58	-0.13	0.52	0.58
1500	-0.62	0.65	0.69	-0.15	0.66	0.75	-0.39	0.66	0.75
1700	-0.74	0.80	0.84	-0.18	0.81	0.90	-0.46	0.81	0.90
1800	-1.08	0.89	0.94	-0.36	0.89	0.99	-0.72	0.89	0.99
2000	-0.75	1.06	1.11	-0.30	1.07	1.18	-0.52	1.07	1.18
2200	-1.23	1.46	1.53	0.08	1.48	1.60	-0.57	1.48	1.60
2400	-0.40	1.70	1.80	-2.88	1.72	1.93	-1.64	1.72	1.93
2500	-0.29	1.79	1.91	-0.48	1.81	2.01	-0.38	1.81	2.01

Table 85 – calculating the difference from the KCRV for the average NPL results

t_{nom} / °C	LP3			Chino thermometer			Average difference from the median (KCRV)/ °C	Maximum U or used U	
	Difference from the median/ °C	U_{lab} / °C	U_{total} / °C	Difference from the median/ °C	U_{lab} / °C	U_{total} / °C		U_{lab} / °C	U_{total} / °C
960	0.14	0.35	0.37	0.00	0.47	0.50	0.07	0.47	0.50
1100	0.15	0.43	0.45	0.00	0.51	0.56	0.07	0.51	0.56
1300	0.18	0.55	0.58	0.02	0.61	0.66	0.10	0.61	0.66
1500	0.20	0.65	0.68	0.00	0.70	0.78	0.10	0.70	0.78
1700	0.23	0.80	0.84	0.00	0.84	0.92	0.12	0.84	0.92
1800	0.23	0.92	0.97	-0.04	0.93	1.02	0.09	0.93	1.02
2000	0.37	1.02	1.08	0.07	1.10	1.21	0.22	1.10	1.21
2200	0.30	1.23	1.31	-0.24	1.30	1.43	0.03	1.30	1.43
2400	0.32	1.41	1.52	0.00	1.48	1.72	0.16	1.48	1.72
2500	0.24	1.52	1.66	-0.15	1.64	1.86	0.04	1.64	1.86
2600	0.28	1.63	1.77	0.01	1.73	1.93	0.14	1.73	1.93
2800	0.62	1.83	2.00	1.26	2.06	2.35	0.94	2.06	2.35
2900	0.20	2.27	2.43	1.00	2.81	3.17	0.60	2.81	3.17
3000	0.30	3.05	3.17	0.59	3.32	3.55	0.45	3.32	3.55

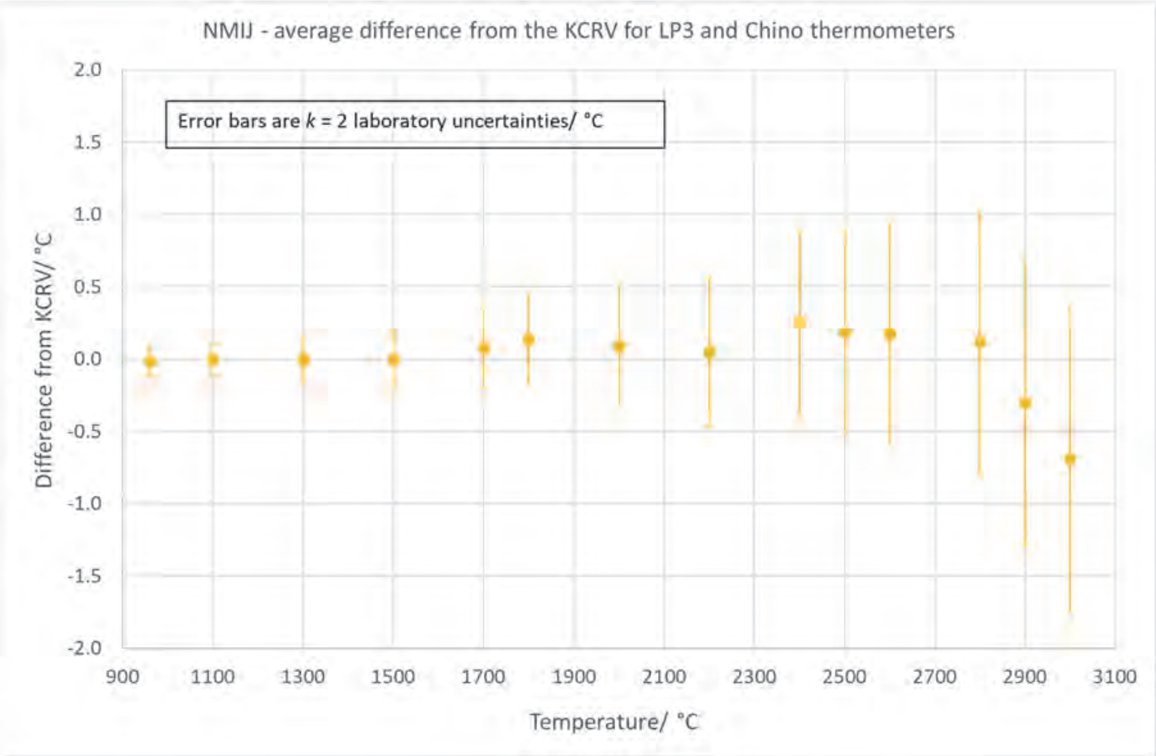


Figure 80 - difference between the NMIJ results and the KCRV (error bars are *k* = 2 laboratory uncertainties)

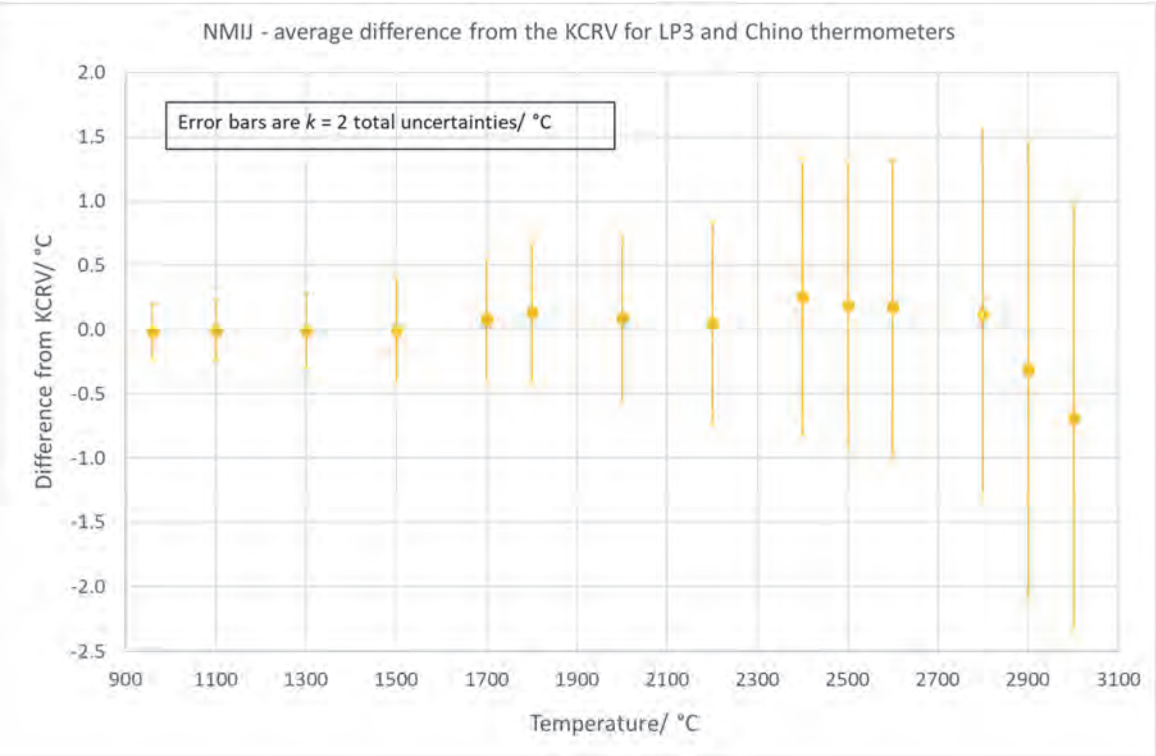


Figure 81 - difference between the NMIJ results and the KCRV (error bars are *k* = 2 total uncertainties)

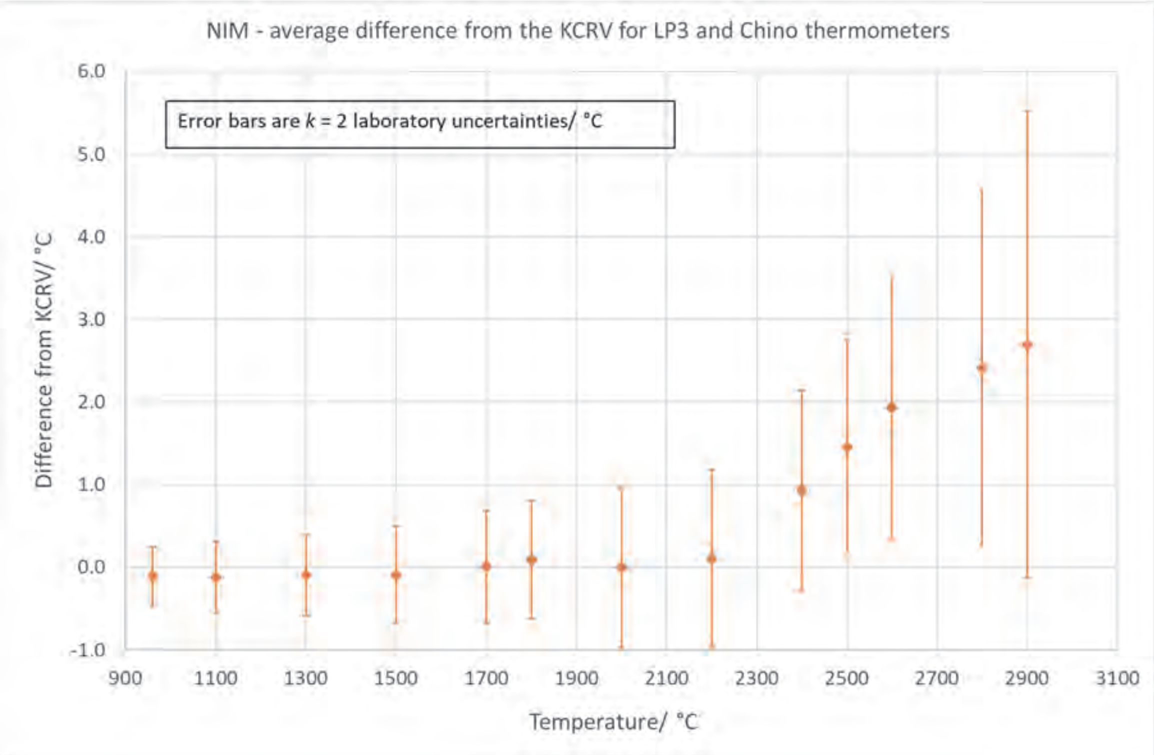


Figure 82 - difference between the NIM results and the KCRV (error bars are *k* = 2 laboratory uncertainties)

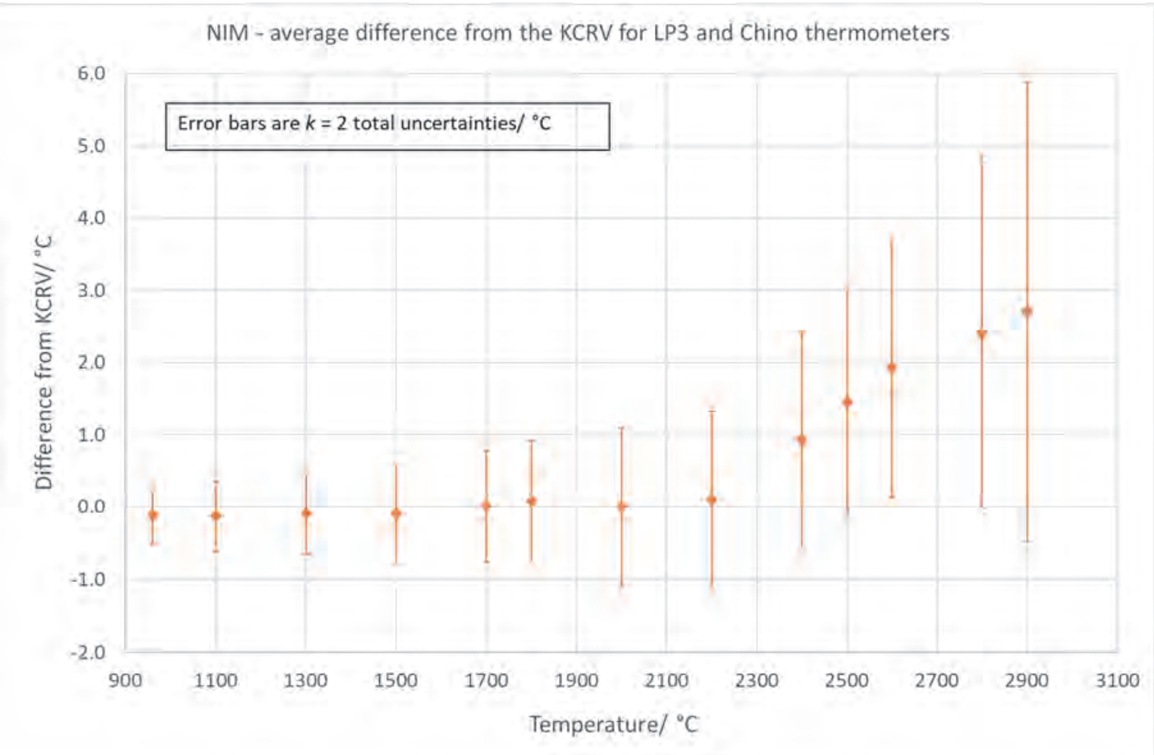


Figure 83 - difference between the NIM results and the KCRV (error bars are *k* = 2 total uncertainties)

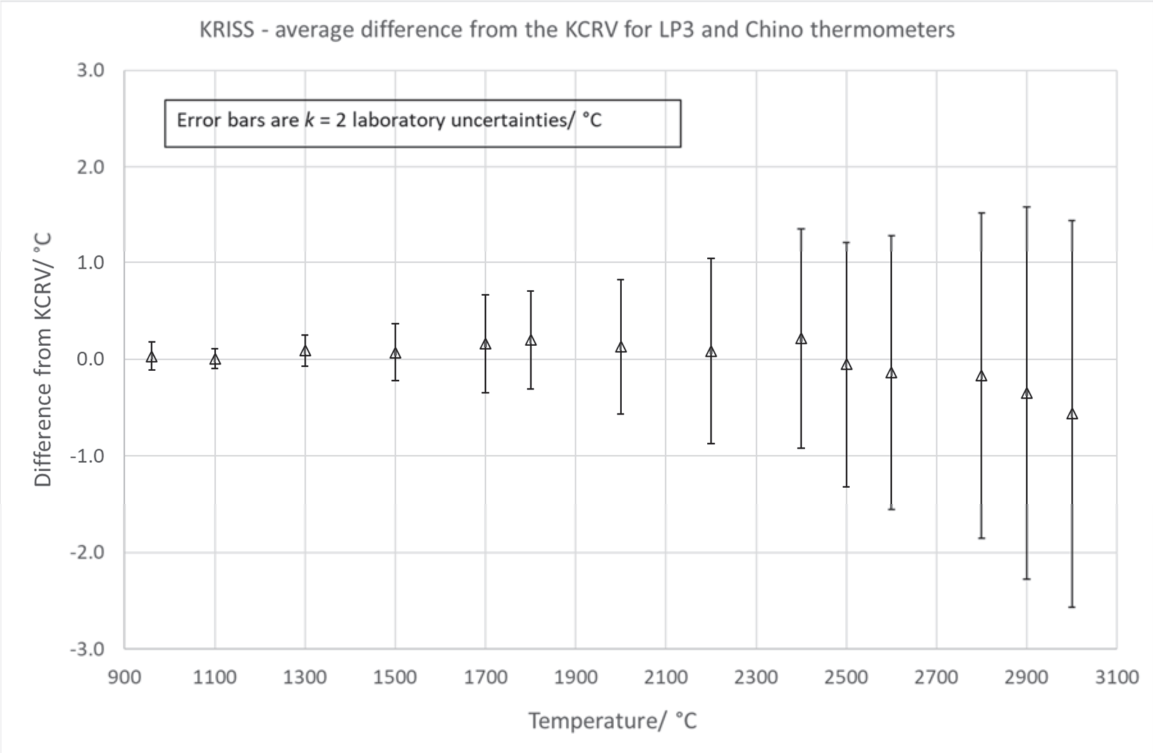


Figure 84 - difference between the KRISS results and the KCRV (error bars are *k* = 2 laboratory uncertainties)

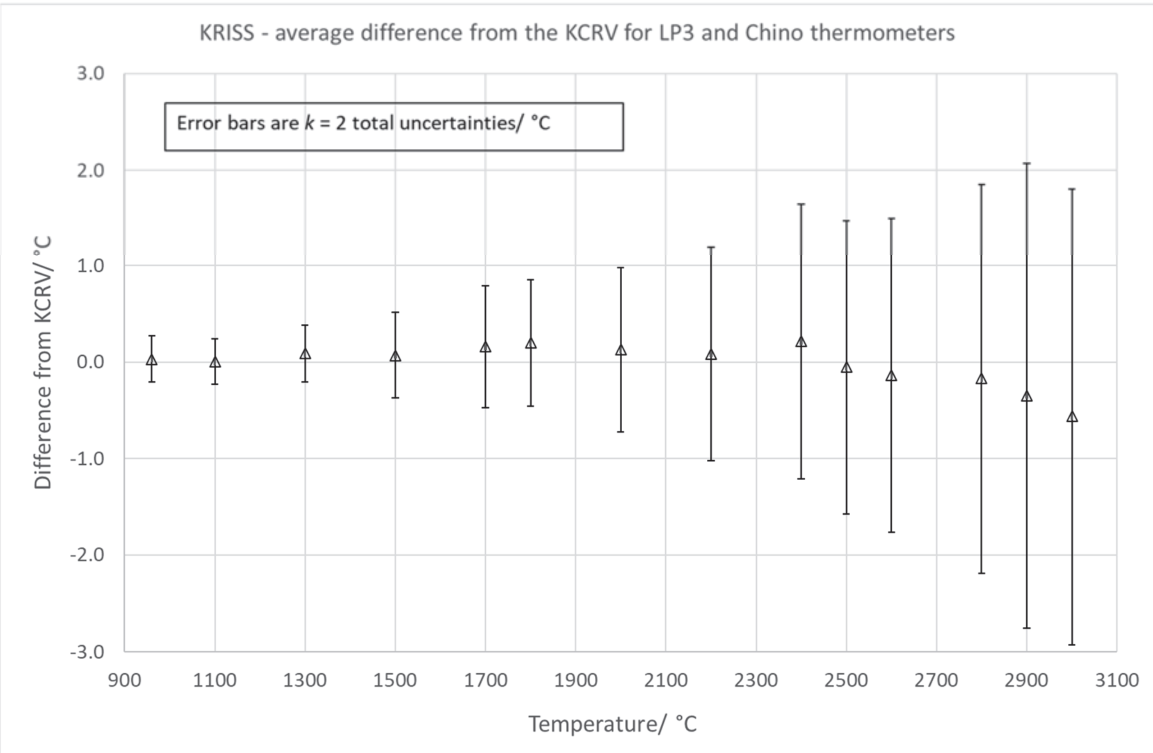


Figure 85 - difference between the KRISS results and the KCRV (error bars are *k* = 2 total uncertainties)

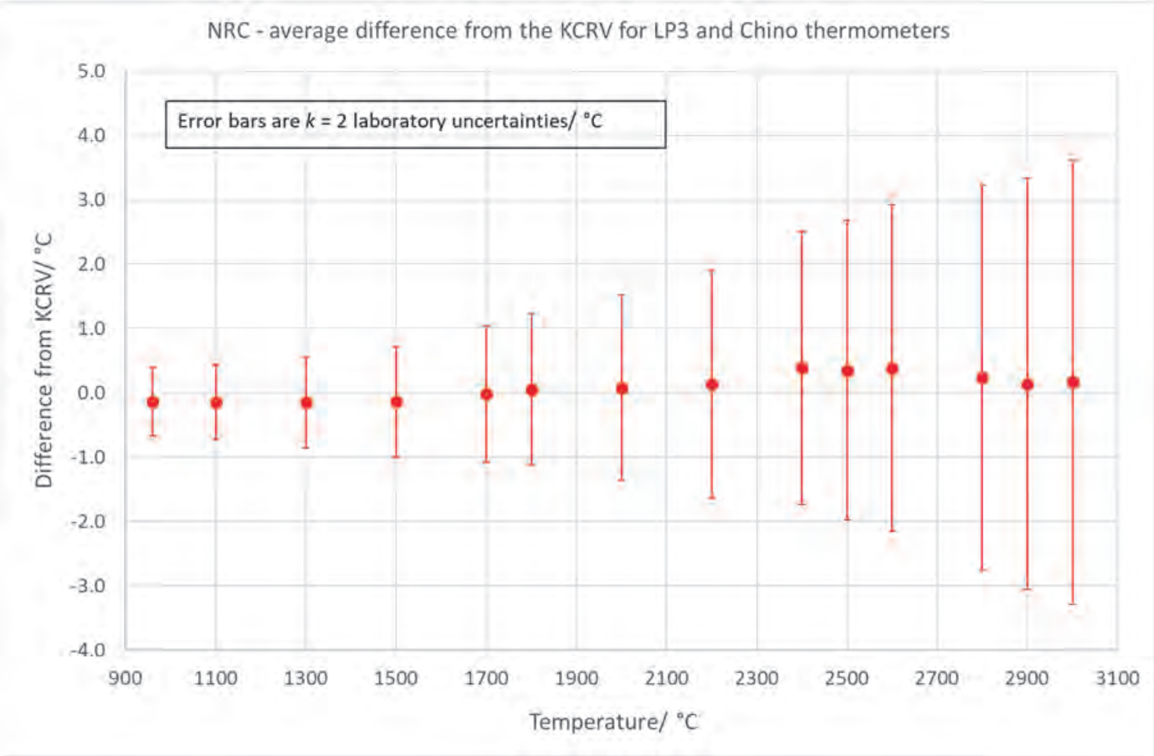


Figure 86 - difference between the NRC results and the KCRV (error bars are *k* = 2 laboratory uncertainties)

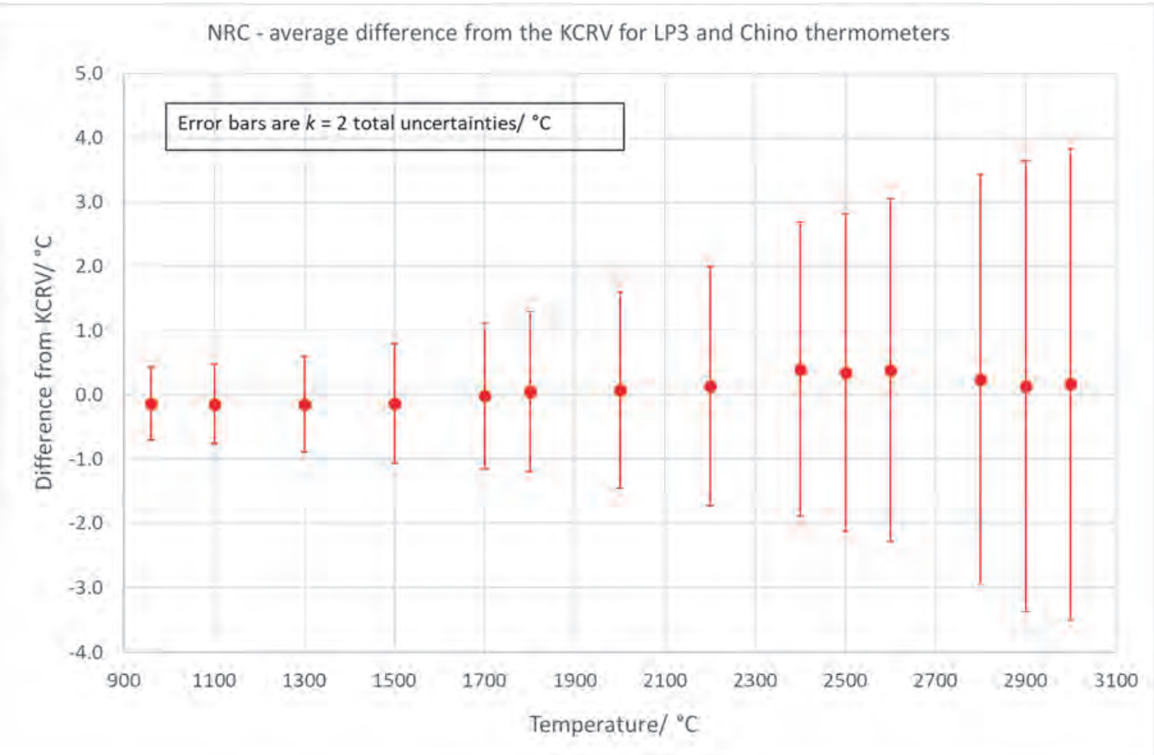


Figure 87 - difference between the NRC results and the KCRV (error bars are *k* = 2 total uncertainties)

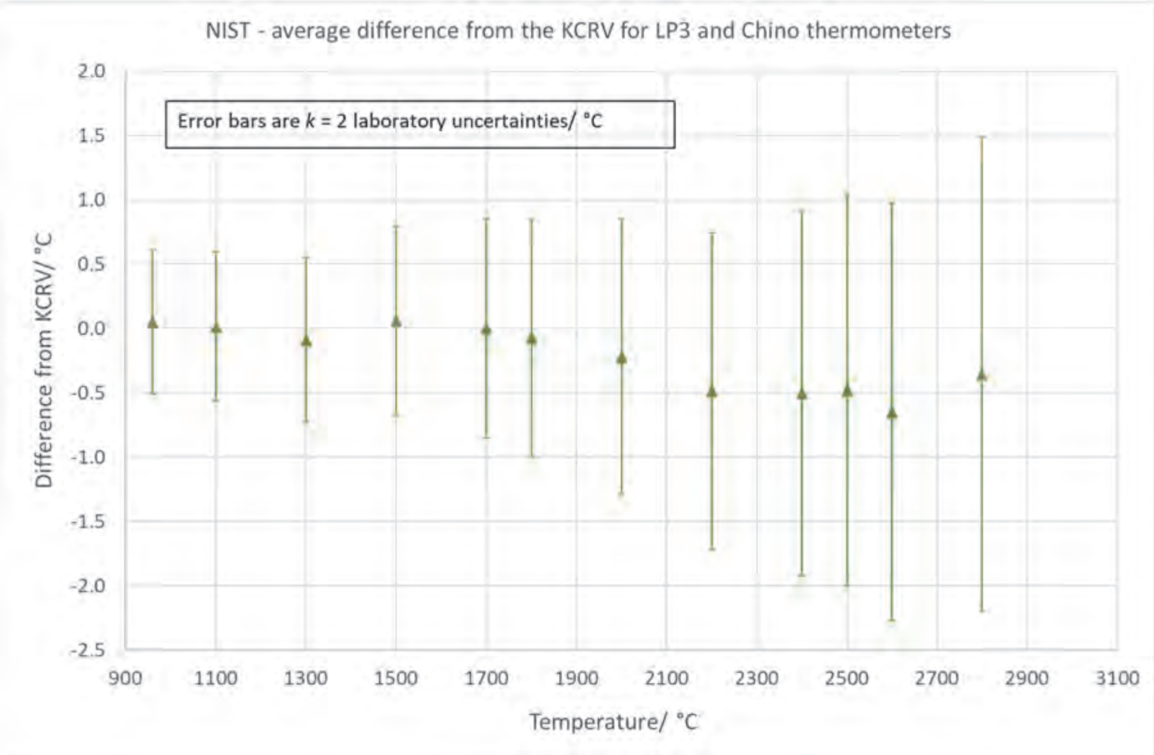


Figure 88 - difference between the NIST results and the KCRV (error bars are *k* = 2 laboratory uncertainties)

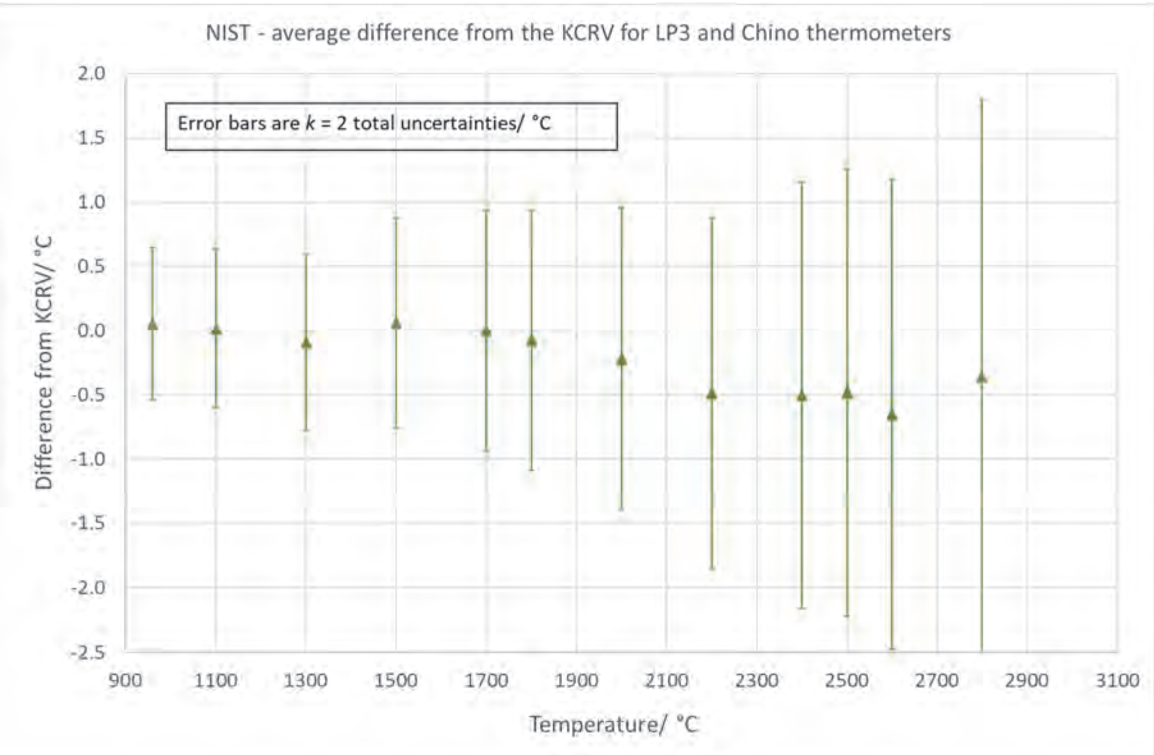


Figure 89 - difference between the NIST results and the KCRV (error bars are *k* = 2 total uncertainties)

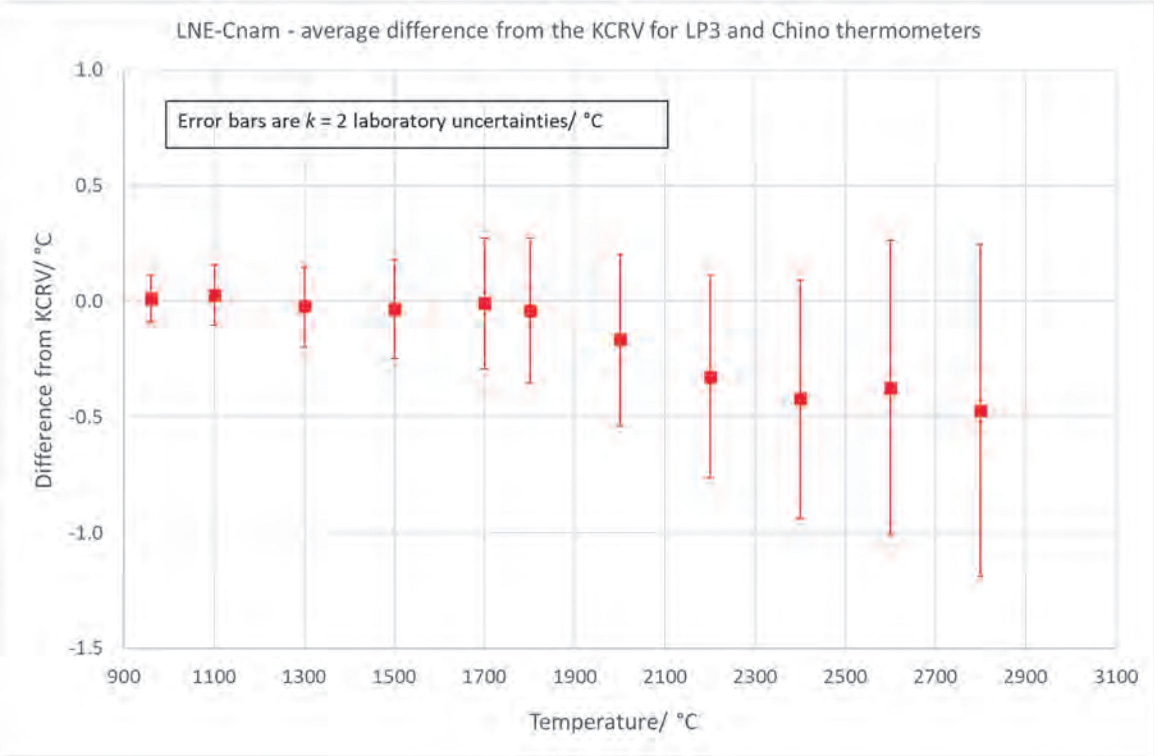


Figure 90 - difference between the LNE-Cnam results and the KCRV (error bars are *k* = 2 laboratory uncertainties)

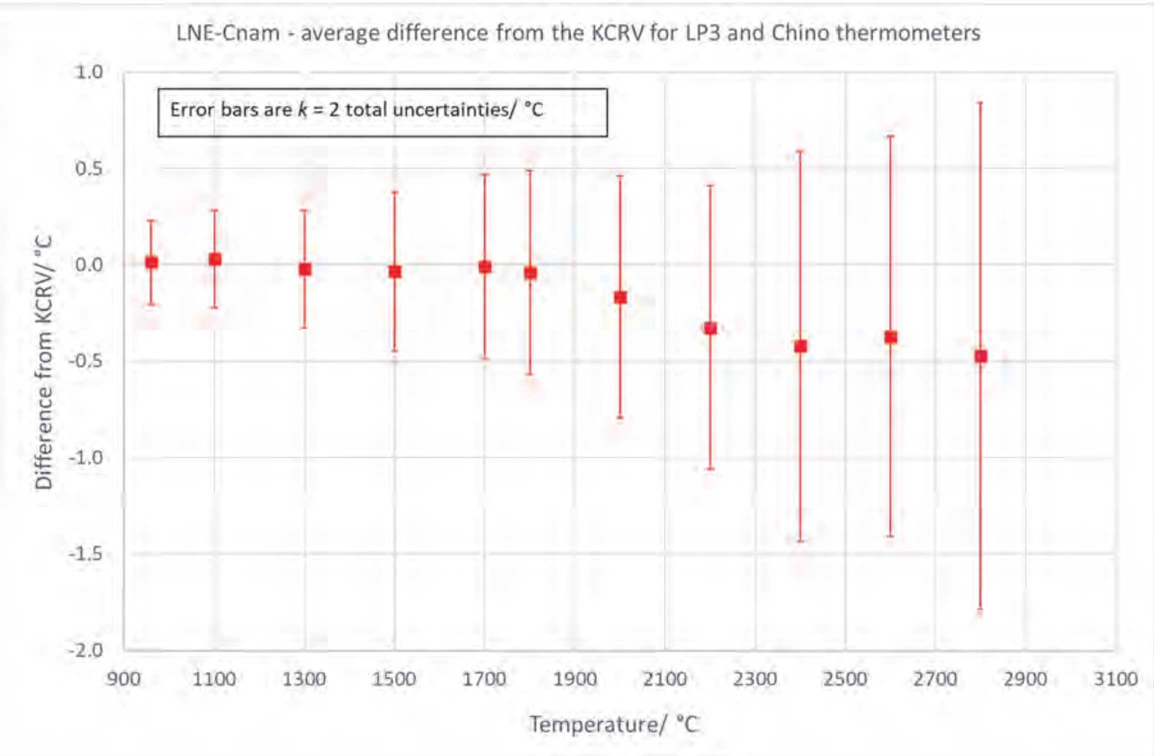


Figure 91 - difference between the LNE-Cnam results and the KCRV (error bars are *k* = 2 total uncertainties)

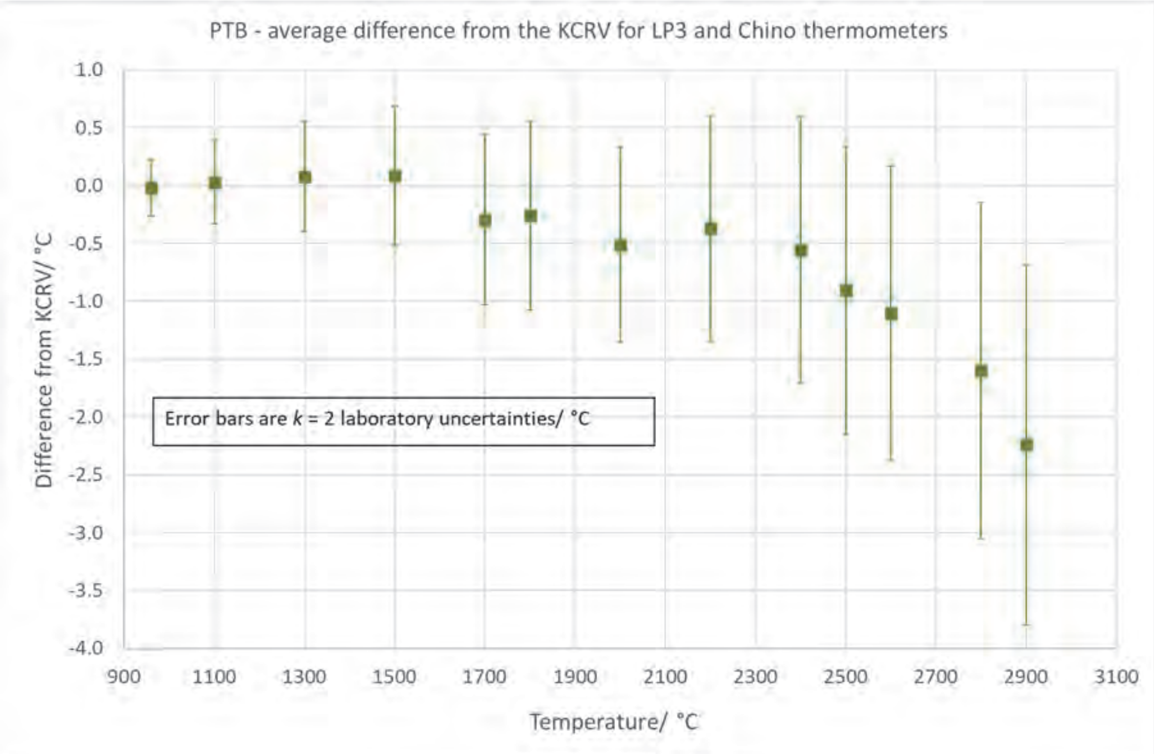


Figure 92 - difference between the PTB results and the KCRV (error bars are *k* = 2 laboratory uncertainties)

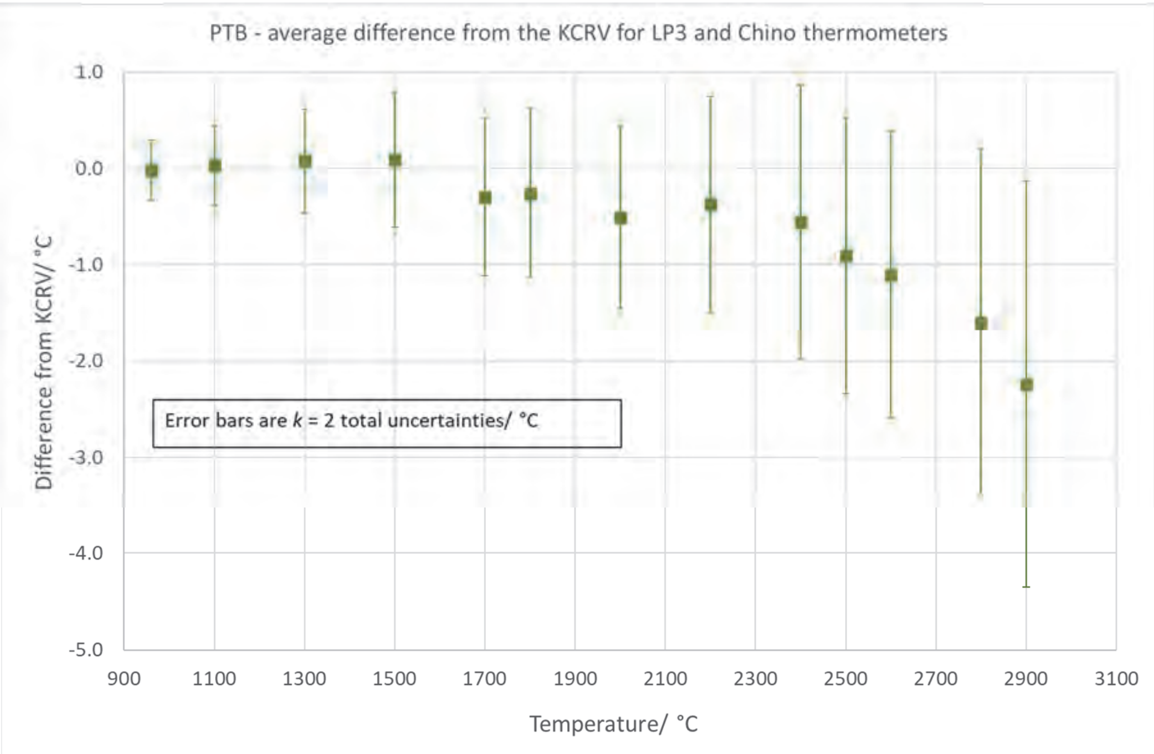


Figure 93 - difference between the PTB results and the KCRV (error bars are *k* = 2 total uncertainties)

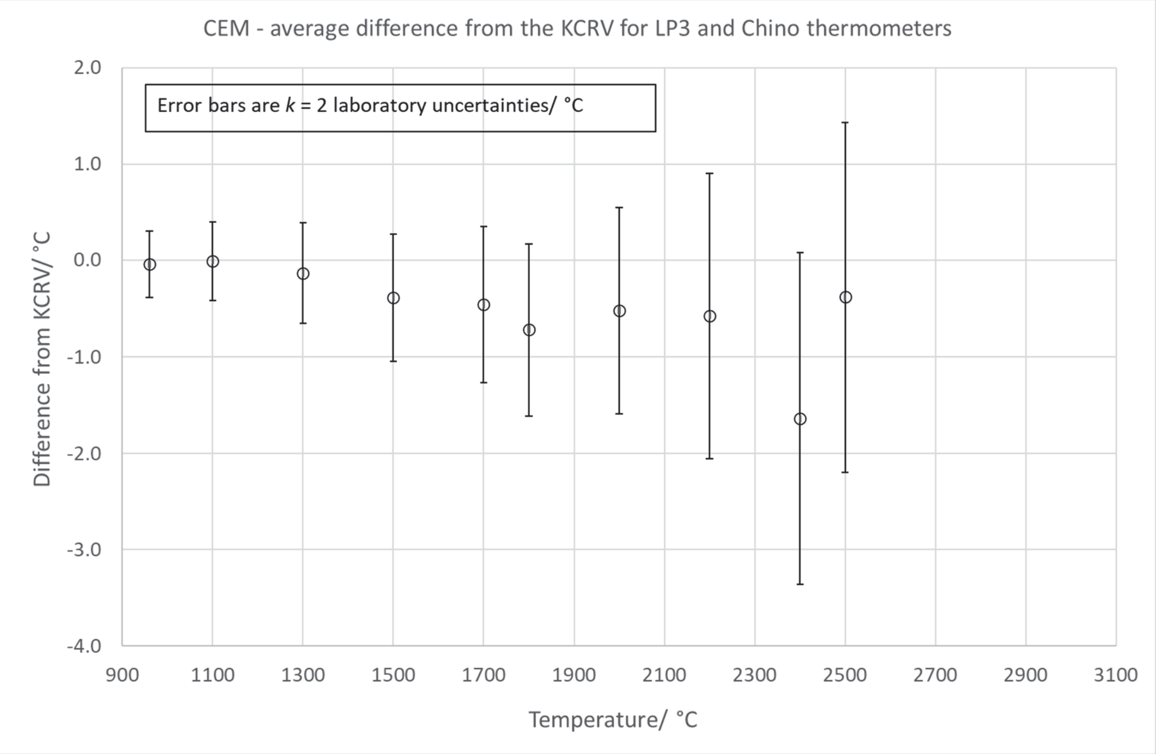


Figure 94 - difference between the CEM results and the KCRV (error bars are *k* = 2 laboratory uncertainties)

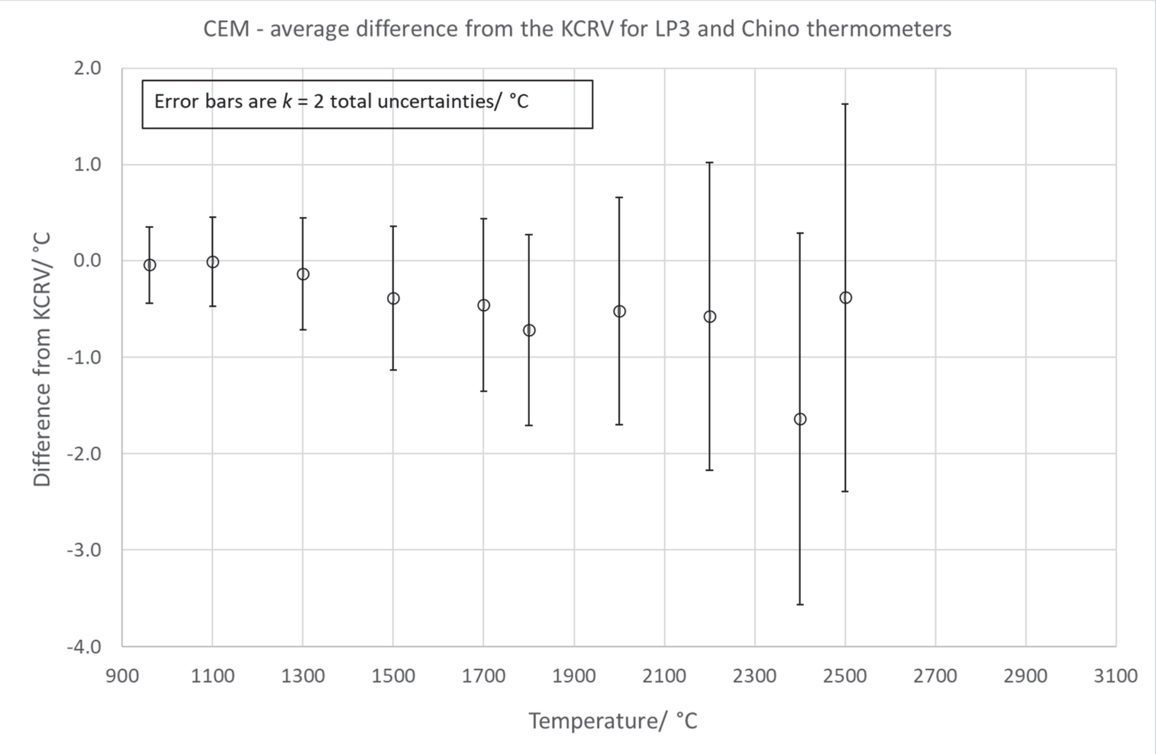


Figure 95 - difference between the CEM results and the KCRV (error bars are *k* = 2 total uncertainties)

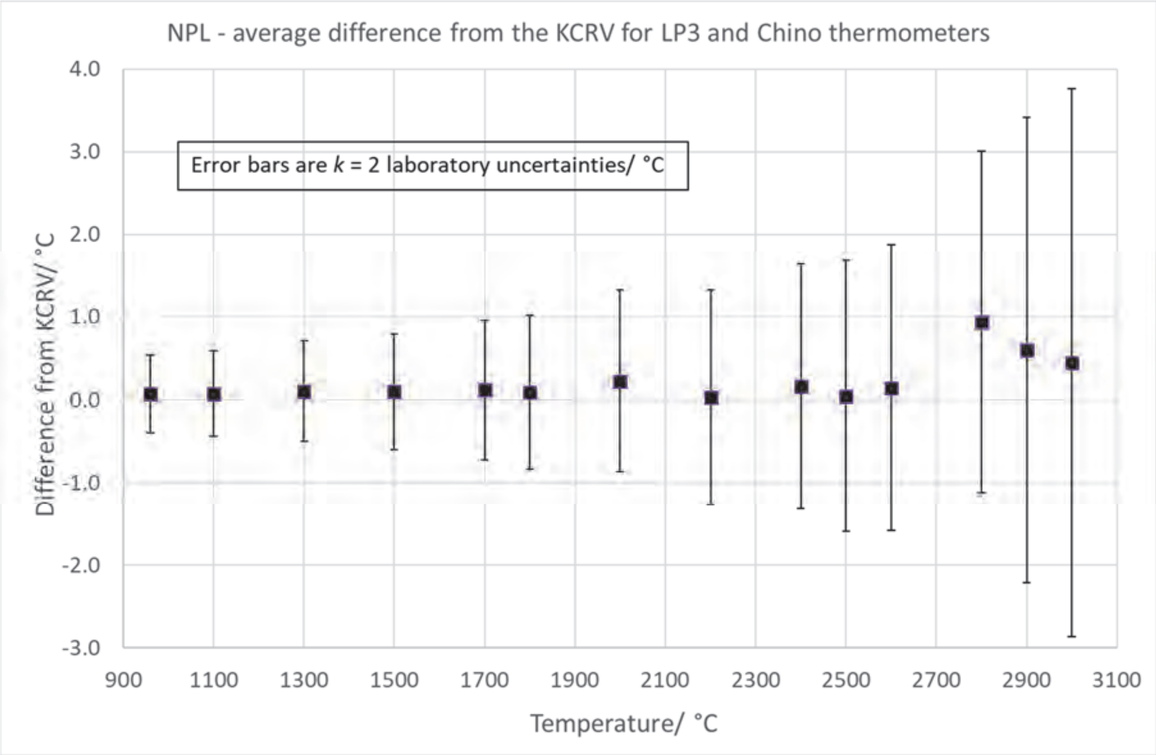


Figure 96 - difference between the average NPL results and the KCRV (error bars are *k* = 2 laboratory uncertainties)

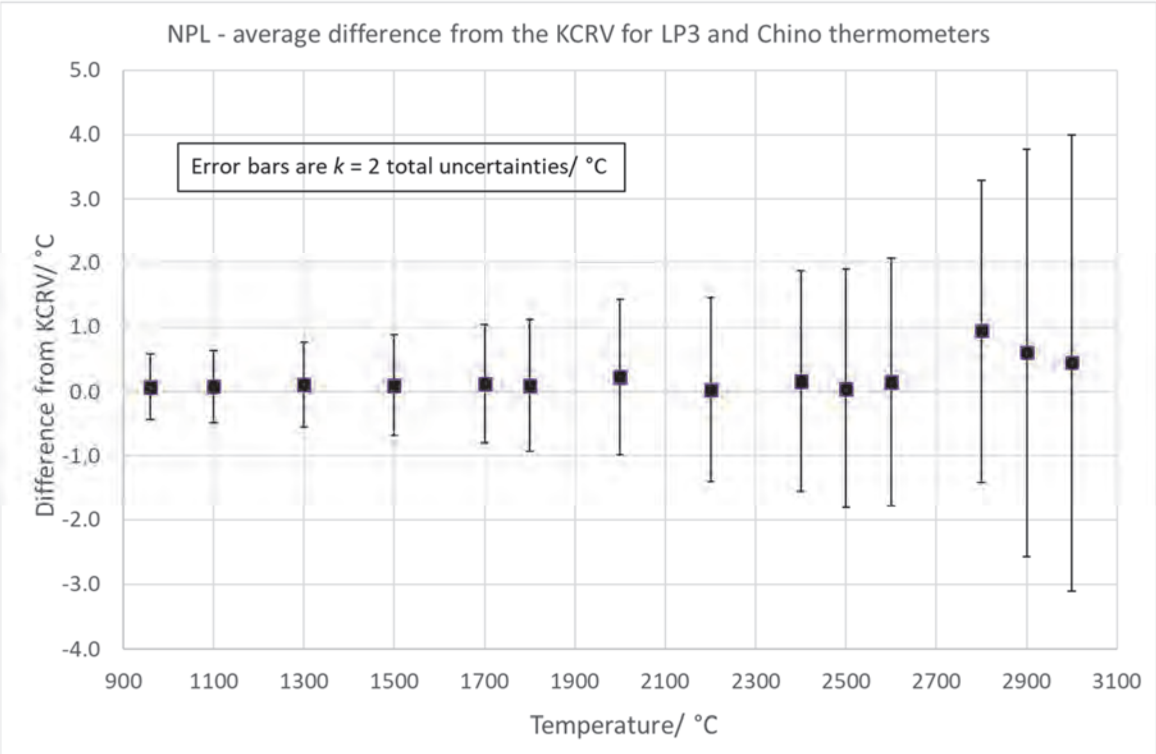


Figure 97 - difference between the average NPL results and the KCRV (error bars are *k* = 2 total uncertainties)

11.2 QDE_{95} AND DOE TABLES FOR THE DIFFERENCES FROM THE KCRV

The following the QDE_{95} (see Equation 7) and DOE tables and accompanying graphs for the differences of the participant results from the KCRV, i.e., the average of the differences of, respectively, the LP3 thermometer results from the LP3 median and the Chino thermometer results from the Chino thermometer median.

Table 86 – DOE and QDE$_{95}$ table of results at 960 °C using the KCRV (all units are in °C) and chart with differences from the median.

	NMIJ	NIM	KRISS	NRC	NIST	LNE-Cnam	PTB	CEM	Average NPL
NMIJ	-	0.10 ± 0.46	-0.05 ± 0.32	0.12 ± 0.60	-0.07 ± 0.63	-0.03 ± 0.31	0.00 ± 0.37	0.03 ± 0.45	-0.09 ± 0.55
NIM	*0.49*	-	-0.15 ± 0.47	0.02 ± 0.70	-0.16 ± 0.72	-0.13 ± 0.46	-0.09 ± 0.51	-0.07 ± 0.57	-0.18 ± 0.65
KRISS	*0.33*	*0.54*	-	0.17 ± 0.61	-0.02 ± 0.64	0.02 ± 0.33	0.05 ± 0.39	0.08 ± 0.46	-0.04 ± 0.56
NRC	*0.64*	*0.68*	*0.68*	-	-0.19 ± 0.82	-0.15 ± 0.61	-0.12 ± 0.64	-0.09 ± 0.69	-0.20 ± 0.76
NIST	*0.63*	*0.77*	*0.63*	*0.88*	-	0.04 ± 0.63	0.07 ± 0.67	0.09 ± 0.71	-0.02 ± 0.78
LNE-Cnam	*0.30*	*0.52*	*0.32*	*0.66*	*0.62*	-	0.03 ± 0.38	0.05 ± 0.45	-0.06 ± 0.55
PTB	*0.37*	*0.54*	*0.40*	*0.67*	*0.67*	*0.37*	-	0.02 ± 0.50	-0.09 ± 0.59
CEM	*0.44*	*0.57*	*0.48*	*0.70*	*0.72*	*0.46*	*0.49*	-	-0.11 ± 0.64
Average NPL	*0.56*	*0.73*	*0.55*	*0.84*	*0.76*	*0.55*	*0.60*	*0.67*	-

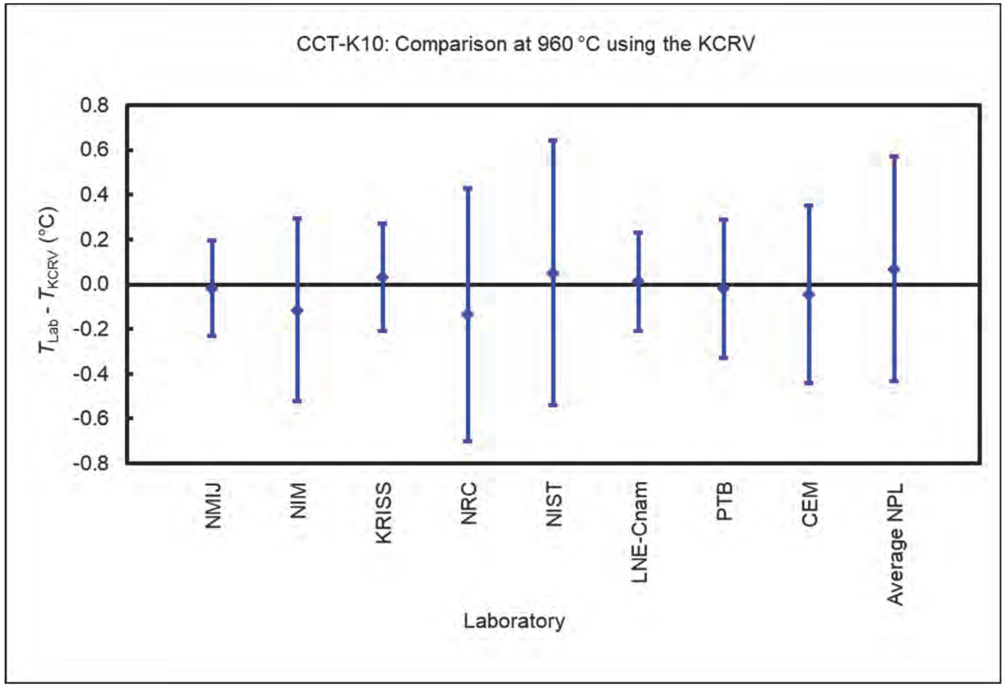


Table 87 – DOE and QDE$_{95}$ table of results at 1100 °C using the KCRV (all units are in °C) and chart with differences from the median.

	NMIJ	NIM	KRISS	NRC	NIST	LNE-Cnam	PTB	CEM	Average NPL
NMIJ	-	0.12 ± 0.54	-0.01 ± 0.34	0.14 ± 0.66	-0.02 ± 0.66	-0.03 ± 0.35	-0.03 ± 0.48	0.01 ± 0.52	-0.08 ± 0.61
NIM	*0.58*	-	-0.13 ± 0.54	0.02 ± 0.79	-0.14 ± 0.78	-0.15 ± 0.54	-0.16 ± 0.63	-0.12 ± 0.67	-0.20 ± 0.74
KRISS	*0.33*	*0.59*	-	0.15 ± 0.66	-0.01 ± 0.66	-0.02 ± 0.35	-0.02 ± 0.48	0.01 ± 0.52	-0.07 ± 0.61
NRC	*0.71*	*0.77*	*0.71*	-	-0.16 ± 0.87	-0.17 ± 0.67	-0.18 ± 0.74	-0.14 ± 0.77	-0.22 ± 0.83
NIST	*0.65*	*0.81*	*0.65*	*0.91*	-	-0.01 ± 0.67	-0.02 ± 0.74	0.02 ± 0.77	-0.06 ± 0.83
LNE-Cnam	*0.34*	*0.61*	*0.34*	*0.74*	*0.65*	-	0.00 ± 0.48	0.04 ± 0.53	-0.05 ± 0.61
PTB	*0.47*	*0.69*	*0.47*	*0.81*	*0.73*	*0.48*	-	0.04 ± 0.62	-0.04 ± 0.69
CEM	*0.51*	*0.69*	*0.51*	*0.80*	*0.76*	*0.52*	*0.61*	-	-0.08 ± 0.72
Average NPL	*0.61*	*0.82*	*0.61*	*0.92*	*0.82*	*0.60*	*0.68*	*0.73*	-

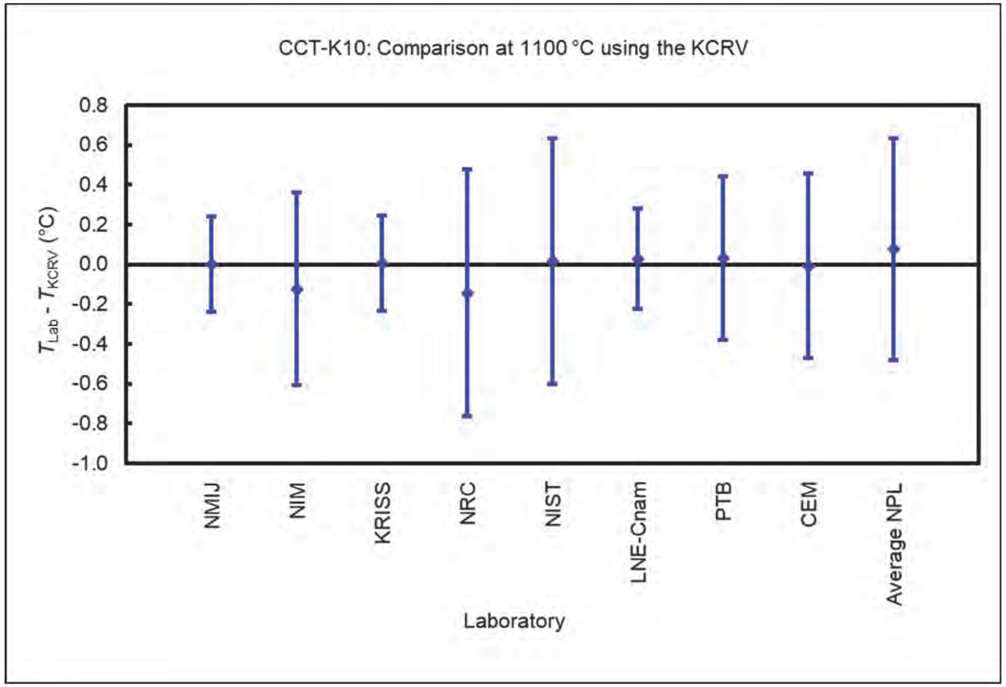


Table 88 – DOE and QDE$_{95}$ table of results at 1300 °C using the KCRV (all units are in °C) and chart with differences from the median.

	NMIJ	NIM	KRISS	NRC	NIST	LNE-Cnam	PTB	CEM	Average NPL
NMIJ	-	0.09 ± 0.62	-0.10 ± 0.41	0.15 ± 0.80	0.08 ± 0.74	0.02 ± 0.42	-0.08 ± 0.61	0.13 ± 0.65	-0.11 ± 0.72
NIM	*0.63*	-	-0.19 ± 0.62	0.05 ± 0.93	-0.01 ± 0.88	-0.07 ± 0.63	-0.17 ± 0.77	0.04 ± 0.80	-0.20 ± 0.86
KRISS	*0.45*	*0.71*	-	0.24 ± 0.80	0.18 ± 0.74	0.11 ± 0.42	0.01 ± 0.61	0.22 ± 0.65	-0.01 ± 0.72
NRC	*0.83*	*0.91*	*0.91*	-	-0.06 ± 1.01	-0.13 ± 0.80	-0.23 ± 0.92	-0.02 ± 0.94	-0.25 ± 0.99
NIST	*0.74*	*0.86*	*0.81*	*1.00*	-	-0.07 ± 0.75	-0.17 ± 0.87	0.04 ± 0.90	-0.19 ± 0.95
LNE-Cnam	*0.41*	*0.63*	*0.47*	*0.83*	*0.74*	-	-0.10 ± 0.62	0.11 ± 0.66	-0.13 ± 0.72
PTB	*0.62*	*0.82*	*0.60*	*1.00*	*0.91*	*0.63*	-	0.21 ± 0.79	-0.03 ± 0.85
CEM	*0.68*	*0.78*	*0.77*	*0.93*	*0.88*	*0.68*	*0.88*	-	-0.24 ± 0.88
Average NPL	*0.73*	*0.92*	*0.71*	*1.09*	*1.00*	*0.75*	*0.83*	*0.97*	-

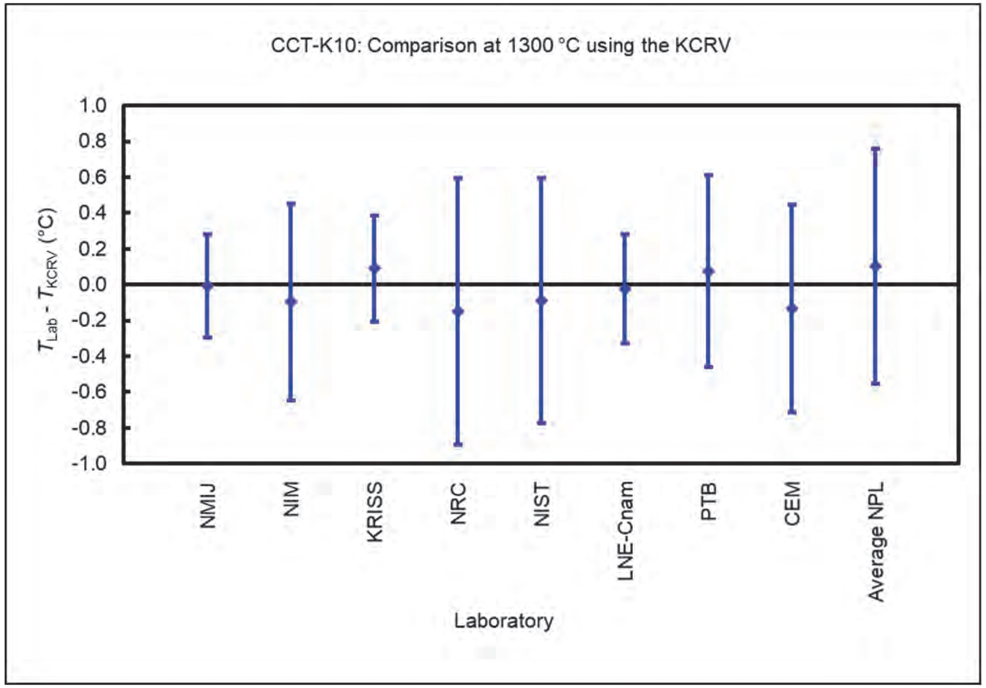


Table 89 - DOE and QDE_{95} table of results at 1500 °C using the KCRV (all units are in °C) and chart with differences from the median.

	NMIJ	NIM	KRISS	NRC	NIST	LNE-Cnam	PTB	CEM	Average NPL
NMIJ	-	0.09 ± 0.79	-0.08 ± 0.60	0.14 ± 1.02	-0.06 ± 0.91	0.03 ± 0.58	-0.09 ± 0.81	0.38 ± 0.85	-0.10 ± 0.88
NIM	*0.79*	-	-0.16 ± 0.81	0.05 ± 1.15	-0.15 ± 1.06	-0.06 ± 0.80	-0.17 ± 0.98	0.29 ± 1.01	-0.19 ± 1.04
KRISS	*0.61*	*0.86*	-	0.21 ± 1.03	0.01 ± 0.92	0.11 ± 0.61	-0.01 ± 0.83	0.46 ± 0.87	-0.03 ± 0.90
NRC	*1.03*	*1.13*	*1.09*	-	-0.20 ± 1.24	-0.11 ± 1.02	-0.22 ± 1.16	0.25 ± 1.20	-0.24 ± 1.22
NIST	*0.89*	*1.08*	*0.91*	*1.27*	-	0.09 ± 0.91	-0.02 ± 1.07	0.45 ± 1.10	-0.04 ± 1.13
LNE-Cnam	*0.57*	*0.79*	*0.63*	*1.02*	*0.91*	-	-0.12 ± 0.81	0.35 ± 0.86	-0.13 ± 0.88
PTB	*0.81*	*1.02*	*0.81*	*1.22*	*1.05*	*0.83*	-	0.47 ± 1.02	-0.01 ± 1.05
CEM	*1.09*	*1.14*	*1.18*	*1.27*	*1.36*	*1.06*	*1.32*	-	-0.48 ± 1.08
Average NPL	*0.88*	*1.08*	*0.88*	*1.28*	*1.10*	*0.90*	*1.03*	*1.38*	-

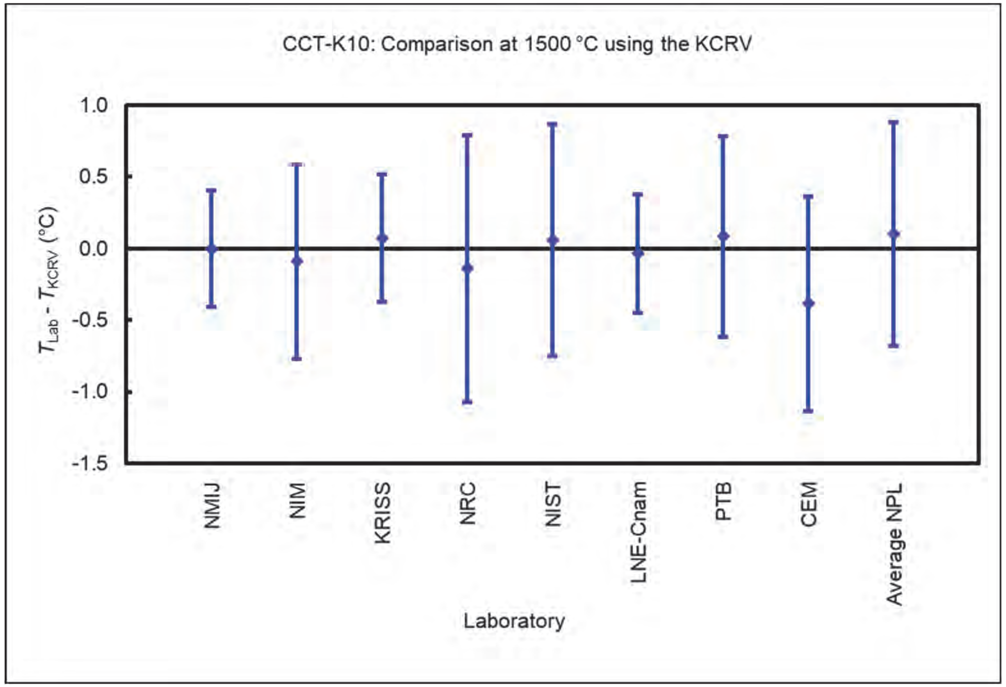


Table 90 - DOE and QDE_{95} table of results at 1700 °C using the KCRV (all units are in °C) and chart with differences from the median.

	NMIJ	NIM	KRISS	NRC	NIST	LNE-Cnam	PTB	CEM	Average NPL
NMIJ	-	0.07 ± 0.91	-0.08 ± 0.79	0.09 ± 1.22	0.08 ± 1.04	0.09 ± 0.67	0.37 ± 0.94	0.54 ± 1.01	-0.04 ± 1.04
NIM	*0.90*	-	-0.15 ± 1.00	0.03 ± 1.37	0.01 ± 1.21	0.02 ± 0.91	0.30 ± 1.13	0.47 ± 1.18	-0.11 ± 1.21
KRISS	*0.79*	*1.02*	-	0.18 ± 1.29	0.16 ± 1.13	0.17 ± 0.79	0.46 ± 1.03	0.62 ± 1.10	0.04 ± 1.12
NRC	*1.21*	*1.35*	*1.31*	-	-0.02 ± 1.46	-0.01 ± 1.23	0.28 ± 1.39	0.44 ± 1.44	-0.14 ± 1.46
NIST	*1.03*	*1.19*	*1.15*	*1.44*	-	0.01 ± 1.05	0.30 ± 1.24	0.46 ± 1.29	-0.12 ± 1.31
LNE-Cnam	*0.68*	*0.89*	*0.84*	*1.21*	*1.03*	-	0.29 ± 0.95	0.45 ± 1.01	-0.13 ± 1.04
PTB	*1.15*	*1.25*	*1.31*	*1.47*	*1.34*	*1.08*	-	0.16 ± 1.21	-0.41 ± 1.23
CEM	*1.37*	*1.45*	*1.52*	*1.65*	*1.53*	*1.29*	*1.23*	-	-0.58 ± 1.29
Average NPL	*1.02*	*1.20*	*1.10*	*1.45*	*1.30*	*1.04*	*1.44*	*1.64*	-

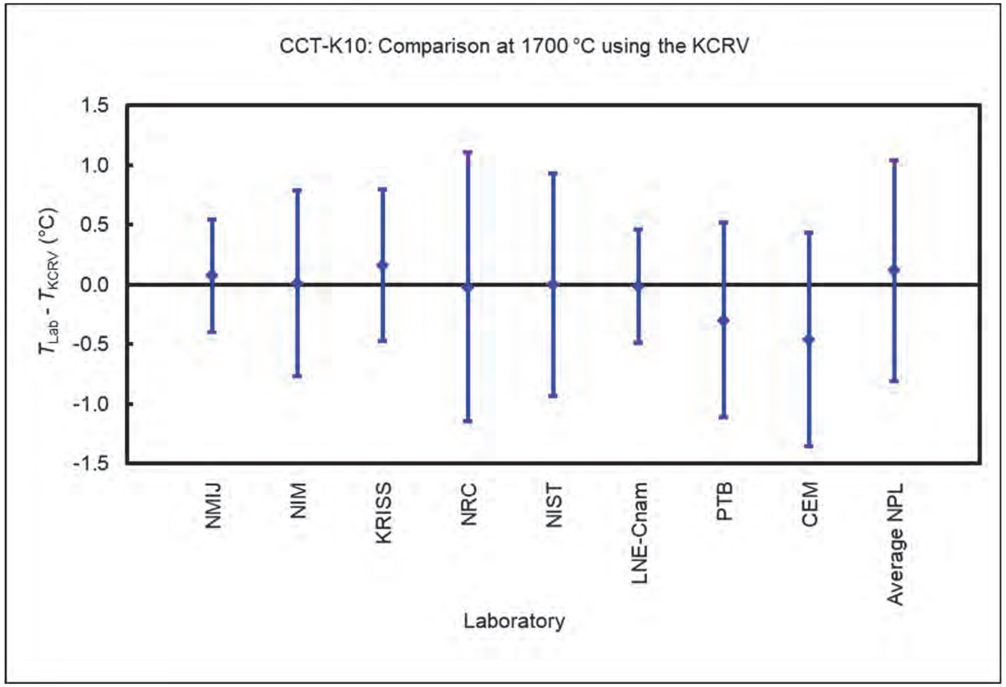


Table 91 - DOE and QDE_{95} table of results at 1800 °C using the KCRV (all units are in °C) and chart with differences from the median.

	NMIJ	NIM	KRISS	NRC	NIST	LNE-Cnam	PTB	CEM	Average NPL
NMIJ	-	0.05 ± 0.99	-0.07 ± 0.85	0.08 ± 1.36	0.21 ± 1.14	0.17 ± 0.75	0.39 ± 1.03	0.85 ± 1.12	0.04 ± 1.15
NIM	*0.97*	-	-0.11 ± 1.06	0.03 ± 1.50	0.16 ± 1.31	0.13 ± 0.99	0.35 ± 1.21	0.81 ± 1.29	-0.01 ± 1.32
KRISS	*0.84*	*1.06*	-	0.15 ± 1.41	0.28 ± 1.21	0.24 ± 0.84	0.46 ± 1.10	0.92 ± 1.19	0.11 ± 1.22
NRC	*1.34*	*1.47*	*1.41*	-	0.13 ± 1.61	0.09 ± 1.36	0.31 ± 1.53	0.77 ± 1.59	-0.04 ± 1.61
NIST	*1.19*	*1.32*	*1.30*	*1.59*	-	-0.03 ± 1.14	0.18 ± 1.34	0.64 ± 1.41	-0.17 ± 1.44
LNE-Cnam	*0.81*	*1.00*	*0.95*	*1.34*	*1.12*	-	0.22 ± 1.03	0.68 ± 1.12	-0.14 ± 1.15
PTB	*1.25*	*1.36*	*1.37*	*1.62*	*1.36*	*1.09*	-	0.46 ± 1.32	-0.35 ± 1.35
CEM	*1.78*	*1.87*	*1.90*	*2.09*	*1.81*	*1.60*	*1.56*	-	-0.81 ± 1.42
Average NPL	*1.13*	*1.30*	*1.20*	*1.58*	*1.44*	*1.16*	*1.49*	*1.99*	-

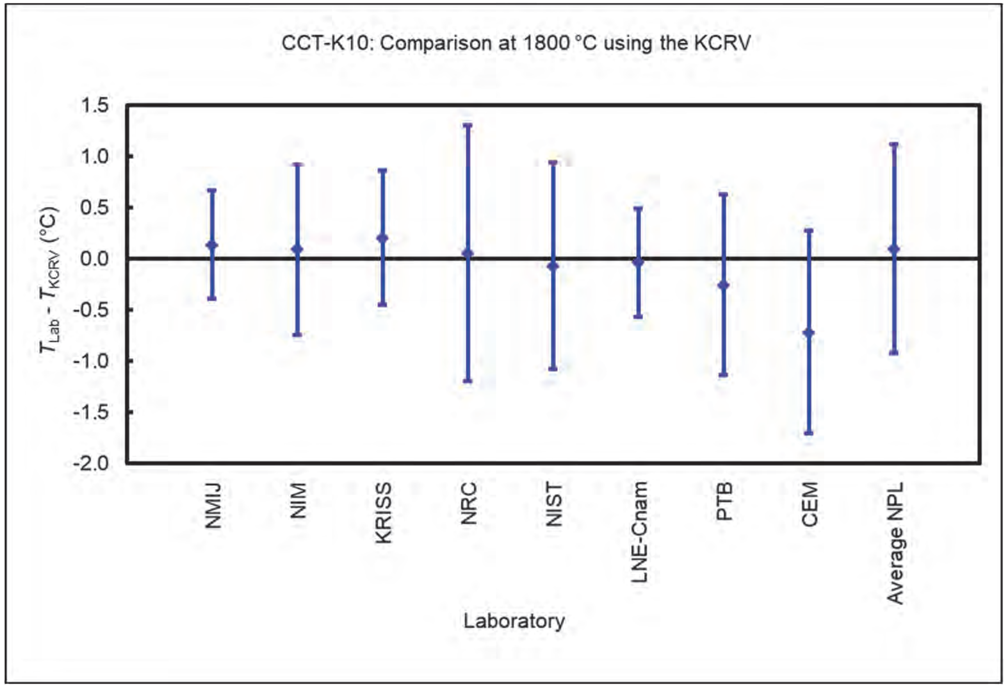


Table 92 - DOE and QDE_{95} table of results at 2000 °C using the KCRV (all units are in °C) and chart with differences from the median.

	NMIJ	NIM	KRISS	NRC	NIST	LNE-Cnam	PTB	CEM	Average NPL
NMIJ	-	0.09 ± 1.27	-0.04 ± 1.07	0.01 ± 1.66	0.31 ± 1.35	0.26 ± 0.91	0.60 ± 1.15	0.61 ± 1.35	-0.13 ± 1.37
NIM	*1.26*	-	-0.13 ± 1.39	-0.08 ± 1.88	0.22 ± 1.61	0.17 ± 1.26	0.51 ± 1.44	0.52 ± 1.61	-0.23 ± 1.63
KRISS	*1.05*	*1.38*	-	0.05 ± 1.75	0.35 ± 1.45	0.30 ± 1.06	0.64 ± 1.27	0.65 ± 1.46	-0.09 ± 1.48
NRC	*1.64*	*1.85*	*1.72*	-	0.30 ± 1.93	0.25 ± 1.65	0.59 ± 1.80	0.60 ± 1.93	-0.15 ± 1.95
NIST	*1.45*	*1.63*	*1.58*	*1.98*	-	-0.05 ± 1.34	0.29 ± 1.51	0.30 ± 1.67	-0.44 ± 1.69
LNE-Cnam	*1.02*	*1.28*	*1.19*	*1.69*	*1.31*	-	0.34 ± 1.13	0.35 ± 1.34	-0.39 ± 1.36
PTB	*1.55*	*1.71*	*1.69*	*2.09*	*1.58*	*1.29*	-	0.01 ± 1.51	-0.74 ± 1.53
CEM	*1.73*	*1.86*	*1.86*	*2.22*	*1.74*	*1.48*	*1.49*	-	-0.74 ± 1.69
Average NPL	*1.36*	*1.65*	*1.46*	*1.92*	*1.86*	*1.53*	*2.00*	*2.14*	-

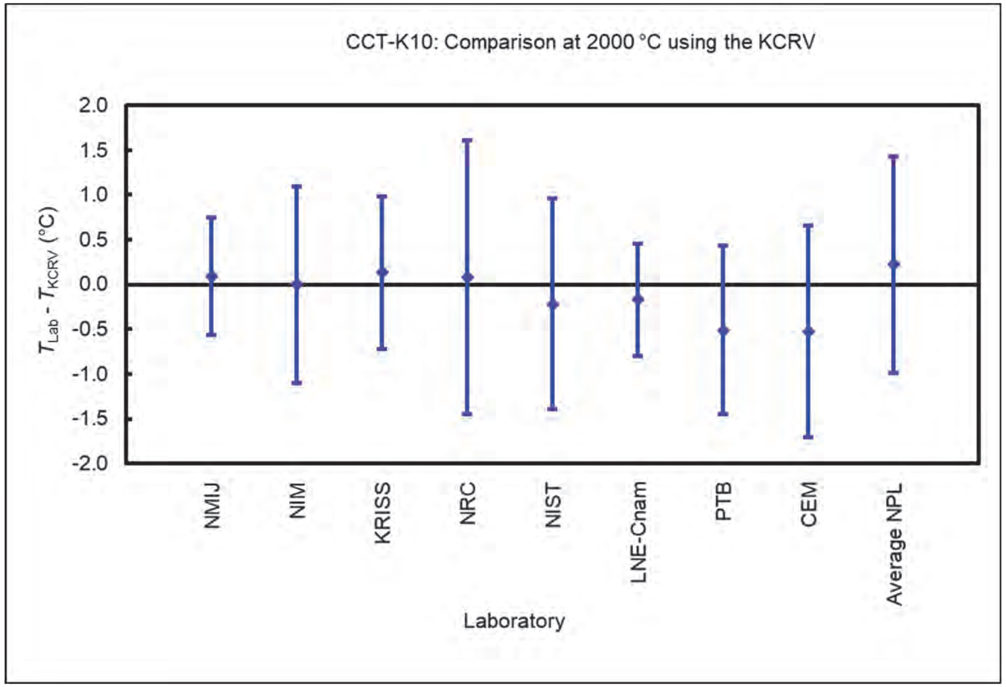


Table 93 - DOE and QDE_{95} table of results at 2200 °C using the KCRV (all units are in °C) and chart with differences from the median.

	NMIJ	NIM	KRISS	NRC	NIST	LNE-Cnam	PTB	CEM	Average NPL
NMIJ	-	-0.05 ± 1.45	-0.04 ± 1.36	-0.08 ± 2.02	0.54 ± 1.57	0.38 ± 1.08	0.42 ± 1.37	0.63 ± 1.78	0.02 ± 1.63
NIM	*1.43*	-	0.02 ± 1.65	-0.03 ± 2.23	0.59 ± 1.83	0.43 ± 1.43	0.47 ± 1.66	0.68 ± 2.01	0.08 ± 1.88
KRISS	*1.34*	*1.63*	-	-0.05 ± 2.17	0.58 ± 1.76	0.42 ± 1.33	0.46 ± 1.58	0.66 ± 1.94	0.06 ± 1.81
NRC	*1.98*	*2.19*	*2.13*	-	0.62 ± 2.31	0.46 ± 2.00	0.50 ± 2.17	0.71 ± 2.45	0.11 ± 2.35
NIST	*1.85*	*2.12*	*2.05*	*2.56*	-	-0.16 ± 1.55	-0.12 ± 1.76	0.08 ± 2.10	-0.52 ± 1.97
LNE-Cnam	*1.27*	*1.63*	*1.53*	*2.16*	*1.55*	-	0.04 ± 1.34	0.25 ± 1.76	-0.36 ± 1.61
PTB	*1.56*	*1.87*	*1.78*	*2.35*	*1.74*	*1.31*	-	0.20 ± 1.95	-0.40 ± 1.81
CEM	*2.10*	*2.35*	*2.28*	*2.76*	*2.06*	*1.78*	*1.94*	-	-0.60 ± 2.14
Average NPL	*1.60*	*1.85*	*1.78*	*2.30*	*2.18*	*1.72*	*1.94*	*2.40*	-

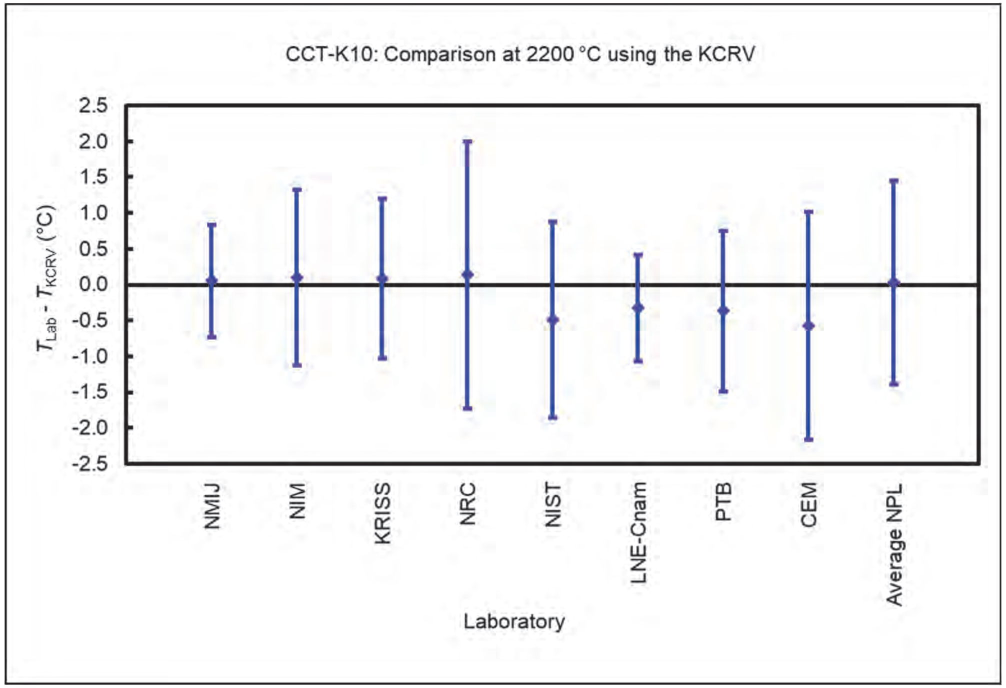


Table 94 - DOE and QDE_{95} table of results at 2400 °C using the KCRV (all units are in °C) and chart with differences from the median.

	NMIJ	NIM	KRISS	NRC	NIST	LNE-Cnam	PTB	CEM	Average NPL
NMIJ	-	-0.67 ± 1.84	0.04 ± 1.79	-0.13 ± 2.54	0.76 ± 1.98	0.68 ± 1.48	0.81 ± 1.78	1.90 ± 2.21	0.10 ± 2.03
NIM	*2.20*	-	0.71 ± 2.07	0.54 ± 2.74	1.43 ± 2.23	1.35 ± 1.81	1.48 ± 2.06	2.57 ± 2.44	0.77 ± 2.28
KRISS	*1.76*	*2.43*	-	-0.17 ± 2.70	0.72 ± 2.19	0.64 ± 1.75	0.78 ± 2.01	1.86 ± 2.40	0.06 ± 2.23
NRC	*2.49*	*2.89*	*2.66*	-	0.89 ± 2.83	0.81 ± 2.51	0.94 ± 2.70	2.03 ± 3.00	0.23 ± 2.87
NIST	*2.40*	*3.27*	*2.55*	*3.26*	-	-0.08 ± 1.95	0.05 ± 2.19	1.14 ± 2.54	-0.66 ± 2.39
LNE-Cnam	*1.90*	*2.84*	*2.10*	*2.90*	*1.91*	-	0.13 ± 1.75	1.22 ± 2.18	-0.58 ± 1.99
PTB	*2.29*	*3.18*	*2.45*	*3.19*	*2.15*	*1.72*	-	1.08 ± 2.39	-0.72 ± 2.23
CEM	*3.71*	*4.57*	*3.83*	*4.49*	*3.24*	*3.01*	*3.06*	-	-1.80 ± 2.58
Average NPL	*1.99*	*2.67*	*2.19*	*2.83*	*2.67*	*2.25*	*2.58*	*3.92*	-

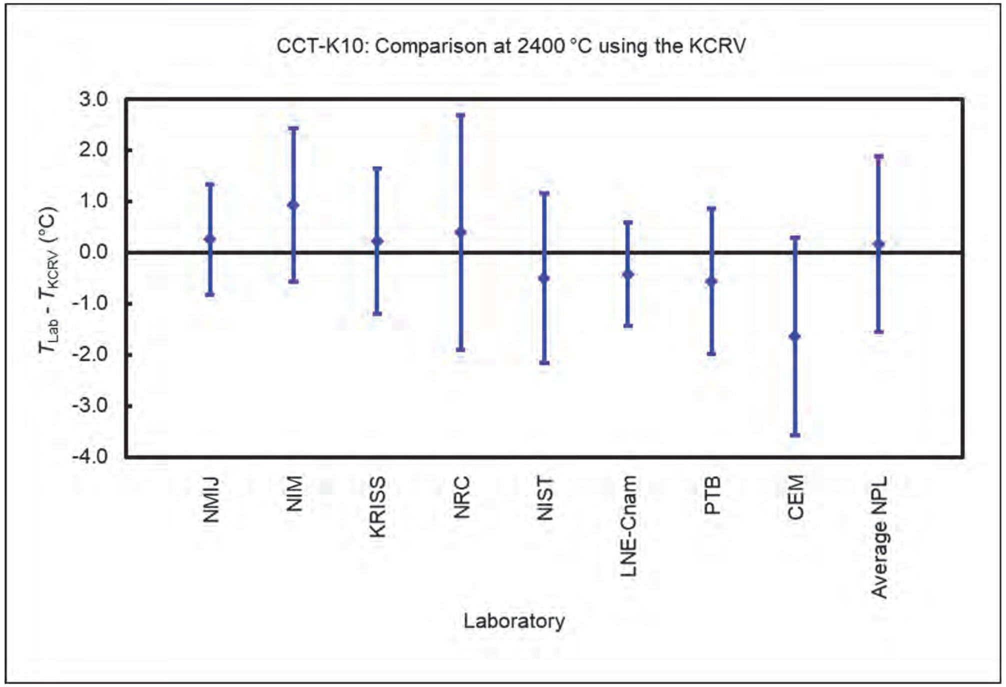


Table 95 - DOE and QDE_{95} table of results at 2500 °C using the KCRV (all units are in °C) and chart with differences from the median.

	NMIJ	NIM	KRISS	NRC	NIST	PTB	CEM	Average NPL
NMIJ	-	-1.27 ± 1.91	0.24 ± 1.89	-0.15 ± 2.71	0.68 ± 2.07	1.10 ± 1.82	0.58 ± 2.30	0.15 ± 2.16
NIM	*2.84*	-	1.51 ± 2.18	1.11 ± 2.92	1.94 ± 2.33	2.36 ± 2.11	1.84 ± 2.54	1.41 ± 2.42
KRISS	*1.91*	*3.30*	-	-0.40 ± 2.91	0.43 ± 2.32	0.85 ± 2.09	0.33 ± 2.52	-0.10 ± 2.40
NRC	*2.67*	*3.53*	*2.95*	-	0.83 ± 3.02	1.25 ± 2.86	0.73 ± 3.18	0.30 ± 3.09
NIST	*2.40*	*3.86*	*2.42*	*3.37*	-	0.42 ± 2.26	-0.10 ± 2.66	-0.53 ± 2.55
PTB	*2.59*	*4.10*	*2.59*	*3.62*	*2.36*	-	-0.52 ± 2.47	-0.95 ± 2.35
CEM	*2.51*	*3.93*	*2.55*	*3.43*	*2.61*	*2.63*	-	-0.43 ± 2.73
Average NPL	*2.13*	*3.41*	*2.36*	*3.08*	*2.70*	*2.89*	*2.80*	-

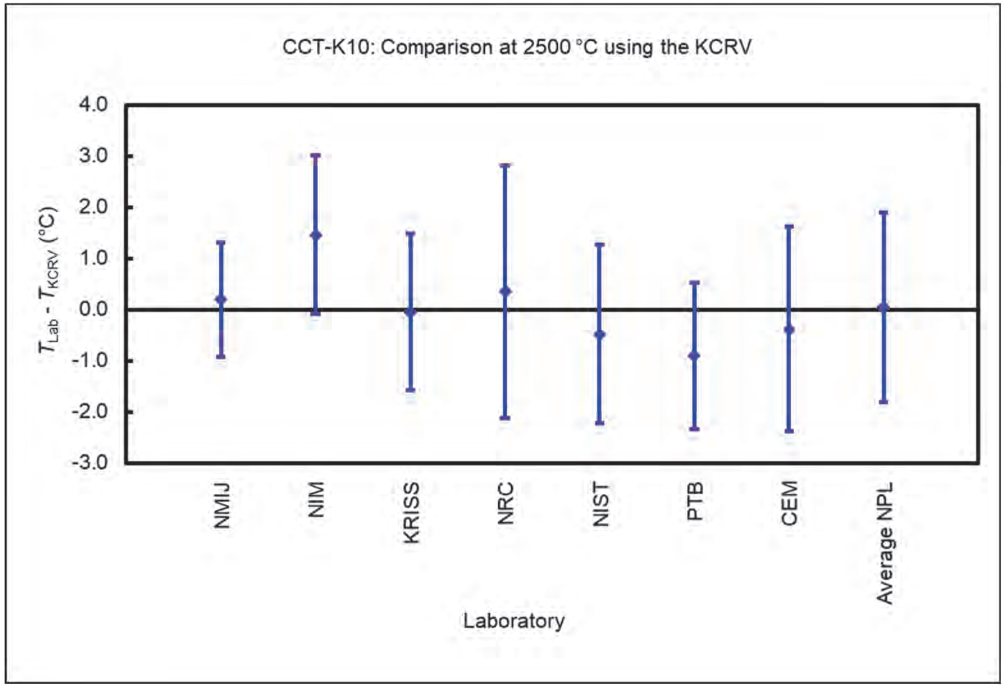


Table 96 - DOE and QDE_{95} table of results at 2600 °C using the KCRV (all units are in °C) and chart with differences from the median.

	NMIJ	NIM	KRISS	NRC	NIST	LNE-Cnam	PTB	Average NPL
NMIJ	-	-1.75 ± 2.13	0.31 ± 1.99	-0.21 ± 2.90	0.82 ± 2.16	0.55 ± 1.55	1.28 ± 1.88	0.03 ± 2.24
NIM	*3.51*	-	2.06 ± 2.43	1.54 ± 3.22	2.58 ± 2.56	2.30 ± 2.08	3.03 ± 2.33	1.79 ± 2.64
KRISS	*2.04*	*4.06*	-	-0.52 ± 3.13	0.52 ± 2.45	0.24 ± 1.93	0.97 ± 2.21	-0.28 ± 2.53
NRC	*2.86*	*4.20*	*3.22*	-	1.03 ± 3.23	0.76 ± 2.86	1.49 ± 3.05	0.24 ± 3.29
NIST	*2.61*	*4.69*	*2.60*	*3.73*	-	-0.27 ± 2.10	0.46 ± 2.36	-0.79 ± 2.66
LNE-Cnam	*1.84*	*4.01*	*1.95*	*3.17*	*2.12*	-	0.73 ± 1.82	-0.52 ± 2.19
PTB	*2.83*	*4.95*	*2.80*	*4.01*	*2.47*	*2.24*	-	-1.25 ± 2.44
Average NPL	*2.21*	*3.96*	*2.53*	*3.25*	*3.02*	*2.37*	*3.26*	-

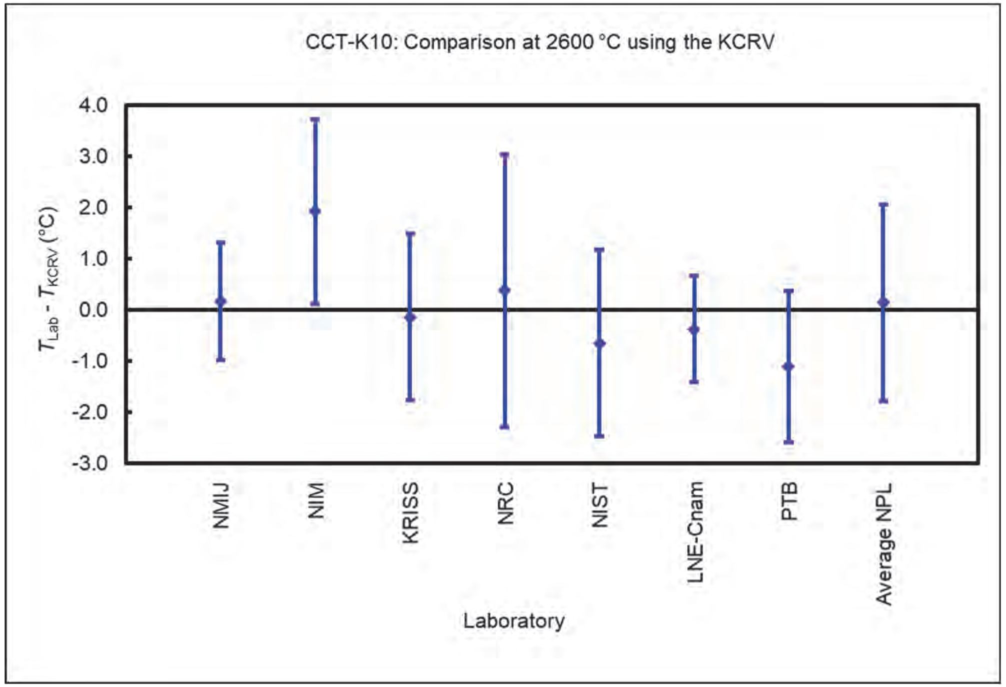


Table 97 - DOE and QDE$_{95}$ table of results at 2800 °C using the KCRV (all units are in °C) and chart with differences from the median.

	NMIJ	NIM	KRISS	NRC	NIST	LNE-Cnam	PTB	Average NPL
NMIJ	-	-2.30 ± 2.83	0.29 ± 2.49	-0.12 ± 3.51	0.48 ± 2.60	0.59 ± 1.96	1.72 ± 2.32	-0.82 ± 2.76
NIM	*4.63*	-	2.58 ± 3.17	2.18 ± 4.02	2.77 ± 3.25	2.89 ± 2.77	4.02 ± 3.03	1.48 ± 3.39
KRISS	*2.50*	*5.19*	-	-0.41 ± 3.78	0.19 ± 2.95	0.30 ± 2.41	1.43 ± 2.71	-1.11 ± 3.10
NRC	*3.44*	*5.49*	*3.78*	-	0.59 ± 3.85	0.71 ± 3.45	1.84 ± 3.67	-0.70 ± 3.97
NIST	*2.71*	*5.45*	*2.91*	*3.94*	-	0.12 ± 2.52	1.25 ± 2.81	-1.30 ± 3.19
LNE-Cnam	*2.23*	*5.16*	*2.43*	*3.66*	*2.48*	-	1.13 ± 2.23	-1.41 ± 2.70
PTB	*3.63*	*6.51*	*3.67*	*4.87*	*3.57*	*2.97*	-	-2.54 ± 2.97
Average NPL	*3.14*	*4.28*	*3.69*	*4.12*	*3.94*	*3.64*	*4.98*	-

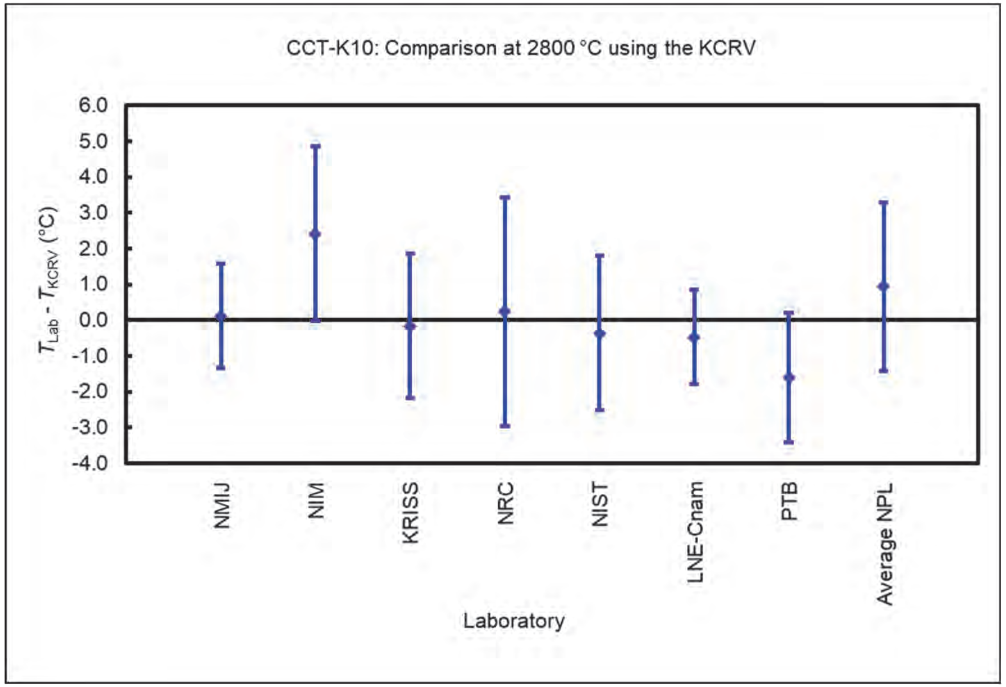


Table 98 - DOE and QDE_{95} table of results at 2900 °C using the KCRV (all units are in °C) and chart with differences from the median.

	NMIJ	NIM	KRISS	NRC	PTB	Average NPL
NMIJ	-	-3.00 ± 3.65	0.04 ± 3.00	-0.44 ± 3.93	1.94 ± 2.75	-0.91 ± 3.63
NIM	*6.00*	-	3.04 ± 4.00	2.56 ± 4.74	4.94 ± 3.82	2.09 ± 4.50
KRISS	*2.95*	*6.33*	-	-0.48 ± 4.26	1.90 ± 3.21	-0.94 ± 3.99
NRC	*3.94*	*6.47*	*4.27*	-	2.38 ± 4.10	-0.47 ± 4.73
PTB	*4.20*	*8.08*	*4.54*	*5.75*	-	-2.84 ± 3.81
Average NPL	*3.98*	*5.81*	*4.32*	*4.71*	*5.98*	-

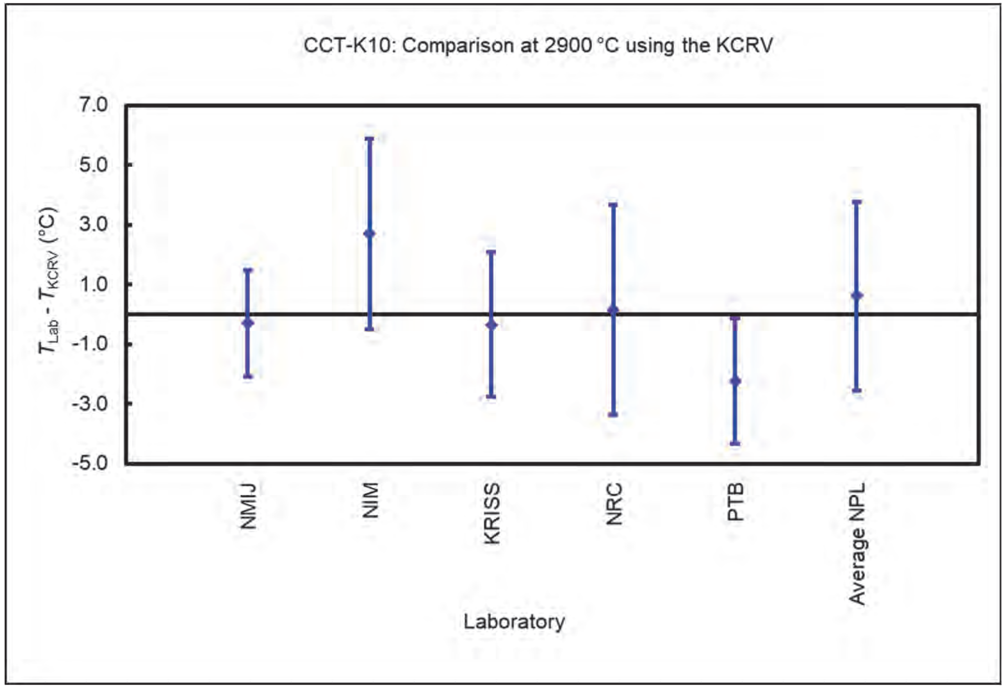
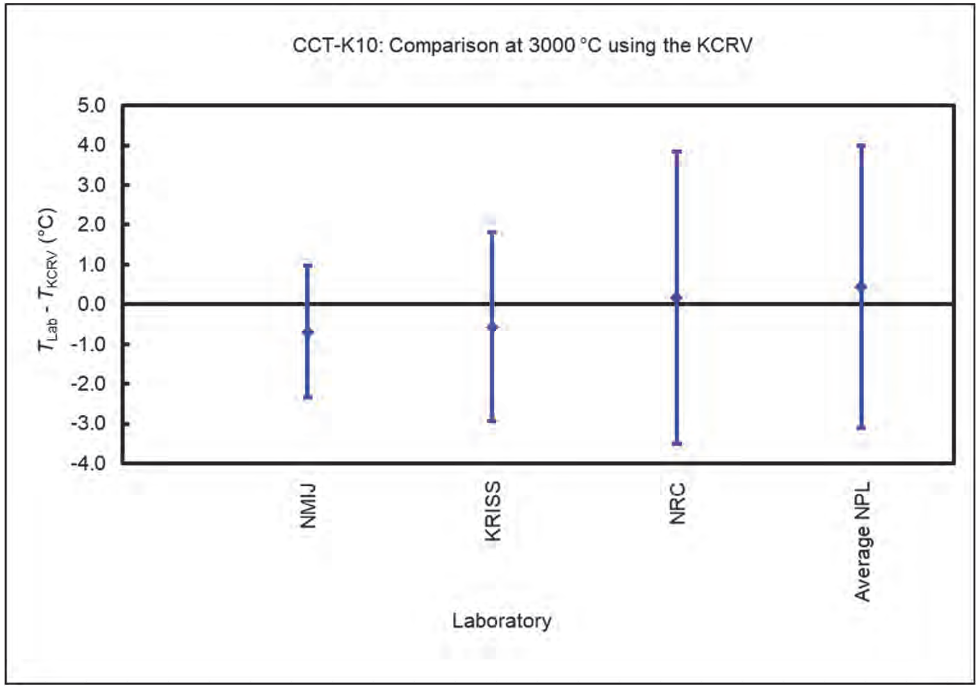


Table 99 - DOE and QDE_{95} table of results at 3000 °C using the KCRV (all units are in °C) and chart with differences from the median.

	NMIJ	KRISS	NRC	Average NPL
NMIJ	-	-0.12 ± 2.88	-0.85 ± 4.02	-1.13 ± 3.91
KRISS	*2.83*	-	-0.73 ± 4.37	-1.01 ± 4.26
NRC	*4.28*	*4.50*	-	-0.28 ± 5.10
Average NPL	*4.41*	*4.62*	*5.02*	-



12 THE HTFP CELL MEASUREMENTS

12.1 RESULTS FOR THE HTFP CELLS

Table 101 to Table 105 give the results of the measurements of each of the HTFP cells by the participants, along with the estimated participant measurement uncertainties.

Table 100 summarises the way each of the participants treated the results of the HTFP measurements, which were made using the participant’s own standard radiation thermometer, to account for the SSE of the thermometer. Most of the participants did not correct the results to any particular aperture diameter but instead included a component to account for SSE in the uncertainty budget. Other participants corrected the results to take into account the diameter of the reference source used to calibrate the standard thermometer.

Table 100: the treatment of the results of the HTFP measurements

Participant	Method for accounting for SSE of standard thermometer
NPL	No correction: component included in uncertainty budget
NMIJ	No correction: component included in uncertainty budget
NIM	No correction: component included in uncertainty budget
KRISS	Corrected for reference source diameter
NRC	No correction: component included in uncertainty budget
NIST	No correction: component included in uncertainty budget
PTB	Corrected for reference source diameter
LNE-Cnam	Corrected to 6 mm diameter (reference diameter for the radiance comparator)
CEM	No correction applied

The results of the Co-C-X and Ni-C-X cell measurements were analysed both by treating the cell types separately and by linking them by applying a correction of -3.46 °C to each of the Ni-C-X cell results. This correction was determined using the averages of all the NPL Ni-C-X results and all the NPL Co-C-X results. The results of the Ni-C-X cell and Co-C-X cell measurements could then be combined.

For each type of cell (Ni-C-X or Co-C-X, Ru-C, WC-C) the results of all the pilot laboratory measurements over the entire period of the comparison were averaged to give one pilot result for each cell type. The final uncertainty associated with the pilot results includes the standard deviation of the pilot measurements.

There was no evidence of any significant drift of the Ni-C-X, Ru-C and WC-C cells during the comparison. However, some drift in the Co-C-X cell was observed. In all cases no correction was applied to any of the results to allow for cell drift. However, as described below, a component was included in the uncertainty budget for the stability of the cells, determined from the NPL measurements of the circulating and reference cells.

For each type of cell (with Ni-C-X and Co-C-X results considered both separately and combined) a reference value was calculated using the weighted mean with cut-off of all the participant results (namely the ITS-90 radiance temperatures of the point of inflection of the melting transitions), including the average pilot results. The weight for each participant, including the pilot, was the inverse of the square of the standard measurement uncertainty for that participant at the cell melting temperature. The cut-off values for the weights were the average of the uncertainty values of those participants with reported uncertainties smaller than or equal to the median uncertainty of all the participants.

The weighted mean, y, was calculated according to Equation 8:

$$y = w_1 x_1 + w_1 x_2 + \cdots . + w_N x_N \tag{8}$$

where x_1 through to x_N are the results from participants 1 through to N and w_1 through to w_N are the weights for participants 1 through to N. The weights, w_i, are given by Equation 9:

$$w_i \frac{\frac{1}{u_{cut}^2(x_i)}}{\sum_{j=1}^{N} \frac{1}{u_{cut}^2(x_j)}} \tag{9}$$

where $u_{cut}(x_i)$ are the uncertainties associated with each participant's measurements: either the participant uncertainty, or, for those participants with uncertainties lower than the cut-off value, the cut-off uncertainty.

The uncertainty in the weighted mean, $u(y)$, is then calculated from Equation 10:

$$u^2(y) = w_1^2 u^2(x_1) + w_2^2 u^2(x_2) + \cdots + w_N^2 u^2(x_N) \tag{10}$$

A consistency check of the results was carried out in the form of a chi-squared test by calculating the observed chi-squared value, χ^2_{obs}, according to Equation 11 and assigning the degrees of freedom, v, according to Equation 12.

$$\chi_{obs}^2 = \frac{(x_1 - y)^2}{u^2(x_1)} + \cdots + \frac{(x_N - y)^2}{u^2(x_N)} \tag{11}$$

$$\upsilon = N - 1 \tag{12}$$

The consistency check was to be regarded as failing if

$$Pr\{\chi^2(\nu) > \chi_{obs}^2\} < 0.05 \tag{13}$$

where *Pr* denotes 'probability of'. The consistency check did not fail; therefore, the calculated reference value (weighted mean with cut-off) was taken as the final reference value for that cell, along with its associated uncertainty.

The following uncertainties associated with the comparison were combined with the participant uncertainties. These uncertainty values are presented in Table 106.

- Stability of the HTFP cell, $u_{stability}$, estimated from the repeat NPL measurements of the circulating and reference cells over the duration of the comparison.
- Uncertainty due to the furnace effect, $u_{furnace}$ estimated from the values given in [7].
- Uncertainty due to any corrections to be applied to the cell temperatures (mainly for linking the Ni-C-X cell measurements to the Co-C-X cell measurements).
- Uncertainty in the weighted mean.

Since the participant uncertainty is correlated with the uncertainty in the KCRV, the overall uncertainty in the difference of each of the participant result to the KCRV is given by Equation 14.

$$u^2(x_i - y) = (1 - 2w_i)u^2(x_i) + u^2(y_{ref}) \qquad (14)$$

where y_{ref} is the combined uncertainty of the comparison (including cell stability, furnace effect, corrections to and uncertainty in the weighted mean).

Table 107 gives the calculated weighted mean for each cell type (with the Ni-C-X and Co-C-X cell results considered both separately and combined) along with the uncertainty in the weighted mean. Table 108 to Table 112 give the differences in the participant results from the weighted mean values as well as the total uncertainties (participant uncertainty combined with the comparison uncertainty). The results presented in graphical form in Figure 98 to Figure 107. Only the average NPL results were used to calculate the weighted mean, but the differences of all the NPL results from the weighted mean are included for completeness.

The QDE_{95} and Degrees of Equivalence (DOE) Tables are given in Section 12.3 for each cell type, and the combined Ni-C-X and Co-C-X results), with accompanying charts.

Table 101 - the results with the Ni-C-X cells treated separately

Participant	**Date**	**Cell reference**	**t_{90}/ °C**	**t_{90} corrected* / °C**	**U_{lab} (k = 2) / °C**	**$u_{average\_NPL}$ (k = 1)/ °C**	**U_{lab} (k = 2)/ °C**
NPL	Sept 2014	Ni-C #12	1328.23	**1328.23**	0.30	-	0.30
NMIJ	~Jan 2015	Ni-C #12	1328.45	1328.45	0.15	-	0.15
NPL	Apr 2015	Ni-C #11	1327.62	**1328.16**	0.30	-	0.30
NPL	Apr 2015	Ni-C #13	1328.23	1328.23	For reference, not used in analysis		
NIM	~May 2015	Ni-C #11	1327.68	1328.22	0.23	-	0.23
KRISS	~Jun 2015	Ni-C #11	1327.76	1328.30	0.18	-	0.18
NPL	Aug 2015	Ni-C #12	1328.23	**1328.23**	0.30	-	0.30
Average NPL**				**1328.21**	0.30	0.04**	0.31

Notes:

* The correction to allow for the difference between cells Ni-C#12 and Ni-C#11, which was measured at the start of the comparison, dt (#12 - #11) = 0.54 °C

** The average of the three NPL measurements being used in the analysis (i.e., ignoring the April 2015 measurement of Ni-C#13 which is for reference only). The $u_{average\_NPL}$ value is the standard deviation of the NPL measurements.

Table 102 - the results for linking the Ni-C-X cell data to the Co-C-X cell data

Participant	**Date**	**Cell reference**	**t_{90}/ °C**	**t_{90} corrected* / °C**	**t_{90} corrected† / °C**	**U_{lab} (k = 2) / °C**	**$u_{average\_NPL}$ (k = 1)/ °C**	**U_{lab} (k = 2)/ °C**
NPL	Sept 2014	Ni-C #12	1328.23	**1328.23**	**1324.77**	0.30	-	0.30
NMIJ	~Jan 2015	Ni-C #12	1328.45	1328.45	1324.99	0.15	-	0.15
NPL	Apr 2015	Ni-C #11	1327.62	**1328.16**	**1324.71**	0.30	-	0.30
NPL	Apr 2015	Ni-C #13	1328.23	1328.23	For reference, not used in analysis			
NIM	~May 2015	Ni-C #11	1327.68	1328.22	1324.76	0.23	-	0.23
KRISS	~Jun 2015	Ni-C #11	1327.76	1328.30	1324.84	0.18	-	0.18
NPL	Aug 2015	Ni-C #12	1328.23	**1328.23**	**1324.77**	0.30	-	0.30
Average NPL**					**1324.75**	0.30	0.04**	0.31

Notes:

* The correction to allow for the difference between cells Ni-C#12 and Ni-C#11 which was measured at the start of the comparison, dt (#12 - #11) = 0.54 °C

† The correction to link the Ni-C cell measurements to the Co-C cell measurements. The correction was determined using the NPL Aug 2015 (Ni-C #12) result and the NPL Oct 2015 ("Co-C_C") result. The correction to be applied to the Ni-C results is -3.46 °C, with an estimated uncertainty of ± 0.08 °C (to allow for any drift in the NPL temperature scale realisation, which was estimated from the measurements of the Co-C reference cell, and treated as type B)

** The average of the three NPL measurements being used in the analysis (i.e., ignoring the April 2015 measurement of Ni-C#13 which is for reference only). The $u_{average\_NPL}$ value is the standard deviation of the NPL measurements.

Table 103 – the results with the Co-C-X cells

Participant	**Date**	**Cell reference**	t_{90}/ °C	U_{lab} (k = 2)/ °C	$u_{average\_NPL}$ (k = 1)/ °C	U_{lab} (k = 2)/ °C
NPL	Feb 2014	"Co-C_C"*	1325.02	For reference, not used in analysis		
NPL	Feb 2014	Co-C ref	1323.98	For reference, not used in analysis		
NPL	Oct 2015	"Co-C_C"*	**1324.90**	0.31	-	0.31
NRC	Nov 2015	Co-C_B1	1325.09	0.93	-	0.93
NIST	~Mar 2016	Co-C_B1	1324.49	0.68	-	0.68
NPL	Oct 2016	Co-C_B1	**1324.84**	0.31	-	0.31
NPL	Oct 2016	Co-C ref	1323.87	For reference, not used in analysis		
NPL	Dec 2017	Co-C_B1	**1324.70**	0.31	-	0.31
NPL	Dec 2017	Co-C ref	1323.82	For reference, not used in analysis		
LNE-Cnam	Apr 2018	Co-C_B1	1324.71	0.12	-	0.12
PTB	Jun 2018	Co-C_B1	1324.24	0.31	-	0.31
CEM	Sept 2018	Co-C_B1	1324.39	0.39	-	0.39
NPL	Jan 2019	Co-C_B1	**1324.56**	0.31	-	0.31
Average NPL**			**1324.75**	0.31	0.07**	0.34

Notes:

* It is assumed that this was subsequently re-named Co-C_B1

** The average of the four NPL values being used in the analysis. The $u_{average\_NPL}$ value is the standard deviation of the NPL measurements.

Table 104 - the results with the Ru-C cells

Participant	**Date**	**Cell reference**	**t_{90}/ °C**	**U_{lab} (k = 2)/ °C**	**$u_{average\_NPL}$ (k = 1)/ °C**	**U_{lab} (k = 2)/ °C**
CEM[†]	Jul 2014	6Ru1	1953.49	For reference, not used in analysis		
CEM[†]	Jul 2014	6Ru2	1953.43	For reference, not used in analysis		
NPL	Sep 2014	6Ru1	**1953.04**	0.65	-	0.65
NMIJ	~Jan 2015	6Ru1	1953.31	0.36	-	0.36
NIM	~May 2015	6Ru1	1952.98	0.43	-	0.43
KRISS	~Jun 2015	6Ru1	1953.23	0.63	-	0.63
NPL	Aug 2015	6Ru1	**1952.91**	0.65	-	0.65
NPL	Aug 2015	6Ru2	1952.94	For reference, not used in analysis		
NRC	Nov 2015	6Ru1	1952.88	1.80	-	1.80
NIST	~Mar 2016	6Ru1	1952.68	1.03	-	1.03
NPL	~Oct 2016	6Ru1	**1952.95**	0.65	-	0.65
NPL	~Oct 2016	6Ru2	1952.85	For reference, not used in analysis		
NPL	Dec 2017	6Ru1	**1952.79**	0.65	-	0.65
NPL	Dec 2017	6Ru2	1952.85	For reference, not used in analysis		
LNE-Cnam	Apr 2018	6Ru1	1952.88	0.17	-	0.17
PTB	Jun 2018	6Ru1	1952.85	0.64	-	0.64
CEM	Sept 2018	6Ru1	1952.29	0.86	-	0.86
NPL	Jan 2019	6Ru1	**1953.11**	0.65	-	0.65
Average NPL[‡]			**1952.96**	0.65	0.06[‡]	0.66

Notes:

[†] CEM compared the two Ru-C cells prior to the start of the comparison, to determine any temperature difference between them.

[‡] The average of the five NPL values being used in the analysis. The $u_{average\_NPL}$ value is the standard deviation of the NPL measurements. The average NPL t_{90} value was used in the calculation of the weighted mean.

Table 105 - results with the WC-C cells

Participant	Date	Cell reference	t_{90}/ °C	t_{90} corrected† / °C	U_{lab} (k = 2)/ °C	$u_{average\_NPL}$ (k = 1)/ °C	U_{lab} (k = 2)/ °C
NPL	Sept 2014	WC-C#2	2746.83	For reference, not used in analysis			
NPL	Sept 2014	WC-C #1	**2746.93**	**2746.93**	1.12	-	1.12
NPL	Sept 2014	WC-C6SSc-2	2746.94	For reference, not used in analysis			
NMIJ	~Jan 2015	WC-C #1	2747.42	2747.42	0.80	-	0.80
NIM	~May 2015	WC-C#1	2747.20	2747.20	0.88	-	0.88
KRISS	~Jun 2015	WC-C#1	2747.44	2747.44	1.59	-	1.59
NPL	Sept 2015	WC-C #1	**2747.16**	**2747.16**	1.12	-	1.12
NPL	Sept 2015	WC-C6SSc-2	2747.36	For reference, not used in analysis			
NRC	Nov 2015	WC-C#1	2747.03	2747.03	3.45	-	3.45
NIST	~Mar 2016	WC-C#1	2746.31	2746.31	1.78	-	1.78
NPL	Oct 2016	WC-C#1	**2747.06**	**2747.06**	1.12	-	1.12
NPL	Oct 2016	WC-C6SSc-2	2747.21	For reference, not used in analysis			
NPL	Jan 2018	WC-C#1	-----	Cell broken			
NPL	Jan 2018	WC-C#2	**2746.02**+	**2746.02**	1.12	-	1.12
NPL	Jan 2018	WC-C6SSc-2	2746.20+	For reference, not used in analysis			
LNE-Cnam	Mar 2018	WC-C#2	2747.38	2747.38	0.33	-	0.33
LNE-Cnam	Apr 2018	6WC-C2	2747.62	2747.38	0.33	-	0.33
PTB	Jun 2018	6WC-C2	N/A	Not measured			
CEM	Sept 2018	6WC-C2	2747.83	2747.59	1.64	-	1.64
NPL	Jan 2019	None measured – cells broken					
Average NPL‡				**2746.79**	1.12	0.26‡	1.24

+ Both of the NPL Jan 2018 values are lower than other values, although the differences are within the combined ITS-90 scale realisation uncertainties.

† The correction to the CEM results for the difference, measured at LNE-Cnam, between cells WC-C#2 and 6WC-C2, dt (6WC-C2 – WC-C#2) = 0.24 °C.

‡ The average of the four NPL values being used in the analysis. The $u_{average\_NPL}$ value is the standard deviation of the NPL measurements. The average NPL t_{90} value was used in the calculation of the weighted mean.

Table 106 - uncertainties associated with the reference values of the HTFP comparisons

Cell type	$u_{stability}$ **(*k* = 1)/ °C**	$u_{furnace}$ **(*k* = 1)/ °C**	$u_{correction}$ **(*k* = 1)/ °C**	$u_{comparison}$ **(*k* = 1)/ °C**	$u_{weighted\ mean}$ **(*k* = 1)/ °C**	**Totals**	
						$u_{ref\ value}$ **(*k* = 1)/ °C**	$U_{ref\ value}$ **(*k* = 2)/ °C**
Ni-C-X	0.02	0.08	-	**0.08**	0.05	**0.10**	**0.19**
Ni-C-X linked to Co-C-X	0.02	0.08	0.05	**0.09**	0.04	**0.10**	**0.20**
Co-C-X	0.13	0.08	-	**0.16**	0.06	**0.17**	**0.34**
Co-C-X linked to Ni-C-X	0.13	0.08	-	**0.16**	0.04	**0.16**	**0.32**
Ru-C	0.06	0.16	-	**0.17**	0.09	**0.19**	**0.37**
WC-C	0.06	0.29	-	**0.30**	0.18	**0.35**	**0.69**

Table 107 - summary of weighted mean calculations, all cells

Cell type	**Median *U* (*k* = 2)/ °C**	**Cut-off *U* (*k* = 2)/ °C**	**Weighted mean / °C**	***U* (*k* = 2) weighted mean (standard deviation)/ °C**
Ni-C-X	0.21	0.17	1328.33	0.10
Co-C-X	0.36	0.25	1324.56	0.13
Ni-C-X and Co-C-X linked	0.31	0.20	1324.75	0.08
Ru-C	0.64	0.45	1952.99	0.17
WC-C	1.41	0.81	2747.25	0.36

12.2 THE FULL ANALYSIS OF THE HTFP RESULTS

Table 108 - differences from the weighted mean, Ni-C-X cells

Cell type	Participant	t_{90}/ °C	U_{lab} (k = 2) / °C	U to use in weighted mean / °C	Difference from weighted mean / °C	$U_{ref\ value}$ (k = 2) / °C	U_{total} / °C
Ni-C-X	NPL Sept 14	1328.23	0.30	0.30	-0.10	0.19	0.32
Ni-C-X	NMIJ	1328.45	0.15	0.17	0.12	0.19	0.21
Ni-C-X	NPL Apr 15	1328.16	0.30	0.30	-0.16	0.19	0.32
Ni-C-X	NIM	1328.22	0.23	0.23	-0.11	0.19	0.26
Ni-C-X	KRISS	1328.30	0.18	0.18	-0.03	0.19	0.22
Ni-C-X	NPL Aug 15	1328.23	0.30	0.30	-0.10	0.19	0.32
	Average NPL*	1328.21	0.31	0.31	-0.12	0.19	0.33

* Note that only the average NPL value (average of the Ni-C-X results) was used in the calculation of the weighted mean

Table 109 - differences from the weighted mean, Co-C-X cells

Cell type	**Participant**	t_{90}/ °C	U_{lab} (k = 2) / °C	U to use in weighted mean / °C	Difference from weighted mean / °C	$U_{ref\ value}$ (k = 2) / °C	U_{total} / °C
Co-C-X	NPL Oct 15	1324.90	0.31	0.31	0.34	0.34	0.40
Co-C-X	NRC	1325.09	0.93	0.93	0.53	0.34	0.97
Co-C-X	NIST	1324.49	0.68	0.68	-0.07	0.34	0.73
Co-C-X	NPL Oct 16	1324.84	0.31	0.31	0.28	0.34	0.40
Co-C-X	NPL Dec 17	1324.70	0.31	0.31	0.14	0.34	0.40
Co-C-X	LNE-Cnam	1324.71	0.12	0.25	0.15	0.34	0.34
Co-C-X	PTB	1324.24	0.31	0.31	-0.31	0.34	0.40
Co-C-X	CEM	1324.39	0.39	0.39	-0.17	0.34	0.47
Co-C-X	NPL Jan 19	1324.56	0.31	0.31	0.00	0.34	0.40
	Average NPL[*]	1324.75	0.34	0.34	0.19	0.34	0.43

[*] Note that only the average NPL value (average of the Co-C-X results) was used in the calculation of the weighted mean

Table 110 - differences from the weighted mean, Co-C-X and Ni-C-X cells

Cell type	Participant	t_{90}/ °C	U_{lab} (k = 2) / °C	U to use in weighted mean / °C	Difference from weighted mean / °C	$U_{ref\ value}$ (k = 2) / °C	U_{total} / °C
Ni-C-X	NPL Sept 14	1324.77	0.30	0.30	0.02	0.20	0.34
Ni-C-X	NMIJ	1324.99	0.15	0.20	0.25	0.20	0.23
Ni-C-X	NPL Apr 15	1324.71	0.30	0.30	-0.04	0.20	0.34
Ni-C-X	NIM	1324.76	0.23	0.23	0.01	0.20	0.28
Ni-C-X	KRISS	1324.84	0.18	0.20	0.09	0.20	0.25
Ni-C-X	NPL Aug 15	1324.77	0.30	0.30	0.02	0.20	0.34
Co-C-X	NPL Oct 15	1324.90	0.31	0.31	0.15	0.32	0.43
Co-C-X	NRC	1325.09	0.93	0.93	0.35	0.32	0.98
Co-C-X	NIST	1324.49	0.68	0.68	-0.26	0.32	0.74
Co-C-X	NPL Oct 16	1324.84	0.31	0.31	0.09	0.32	0.43
Co-C-X	NPL Dec 17	1324.70	0.31	0.31	-0.05	0.32	0.43
Co-C-X	LNE-Cnam	1324.71	0.12	0.20	-0.04	0.32	0.33
Co-C-X	PTB	1324.24	0.31	0.31	-0.50	0.32	0.43
Co-C-X	CEM	1324.39	0.39	0.39	-0.36	0.32	0.49
Co-C-X	NPL Jan 19	1324.56	0.31	0.31	-0.19	0.32	0.43
	Average NPL*	1324.76	0.32	0.32	0.01	0.32	0.43

* Note that only the average NPL value (average of the Co-C-X and corrected Ni-C-X results) was used in the calculation of the weighted mean

Table 111 - differences from the weighted mean - Ru-C cells

Participant	t_{90}/ °C	U_{lab} (k = 2) / °C	U to use in weighted mean/ °C	Difference from weighted mean/ °C	$U_{ref\ value}$ (k = 2) / °C	U_{total} / °C
NPL Sept 14	1953.04	0.65	0.65	0.06	0.37	0.69
NMIJ	1953.31	0.36	0.45	0.32	0.37	0.47
NIM	1952.98	0.43	0.45	-0.01	0.37	0.50
KRISS	1953.23	0.63	0.63	0.24	0.37	0.68
NPL Aug 15	1952.91	0.65	0.65	-0.08	0.37	0.69
NRC	1952.88	1.80	1.80	-0.11	0.37	1.82
NIST	1952.68	1.03	1.03	-0.31	0.37	1.06
NPL Oct 16	1952.95	0.65	0.65	-0.04	0.37	0.69
NPL Dec 17	1952.79	0.65	0.65	-0.20	0.37	0.69
LNE-Cnam	1952.88	0.17	0.45	-0.11	0.37	0.40
PTB	1952.85	0.64	0.64	-0.13	0.37	0.68
CEM	1952.29	0.86	0.86	-0.70	0.37	0.89
NPL Jan 19	1953.11	0.65	0.65	0.13	0.37	0.69
Average NPL**	1952.96	0.66	0.66	-0.03	0.37	0.70

** Only the average NPL result was used in the calculation of the weighted mean

Table 112 - differences from the weighted mean - WC-C cells.

Participant	t_{90}/ °C	U_{lab_total} (k = 2)/ °C	U to use in weighted mean/ °C	Difference from weighted mean/ °C	$U_{ref\ value}$ (k = 2) / °C	U_{total} / °C
NPL Sept 14	2746.93	1.12	1.12	-0.32	0.69	1.19
NMIJ	2747.42	0.80	0.81	0.18	0.69	0.90
NIM	2747.20	0.88	0.88	-0.05	0.69	0.96
KRISS	2747.44	1.59	1.59	0.20	0.69	1.64
NPL Sept 15	2747.16	1.12	1.12	-0.09	0.69	1.19
NRC	2747.03	3.45	3.45	-0.22	0.69	3.47
NIST	2746.31	1.78	1.78	-0.94	0.69	1.83
NPL Oct 16	2747.06	1.12	1.12	-0.19	0.69	1.19
NPL Jan 18	2746.02	1.12	1.12	-1.23	0.69	1.19
LNE-Cnam	2747.38	0.33	0.81	0.13	0.69	0.73
CEM	2747.59	1.64	1.64	0.34	0.69	1.69
Average NPL**	2746.79	1.24	1.24	-0.45	0.69	1.30

Notes:

** Only the average NPL result was used in the calculation of the weighted mean

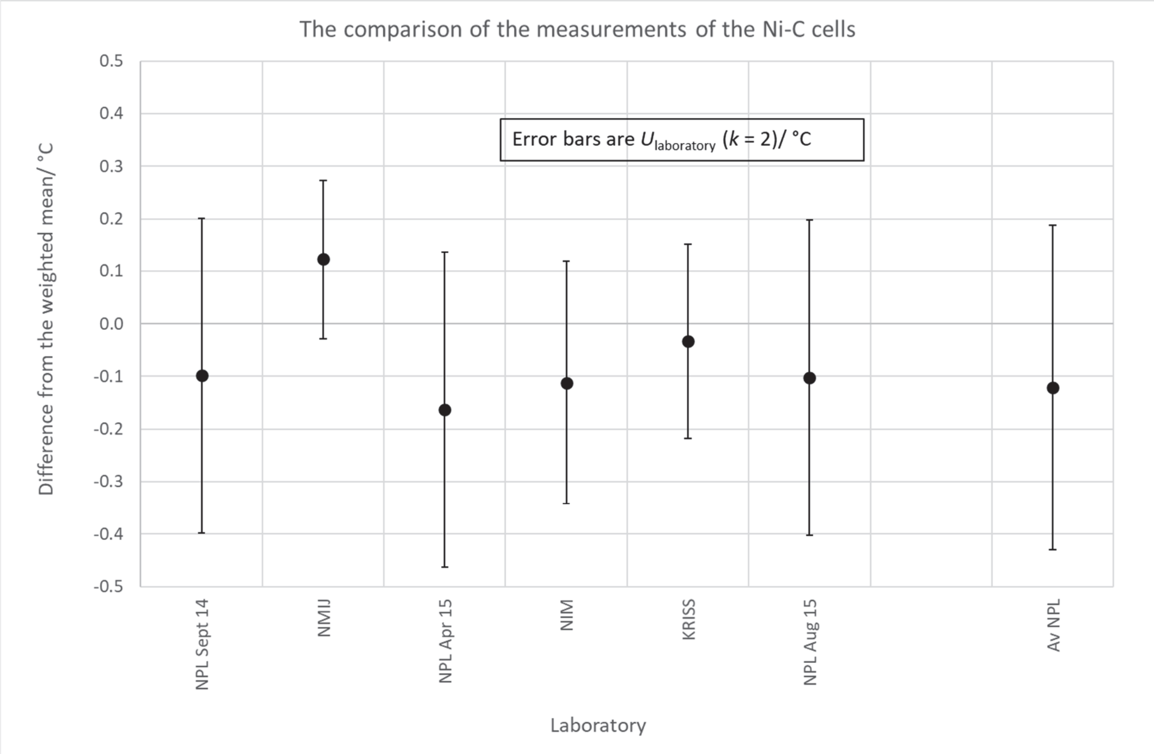


Figure 98 - the differences from the weighted mean for the corrected Ni-C-X cell results – all data, with *U* (*k* = 2) laboratory uncertainty

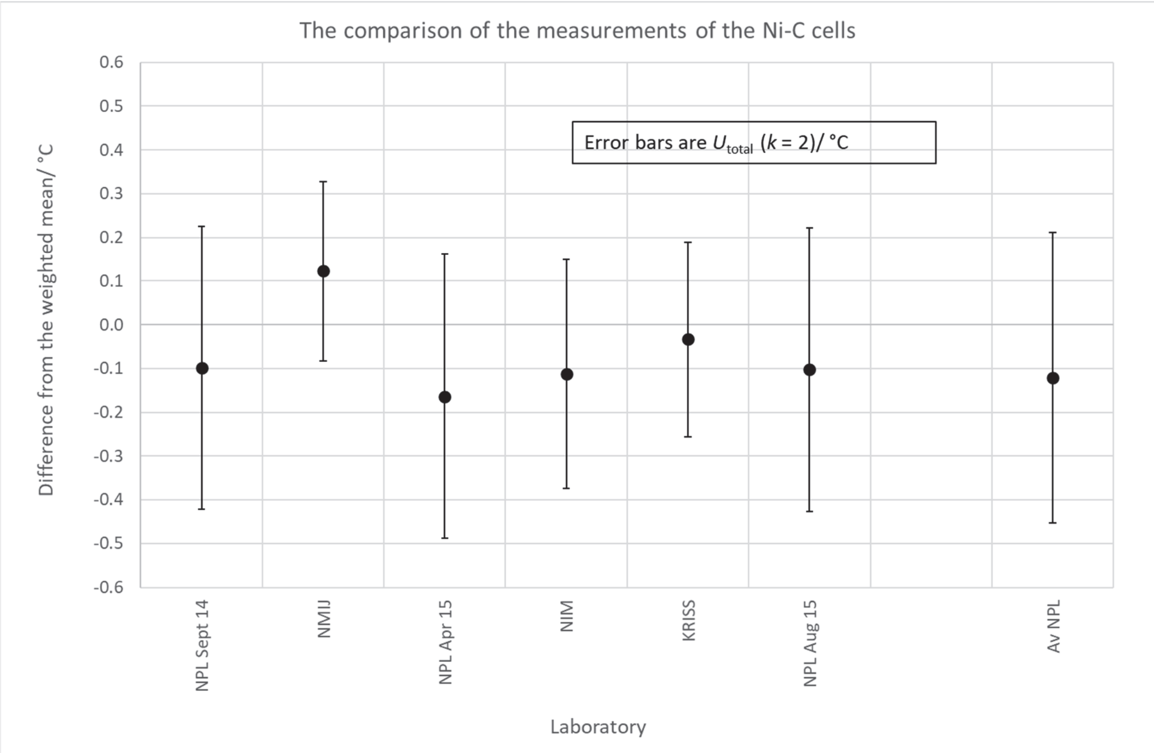


Figure 99 - the differences from the weighted mean for the corrected Ni-C-X cell results – all data, with *U* (*k* = 2) total uncertainty

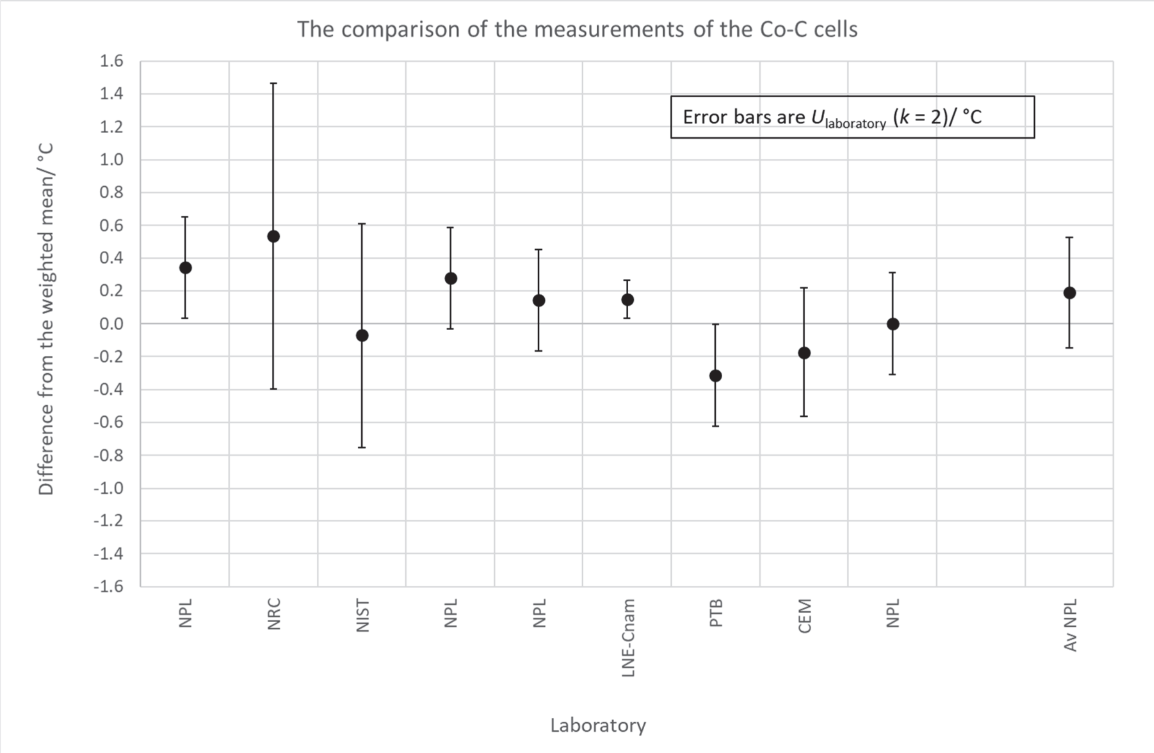


Figure 100 - the differences from the weighted mean for the Co-C-X cell results – all data, with *U* (*k* = 2) laboratory uncertainty

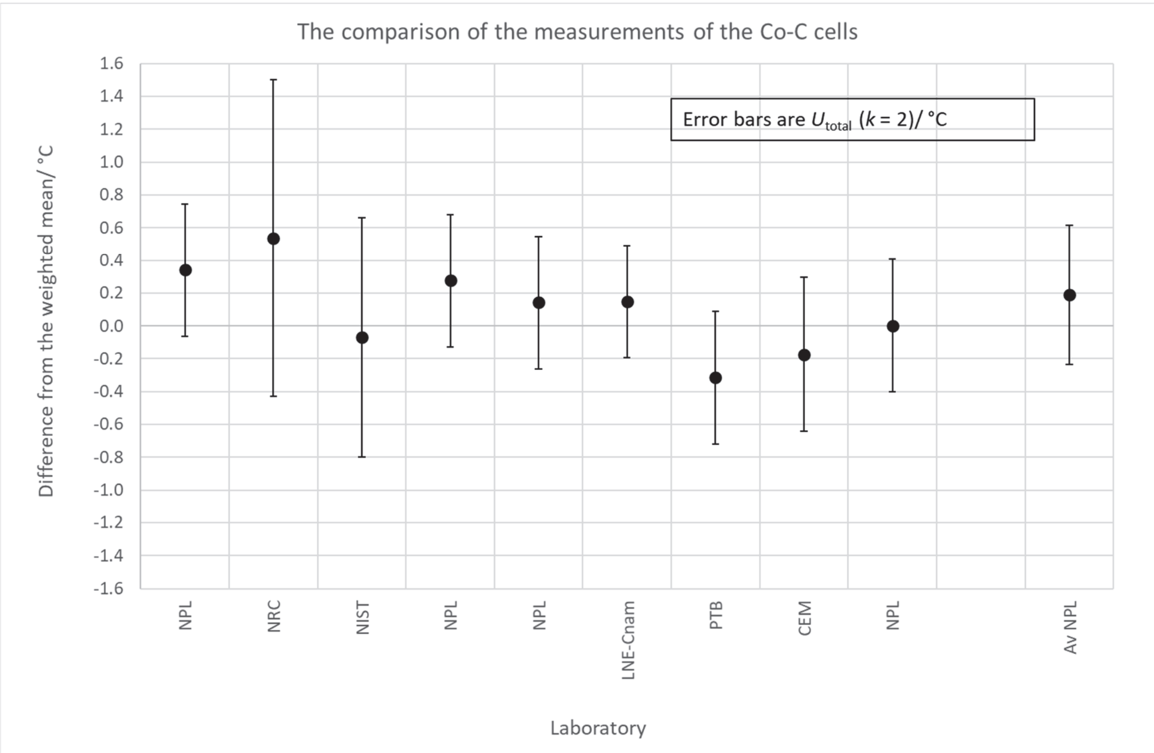


Figure 101 - the differences from the weighted mean for the Co-C-X cell results – all data, with *U* (*k* = 2) total uncertainty

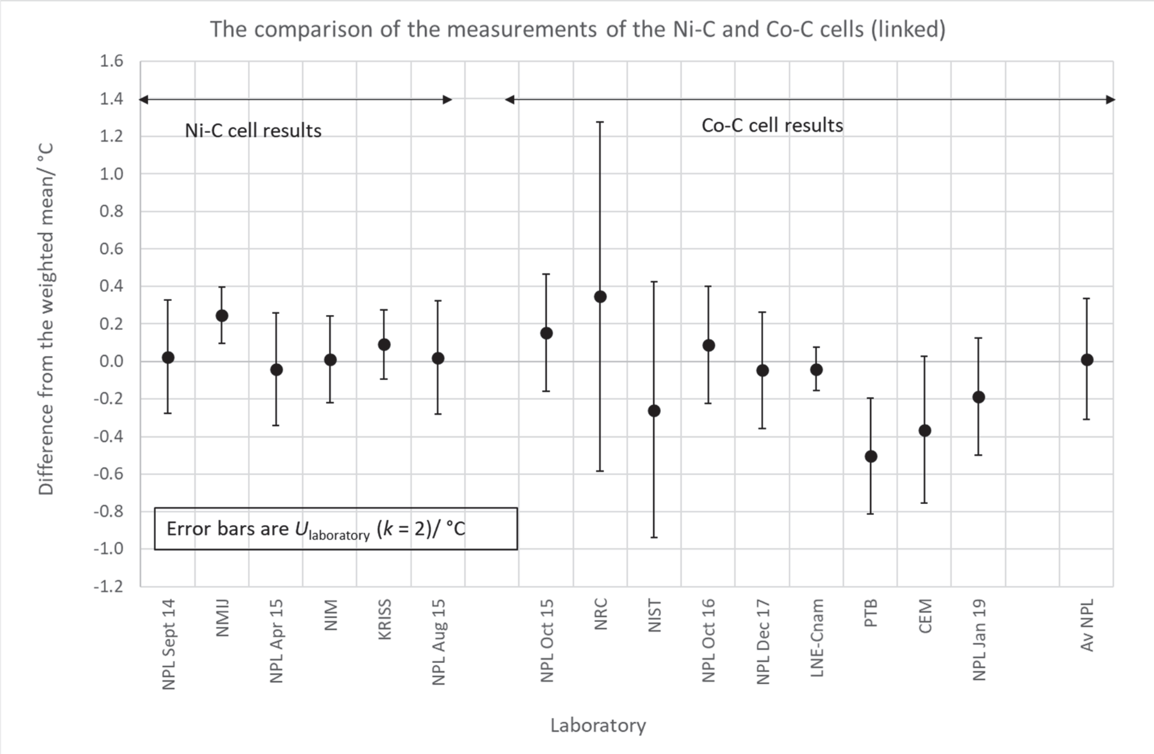


Figure 102 - the differences from the weighted mean for the corrected Ni-C-X and the Co-C-X cell results – all data, with *U* (*k* = 2) laboratory uncertainty

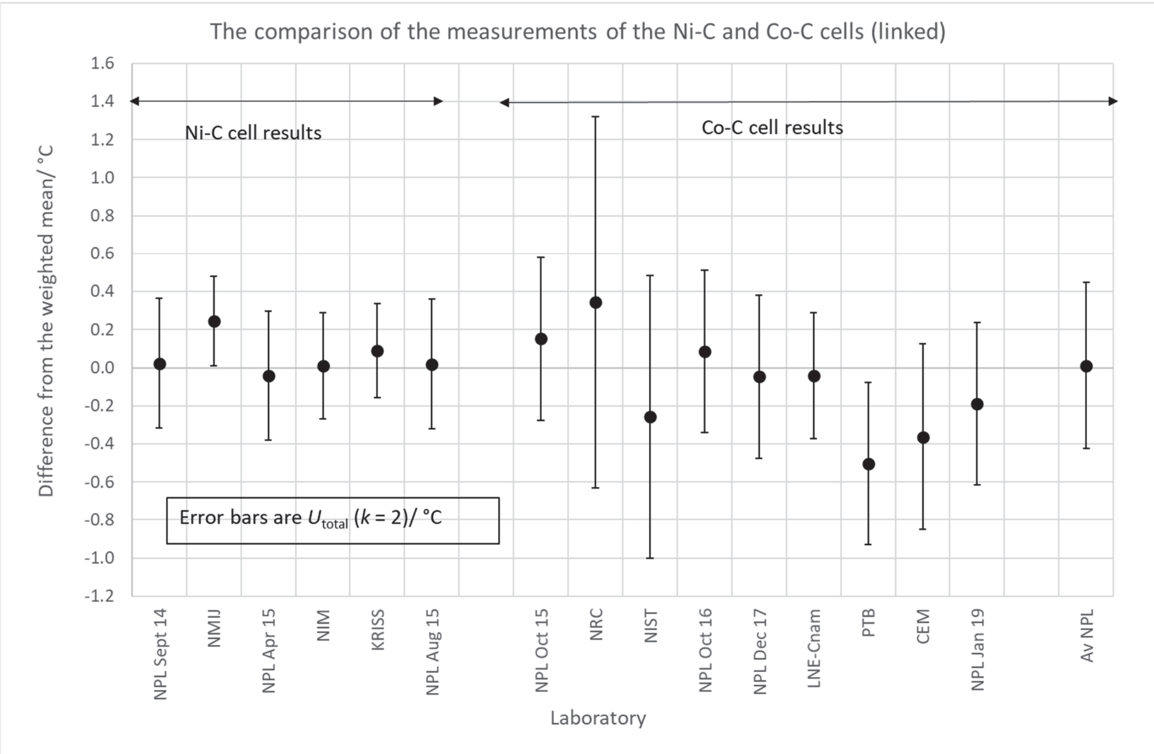


Figure 103 - the differences from the weighted mean for the corrected Ni-C-X and the Co-C-X cell results – all data, with *U* (*k* = 2) total uncertainty

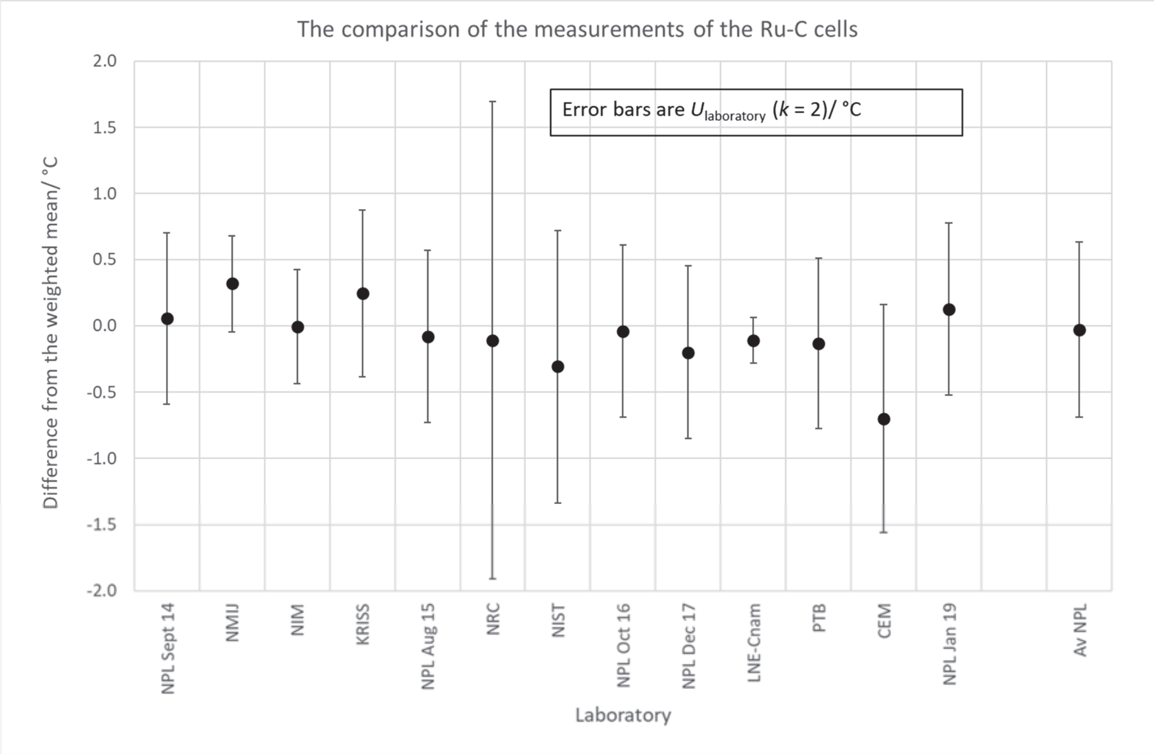


Figure 104 - the differences from the weighted mean for the Ru-C cell results – all data, with *U* (*k* = 2) laboratory uncertainty

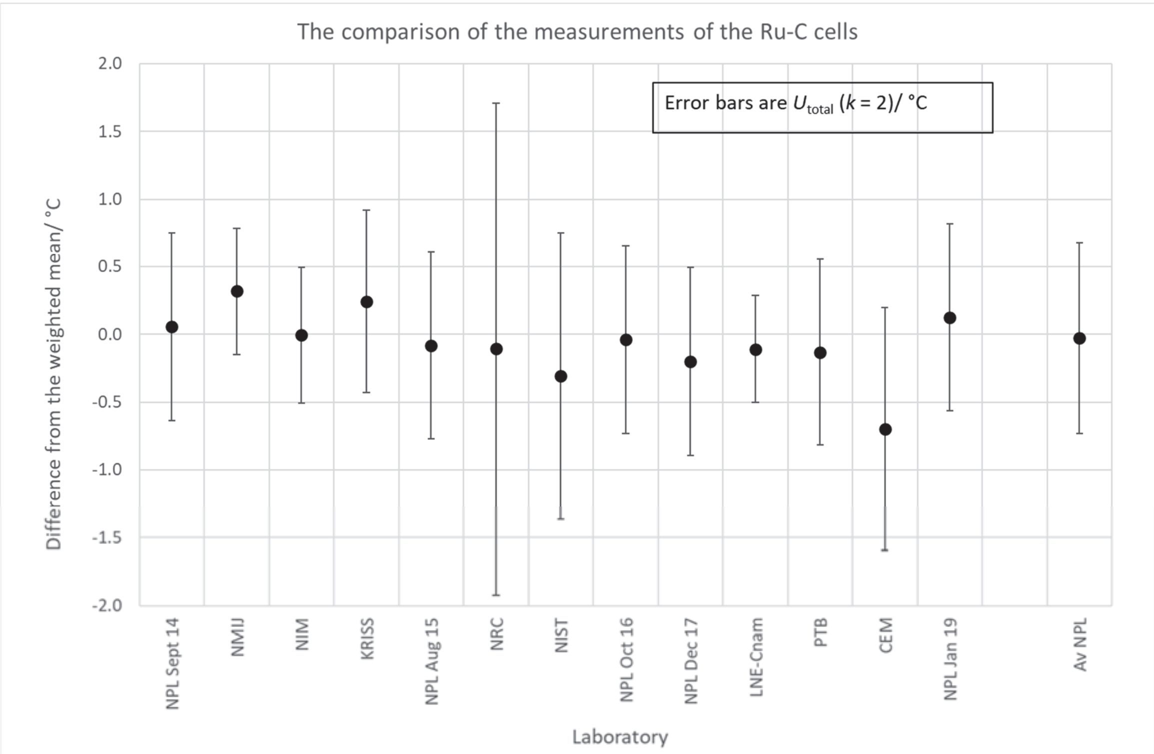


Figure 105 - the differences from the weighted mean for the Ru-C cell results – all data, with *U* (*k* = 2) total uncertainty

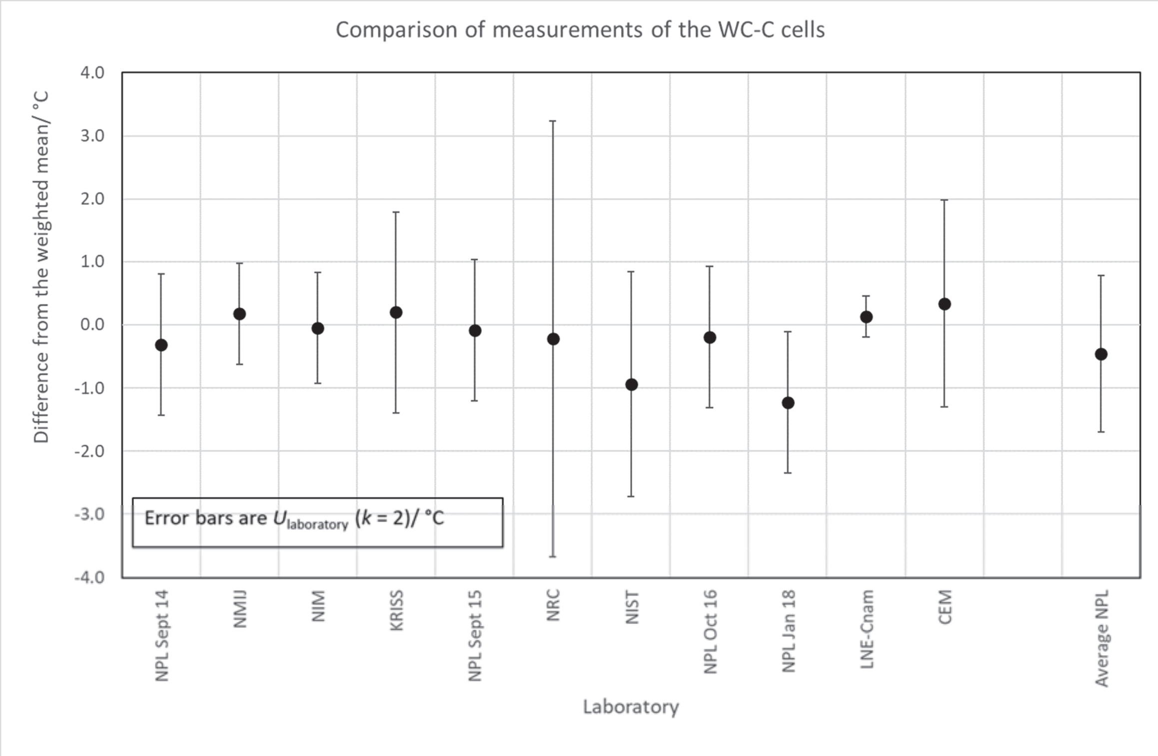


Figure 106 - the differences from the weighted mean for the WC-C cell results – all data, with *U* (*k* = 2) laboratory uncertainty

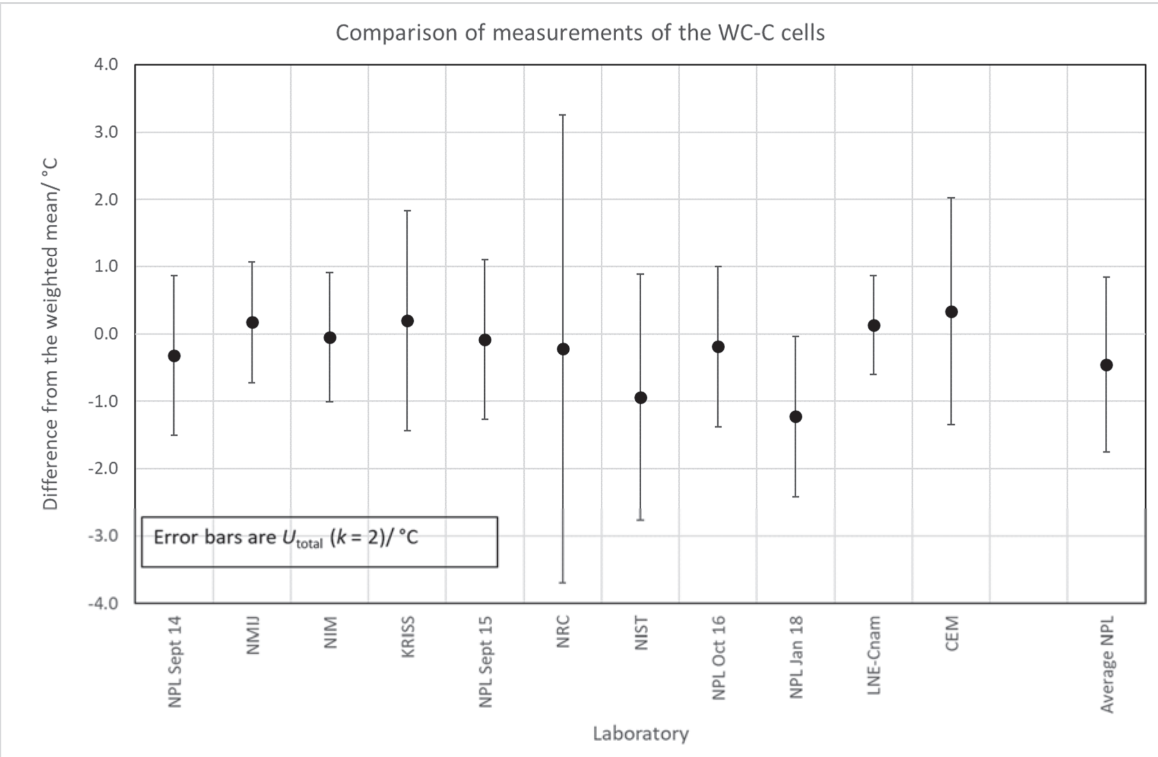


Figure 107 - the differences from the weighted mean for the WC-C cell results – all data, with *U* (*k* = 2) total uncertainty

12.3 QDE_{95} AND DOE TABLES AND CHARTS – HTFP MEASUREMENTS

The QDE_{95} and DOE values and charts are given in this Section for the HTFP measurements (refer to Section 10.6 and Equation 7).

Table 113 – DOE and QDE$_{95}$ table of results for the Ni-C measurements (all units are in °C) and chart with differences from the weighted mean

	NMIJ	NIM	KRISS	Average NPL
NMIJ	-	0.23 ± 0.33	0.16 ± 0.30	0.24 ± 0.39
NIM	*0.51*	-	-0.08 ± 0.34	0.01 ± 0.42
KRISS	*0.41*	*0.37*	-	0.09 ± 0.40
Average NPL	*0.57*	*0.42*	*0.43*	-

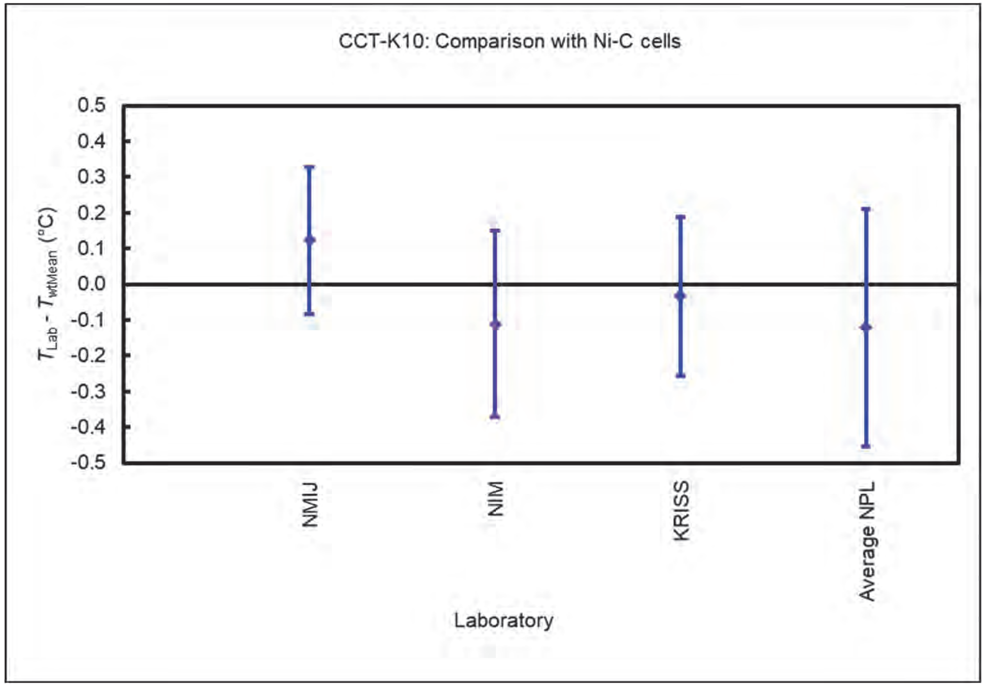


Table 114 - DOE and QDE$_{95}$ table of results for the Co-C measurements (all units are in °C) and chart with differences from the weighted mean

	NRC	NIST	LNE-Cnam	PTB	CEM	Average NPL
NRC	-	0.60 ± 1.21	0.39 ± 1.02	0.85 ± 1.05	0.71 ± 1.07	0.34 ± 1.06
NIST	*1.60*	-	-0.22 ± 0.81	0.25 ± 0.83	0.10 ± 0.87	-0.26 ± 0.84
LNE-Cnam	*1.24*	*0.89*	-	0.46 ± 0.53	0.32 ± 0.58	-0.04 ± 0.55
PTB	*1.71*	*0.94*	*0.90*	-	-0.14 ± 0.62	-0.50 ± 0.59
CEM	*1.59*	*0.87*	*0.80*	*0.67*	-	-0.36 ± 0.63
Average NPL	*1.23*	*0.97*	*0.54*	*0.99*	*0.89*	-

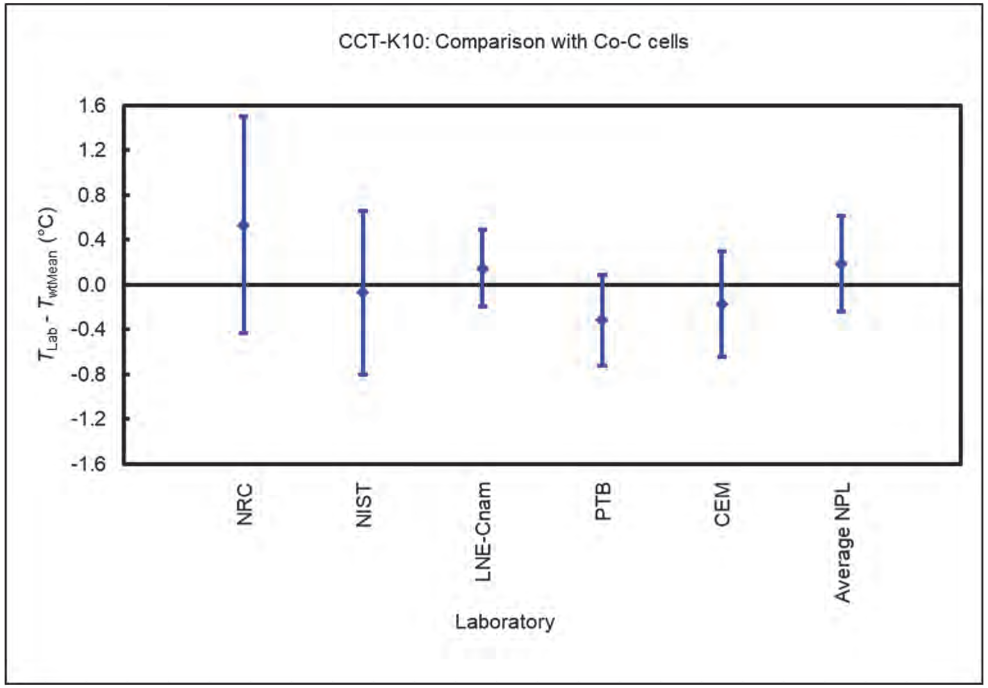


Table 115 - DOE and QDE_{95} table of results for the linked Ni-C and Co-C measurements (all units are in °C) and chart with differences from the weighted mean

	NMIJ	NIM	KRISS	NRC	NIST	LNE-Cnam	PTB	CEM	Average NPL
NMIJ	-	0.23 ± 0.36	0.16 ± 0.34	-0.10 ± 1.00	0.50 ± 0.78	0.29 ± 0.41	0.75 ± 0.49	0.61 ± 0.54	0.23 ± 0.49
NIM	*0.54*	-	-0.08 ± 0.37	-0.33 ± 1.01	0.27 ± 0.79	0.05 ± 0.43	0.51 ± 0.51	0.37 ± 0.56	0.00 ± 0.52
KRISS	*0.44*	*0.40*	-	-0.26 ± 1.01	0.35 ± 0.78	0.13 ± 0.41	0.59 ± 0.49	0.45 ± 0.55	0.08 ± 0.50
NRC	*1.00*	*1.18*	*1.10*	-	0.60 ± 1.23	0.39 ± 1.03	0.85 ± 1.06	0.71 ± 1.09	0.33 ± 1.07
NIST	*1.14*	*0.93*	*0.99*	*1.62*	-	-0.22 ± 0.81	0.25 ± 0.86	0.10 ± 0.89	-0.27 ± 0.86
LNE-Cnam	*0.62*	*0.44*	*0.48*	*1.24*	*0.90*	-	0.46 ± 0.54	0.32 ± 0.59	-0.05 ± 0.55
PTB	*1.15*	*0.93*	*1.00*	*1.73*	*0.96*	*0.91*	-	-0.14 ± 0.65	-0.52 ± 0.61
CEM	*1.05*	*0.84*	*0.90*	*1.61*	*0.89*	*0.81*	*0.69*	-	-0.38 ± 0.65
Average NPL	*0.64*	*0.51*	*0.51*	*1.23*	*0.99*	*0.54*	*1.02*	*0.91*	-

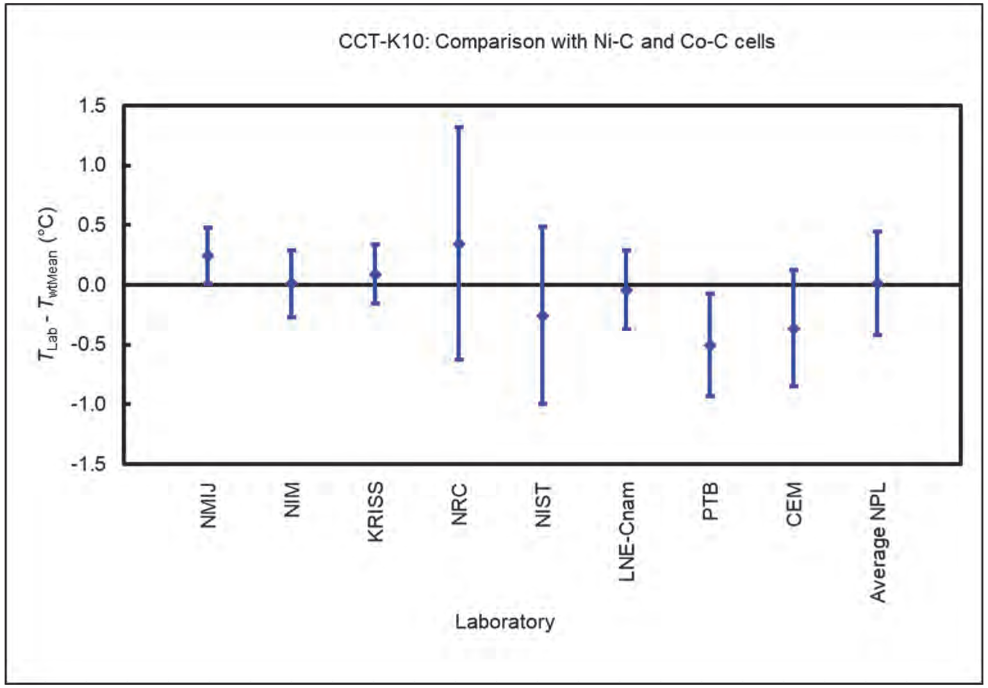


Table 116 - DOE and QDE$_{95}$ table of results for Ru-C measurements (all units are in °C) and chart with differences from the weighted mean

	NMIJ	NIM	KRISS	NRC	NIST	LNE-Cnam	PTB	CEM	Average NPL
NMIJ	-	0.32 ± 0.68	0.08 ± 0.82	0.43 ± 1.88	0.63 ± 1.16	0.43 ± 0.61	0.45 ± 0.83	1.02 ± 1.01	0.35 ± 0.84
NIM	*0.89*	-	-0.25 ± 0.84	0.10 ± 1.88	0.30 ± 1.17	0.10 ± 0.64	0.13 ± 0.85	0.69 ± 1.02	0.02 ± 0.86
KRISS	*0.82*	*0.95*	-	0.35 ± 1.94	0.55 ± 1.26	0.35 ± 0.78	0.38 ± 0.96	0.94 ± 1.12	0.27 ± 0.97
NRC	*2.02*	*1.85*	*2.02*	-	0.20 ± 2.10	0.00 ± 1.86	0.03 ± 1.94	0.59 ± 2.02	-0.08 ± 1.95
NIST	*1.58*	*1.29*	*1.59*	*2.09*	-	-0.20 ± 1.13	-0.17 ± 1.26	0.39 ± 1.38	-0.28 ± 1.27
LNE-Cnam	*0.93*	*0.66*	*1.00*	*1.83*	*1.17*	-	0.02 ± 0.79	0.59 ± 0.98	-0.08 ± 0.81
PTB	*1.13*	*0.86*	*1.17*	*1.91*	*1.28*	*0.78*	-	0.57 ± 1.13	-0.10 ± 0.98
CEM	*1.85*	*1.53*	*1.86*	*2.29*	*1.55*	*1.39*	*1.49*	-	-0.67 ± 1.14
Average NPL	*1.05*	*0.85*	*1.09*	*1.91*	*1.36*	*0.80*	*0.98*	*1.61*	-

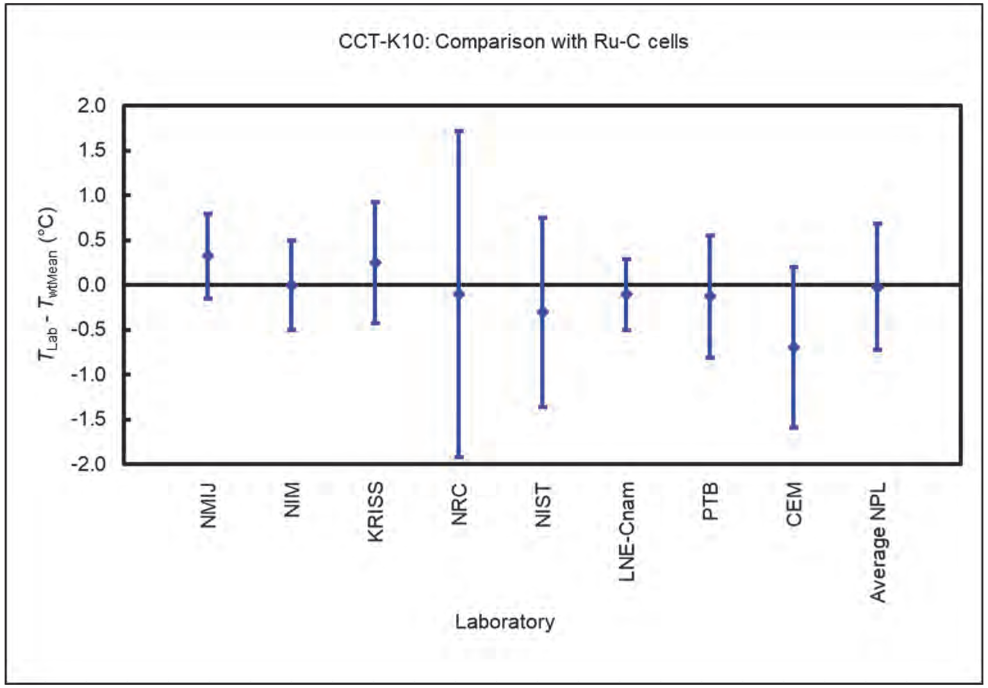
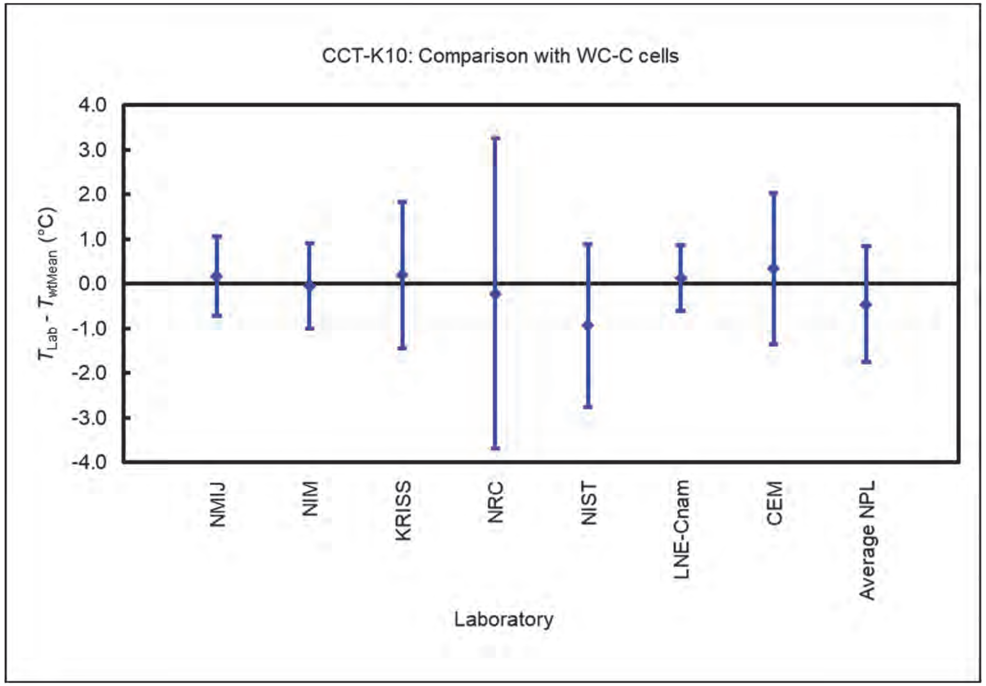


Table 117 - DOE and QDE_{95} table of results for WC-C measurements (all units are in °C) and chart with differences from the weighted mean

	NMIJ	NIM	KRISS	NRC	NIST	LNE-Cnam	CEM	Average NPL
NMIJ	-	0.22 ± 1.32	-0.02 ± 1.87	0.39 ± 3.59	1.11 ± 2.03	0.04 ± 1.16	-0.16 ± 1.91	0.63 ± 1.58
NIM	*1.36*	-	-0.25 ± 1.90	0.17 ± 3.60	0.89 ± 2.06	-0.18 ± 1.21	-0.39 ± 1.94	0.41 ± 1.61
KRISS	*1.84*	*1.92*	-	0.41 ± 3.84	1.13 ± 2.45	0.07 ± 1.79	-0.14 ± 2.35	0.65 ± 2.09
NRC	*3.58*	*3.54*	*3.84*	-	0.72 ± 3.92	-0.35 ± 3.55	-0.56 ± 3.86	0.24 ± 3.71
NIST	*2.79*	*2.59*	*3.16*	*4.09*	-	-1.07 ± 1.97	-1.28 ± 2.48	-0.48 ± 2.24
LNE-Cnam	*1.13*	*1.23*	*1.76*	*3.53*	*2.69*	-	-0.21 ± 1.84	0.59 ± 1.49
CEM	*1.89*	*2.05*	*2.31*	*3.93*	*3.33*	*1.84*	-	0.79 ± 2.13
Average NPL	*1.94*	*1.77*	*2.40*	*3.65*	*2.39*	*1.82*	*2.56*	-



13 CONCLUSIONS

A comparison of ITS-90 radiance temperature scales has been carried out over the temperature range from 962 °C to 3000 °C using two transfer thermometers and a set of high temperature fixed points.

There were some outliers in the results using the two transfer thermometers (more with the Chino thermometer than with the LP3) but, in general, the results from the different participants agreed within the measurement uncertainties. The results with the HTFPs were, generally, more in agreement, with, again, most of the participant results agreeing with each other within the measurement uncertainties.

The results of this comparison can be used to underpin the Calibration and Measurement Capabilities (CMCs) of the participants, both for the calibration of radiation thermometers using the differences in the results from the KCRV (Section 11) and for the calibration of high temperature fixed point cells at ~1325 °C, 1952 °C and 2747 °C using the results of the measurements of the Ni-C/ Co-C, Ru-C and WC-C fixed points (Section 12 of the report).

14 REFERENCES

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[6] Wood, B. M., Douglas, R. J., *Metrologia*, 1998, **35**, pp 187-196

[7] Todd, A.D.W., Anhalt K., Bloembergen P., Khlevnoy B., Lowe D.H., Machin G., Sadli M., and Sasajima N., Report from the CCT Task Group for Non-Contact Thermometry HTFP Uncertainties (CCT TG-NCTh-HTFPU), 2018

15 APPENDIX 1 – THE PROTOCOL OF THE KEY COMPARISON

CCT-K10

PROTOCOL FOR CCT COMPARISON OF ITS-90 REALISATIONS ABOVE THE SILVER POINT USING TWO TRANSFER RADIATION THERMOMETERS AND A SET OF HIGH TEMPERATURE FIXED-POINT BLACKBODY CELLS

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UNITED KINGDOM

24 September 2015

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PROTOCOL FOR HIGH TEMPERATURE KEY COMPARISON

1 INTRODUCTION

There is a strong requirement for a CCT Key Comparison of the ITS-90 above the silver point (961.78 °C). Over this temperature range the ITS-90 is realised using a characterised radiation thermometer calibrated using a blackbody at one of the defining fixed points (i.e., Ag, Au (1064.18 °C) or Cu (1084.62 °C)) and extrapolated upwards from the reference fixed point using Planck's law in ratio form. The definition can result in undetected scale realisation uncertainties which generally increase as T^2. In addition there are various ways in which the scale can be realised leading to different sources of uncertainty, dependent upon the method used. It is essential to substantiate claimed Calibration and Measurement Capabilities (CMCs) for the ITS-90 above the silver point by undertaking a key comparison led from CCT-WG5 involving leading NMIs in different regions.

The results of the previous CCT-led key comparison (CCT K5) for the range up to 1700 °C, which took place around 15 years ago, were unsatisfactory for the following reasons:

1. the comparison was carried out using tungsten ribbon lamps which inherently have a relatively large associated uncertainty and also the radiance temperature of the ribbon is strongly dependent on the wavelength;
2. the comparison was only up to a temperature of 1700 °C whereas NMIs can routinely realise the ITS-90 up to much higher temperatures, up to 3000 °C;
3. there was evidence of some artefact instability in some of the results obtained;
4. the comparison results showed differences which were thought not to be representative of participants' actual ability to realise the high temperature scale.

As a consequence CCT K5 cannot satisfactorily substantiate NMIs' claimed CMCs, either to the level of uncertainty or over the required temperature range. This new CCT Key Comparison (KC) will address this issue, and will support CMCs for ITS-90 calibration of radiation thermometers and future CMCs for fixed point calibration above the Ag point.

The proposed KC will consist of two parts:

1. a comparison of ITS-90 scale realisations over the range from the Ag point to 3000 °C (or the highest temperature participants realise) using two transfer radiation thermometers (an IKE Linear Pyrometer LP3 and a Chino radiation thermometer IR-RST65). The transfer thermometers will be supplied along with a transportable copper fixed-point blackbody source which will be used to confirm the stability of the radiation thermometers throughout the comparison;
2. Three high temperature fixed-point (HTFP) blackbody cells (Ru-C and WC-C along with either doped Ni-C (Ni-C-X) or doped Co-C (Co-C-X) will also be measured to probe scale realisation uncertainties at these particular temperatures with better precision.

The instruments and artefacts will be circulated in the form of a semi-collapsed star or 'flower' as described below. This will enable the performance of the instruments to be regularly checked throughout the comparison by the pilot laboratory and should help to minimise issues due to incorrect operation or drift.

2 PARTICIPANTS

The participants are drawn from a number of regions, namely EURAMET, SIM, COOMET and APMP. The details of NMI and contact person are given in Table A1-1 below.

Region	NMI	Details of contact person
EURAMET	NPL (pilot)	Helen McEvoy/Graham Machin National Physical Laboratory Hampton Road, Teddington, Middlesex, United Kingdom TW11 0LW E-mail: helen.mcevoy@npl.co.uk
EURAMET	CEM	Maria José Martín Centro Español de Metrologia Temperature Division C/ del Alfar 2. 28760 Tres Cantos. Madrid. Spain E-mail: mjmartinh@cem.minetur.es
EURAMET	PTB	Klaus Anhalt and Jörg Hollandt Physikalisch-Technische Bundesanstalt FB 7.3 Detektorradiometrie und Strahlungsthermometrie Abbestraße 2-12 10587 Berlin E-mail: klaus.anhalt@ptb.de/ joerg.hollandt@ptb.de
EURAMET	LNE-Cnam	Mohamed Sadli Lab. Commun de Métrologie 61, rue du Landy 93210 Saint-Denis, La Plaine France E-mail: mohamed.sadli@cnam.fr

Table A1-1: Participants and contact details for the CCT high temperature KC

APMP	NMIJ	Yoshiro Yamada National Metrology Institute of Japan AIST Tsukuba Central 3-1 1-1-1 Tsukuba Ibaraki 305-8563 Japan E-mail: y.yamada@aist.go.jp
APMP	NIM	Lu Xiaofeng National Institute of Metrology 18 Bei San Huan Dong Lu Beijing, 100013 China E-mail: luxf@nim.ac.cn
APMP	KRISS	YongShim Yoo Korea Research Institute of Standards and Science 1 Doryong-dong Yuseong-gu Daejeon 305-340 Korea E-mail: ysyoo@kriss.re.kr
SIM	NIST	Howard Yoon National Institute of Standards and Technology 100 Bureau Dr. Stop 1070 Gaithersburg MD 20899-1070 United States E-mail: howard.yoon@nist.gov
SIM	NRC	Andrew Todd National Research Council of Canada M-36, room 1209 1200 Montreal Road Building M-58 Ottawa, Ontario K1A 0R6 Canada E-mail: andrew.todd@nrc-cnrc.gc.ca
COOMET	VNIIM	Mikhail Matveyev D. I. Mendeleyev Institute for Metrology (VNIIM) Moskovsky pr.19 St.Petersburg 190005 Russia E-mail: M.S.Matveyev@vniim.ru

Table A1-1: Participants and contact details for the CCT high temperature KC - continued

3 COMPARISON SCHEME

The comparison will be in the form of a ‘semi-collapsed star’ or ‘flower’. In other words, the comparison artefacts will be sent from the pilot laboratory to one of the regional NMIs, and measurements will then run in a loop around that region before the artefacts are sent back to the pilot laboratory. Following checks on the artefacts, the pilot will then send them to an NMI in the next region for a further loop. This will continue for each of the regions.

The measurements are due to be completed by the autumn of 2016 with the final project report to be completed by the end of Dec 2016. Refer to the Table in Appendix 1 for the full details of the circulation).

4 CIRCULATING INSTRUMENTS

The circulating instruments will be:

An IKE LP3 radiation thermometer supplied by PTB;
A Chino radiation thermometer IR-RST65 supplied by NMIJ;
A Chino copper fixed-point source (for checking the stability of the radiation thermometers prior to the measurements at each NMI) supplied by NRC.

Additionally HTFP cells of either doped Ni-C (Ni-C-X) or doped Co-C (Co-C-X), Ru-C and WC-C will be circulated to allow participants to probe the uncertainty of their primary ITS-90 scale realisation at the fixed point temperatures. One of each type of cell will be circulated.

The technical specifications of each of the instruments are given in the following tables. Operational guidelines for the use of each instrument are given in Appendix 2. Additionally, each instrument is supplied with an operating manual giving further details. Participants should familiarise themselves with the operating manuals for each instrument before starting measurements to minimise the risk of accidental damage or incorrect operation.

Chino radiation thermometer	
Model	IR-RST65
Serial number	IS143A001
Spectral range	650 nm, FWHM 12 nm
Measuring temperature range	960 °C to 3000 °C
Distance Ratio (Distance / Target size)	650 (400 mm/ 0.6 mm Ø)
Output	Radiance signal: 0 to 10 V Internal temperature stabilization monitor signal: 0 to 5 V (0 to 50 °C)
Measurement distance	400 mm to ∞
Warm up time	Half a day
Power requirements	24 VDC, DC power supply (for 100-240 VAC) accompanies the instrument

Table A1-2: Specifications for the Chino radiation thermometer

<u>Working distance:</u> Note: for the calibration the thermometer should be set at a **working distance of 700 mm**. The distance should be measured from **the front of the thermometer casing** to the defining point of the source (e.g. the defining aperture).

IKE Linear Pyrometer	
Model	LP3
Serial number	80-13
Spectral range	650 nm (and 950 nm†)
Measuring temperature range (at 0.65 μm)	800 °C to 3030 °C Neutral density filter (filter A2) to be used above 2400 °C
Measuring temperature range (at 0.95 μm)	600 °C to 2500 °C Neutral density filter (filter A2) to be used above 2000 °C
Measurement ranges	R1 for photocurrents from 100 pA to 8 nA; R2 for photocurrents from 500 pA to 800 nA
Target size versus distance	1 mm at 700 mm; 1.7 mm at 1000 mm
Output	Photocurrent and temperature* via serial RS232 interface and PC using supplied LP3DE.exe software‡
Measurement distance	730 mm to 1000 mm
Warm up time	2 hours (until cell is stabilised at 29.5 °C)
Power requirements	110 V or 220 V, 50/60 Hz, 2 x supplied power cables (one for 110 V, one for 220 V) and plug in accordance with CEE 7/7

Table A1-3: Specifications for the LP3 radiation thermometer

† For the comparison only the 650 nm filter should be used (filter B1)
* For the comparison only the photocurrent reading should be used
‡ Participants are not required to use the supplied software. Alternative (participant's own) software can be used to record the LP3 photocurrent provided that the software doesn't apply any data manipulation to the raw photocurrent values.

Working distance: Note: for the calibration the thermometer should be set at a **working distance of 750 mm**. The distance should be measured from the **front of the thermometer casing** to the defining point of the source (e.g. defining aperture).

Transportable copper fixed-point blackbody source	
Furnace model	IR-R0A
Serial number	RA12YB002
Fixed-point blackbody	Cu point
Blackbody cavity	8 mm Ø× ~53 mm, with 120 °conical end and 6 mm Ø aperture
Effective emissivity	~0.9998
Plateau duration	Approximately 10 min
Heat-up time	Approx. 120 min from room temperature to Cu point
Cool-down time	Approx. 120 min from Cu point to 150 °C
Power	110-120/ 220-240VAC, 50 – 60 Hz, 750 VA max
Gas requirements	Pure argon, 0.2 to 0.25 l/min
Temperature control	PID control by a pre-programmed controller

Table A1-4: Specifications for the transfer Cu point source

High temperature fixed point cells						
HTFP cell	Identification number	Supplied by	Length/ mm	Outer diameter/ mm	Aperture diameter/ mm	Emissivity
Ru-C cell	6Ru1	LNE-Cnam	44	24	3	0.9997
Ru-C cell	6Ru2	LNE-Cnam	44	24	3	0.9997
Ru-C cell	Ru-C-4	Tubitak	24	24	3	0.9990
Ni-C cell	NiC #11	INMETRO	40	24	3	0.9997
Ni-C cell	NiC #12	INMETRO	40	24	3	0.9997
Co-C cell*	dəo	NPL	44	24	3	0.9996
WC-C cell	W2 6SSC-2	NIM	45	24	3	0.9997
WC-C cell	WC-C#1	NPL	44	24	3	0.9996
WC-C cell	WC-C#2	NPL	44	24	3	0.9996

Table A1-5: Dimensions and emissivity values for the high temperature fixed-point cells

The two/ three cells of each of the fixed point types will be cross-compared prior to the start of the comparison to determine the temperature difference between the cells. One of each type of cell (i.e., one Ni-C cell, one Ru-C cell and one WC-C cell) will be chosen at random for circulation among the participants. The remaining cell(s) of each type will be kept at NPL in **case of breakage of any transfer cell during the comparison. (* Replacement cell due to issues with breakage of Ni-C).**

5 SHIPPING

The NMI performing the measurements should arrange for the thermometers and cells to be transferred to the next NMI by the date given in the schedule in Appendix 1. Wherever possible, door-to-door transportation should be used to minimise the risk of damage to the instruments. The NMI performing the measurements is required to arrange the safe transportation of the instruments to the next NMI and for paying the transport costs. Therefore it is strongly recommended that the NMI arranging the shipping takes out insurance in case of loss or damage of the instruments and cells during the transportation. The value of the goods, for insurance purposes, should be taken to be in the region of £115000. The NMI receiving the instruments should carry out the checks described in Section 9.1 and confirm to the pilot laboratory by e-mail that the instruments have arrived safely.

NPL will provide all necessary documentation including customs documentation for shipping the instruments from NPL to the particular region and then back to NPL. For customs purposes, during the comparison the instruments will be considered to be a temporary export out of the UK. It is important that all the items within the shipment are kept together and transported as one consignment with all the accompanying paperwork.

The approximate dimensions and weights of each of the items are given in Table A1-6.

Item	Packaging	Dimensions*/ mm	Gross weight*/ kg	Number of units
LP3 radiation thermometer	Aluminium box placed inside wooden box on EUR pallet	700 x 800 x 1200	50	1
Chino radiation thermometer	Duralumin carrying case in corrugated cardboard box reinforced on the inside with ply wood boards	520 × 460 × 330	12.3	1
Transfer Cu fixed point	Pelican™ 500 transport case	1015 x 600 x 730	40	1
Ni-C or Co-C cell				1
Ru-C cell	Carrying case/ box	300 x 300 x 300	3	1
WC-C cell				1

Table A1-6: Approximate dimensions and weights of items in consignment

6 PROBLEMS

During the measurement process participants should endeavour to make sure that all the instruments are safely and correctly handled while they are at their laboratory. If desired, insurance may be taken out to cover against loss or damage. The NMI arranging shipping to the next participant will be responsible should anything go wrong during the shipping process resulting in any damage to any of the instruments. It is therefore strongly recommended that insurance is taken out in case of loss or damage of the instruments or the cells during transportation.

Should the results of the copper fixed point check (Section 9.1.5) indicate that there is a problem with either of the radiation thermometers then it might be necessary to return that thermometer to the pilot laboratory so that a further assessment can be carried out.

Should any problems arise with the operation of the instruments, both the coordinator and the NMI supplying the equipment should be contacted.

7 PREPARATION FOR MEASUREMENTS

Prior to receiving the instruments each participant should prepare for the measurements. Please ensure sufficient time is given for this activity so the measurement schedule is not delayed.

Preparation for measurements includes:

- Ensuring that the radiation thermometer used for primary ITS-90 scale realisation is fully characterised/ calibrated according to the local methodology (i.e., in terms of spectral response, linearity, size-of-source effect, range ratios, ITS-90 fixed point reference calibration etc.);
- The high temperature furnace to be used for the calibration of the radiation thermometers is operational;
- The furnace to be used for the HTFP measurements has been prepared for these measurements, including: baking out to minimise the risk of cell contamination; determination of the optimum cell position within the furnace; ensuring furnace

insulation, cell holders are available etc.. Further guidance and details of this process are given in Appendix 3. This guidance has been adapted from the protocol for the InK Workpackage 1 HTFP measurement campaign.

8 MEASUREMENTS AT THE PILOT LABORATORY (NPL)

The pilot laboratory will fully calibrate and characterise the two radiation thermometers prior to the start of the comparison and at the end of the comparison, and will also validate the transfer Cu fixed point and the HTFP cells. The calibration/ validation will consist of:

- Size-of-source effect measurements;
- Gain or range ratio measurements as appropriate;
- Non-linearity;
- Spectral response of the LP3 (the spectral response of the Chino thermometer will be carried out by NMIJ prior to sending the thermometer to NPL);
- Validation of the transfer Cu fixed point source using the NPL primary Cu point and radiation thermometer (the NPL IKE LP3);
- Measurement of the KC radiation thermometer outputs using the transfer Cu point (to provide a baseline reference signal);
- Calibration of the KC radiation thermometers at the comparison temperatures, namely 960, 1100, 1300, 1500, 1700, 1800, 2000, 2200, 2400, 2500, 2600, 2800, 2900, 3000 °C, using the NPL high temperature blackbody source and primary reference thermometer (the NPL LP3);
- Assignment of the NPL ITS-90 temperatures to a set of HTFP cells, consisting of one of each of Ni-C-X or Co-C-X, Ru-C and WC-C, using the usual NPL method for determining the point of inflection (poi) temperature of the melt of the HTFPs using the NPL LP3. This set of cells will be circulated among participants. The remaining cells will be held at NPL, to serve as a reference to test for any possible drift of the HTFPs during the comparison and to provide a spare in case of breakage during the comparison. (Note that the temperature difference between the cells of each type will already have been measured prior to the start of the comparison.)

When the instruments are returned to the pilot during the comparison a limited number of the above measurements will be carried out in order to check the correct operation and stability of the instruments. These measurements will be:

- check of the operation of the transfer Cu fixed point using the NPL LP3 and the NPL primary Cu point;
- check of the output of each of the two KC thermometers using the melt/ freeze transition of the transfer Cu fixed point source;
- size-of-source effect of the two transfer thermometers;
- re-calibration of the two KC radiation thermometers at the temperature points listed above, including check of gain and range ratios and LP3 ND filter transmission;
- measurement of the circulating HTFP cells, including a cross-comparison of the each of the transfer cells with the appropriate reference cell(s) being retained at NPL to check the stability of the circulating HTFPs.

9 MEASUREMENTS AT THE PARTICIPATING NMIS

9.1 CHECK ON ARRIVAL AT EACH NMI

A visual inspection of the packaging and all the instruments and cells should be made on arrival of the equipment at each NMI. Any evidence of damage should be reported immediately both to the pilot and the NMI responsible for the shipment using the form in Appendix 4.

In the case of the HTFP cells they should be carefully inspected both before and following transportation for any obvious damage and for any sign of metal diffusing through the cell walls. Both on receipt of the cells and before shipping them, each participant should report the appearance of the cells, if appropriate with a photograph, by sending an email to the pilot and the previous participant (on receipt) or next participant (before posting).

As a further check of the KC transfer thermometers, to make sure that they have not been damaged during transport, within one week of their receipt the output of each radiation thermometer should be measured using two melt/ freeze cycles of the supplied Cu fixed-point blackbody source (refer to Section 9.1.5) and the result reported to the pilot.

9.1.1 Stabilisation/ warm up

The stabilisation (warm up) times for the thermometers are given in Tables A1-2 and A1-3 and must be adhered to. The thermometers should subsequently be left switched on, if possible, for the duration of all the measurements.

9.1.2 Lens cleaning

Superficial dust should be blown off the front lens of the thermometer using clean air or other means but otherwise the lens should NOT be cleaned. The protective lens cap should be placed on the front of the thermometer between measurements and great care should be taken not to touch the front lens. The LP3 is provided with an objective extension ring as a further protection of the front lens. This should not be removed.

9.1.3 Positioning

The thermometers should be set up and aligned at the prescribed working distance, namely 700 mm (Chino thermometer) or 750 mm (LP3) from the front of the thermometer casing to the source, according to the local procedure, with reference to any specific instructions supplied with the thermometers.

9.1.4 Background (dark reading) measurements

Background measurements should be carried out by placing the protective lens cap on the front of the thermometer.

9.1.5 Check using transfer Cu fixed point source

Within one week of their receipt the output of each transfer radiation thermometer should be measured using two melt/ freeze cycles of the supplied Cu fixed-point blackbody source, using the supplied instructions for using the source (refer to Appendix 2 and the instruction manual supplied with source). Another Cu measurement with both instruments should be

carried out at the end of all the other measurements and before shipment to the next laboratory in order to provide better information about the stability of the transfer thermometers.
The fixed point aperture is located at a distance of 155 mm behind the front panel of the furnace. The measurements should be made at the prescribed working distance (i.e., 700 mm for the Chino thermometer and 750 mm for the LP3, measured from the front of the thermometer casing to the fixed point aperture), with the thermometer focused and aligned on the centre of the Cu fixed point aperture. This can be achieved by focusing and aligning on the centre of the white alumina aperture, which is located 4 mm in front of the fixed point aperture, and then linearly moving the thermometer towards the furnace by 4 mm.

The measurements of the Cu point with the Chino thermometer should be made with the thermometer set on gain L; the measurements for the LP3 should be made with the thermometer set on Range R1.

Measurements over the central half of the Cu freezing plateau will be used for the check. The results of the check (i.e., average output signals of the thermometers during the central half of the two Cu freezing plateaux, corrected for dark reading (background)), along with the internal temperature of the thermometer and the laboratory ambient conditions, should be e-mailed to the pilot laboratory using the template form in Appendix 5, within one week of receipt of the thermometers. The results of the second check measurement (before shipping to the next participant) should be included in the laboratory measurement report.

9.2 COMPARISON MEASUREMENTS

This is a Key Comparison of ITS-90 temperature scales.

Each NMI will:

i. calibrate each transfer radiation thermometer using their realisation of the ITS-90 scale (i.e., usually via a high temperature blackbody source and a reference thermometer);
ii. determine the ITS-90 temperature of the point of inflection (poi) of the melt of the supplied HTFPs using their own primary radiation thermometer used for high temperature ITS-90 scale realisation.

9.2.1 Calibration of the transfer thermometers

The calibration of the transfer (KC) thermometers should be carried out according to the local procedure for the calibration of such devices using the participant’s high temperature blackbody (HTBB) source, the temperature of which should be assigned according to the usual method at the NMI[†]. The calibration should be carried out with the thermometers set at the prescribed working distance from the blackbody source, i.e., 700 mm (Chino thermometer) or 750 mm (LP3) from the front of the thermometer casing to the source.

The calibration of the KC thermometers is to be carried out at all of the following temperatures, although the maximum calibration temperature can be reduced to fit the particular capability within an NMI.

960, 1100, 1300, 1500, 1700, 1800, 2000, 2200, 2400, 2500, 2600, 2800, 2900, 3000 °C.

The calibration at all temperatures should be carried out using an HTBB. The HTBB should be set to be within 0.5 °C of the specified temperatures. The gain/ range settings for each instrument should be set appropriately for each temperature as specified in Appendix 6. For the LP3 the neutral density (ND) filter, filter A2, needs to be used for temperatures above 2400 °C, again as specified in Appendix 6.

Participants should carry out repeat measurements at a minimum of three of the above calibration temperatures spread over the range; e.g. 960 °C, 1800 °C and 2800 °C.

The reference source size for the comparison is 25 mm diameter.

(†Note: as an alternative, participants can instead realise the ITS-90 directly using the transfer radiation thermometers, by fully characterising them in terms of the spectral response, linearity etc. and performing an ITS-90 reference fixed point measurement. In this case measurements using a high temperature blackbody source are not carried out. Instead the thermometer signal output for each of the calibration temperatures will be derived by calculation.)

Participants should measure the size-of-source effect (SSE) of the two transfer thermometers so that the calibration results can be corrected to a source size of 25 mm, if the size of the HTBB used in the NMI is different from 25 mm. The measurement of the SSE will also allow the NMI to calculate any uncertainty to take into account the thermal uniformity of their HTBB (see Section 9.2.3). Alternatively, if an NMI does not wish to measure the SSE, the pilot laboratory will provide the SSE results measured by the pilot at the start of the comparison for the NMI to calculate its own correction. (An additional uncertainty component might subsequently need to be included for that NMI if it is found that the SSE of the transfer thermometers changes during the comparison, for example as a result of contamination of the front lens).

Participants should also measure the transmission of the LP3 neutral density (ND) filter using a stable blackbody source at an appropriate temperature so that any changes in transmission with time can be taken into account in the results analysis.

Additionally participants should measure the range/ gain ratios of the transfer thermometers using a stable blackbody source maintained at a temperature appropriate for the range/ gain ratio being measured. Again this is so that any changes in the ratios with time can be monitored and can be taken into account in the results analysis if appropriate.

Any additional supplementary measurements should also be carried out if these form part of the usual necessary calibration procedure for a high temperature radiation thermometer (for example if they are required to fully assess the calibration uncertainties).

The report giving measurement method, details of equipment used, calibration results for each thermometer and estimated calibration uncertainties for each thermometer should be sent to the pilot within one month of completion of the measurements. For further details of the reporting format refer to Section 10.

9.2.2 Measurement of the HTFPs

The measurements of the HTFPs should be carried out according to the local procedures using the radiation thermometer usually used for primary ITS-90 scale realisation at the participant's NMI. Participants are required to measure the ITS-90 radiance temperature of the point of inflection (poi) of the melt of each cell (see for example [A1-1]) using the usual method at their NMI.

The measurements of the HTFPs should be carried out at a wavelength of 650 nm. Where this is not possible (the radiation thermometer operates at a different wavelength for example) measurements may be carried out at a different wavelength which should be clearly reported.

The reference source size for the HTFP measurements is 3 mm diameter.

It is recommended that measurements be performed in the sequence WC-C, Ru-C, Ni-C-X or Co-C-X. As a minimum four melt/ freeze cycles should be carried out for each cell, over one day. It is recommended that a second set of four melt/ freeze cycles is carried out on a subsequent day, with the cell removed and replaced within the furnace in-between the two days, in order to assess the reproducibility of the measurements due to (re-)positioning of the cell within the furnace. The first melt and freeze cycle of each day is **not** to be included in the analysis [i.e., only the second, third and fourth cycles are analysed] and so can be used for checking the alignment of the radiation thermometer on the cell aperture, temperature profile checks etc..

The melt and freeze transitions should be initiated using step sizes of, respectively, +20 K and -20 K from the melt temperature. (Note that these are approximate temperature steps for guidance only. If it is not possible to set the furnace to exactly these steps then the step size can be adapted.)

If the first cycle (the one not analysed) takes less than 30 minutes, then the furnace should be held at the below-melt temperature (the end point of the first cycle) for additional time to ensure that at least 30 minutes have passed between *the start of* the first cycle and *the start of* the second cycle (i.e., if the first cycle takes 20 minutes, this temperature should be held for 10 minutes before the start of the second cycle). Subsequent cycles can be closer together. However, it is necessary to wait until the cells have reached the offset temperatures (+20 K) following the melt to ensure that they are fully molten before starting the freeze (but see comment below about WC-C[†]), and then that they reach the offset temperature (-20K) following the freeze to ensure that they are fully frozen before attempting the next melt.

[†]Note: WC-C cells can experience a very deep undercool and can become difficult to freeze. To avoid problems with WC-C, the cell should be frozen soon after it completes the melt. It is important to ensure the melt is completed, but also to ensure that it does not remain molten for long.

If a cell is damaged while measurements are being carried out, then the participant should contact the pilot laboratory immediately with a description of the damage or poor performance. Damage includes, but is not limited to:

- Structural damage following accident (e.g. dropping cell)
- Structural damage following a heating/cooling cycle (e.g. cracking)
- Excess metal diffusing through cell wall as a result of cell ageing

9.2.3 Supplementary information

i) Furnace lateral uniformity for SSE correction

The lateral uniformity of the furnace should be measured by scanning horizontally and, if feasible, vertically across the furnace aperture. This scan should be performed for both the high temperature furnace used for the calibration of the KC radiation thermometers and the furnace used for the HTFP cell measurements. This will enable corrections and/ or uncertainty contributions to be estimated taking into consideration the different thermal profiles of each of the furnaces used by the participants and the size-of-source effect of the radiation thermometers, and enable the results to be corrected, if applicable, to the appropriate reference source diameter (25 mm for the KC radiation thermometer calibration and 3 mm for the HTFP measurements; see Sections 9.2.1 and 9.2.2 above). Participants can choose whether to measure the uniformity at one temperature or all temperatures according to their usual local procedure.

ii) Uncertainty components due to furnace performance

For the measurements of the HTFPs an uncertainty component will be included by the pilot for each participant's results to account for emissivity, temperature drop and other furnace effects. For this, the participant must provide a detailed description of the furnace geometry (diameters and positioning of baffles, furnace wall etc.). Uncertainty estimates will be taken from [A1-2].

iii) Uncertainty component due to the emissivity of the cells and the operating wavelength of the radiation thermometer

For those HTFP measurements which were carried out at the specified wavelength of 650 nm, no correction to the participant's results is necessary to take into account the emissivity of the cell, and therefore there is also no additional uncertainty due to a correction. For those participants who carry out the HTFP measurements at a wavelength other than 650 nm the pilot laboratory will apply a correction to the results to take into account the difference between the participant's wavelength and the specified wavelength and the calculated estimated emissivity of the cell. An additional component to allow for the uncertainty in the correction due to the uncertainty in the estimated emissivity of the HTFP cell will be included in the overall uncertainty budget for that participant.

10 REPORTING

The following information should be provided to the pilot laboratory within one month of completion of the measurements.

10.1 GENERAL INFORMATION

This should take the form of a Word document and should contain a description of the equipment and the measurement method used at the NMI, including:

- make, model, serial number and geometry of the high temperature blackbody source used for the calibration of the KC thermometers (if applicable[†]);

- details about the reference thermometer used if applicable† (e.g. type (radiation thermometer or thermocouple), make, model, serial number, spot (target) size, operational wavelength(s) etc.);
- methodology used in the calibration of the transfer KC thermometers (procedure followed; working distance from thermometer to blackbody if different from that prescribed; additional checks or measurements performed etc.);
- make, model, serial number and geometry of the high temperature furnace used for the measurements of the HTFP cells, if different from above;
- steps taken to prepare the furnace for the HTFP measurements;
- details of the primary reference radiation thermometer used for the HTFP measurements (make, model, serial number, spot (target) size, operational wavelength(s) etc.) if different from above;
- methodology used in the measurement of the HTFP cells (procedure followed, additional checks or measurements performed, including any additional melt/ freeze cycles carried out for e.g. optimising the position of the cell in the furnace etc.);

(† In the case where the transfer (KC) radiation thermometers are fully characterised so that they can be used for direct realisation of the ITS-90 then no measurements of a high temperature blackbody will be carried out and this information is not applicable.)

10.2 RESULTS

The results should be provided in the form of an Excel spreadsheet and should include the following information. Templates for reporting the results and uncertainties are given in Appendices 6 and 7.

10.2.1 For the calibration of the KC radiation thermometers:

- Results of the two stability checks using the transfer Cu fixed-point;

and, for each calibration point†:

- The ITS-90 temperature of the blackbody source;
- Thermometer output/ reading, after correction for the dark reading (background), measured with the appropriate gain or range, and ND filter setting for the LP3, as specified in Appendix 6;
- The internal temperature of the thermometer;
- The laboratory ambient temperature;

The following additional information must be given:

- The size-of-source effect of the KC radiation thermometers (if measured);
- The transmission of the LP3 ND filter;
- The results of the range/ gain ratio measurements for the comparison thermometers;
- Uncertainty budget identifying all components of uncertainty and their values, and the total expanded uncertainty. The budget should take the form of the template supplied in Appendix 7 and should include:
    - Uncertainty in the ITS-90 scale realisation, with all components identified;

        - Uncertainty due to HTBB window transmittance (if applicable);
        - Radiance temperature uniformity across the blackbody aperture;
        - Temperature stability of the blackbody source;
        - Effect of emissivity of the blackbody source (e.g. due to difference in wavelength between the participant reference thermometer and the wavelength of operation of the KC radiation thermometer);
    - Uncertainty due to alignment on the blackbody source;
    - Repeatability / reproducibility of the calibration measurements;
    - SSE of the KC thermometer (if measured);
    - Correction of the results to the reference source size of 25 mm diameter;
    - Resolution of the KC thermometer;
    - Any additional uncertainty components not listed above.

†In the case where the transfer thermometers are fully characterised for direct ITS-90 realisation then the following should instead be reported:

- Thermometer output/ reading after correction for the dark reading (background) for each of the comparison temperatures at the appropriate gain or range, and ND filter setting for the LP3, as specified in Appendix 6;
- The gain or range setting of the thermometer;
- The size-of-source effect of the KC radiation thermometers (if measured);
- The transmission of the LP3 ND filter;
- The results of the range/ gain ratio measurements;
- Uncertainty budget identifying all components of uncertainty and their values, and the total expanded uncertainty. The budget should take the form of the template supplied in Appendix 7 and should include
    - Uncertainty in the ITS-90 scale realisation, with all components identified;
    - SSE of the KC thermometer (if measured);
    - Resolution of the KC thermometer;
    - Any additional uncertainty components not listed above.

10.2.2 For the HTFP measurements the following information must be supplied:

- Cell identification;
- Measured ITS-90 radiance temperature of the point of inflection of the melt transition;
- The temperature profile of the high temperature furnace (if measured);
- Uncertainty budget identifying all components of uncertainty and their values, and the total expanded uncertainty. The budget should take the form of the template supplied in Appendix 7 and should include:

    - Uncertainty in the ITS-90 scale realisation, with all components identified;
    - Uncertainty in the determination of the point of inflection;
    - Repeatability of HTFP melt transition;
    - Uncertainty due to HTBB window transmittance (if applicable);
    - Uncertainty due to alignment;
    - Uncertainty due to lateral temperature uniformity/ effective source diameter, including correction of the results to the reference diameter of 3 mm;
    - Any additional uncertainty components not listed above;

(Note that it is not necessary to include uncertainty components to account for emissivity, temperature drop and other furnace effects as this will be done by the pilot laboratory – see Section 9.2.3.)

11 ANALYSIS OF FINAL RESULTS

The pilot laboratory will analyse the overall final results taking into account the measurements made at the pilot laboratory before, during and after the comparison and the results from the individual participants.

The analysis method will be as follows.

11.1 Analysis of the results of the two KC thermometers

For each of the two transfer thermometers the result (background corrected output versus the ITS-90 temperature) at each nominal comparison temperature will first be normalised [corrected] to a common comparison temperature, t_{nom}, using the sensitivity of the thermometer using Equation (1) (e.g. suppose a participant provides results for t_{90} = 1699.9 °C then the thermometer output will be corrected to give the equivalent output at t_{nom} = 1700 °C).

$$\Delta S = \Delta T \frac{c_2}{\lambda T^2} S \tag{1}$$

where ΔS is correction to be applied to the thermometer output signal S, ΔT is the difference between the participant measurement temperature T (= t_{90} in K) and the comparison temperature T_{nom} (= t_{nom} in K), c_2 is the second radiation constant and λ is the thermometer wavelength.

The results of the measurements using the transfer Cu fixed-point blackbody will be used to assess whether or not there has been any drift of the transfer thermometers over the course of the comparison. If any drift is evident for either of the thermometers then the thermometer output signal will be corrected to take into account the drift, using the change in output signal at the Cu point from the start of the comparison (the first set of measurements by the pilot). The results at each t_{nom} will be corrected using the Cu point drift and the sensitivity of the thermometer at that t_{nom} (i.e., the drift will be scaled according to t_{nom}). An additional component of uncertainty will be included to take into account either the thermometer drift or the correction due to the thermometer drift, depending on the magnitude of the drift.

Similarly the results of the LP3 ND filter transmission and the KC thermometer range and gain ratio measurements will be analysed and if there is any evidence of drift during the course of the comparison, a further uncertainty component might need to be included and/ or the results corrected to minimise the effect of the drift.

The proposed analysis method follows that given in Section 5 of [A1-3].

For each transfer thermometer the results of all the pilot laboratory measurements over the entire period of the comparison will be averaged for each t_{nom}, after correction of the results to allow for drift of the thermometer if necessary, to give one pilot result for each thermometer for each t_{nom}. The final uncertainty associated with the pilot results will include the standard deviation of the pilot measurements (after correction of results for any drift).

Where a participant has more than one result for a particular t_{nom}, as a result of carrying out repeat measurements, then the results will be averaged to give one result for that t_{nom} for that participant and this will be used in the subsequent analysis.

For each transfer radiation thermometer a reference value will be calculated for each t_{nom} using the weighted mean with cut-off of all the participant results, including the average pilot results, at that t_{nom}. The weight for each participant, including the pilot, is the inverse of the square of the standard measurement uncertainty for that participant at that t_{nom}. The cut-off values for the weights will be the average of the uncertainty values of those participants that reported uncertainties smaller than or equal to the median uncertainty of all the participants.

The weighted mean, y, will be calculated according to Equation (2):

$$y = \frac{x_1/u^2(x_1) + \cdots + x_N/u^2(x_N)}{1/u^2(x_1) + \cdots + 1/u^2(x_N)} \qquad (2)$$

where x_1 through to x_N are the results from participants 1 through to N and $u\,(x_1)$ through to $u\,(x_N)$ are the associated standard uncertainties for participants 1 through to N, which will include any additional uncertainty components such as that due to the thermometer drift (if any).

If, as is likely, the participant uncertainties are expressed in terms of temperature, then the equivalent uncertainty in terms of thermometer output signal will be calculated using the thermometer sensitivity at that temperature (Equation (1)) before calculating y using Equation (2).

The standard deviation $u(y)$ associated with y will be calculated according to Equation (3):

$$\frac{1}{u^2(y)} = \frac{1}{u^2(x_1)} + \cdots + \frac{1}{u^2(x_N)} \qquad (3)$$

A consistency check of the results will be carried out in the form of a chi-squared test by calculating the observed chi-squared value, χ^2_{obs}, according to Equation (4) and assigning the degrees of freedom, v, according to Equation (5)

$$\chi^2_{obs} = \frac{(x_1 - y)^2}{u^2(x_1)} + \cdots + \frac{(x_N - y)^2}{u^2(x_N)} \qquad (4)$$

$$\upsilon = N - 1 \qquad (5)$$

The consistency check will be regarded as failing if

$$Pr\{\chi^2(\nu) > \chi^2_{obs}\} < 0.05 \qquad (6)$$

where *Pr* denotes 'probability of'.

Provided that the consistency check does not fail then y will be accepted as the KCRV for that particular transfer thermometer with an associated standard uncertainty of $u(y)$. If the consistency check fails then an alternative method for calculating the KCRV, such as the median of all the participant results, will be considered following the procedure given in Section 6 of [A1-3].

The degrees of equivalence for each participant for each thermometer and for each t_{nom} will be calculated using the difference between the result of that participant and the KCRV for that particular thermometer at that t_{nom} and the uncertainty of the difference, which will be the participant uncertainty combined with the uncertainty of the KCRV. The degrees of equivalence between each pair of participants will also be calculated in a similar way.

Finally, the degrees of equivalence for each participant, both in relation to the KCRV and between each pair of participants, will be converted to be in terms of equivalent temperature differences along with the associated uncertainties, again in terms of temperature.

The final result for each participant will therefore be, for each thermometer, the difference from the KCRV for that thermometer and the other participants, along with the overall combined expanded (k = 2) uncertainty of the comparison at that temperature, which will include the participant uncertainty, the uncertainty in the KCRV value and any other associated uncertainties of the comparison, for example due to thermometer drift. All the differences and the associated uncertainties will be expressed in terms of temperature.

The use of two KCRVs, one for each transfer thermometer, will avoid potential difficulties that could arise should an average KCRV be specified but one of the transfer thermometers performs less well than the other during the comparison, for example due to drift. If appropriate, the degrees of equivalence for each participant for each transfer thermometer can subsequently either be combined by taking the average or the larger values used to provide a single degree of equivalence for future regional comparison linkage.

11.2 Analysis of the results of the HTFP cells

For each type of cell (Ni-C or Co-C, Ru-C, WC-C) the results of all the pilot laboratory measurements over the entire period of the comparison will be averaged to give one pilot result for each cell type. The final uncertainty associated with the pilot results will include the standard deviation of the pilot measurements.

For each type of cell a reference value will be calculated using the weighted mean with cut-off of all the participant results (namely the ITS-90 radiance temperatures of the point of inflection of the melt transitions), including the average pilot results. The weight for each participant, including the pilot, is the inverse of the square of the standard measurement uncertainty for that participant at the cell melt temperature. The cut-off values for the weights will be as described in Section 11.1 above for the radiation thermometer measurements. The reference value for each cell will be calculated according to Equation (2). The uncertainty of the reference value will be calculated according to Equation (3). A consistency check will be carried out as per Equations (4), (5) and (6) and assuming that the check does not fail then the calculated reference value (weighted mean with cut-off) will be taken as the final reference value for that cell, along with its associated uncertainty.

It is assumed that the cells will not drift during the comparison. However, if the results of the repeat measurements at the pilot laboratory show drift (as determined from the cross-comparison measurements between the circulating cell and the reference cell held at the pilot) then a correction will need to be applied to the affected participant results with the corresponding uncertainty of the correction being included in the overall uncertainty of the reference value(s)

The degrees of equivalence for each participant for each cell will be calculated using the difference between the result of that participant and the reference value for that particular cell and the uncertainty of the difference, which will be the participant uncertainty combined with the uncertainty of the reference value. The degrees of equivalence between each pair of participants will also be calculated in a similar way.

12 REFERENCES

[A1-1] Lowe, D and Machin, G, Evaluation of methods for characterizing the melting curves of a high temperature cobalt–carbon fixed point to define and determine its melting temperature, *Metrologia*, 2012, **49(3)**, pp 189-199

[A1-2] Castro, P, Machin, G, Bloembergen, P, Lowe, D, Thermodynamic Temperatures of High Temperature Fixed Points: Uncertainties due to Temperature Drop and Emissivity, to be published in the *International Journal of Thermophysics*

[A1-3] Cox, M G, The evaluation of key comparison data, *Metrologia*, 2002, **39**, pp 580 – 595.

[A1-4] Fischer, J et al, Uncertainty budgets for realisation of scales by radiation thermometry, CCT-WG5 document, CCT/03-03, 2003

APPENDIX 1 – CIRCULATION TIMETABLE

NMI	Measurement period	Instruments to be received at next lab by
NPL (pilot)	to end Sept 14	mid-Oct 2014
NMIJ	to end Jan 15	end Mar 2015
NIM	end Mar 15 to end Apr 15	mid May 2015
KRISS	mid-June 15 to mid-July 15	end July 2015
NPL (pilot)	August 15	mid-Sept 2015
NRC	mid-Sept 15 to mid-Oct 15	end Oct 2015
NIST	Nov 15	mid-Dec 2015
NPL (pilot)	Mid-Dec to end Jan 16	Mid Feb 2016
VNIIM	Mid-Feb 16 to mid-Mar 16	end Mar 2016
NPL (pilot)	Apr 16	mid-May 2016
LNE-Cnam	Mid-May 16 to mid-June 16	end June 2016
PTB	July16	mid-Aug 2016
CEM	Mid-Aug to end Sept	Mid Sept 2016
NPL (pilot)	Mid-Sept 16 to mid-Nov 16	-

Table A1-7: The timetable of the comparison

* If possible the consignment should be sent to NIM earlier, and NMIs immediately following should anticipate some variation (slippage) in the schedule dates to try and accommodate potential delays with getting the goods through Chinese customs.

APPENDIX 2 – OPERATIONAL GUIDELINES FOR THE TRANSFER INSTRUMENTS

A summary of the steps necessary for the correct setting-up, use and re-packing for each of the two transfer radiation thermometers and the transfer copper fixed point is given below. Note that this includes key points only. For full operating instructions please refer to the instruction manuals supplied with the instruments. Additionally videos, prepared by NMIJ, for the Chino radiation thermometer and the Chino transfer copper fixed point, are available on-line; see

https://skydrive.live.com/redir.aspx?cid=0e97d241fa436fea&page=self&resid=E97D241FA436FEA!105&parid=E97D241FA436FEA!103&authkey=!Au5ltrffW4NfXmA&Bpub=SDX.SkyDrive&Bsrc=Share

Note however that the assembly/ disassembly instructions for the NRC Cu fixed point are different to those described in the video – see Section 3.1 in this Appendix.

1. User instructions for the LP3

1.1 On receipt:

1. Wait for instrument to acclimatise to room temperature before starting to unpack;
2. Check that all items and accessories are present. Note how the items are packed into the crate so that they can be repacked in the same manner;
3. Insert the eyepiece into the rear of the thermometer, removing the plastic protection cover on the eyepiece holder first, and lock into position;
4. Remove the locking screw from just under the objective tube on the front of the casing and replace with the smaller screw supplied to block to hole;
5. Unlock the objective lens adjustment control on the side of the casing and adjust the position of the lens so that a target at 750 mm from the front of the thermometer casing appears sharply in focus. Lock the lens tube in position;
6. Plug the power supply unit appropriate to the laboratory mains voltage (230V or 110 V) into the back of the thermometer and plug the power supply unit into the mains;
7. Turn the power on using the switch on the power supply unit. Allow the thermometer to warm up for at least 2 hours (until the cell is stabilised at 29.5 °C) before starting measurements.

1.2 Shipment to the next participant:

1. Replace the lens cap on the thermometer objective;
2. Unplug, switch off and disconnect the power cable;
3. Unlock the objective lens tube using the locking screw at the side of the thermometer case and slide it completely back towards the front plate, then lock in position;
4. Remove the small screw from just under the objective lens tube on the front of the case and replace with the larger locking screw to keep the objective lens firmly in place during shipping;
5. Unlock and remove the eyepiece and replace the plastic protection cover onto the eyepiece holder;
6. Pack everything carefully into the packing crate in the same manner in which the instrument arrived.

2. User instructions for the Chino radiation thermometer

2.1 On receipt and setting up for use:

1. Wait for instrument to acclimatise to room temperature before starting to unpack;
2. Check that all items and accessories are present. Note how the items are packed into the crate so that they can be repacked in the same manner;
3. Connect the signal cable to the back of the thermometer. Connect the output terminals to two digital voltmeters, one for reading the thermometer radiance signal output, and the other for monitoring the instrument internal temperature;
4. Connect an AC power cable to the DC power supply unit of the thermometer then connect the DC power supply cable to the back of the thermometer;
5. Plug the power supply into the mains. The LED on the rear of the thermometer will light up red, and will change to green when the thermometer has warmed up;
6. Select the appropriate gain using the knob at the back of the instrument.
7. Allow the thermometer to warm up for at least half a day before starting measurements.

2.2 Shipment to the next participant:

1. Replace the lens cap on the thermometer objective;
2. Unplug and disconnect the power cable from the back of the thermometer;
3. Disconnect the signal cable from the back of the thermometer;
4. Pack everything carefully into the packing crate in the same manner in which the instrument arrived.

3. User instructions for the Chino copper fixed point source

3.1 On receipt and setting up for use:

1. Wait for instrument to acclimatise to room temperature before starting to unpack;
2. Check that all items and accessories are present. Note how the items are packed into the crate, and how the fixed point components are packed in the inner cardboard box, so that they can be repacked in the same manner;
3. Unscrew and remove the ‘top plate’ cover of the furnace;
4. Unscrew and remove the metal protection plate at the rear of the furnace;
5. Remove the rear alumina insulation block;
6. Remove the plastic packing material;
7. <u>Wearing gloves</u> assemble the fixed point unit within the soaking tube according to the diagram and photograph in the accompanying documentation; namely insert the components in the following order from back to front within the tube:

   Insulation block 3; buffer; crucible; alumina aperture; graphite ring; insulation block 2

   Notes: The mark on the crucible assembly should face upwards. Hold the fixed-point unit carefully with both hands and do not hold just by the thin tube as this could result in breakage.

8. Put the two soaking tube holders on to the front and back of the soaking tube, then slide all the components into the furnace in the order: insulation block 1-1; insulation block 1-2; fixed point unit; insulation block 4;
9. Put back and screw on the metal protection plate;
10. Connect the rubber hose on to the centre tube of the metal protecting plate;

11. Screw into place the ‘top plate’ cover of the furnace
12. IMPORTANT: Check that the correct fuse is installed for the mains supply voltage: 5 A for 230 VAC and 10 A for 110 VAC;
13. Connect the argon gas supply to the inlet on the bottom rear of the furnace and connect the power supply cable
14. Ensure that the ‘fixed point pin’ is placed in the Cu fixed point position.

3.2 Fixed point realisation

1. Set the argon gas flow rate to maximum on the regulator and let it flow for a few minutes, then set the flow rate to 0.2 to 0.25 litres/ minute on the flow regulator;
2. Turn on the mains power supply switch;
3. Set the correct pattern (program) number for the Cu fixed point (refer to the instruction manual and/ or the video for full details of how to do this, and how to subsequently run the program). The correct pattern is number 1;
4. Press the heater on/ off switch and then run the program. The argon gas will start to flow automatically when the furnace reaches the appropriate temperature (230 to 250 °C); check that the gas flow light is green and also check the flow periodically;
5. The melt is realised automatically using the pre-set program. When this is complete the freeze should be initiated (again refer to the full operating instructions and/ or video);
6. Once the freeze is complete the cycle can be repeated if necessary;
7. At the end of the measurements switch the heater on/ off switch off;
8. DO NOT turn off the mains power supply switch until the argon gas automatically shuts off, and DO NOT turn off the argon gas supply until the furnace reaches the temperature for automatic gas shut-off.

3.3 Shipment to the next participant:

Notes: Do not ship the furnace with the fixed-point cell inside the furnace, and make sure that the power cable is disconnected from the furnace and the furnace is cold before removing the top cover.

1. Disconnect the argon gas supply tube;
2. Unscrew and open the ‘top plate’ cover of the furnace;
3. Disconnect the rubber tube from the inlet of the protection plate at the rear of the furnace;
4. Unscrew and remove the back protection plate;
5. Remove the alumina insulation block and the fixed point cell assembly;
6. Replace the plastic packing material into the furnace tube;
7. Re- insert the alumina insulation block and replace and screw on the back protection plate;
8. Screw the ‘top plate’ into place;
9. Carefully disassemble the fixed point unit (the reverse of Section 3.1 points 6) and 7)) and re-pack all the components in bubble wrap within the cardboard box;
10. Replace all the items into the shipping crate in the same manner as they arrived.

APPENDIX 3 – HTFP MEASUREMENTS

1 Preparing the furnace for the HTFP measurements

Prior to the start of the measurement campaign, in order to minimise the risk of contamination of the HTFPs, the furnace and its component parts should be baked out.

By way of precaution, the furnace should be considered **heavily contaminated,** if it has ever been used for filling of a fixed point cell, or if it has been used extensively for realising fixed points of high vapour pressure, such as Pd-C, Cu, Cr_3C_2-C or TiC-C. In this situation participants should consider more extensive replacement of furnace parts and/or extra baking to ensure these metals cannot possibly contaminate the HTFP.

Contamination of a cell by a polluted heater or furnace insulator can happen not only during the filling process, but also during the normal implementation of the cell. This is why the bake-out procedure described below must be followed at the start of the measurement campaign.

In addition, participants will need to have a set of cell holders (if applicable for their furnace type) and insulation material dedicated to each *type* of fixed-point. All components that touch the cell directly should be replaced when the cell *type* is changed. Any new materials need baking out (according to the procedure below) before use. As long as they are used only with one type of fixed-point material, this can happen prior to the start of the measurement campaign. Such materials may be used for other cells (i.e., cells not participating in this measurement campaign) prior to the measurement campaign – but only cells of the same type. So, taking Ru-C as an example, materials that touch the cell (insulation, cell holders, etc.) used for Ru-C cells can only be used with other Ru-C cells. Such materials need baking out according to the procedure for Ru-C (below) before their first use, which may be before the measurement campaign, or before the participant’s own measurements with different Ru-C cells. The same is true for the other fixed-point materials.

If all materials have been purified before the start of the measurement campaign, and measurements are made in the order WC-C, Ru-C, Ni-C-X or Co-C-X, then during the measurement campaign only a single bake-out is required at the start at the WC-C temperature. Participants may choose to bake-out their furnace between cell types.

The following sections describe the bake-out procedure, if needed, for each furnace and at different temperatures. If only one bake-out is used, then this should be the bake-out for WC-C at the start of the measurements.

<u>For *VNIIOFI/Vega HTBB* type furnaces:</u>

To prevent contamination of the fixed-point cells the following steps should be followed. Note, however, that due to the high temperature of the WC-C melting point no final baking temperature is prescribed. Instead participants should take whatever steps they deem necessary for their particular furnace to minimise the risk of cross-contamination of the cells.

For Ru-C, Ni-C-X or Co-C-X

a. The furnace, equipped with a quartz window or solid plate, must be baked at 2000 °C for approximately half an hour under vacuum and then at 2100 °C under pure argon purge (obtained by slightly unfastening the window) for a minimum time of 30 min.

b. If any deposition is observed on the quartz window/solid plate that cannot be removed by just a blast of dry air then the window/solid plate should be cleaned using an alcohol soaked wipe and the procedure in a. above, should be continued until no more deposition is observed. The furnace is then ready for installation of the cell.

For WC-C

a. The furnace, equipped with a quartz window, must be baked at 2000 °C for approximately half an hour under vacuum. Participants should then take whatever additional steps (e.g. baking) they deem appropriate to ensure the chance of contamination is minimised.

<u>For *Nagano/Chino* type furnaces:</u>

To prevent contamination of the fixed-point cells the following steps should be followed:

a. The furnace must be baked at 2000 °C under vacuum for at least three hours for all cell types. In the case of WC-C participants should take whatever additional steps (e.g. baking) they deem appropriate to ensure that the chance of cross-contamination is minimised.
b. If any contamination is observed on the quartz window that cannot be removed by air blow but requires wiping with an alcohol-humidified towel, the procedure in a. above should be continued until no more deposition is observed.

<u>For *Thermo Gauge* type furnaces:</u>

To prevent contamination of the fixed point cells the following steps should be followed:

a. the heating tube must be replaced by a new one for each cell type.
b. The furnace is baked under argon purge for at least three hours at 2000 °C before using the Ni-C–X or Co-C-X and Ru-C cells. For the WC-C cells participants should take whatever steps (e.g. baking) they deem appropriate to ensure that the chance of cross-contamination is minimised.

IMPORTANT : Information on the use of the furnace prior to the comparison measurements (such as use for filling of cells), the cleaning procedures performed, and any indication as to the cleanliness of the furnace as a result of cleaning (e.g. observation of deposits and their disappearance) should be included in the measurement report.

2 Furnace insulation, cell holder and optimum cell position

The furnace should be made as uniform in temperature as possible around the cell. This may require the use of appropriate insulation (graphite felt, or possibly CC-sheet) around the cell, along with baffles placed both before and after the cell in the furnace tube.

It is recommended that participants test their furnace to determine the optimum arrangement of insulating materials and baffles. The HTFP cell should be placed in the most uniform part of the furnace to ensure even heating of the entire ingot. Determining the optimum position requires some preparative measurements. Initial tests should be performed <u>**using an alternative (in-house) cell**</u> by ‘trial-and-error’. However it is recognised that a few measurements may be needed with the cells actually used for the comparison, as the optimum position may differ from cell to cell. These measurements should be kept to an absolute minimum and included in the total number of cycles for which the cell is used (see also Section 10.1).

The best location is identified where the melting plateau is flattest, and longest, with a clean entrance into and exit from the melt, neither of which should be ‘rounded’.

There are some guidance papers concerned with setting up furnaces for HTFP measurements in the literature, including [A3-1 - A3-3].

3 Furnace operation

In order to avoid breakage of the cells during the comparison the ramp rates for heating the furnace from room temperature should be:

- ≤ 300 K/ hr for Ni-C-X
- ≤ 1000 K/ hr for Co-C-X
- < 1200 K/hr for Ru-C and WC-C

The ramp rates for cooling the furnace back to room temperature after measurements should be:

- < 400 K/hr for Ni-C-X
- < 700 K/ hr for Co-C-X
- < 1000 K/hr for Ru-C and WC-C

4 References

[A3-1] Khlevnoy, B, Sakharov, M, Ogarev, S, Sapritsky, V, Yamada, Y and Anhalt, K 2008 Investigation of Furnace Uniformity and its Effect on High-Temperature Fixed-Point Performance *International Journal of Thermophysics* **29**(**1**) 271-284

[A3-2] Salim, S G R, Woolliams, E R, Dury, M, Lowe, D H, Pearce, J V, Machin, G, Fox, N P, Sun, T and Grattan, K T V 2009 Furnace uniformity effects on Re-C fixed-point melting plateaux *Metrologia* **46**(**1**) 33-42

[A3-3] Bourson, F, Briaudeau, S, Rougié, B and Sadli, M 2012 Determination of the furnace effect of two high-temperature furnaces on metal-carbon eutectic points. *Proceedings of ITS-9* AIP Conf. Proc. **1552** , 380 (20 AIP Conf. Proc. 1552 , 380 (2013) 13)

APPENDIX 4 – RECEIPT OF INSTRUMENTATION

Receiving NMI:

Date:

Artefact/ component	Received (yes/ no)	Damage (yes/ no)	Nature of damage
LP3			
Eyepiece			
Lens cap			
Objective extension ring			
110 V power unit			
230 V power unit			
RS232 cable			
Operating manual			
LP3DE.exe software			
Chino thermometer			
Lens cap			
DC power unit			
DC power cable			
Signal cable			
Lens blower			
Operating manual			
Power unit manual			
Cu fixed point			
Insulation block 1-1			
Insulation block 1-2			
Insulation block 4			
2 x Soaking tube holder			
Insulation block 2			
Graphite ring			
Alumina aperture			
Fixed-point crucible			
Buffer			
Insulation block 3			
Soaking tube			
Rubber gas tube			
Fuses (5A and 10A)			
Operating manual			
Ni-C-X or Co-C-X fixed point			
Ru-C fixed point			
WC-C fixed point			

APPENDIX 5 – INITIAL STABILITY MEASUREMENT CHECK USING THE TRANSFER COPPER FIXED POINT

Participant:

Date of check (day, month, year):

Thermometer identification	Gain/ range	Output signal† /V or /A	Ambient temperature/ °C	Thermometer internal temperature/ °C
LP3	R1			
Chino	L			

The working distance (distance from the thermometer to the fixed point aperture) should be as prescribed in Section 4, namely 700 mm (Chino thermometer) or 750 mm (LP3) from the fixed point aperture to the front of the thermometer casing.

† The reported output signal should be the average of the signals obtained during the central half of two freezing plateaux for each thermometer, and must be corrected for the dark reading (background).

(Note: the results of the second stability check (before onward shipment of instruments) should be included in the laboratory measurement report.)

APPENDIX 6 – CALIBRATION RESULTS FOR THE KC RADIATION THERMOMETERS

1) RESULTS FOR THE LP3

Nominal temperature / °C	ITS-90 temperature / °C	Output signal† / A	Range setting	ND filter	LP3 internal temperature / °C	Ambient temperature / °C	U (k = 2) / °C
960			R1	No			
1100			R1	No			
1300			R1	No			
1500			R2	No			
1700			R2	No			
1800			R2	No			
2000			R2	No			
2200			R2	No			
2400			R2	No			
2500			R2	Yes			
2600			R2	Yes			
2800			R2	Yes			
2900			R2	Yes			
3000			R2	Yes			
*							
*							
*							

* Repeat temperatures; fill in as appropriate

Working distance (distance from front of thermometer casing to blackbody)

= …………….. mm

Aperture size of HTBB = …………….. mm

† the output signals must be corrected for dark reading (background). For the measurements above 2400 °C the output signals should be those obtained with the filter in place, i.e., do not adjust the results to take into account the filter transmission.

2) RESULTS FOR THE CHINO THERMOMETER

Nominal temperature / °C	ITS-90 temperature / °C	Output signal† / V	Gain setting	Chino internal temperature / °C	Ambient temperature / °C	U(k = 2) / °C
960			L range			
1100			L range			
1300			L range			
1500			L range			
1700			L range			
1800			L range			
2000			M range			
2200			M range			
2400			M range			
2500			H range			
2600			H range			
2800			H range			
2900			H range			
3000			H range			
*						
*						
*						

* Repeat temperatures; fill in as appropriate

Working distance (distance from front of thermometer casing to blackbody)
= …………….. mm

Aperture size of HTBB = …………….. mm

† the output signals must be corrected for dark reading (background)

3) RESULTS FOR THE HTFP CELLS

Cell	Day	Melt number†	Melt transition step size / K	ITS-90 radiance temperature of poi of the melt / °C	U (k = 2) / °C
Ni-C-X	Day 1	2			
or Co-C-X		3			
		4			
		Average day 1			
Ni-C-X	Day 2	2			
or Co-C-X		3			
		4			
		Average day 2			
Ni-C-X or Co-C-X		**Overall average**			
Ru-C	Day 1	2			
		3			
		4			
		Average day 1			
Ru-C	Day 2	2			
		3			
		4			
		Average day 2			
Ru-C		**Overall average**			
WC-C	Day 1	2			
		3			
		4			
		Average day 1			
WC-C	Day 2	2			
		3			
		4			
		Average day 2			
WC-C		**Overall average**			

† As stated in Section 9.2.2, the first melt of each day is not to be included in the analysis.

APPENDIX 7 – SAMPLE UNCERTAINTY COMPONENTS

1) Example of uncertainty components to be included for the radiation thermometer calibration

Uncertainty in the reference thermometer (uncertainty in ITS-90 realisation)	Reference fixed point uncertainty
	Reference fixed point measurement
	Spectral responsivity measurement
	SSE measurement and correction
	Nonlinearity
	Drift
	Ambient conditions
	Gain ratios
	Repeatability
Uncertainty in the comparison	HTBB window transmittance (if applicable)
	HTBB uniformity
	HTBB temperature stability
	HTBB emissivity
	HTBB effective source diameter and correction to reference diameter of 25 mm)
	Transfer device alignment on HTBB
	Transfer device short term stability
	Transfer device SSE
	Digital voltmeter
	Repeatability

2) Example of uncertainty components to be included for the HTFP measurements

Uncertainty in the reference thermometer (uncertainty in ITS-90 realisation)	Reference fixed point uncertainty
	Reference fixed point measurement
	Spectral responsivity measurement
	SSE measurement and correction
	Nonlinearity
	Drift
	Ambient conditions
	Gain ratios
	Repeatability
Uncertainty in the measurements	HTBB window transmittance (if window is used)
	HTBB effective source diameter and correction to reference diameter of 3 mm
	Alignment on HTFP aperture
	Determination of the point of inflection
	Repeatability

16 APPENDIX 2 –THE PARTICIPANT RESULTS FOR THE LP3

Table 118 - NPL September 2014 calibration of the LP3 thermometer

t_{nom}/ °C	t_{90}/ °C	Iph/ A	Iph corrected to t_{nom}/ A	Iph corrected for range and ND filter/ A	Correction for drift/ °C	Iph corrected for range, ND filter and drift/ A	U_{lab} (k = 2)/ °C	U_{lab} including drift* (k = 2)/ °C
960	960.3	4.22298E-11	4.20242E-11	4.20423E-11	0.00	4.20423E-11	0.21	0.21
1100	1100.1	2.60876E-10	2.60532E-10	2.60645E-10	0.00	2.60645E-10	0.28	0.28
1300	1300.1	2.01550E-09	2.01386E-09	2.01473E-09	0.00	2.01473E-09	0.34	0.34
1500	1500.0	9.80727E-09	9.80653E-09	9.80653E-09	0.00	9.80653E-09	0.42	0.42
1700	1700.3	3.47083E-08	3.46544E-08	3.46544E-08	0.00	3.46544E-08	0.56	0.56
1800	1800.5	5.95881E-08	5.94331E-08	5.94331E-08	0.00	5.94331E-08	0.63	0.63
2000	2000.3	1.52056E-07	1.51880E-07	1.51880E-07	0.00	1.51880E-07	0.74	0.75
2200	2200.0	3.32840E-07	3.32830E-07	3.32830E-07	0.00	3.32830E-07	0.93	0.93
2400	2400.4	6.50586E-07	6.49723E-07	6.49723E-07	0.00	6.49723E-07	1.11	1.12
2500	2500.1	1.07930E-07	1.07888E-07	8.75072E-07	0.00	8.75072E-07	1.21	1.22
2600	2600.2	1.42413E-07	1.42350E-07	1.15460E-06	0.00	1.15460E-06	1.34	1.35
2800	2801.1	2.35662E-07	2.35065E-07	1.90660E-06	0.00	1.90660E-06	1.51	1.52
2900	2900.7	2.95262E-07	2.94825E-07	2.39132E-06	0.00	2.39132E-06	1.49	1.49
3000	2999.6	3.64380E-07	3.64705E-07	2.95811E-06	0.00	2.95811E-06	1.49	1.49
1300	1299.8	2.01028E-09	2.01339E-09	2.01426E-09	0.00	2.01426E-09	0.34	0.34
1700	1700.1	3.46649E-08	3.46420E-08	3.46420E-08	0.00	3.46420E-08	0.56	0.56
2400	2399.7	6.49210E-07	6.49806E-07	6.49806E-07	0.00	6.49806E-07	1.11	1.12

* the drift uncertainty was calculated from the semi-range of the maximum difference between the repeat measurements of the transfer Cu cell (±0.020 °C – see Table 7), treated as a type B uncertainty (divided by √3) and scaled as the ratio of the squares of the temperatures in kelvin.

Table 119 - NPL August 2015 calibration of the LP3 thermometer

t_{nom}/ °C	t_{90}/ °C	Iph/ A	Iph corrected to t_{nom}/ A	Iph corrected for range and ND filter/ A	Correction for drift/ °C	Iph corrected for range, ND filter and drift/ A	dT from start/ °C	U_{lab} (k = 2)/ °C	U_{lab} including drift* (k = 2)/ °C
960	960.1	4.21150E-11	4.20434E-11	4.20639E-11	0.11	4.19972E-11	-0.07	0.32	0.33
1100	1100.0	2.60891E-10	2.60878E-10	2.61006E-10	0.14	2.60591E-10	-0.02	0.35	0.36
1300	1300.0	2.01628E-09	2.01557E-09	2.01656E-09	0.18	2.01336E-09	-0.06	0.42	0.43
1500	1499.8	9.81045E-09	9.82209E-09	9.82209E-09	0.23	9.80651E-09	0.00	0.50	0.51
1700	1699.9	3.46818E-08	3.46951E-08	3.46951E-08	0.28	3.46400E-08	-0.04	0.62	0.63
1800	1799.8	5.94555E-08	5.95151E-08	5.95151E-08	0.31	5.94207E-08	-0.04	0.70	0.72
2000	1999.9	1.51892E-07	1.51988E-07	1.51988E-07	0.37	1.51747E-07	-0.20	0.82	0.84
2200	2199.8	3.33227E-07	3.33431E-07	3.33431E-07	0.44	3.32902E-07	0.06	1.03	1.05
2400	2399.7	6.49708E-07	6.50356E-07	6.50356E-07	0.51	6.49324E-07	-0.22	1.21	1.24
2500	2498.7	1.07832E-07	1.08225E-07	8.75997E-07	0.55	8.74607E-07	-0.18	1.34	1.37
2600	2598.8	1.42322E-07	1.42770E-07	1.15562E-06	0.59	1.15378E-06	-0.26	1.47	1.50
2800	2799.5	2.35600E-07	2.35855E-07	1.90907E-06	0.68	1.90604E-06	-0.13	1.32	1.36
2900	2899.6	2.95456E-07	2.95738E-07	2.39378E-06	0.72	2.38998E-06	-0.25	2.06	2.09
3000	2999.8	3.65995E-07	3.66134E-07	2.96358E-06	0.77	2.95888E-06	0.13	3.07	3.09
960	959.9	4.19792E-11	4.20178E-11	4.20383E-11	0.11	4.19716E-11	-0.12	0.32	0.33
2200	2199.6	3.33050E-07	3.33536E-07	3.33536E-07	0.44	3.33006E-07	0.15	1.03	1.05
2500	2499.8	1.08217E-07	1.08284E-07	8.76480E-07	0.55	8.75089E-07	0.01	1.34	1.37
2600	2599.4	1.42607E-07	1.42856E-07	1.15631E-06	0.59	1.15447E-06	-0.04	1.47	1.50
2800	2800.0	2.35827E-07	2.35809E-07	1.90870E-06	0.68	1.90567E-06	-0.21	1.32	1.36
3000	2999.6	3.65967E-07	3.66257E-07	2.96457E-06	0.77	2.95987E-06	0.29	3.07	3.09

*the drift uncertainty was calculated from the semi-range of the maximum difference between the repeat measurements of the transfer Cu cell (±0.055 °C – see Table 7), treated as a type B uncertainty (divided by √3) and scaled as the ratio of the squares of the temperatures in kelvin.

Table 120 - NPL October 2016 calibration of the LP3 thermometer

t_{nom}/ °C	t_{90}/ °C	Iph/ A	Iph corrected to t_{nom}/ A	Iph corrected for range and ND filter/ A	Correction for drift/ °C	Iph corrected for range, ND filter and drift/ A	dT from start/ °C	U_{lab} (k = 2)/ °C	U_{lab} including drift* (k = 2)/ °C
960	960.0	4.20982E-11	4.21167E-11	4.21434E-11	0.15	4.20515E-11	0.02	0.31	0.33
1100	1100.1	2.61739E-10	2.61368E-10	2.61534E-10	0.19	2.60964E-10	0.10	0.34	0.36
1300	1300.2	2.02323E-09	2.01903E-09	2.02031E-09	0.24	2.01590E-09	0.08	0.39	0.42
1500	1500.1	9.84495E-09	9.83916E-09	9.83916E-09	0.31	9.81771E-09	0.16	0.47	0.51
1700	1700.1	3.47810E-08	3.47547E-08	3.47547E-08	0.38	3.46789E-08	0.16	0.59	0.63
1800	1800.3	5.97640E-08	5.96733E-08	5.96733E-08	0.42	5.95432E-08	0.36	0.79	0.83
2000	2000.2	1.52611E-07	1.52485E-07	1.52485E-07	0.51	1.52152E-07	0.42	0.79	0.85
2200	2200.2	3.34672E-07	3.34373E-07	3.34373E-07	0.60	3.33644E-07	0.68	0.91	0.98
2400	2400.2	6.52660E-07	6.52157E-07	6.52157E-07	0.70	6.50735E-07	0.49	1.07	1.15
2500	2500.1	1.08824E-07	1.08796E-07	8.78522E-07	0.76	8.76606E-07	0.61	1.16	1.24
2600	2600.2	1.43624E-07	1.43537E-07	1.15906E-06	0.81	1.15653E-06	0.63	1.28	1.36
2800	2800.9	2.37156E-07	2.36668E-07	1.91109E-06	0.93	1.90692E-06	0.07	1.69	1.78
2900	2902.8	2.98333E-07	2.96508E-07	2.39430E-06	0.99	2.38908E-06	-0.42	3.29	3.34
3000	3003.5	3.69176E-07	3.66475E-07	2.95927E-06	1.06	2.95282E-06	-0.86	4.71	4.75
960	960.0	4.21325E-11	4.21295E-11	4.21563E-11	0.15	4.20642E-11	0.04	0.31	0.33
1800	1800.0	5.96116E-08	5.96164E-08	5.96164E-08	0.42	5.94874E-08	0.18	0.79	0.83
2600	2600.1	1.43564E-07	1.43516E-07	1.15889E-06	0.81	1.15637E-06	0.58	1.28	1.36

*the drift uncertainty was calculated from the semi-range of the maximum difference between the repeat measurements of the transfer Cu cell (±0.093 °C – see Table 7), treated as a type B uncertainty (divided by √3) and scaled as the ratio of the squares of the temperatures in kelvin.

Table 121 - NPL January 2018 calibration of the LP3 thermometer

t_{nom}/ °C	t_{90}/ °C	Iph/ A	Iph corrected to t_{nom}/ A	Iph corrected for range and ND filter/ A	Correction for drift/ °C	Iph corrected for range, ND filter and drift/ A	dT from start/ °C	U_{lab} (k = 2)/ °C	U_{lab} including drift* (k = 2)/ °C
960	960.2	4.24039E-11	4.22885E-11	4.23091E-11	0.41	4.20551E-11	0.02	0.46	0.47
1100	1100.2	2.62771E-10	2.62234E-10	2.62362E-10	0.51	2.60787E-10	0.05	0.59	0.59
1300	1300.2	2.02734E-09	2.02354E-09	2.02452E-09	0.67	2.01237E-09	-0.11	0.76	0.76
1500	1500.1	9.87141E-09	9.86179E-09	9.86179E-09	0.85	9.80258E-09	-0.05	0.84	0.84
1700	1700.0	3.48148E-08	3.48230E-08	3.48230E-08	1.06	3.46139E-08	-0.17	0.99	0.99
1800	1800.3	5.97901E-08	5.97124E-08	5.97124E-08	1.17	5.93539E-08	-0.25	1.10	1.10
2000	2000.3	1.52720E-07	1.52540E-07	1.52540E-07	1.40	1.51624E-07	-0.39	1.25	1.25
2200	2200.4	3.35018E-07	3.34511E-07	3.34511E-07	1.66	3.32503E-07	-0.26	1.53	1.53
2400	2400.3	6.52794E-07	6.52200E-07	6.52200E-07	1.94	6.48284E-07	-0.73	1.79	1.80
2500	2500.3	1.09019E-07	1.08935E-07	8.78365E-07	2.09	8.73091E-07	-0.78	1.99	1.99
2600	2600.4	1.43986E-07	1.43836E-07	1.15978E-06	2.24	1.15281E-06	-0.57	2.13	2.13
2800	2800.6	2.37809E-07	2.37489E-07	1.91492E-06	2.56	1.90342E-06	-0.70	2.53	2.54
960	960.1	4.22935E-11	4.22586E-11	4.22792E-11	0.41	4.20269E-11	-0.02	0.46	0.46
2000	2000.3	1.52867E-07	1.52669E-07	1.52669E-07	1.40	1.51753E-07	-0.19	1.42	1.42
2600	2600.5	1.44042E-07	1.43849E-07	1.15988E-06	2.24	1.15291E-06	-0.53	2.16	2.16

*the drift uncertainty was calculated from the semi-range of the maximum difference between the repeat measurements of the transfer Cu cell (±0.018 °C – see Table 7), treated as a type B uncertainty (divided by √3) and scaled as the ratio of the squares of the temperatures in kelvin.

Table 122 - NPL January 2020 calibration of the LP3 thermometer

t_{nom}/ °C	t_{90}/ °C	Iph/ A	Iph corrected to t_{nom}/ A	Iph corrected for range and ND filter/ A	Correction for drift/ °C	Iph corrected for range, ND filter and drift/ A	dT from start/ °C	U_{lab} (k = 2)/ °C	U_{lab} including drift* (k = 2)/ °C
960	960.4	4.28036E-11	4.25610E-11	4.25835E-11	0.54	4.22469E-11	0.34	0.27	0.28
1100	1100.1	2.64528E-10	2.64126E-10	2.64266E-10	0.67	2.62177E-10	0.51	0.34	0.34
1300	1300.3	2.04503E-09	2.04021E-09	2.04130E-09	0.88	2.02516E-09	0.60	0.48	0.49
1500	1499.7	9.91598E-09	9.93786E-09	9.93786E-09	1.12	9.85929E-09	0.78	0.59	0.60
1700	1700.3	3.51610E-08	3.51079E-08	3.51079E-08	1.39	3.48303E-08	0.94	0.68	0.69
1800	1800.5	6.03364E-08	6.01958E-08	6.01958E-08	1.54	5.97199E-08	0.96	0.81	0.82
2000	2000.4	1.53970E-07	1.53708E-07	1.53708E-07	1.85	1.52493E-07	0.96	0.87	0.88
2200	2200.5	3.37643E-07	3.37014E-07	3.37014E-07	2.18	3.34349E-07	1.29	1.01	1.02
2400	2400.7	6.58039E-07	6.56669E-07	6.56669E-07	2.55	6.51478E-07	0.88	1.19	1.20
2500	2500.5	1.10055E-07	1.09892E-07	8.83761E-07	2.75	8.76774E-07	0.70	1.30	1.31
2600	2600.8	1.45326E-07	1.45027E-07	1.16632E-06	2.95	1.15710E-06	0.84	1.43	1.45
2800	2800.5	2.39826E-07	2.39544E-07	1.92643E-06	3.37	1.91120E-06	1.06	1.53	1.54
2900	2900.5	3.00867E-07	3.00522E-07	2.41682E-06	3.60	2.39771E-06	1.25	1.66	1.67
3000	3001.1	3.72835E-07	3.72023E-07	2.99184E-06	3.83	2.96818E-06	1.69	2.13	2.14
960	960.0	4.25683E-11	4.25414E-11	4.25639E-11	0.54	4.22274E-11	0.31	0.27	0.28
2000	2000.1	1.53653E-07	1.53564E-07	1.53564E-07	1.85	1.52350E-07	0.74	0.87	0.88
2600	2600.8	1.45303E-07	1.44981E-07	1.16595E-06	2.95	1.15673E-06	0.72	1.43	1.45

* Only one measurement of the transfer Cu cell had been carried out. Therefore, the drift uncertainty was calculated from the semi-range of the maximum difference of the other NPL transfer Cu cell repeat values (±0.037 °C), treated as a type B uncertainty (divided by √3) and scaled as the ratio of the squares of the temperatures in kelvin.

Table 123- NMIJ calibration of the LP3 thermometer

t_{nom}/ °C	t_{90}/ °C	Average Iph/ A	Iph corrected to t_{nom}/ A	Iph corrected for range and ND filter/ A	Correction for drift/ °C	Iph corrected for range, ND filter and drift/ A	d*T* from start/ °C	U_{lab} (k = 2)/ °C	U_{lab} including drift* (k = 2)/ °C
960	960	4.20565E-11	4.20565E-11	4.20766E-11	0.12	4.20018E-11	-0.07	0.07	0.07
1100	1100	2.60983E-10	2.60983E-10	2.61108E-10	0.15	2.60644E-10	0.00	0.09	0.09
1300	1300	2.01578E-09	2.01578E-09	2.01675E-09	0.20	2.01316E-09	-0.07	0.12	0.12
1500	1500	9.82300E-09	9.82300E-09	9.82300E-09	0.25	9.80554E-09	-0.01	0.17	0.17
1700	1700	3.47119E-08	3.47119E-08	3.47119E-08	0.31	3.46502E-08	0.01	0.23	0.23
1800	1800	5.95578E-08	5.95578E-08	5.95578E-08	0.35	5.94519E-08	0.06	0.26	0.26
2000	2000	1.52052E-07	1.52052E-07	1.52052E-07	0.42	1.51782E-07	-0.15	0.33	0.33
2200	2200	3.33610E-07	3.33610E-07	3.33610E-07	0.49	3.33016E-07	0.16	0.41	0.41
2400	2400	6.50815E-07	6.50815E-07	6.50815E-07	0.57	6.49658E-07	-0.05	0.51	0.51
2500	2500	1.08139E-07	1.08139E-07	8.76770E-07	0.62	8.75211E-07	0.06	0.56	0.56
2600	2600	1.42698E-07	1.42698E-07	1.15696E-06	0.66	1.15490E-06	0.10	0.61	0.61
2800	2800	2.35403E-07	2.35403E-07	1.90860E-06	0.76	1.90520E-06	-0.31	0.72	0.72
2900	2900	2.95298E-07	2.95298E-07	2.39421E-06	0.81	2.38995E-06	-0.26	0.78	0.78
3000	3000	3.65353E-07	3.65353E-07	2.96220E-06	0.86	2.95693E-06	-0.19	0.84	0.84

* the drift uncertainty was 0.00 °C because a component for drift had already been included in NMIJ’s uncertainty budgets

Table 124 - NIM calibration of the LP3 thermometer

t_{nom}/ °C	t_{90}/ °C	Iph/ A	Iph corrected to t_{nom}/ A	Iph corrected for range and ND filter/ A	Correction for drift/ °C	Iph corrected for range, ND filter and drift/ A	dT from start/ °C	U_{lab} (k = 2)/ °C	U_{lab} including drift* (k = 2)/ °C
960	960.1	4.2071E-11	4.20082E-11	4.20259E-11	0.12	4.19529E-11	-0.15	0.27	0.28
1100	1100.1	2.6123E-10	2.60819E-10	2.60928E-10	0.15	2.60475E-10	-0.06	0.30	0.30
1300	1300.1	2.0168E-09	2.01560E-09	2.01644E-09	0.19	2.01294E-09	-0.09	0.34	0.34
1500	1499.8	9.8108E-09	9.82335E-09	9.82335E-09	0.25	9.80629E-09	0.00	0.40	0.40
1700	1700.0	3.4721E-08	3.47189E-08	3.47189E-08	0.31	3.46587E-08	0.05	0.48	0.49
1800	1799.9	5.9554E-08	5.95752E-08	5.95752E-08	0.34	5.94718E-08	0.13	0.52	0.53
2000	2000.0	1.5208E-07	1.52096E-07	1.52096E-07	0.41	1.51832E-07	-0.07	0.75	0.75
2200	2199.7	3.3327E-07	3.33691E-07	3.33691E-07	0.48	3.33111E-07	0.23	0.82	0.83
2400	2400.2	6.5132E-07	6.51020E-07	6.51020E-07	0.56	6.49890E-07	0.06	0.93	0.95
2500	2500.1	1.0823E-07	1.08201E-07	8.76975E-07	0.60	8.75452E-07	0.15	0.99	1.00
2600	2600.2	1.4284E-07	1.42776E-07	1.15721E-06	0.65	1.15520E-06	0.20	1.32	1.33
2800	2799.6	2.3530E-07	2.35496E-07	1.90871E-06	0.74	1.90539E-06	-0.27	1.90	1.90
2900	2897.9	2.9441E-07	2.95773E-07	2.39725E-06	0.79	2.39309E-06	0.34	2.60	2.61

*the drift uncertainty was calculated from the semi-range of the maximum difference between the repeat measurements of the transfer Cu cell (±0.031 °C – see Table 7), treated as a type B uncertainty (divided by √3) and scaled as the ratio of the squares of the temperatures in kelvin.

Table 125 - KRISS calibration of the LP3 thermometer

t_{nom}/ °C	t_{90}/ °C	Iph/ A	Iph corrected to t_{nom}/ A	Iph corrected for range and ND filter/ A	Correction for drift/ °C	Iph corrected for range, ND filter and drift/ A	d*T* from start/ °C	U_{lab} (k = 2)/ °C	U_{lab} including drift* (k = 2)/ °C
960	960.0	4.21108E-11	4.21215E-11	4.21387E-11	0.25	4.19878E-11	-0.09	0.14	0.15
1100	1100.1	2.61646E-10	2.61478E-10	2.61585E-10	0.31	2.60648E-10	0.00	0.09	0.10
1300	1299.9	2.01841E-09	2.01999E-09	2.02082E-09	0.40	2.01358E-09	-0.05	0.15	0.16
1500	1500.1	9.84491E-09	9.84030E-09	9.84030E-09	0.51	9.80505E-09	-0.02	0.28	0.29
1700	1700.0	3.47649E-08	3.47711E-08	3.47711E-08	0.63	3.46465E-08	-0.01	0.43	0.44
1800	1799.9	5.96110E-08	5.96487E-08	5.96487E-08	0.70	5.94351E-08	0.01	0.50	0.51
2000	1999.8	1.52156E-07	1.52280E-07	1.52280E-07	0.84	1.51734E-07	-0.22	0.68	0.69
2200	2199.5	3.33533E-07	3.34090E-07	3.34090E-07	0.99	3.32893E-07	0.06	0.95	0.96
2400	2399.8	6.51181E-07	6.51612E-07	6.51612E-07	1.16	6.49278E-07	-0.24	1.13	1.14
2500	2499.8	1.08308E-07	1.08363E-07	8.77196E-07	1.24	8.74053E-07	-0.40	1.26	1.27
2600	2600.0	1.43005E-07	1.42988E-07	1.15748E-06	1.34	1.15334E-06	-0.40	1.41	1.42
2800	2799.5	2.35585E-07	2.35863E-07	1.90931E-06	1.53	1.90247E-06	-0.92	1.68	1.69
2900	2900.0	2.96049E-07	2.96022E-07	2.39630E-06	1.63	2.38771E-06	-0.68	1.92	1.93
3000	3000.0	3.66006E-07	3.65991E-07	2.96270E-06	1.73	2.95208E-06	-0.98	1.99	2.01

*the drift uncertainty was calculated from the semi-range of the maximum difference between the repeat measurements of the transfer Cu cell (±0.036 °C – see Table 7), treated as a type B uncertainty (divided by √3) and scaled as the ratio of the squares of the temperatures in kelvin.

Table 126 - NRC calibration of the LP3 thermometer

t_{nom}/ °C	t_{90}/ °C	Iph/ A	Iph corrected to t_{nom}/ A	Iph corrected for range and ND filter/ A	Correction for drift / °C	Iph corrected for range, ND filter and drift/ A	dT from start/ °C	U_{lab} (k = 2)/ °C	U_{lab} including drift* (k = 2)/ °C
960	960.1	4.20903E-11	4.20438E-11	4.20677E-11	0.24	4.19191E-11	-0.20	0.53	0.53
1100	1100.1	2.61200E-10	2.61010E-10	2.61158E-10	0.30	2.60236E-10	-0.13	0.58	0.58
1300	1300.0	2.01625E-09	2.01670E-09	2.01785E-09	0.40	2.01072E-09	-0.21	0.70	0.70
1500	1499.9	9.82509E-09	9.83035E-09	9.83035E-09	0.50	9.79562E-09	-0.16	0.86	0.86
1700	1700.0	3.47441E-08	3.47471E-08	3.47471E-08	0.62	3.46243E-08	-0.12	1.06	1.06
1800	1800.0	5.96280E-08	5.96314E-08	5.96314E-08	0.69	5.94207E-08	-0.04	1.17	1.17
2000	2000.0	1.52300E-07	1.52301E-07	1.52301E-07	0.82	1.51763E-07	-0.18	1.44	1.44
2200	2200.3	3.34670E-07	3.34319E-07	3.34319E-07	0.98	3.33137E-07	0.26	1.75	1.75
2400	2400.2	6.52620E-07	6.52222E-07	6.52222E-07	1.14	6.49917E-07	0.08	2.12	2.13
2500	2500.2	1.08641E-07	1.08574E-07	8.78745E-07	1.23	8.75640E-07	0.23	2.32	2.33
2600	2600.4	1.43474E-07	1.43337E-07	1.16010E-06	1.32	1.15600E-06	0.46	2.53	2.54
2800	2800.4	2.36582E-07	2.36385E-07	1.91318E-06	1.51	1.90642E-06	-0.04	2.99	3.00
2900	2900.4	2.96866E-07	2.96602E-07	2.40055E-06	1.61	2.39207E-06	0.15	3.19	3.20
3000	3000.3	3.67097E-07	3.66849E-07	2.96909E-06	1.71	2.95860E-06	0.09	3.45	3.46
960	960.0	4.20578E-11	4.20444E-11	4.20683E-11	0.24	4.19214E-11	-0.20	0.53	0.53
1800	1800.0	5.96398E-08	5.96327E-08	5.96327E-08	0.69	5.94208E-08	-0.04	1.17	1.17
2400	2400.1	6.52500E-07	6.52215E-07	6.52215E-07	1.14	6.49912E-07	0.08	2.12	2.13
2500	2500.2	1.08643E-07	1.08589E-07	8.78866E-07	1.23	8.75755E-07	0.28	2.32	2.33
2800	2800.4	2.36499E-07	2.36268E-07	1.91224E-06	1.51	1.90547E-06	-0.25	2.99	3.00
1300	1300.0	2.01682E-09	2.01621E-09	2.01736E-09	0.40	2.01014E-09	-0.24	0.70	0.70
2200	2200.2	3.34481E-07	3.34275E-07	3.34275E-07	0.98	3.33090E-07	0.22	1.75	1.75
1800	1800.0	5.96197E-08	5.96258E-08	5.96258E-08	0.69	5.94139E-08	-0.06	1.17	1.17
2800	2800.3	2.36480E-07	2.36333E-07	1.91276E-06	1.51	1.90599E-06	-0.13	2.99	3.00

*the drift uncertainty was calculated from the semi-range of the maximum difference between the repeat measurements of the transfer Cu cell (±0.032 °C – see Table 7), treated as a type B uncertainty (divided by √3) and scaled as the ratio of the squares of the temperatures in kelvin.

Table 127 - NIST calibration of the LP3 thermometer

t_{nom}/ °C	t_{90}/ °C	Iph/ A	Iph corrected to t_{nom}/ A	Iph corrected for range and ND filter/ A	Correction for drift/ °C	Iph corrected for range, ND filter and drift/ A	dT from start/ °C	U_{lab} (k = 2)/ °C	U_{lab} including drift* (k = 2)/ °C
960	959.5	4.17470E-11	4.20704E-11	4.20791E-11	0.13	4.19991E-11	-0.07	0.56	0.56
1100	1099.4	2.59168E-10	2.60941E-10	2.60995E-10	0.16	2.60499E-10	-0.05	0.58	0.58
1300	1299.2	1.99941E-09	2.01444E-09	2.01486E-09	0.21	2.01103E-09	-0.19	0.64	0.64
1500	1498.9	9.75337E-09	9.82603E-09	9.82603E-09	0.27	9.80733E-09	0.01	0.73	0.74
1700	1698.6	3.44261E-08	3.47022E-08	3.47022E-08	0.33	3.46361E-08	-0.06	0.85	0.85
1800	1798.5	5.90555E-08	5.95181E-08	5.95181E-08	0.37	5.94049E-08	-0.09	0.92	0.92
2000	1998.2	1.50783E-07	1.51943E-07	1.51943E-07	0.44	1.51654E-07	-0.35	1.06	1.07
2200	2197.7	3.30537E-07	3.33253E-07	3.33253E-07	0.53	3.32619E-07	-0.18	1.23	1.23
2400	2397.2	6.44241E-07	6.49866E-07	6.49866E-07	0.61	6.48629E-07	-0.56	1.41	1.42
2500	2496.8	1.07287E-07	1.08263E-07	8.75826E-07	0.66	8.74159E-07	-0.36	1.51	1.52
2600	2597.0	1.41715E-07	1.42843E-07	1.15556E-06	0.71	1.15336E-06	-0.40	1.61	1.62
2800	2796.8	2.33839E-07	2.35621E-07	1.90612E-06	0.81	1.90249E-06	-0.92	1.83	1.84
960	959.6	4.18411E-11	4.21095E-11	4.21182E-11	0.13	4.20385E-11	-0.01	0.56	0.56
1800	1798.6	5.90933E-08	5.95133E-08	5.95133E-08	0.37	5.93999E-08	-0.11	0.92	0.92
2800	2796.8	2.33904E-07	2.35671E-07	1.90653E-06	0.81	1.90291E-06	-0.83	1.83	1.84

*the drift uncertainty was calculated from the semi-range of the maximum difference between the repeat measurements of the transfer Cu cell (±0.032 °C – see Table 7), treated as a type B uncertainty (divided by √3) and scaled as the ratio of the squares of the temperatures in kelvin.

Table 128 - LNE-Cnam calibration of the LP3 thermometer

t_{nom}/ °C	t_{90}/ °C	Iph/ A	Iph corrected to t_{nom}/ A	Iph corrected for range and ND filter/ A	Correction for drift/ °C	Iph corrected for range, ND filter and drift/ A	dT from start/ °C	U_{lab} (k = 2)/ °C	U_{lab} including drift* (k = 2)/ °C
960	960	4.22528E-11	4.22528E-11	4.22734E-11	0.45	4.19990E-11	-0.07	0.10	0.10
1100	1100	2.62156E-10	2.62156E-10	2.62284E-10	0.55	2.60581E-10	-0.02	0.13	0.13
1300	1300	2.02397E-09	2.02397E-09	2.02496E-09	0.73	2.01181E-09	-0.15	0.17	0.17
1500	1500	9.86193E-09	9.86193E-09	9.86193E-09	0.92	9.79790E-09	-0.12	0.21	0.21
1700	1700	3.48272E-08	3.48272E-08	3.48272E-08	1.14	3.46011E-08	-0.23	0.28	0.28
1800	1800	5.97435E-08	5.97435E-08	5.97435E-08	1.26	5.93556E-08	-0.25	0.31	0.31
2000	2000	1.52507E-07	1.52507E-07	1.52507E-07	1.52	1.51517E-07	-0.55	0.37	0.37
2200	2200	3.34550E-07	3.34550E-07	3.34550E-07	1.79	3.32378E-07	-0.37	0.43	0.44
2400	2400	6.52388E-07	6.52388E-07	6.52388E-07	2.10	6.48153E-07	-0.79	0.51	0.51
2600	2600	1.43944E-07	1.43944E-07	1.16083E-06	2.42	1.15329E-06	-0.41	0.64	0.64
2800	2800	2.37476E-07	2.37476E-07	1.91512E-06	2.77	1.90269E-06	-0.86	0.72	0.72
960	960	4.22623E-11	4.22623E-11	4.22830E-11	0.45	4.20060E-11	-0.06	0.10	0.10
1800	1800	5.97417E-08	5.97417E-08	5.97417E-08	1.26	5.93541E-08	-0.25	0.31	0.31
2800	2800	2.37531E-07	2.37531E-07	1.91556E-06	2.77	1.90312E-06	-0.77	0.72	0.72

*the drift uncertainty was calculated from the semi-range of the maximum difference between the repeat measurements of the transfer Cu cell (±0.006 °C – see Table 7), treated as a type B uncertainty (divided by √3) and scaled as the ratio of the squares of the temperatures in kelvin.

Table 129 - PTB calibration of the LP3 thermometer

t_{nom}/ °C	t_{90}/ °C	Iph/ A	Iph corrected to t_{nom}/ A	Iph corrected for range and ND filter/ A	Correction for drift/ °C	Iph corrected for range, ND filter and drift/ A	dT from start/ °C	U_{lab} (k = 2)/ °C	U_{lab} including drift* (k = 2)/ °C
960	960.1	4.2261E-11	4.22183E-11	4.22484E-11	0.48	4.19539E-11	-0.14	0.24	0.25
1100	1100.7	2.6467E-10	2.62500E-10	2.62687E-10	0.59	2.60856E-10	0.07	0.35	0.36
1300	1300.9	2.0456E-09	2.02838E-09	2.02983E-09	0.78	2.01568E-09	0.07	0.46	0.47
1500	1500.9	9.9233E-09	9.85957E-09	9.86659E-09	0.99	9.79782E-09	-0.12	0.58	0.60
1700	1701.3	3.5071E-08	3.48074E-08	3.48074E-08	1.23	3.45648E-08	-0.42	0.72	0.74
1800	1801.0	6.0078E-08	5.97621E-08	5.97621E-08	1.35	5.93455E-08	-0.28	0.79	0.82
2000	2001.7	1.5363E-07	1.52512E-07	1.52512E-07	1.63	1.51449E-07	-0.66	0.81	0.84
2200	2200.3	3.3525E-07	3.34935E-07	3.34935E-07	1.93	3.32601E-07	-0.18	0.94	0.97
2400	2400.2	6.5301E-07	6.52694E-07	6.52694E-07	2.25	6.48145E-07	-0.79	1.11	1.15
2500	2498.5	1.0858E-07	1.09042E-07	8.78728E-07	2.42	8.72603E-07	-0.97	1.20	1.24
2600	2599.2	1.4354E-07	1.43843E-07	1.15918E-06	2.60	1.15110E-06	-1.12	1.22	1.27
2800	2799.8	2.3704E-07	2.37154E-07	1.91114E-06	2.97	1.89782E-06	-1.96	1.39	1.45
2900	2897.9	2.9605E-07	2.97395E-07	2.39661E-06	3.17	2.37990E-06	-2.16	1.49	1.55
1100	1102.2	2.6931E-10	2.62256E-10	2.62443E-10	0.59	2.60614E-10	-0.01	0.35	0.36
1700	1700.6	3.4953E-08	3.48367E-08	3.48367E-08	1.23	3.45939E-08	-0.27	0.72	0.74
2900†	*2898.3*	*1.8591E-07*	*1.86595E-07*	*1.50370E-06*	*3.17*	*1.49322E-06*	*-172.01*	*1.49*	*1.55*

*only one transfer Cu cell measurement was carried out by PTB. Therefore the drift uncertainty was calculated from the semi-range of the difference between the LNE-Cnam and CEM measurements of the transfer Cu cell (±0.069 °C – see Table 7), treated as a type B uncertainty (divided by √3) and scaled as the ratio of the squares of the temperatures in kelvin.

† The repeat 2900 °C *I*ph value is a clear outlier and has not been included in the calculation of the weighted mean

Table 130 - CEM calibration of the LP3 thermometer

t_{nom}/ °C	t_{90}/ °C	Iph/ A	Iph corrected to t_{nom}/ A	Iph corrected for range and ND filter/ A	Correction for drift/ °C	Iph corrected for range, ND filter and drift/ A	dT from start/ °C	U_{lab} (k = 2)/ °C	U_{lab} including drift* (k = 2)/ °C
960	959.9	4.21582E-11	4.22503E-11	4.22709E-11	0.56	4.19262E-11	-0.19	0.34	0.34
1100	1100.1	2.62444E-10	2.62167E-10	2.62295E-10	0.69	2.60156E-10	-0.16	0.40	0.40
1300	1300.1	2.02779E-09	2.02579E-09	2.02678E-09	0.91	2.01025E-09	-0.23	0.51	0.51
1500	1500.0	9.84181E-09	9.84250E-09	9.84250E-09	1.16	9.76223E-09	-0.64	0.64	0.65
1700	1699.9	3.47523E-08	3.47740E-08	3.47740E-08	1.43	3.44904E-08	-0.80	0.79	0.80
1800	1800.3	5.97727E-08	5.96911E-08	5.96911E-08	1.58	5.92043E-08	-0.74	0.87	0.88
2000	2000.8	1.52998E-07	1.52494E-07	1.52494E-07	1.90	1.51250E-07	-0.96	1.04	1.06
2200	2200.1	3.33485E-07	3.33400E-07	3.33400E-07	2.25	3.30681E-07	-1.78	1.45	1.46
2400	2400.0	6.53891E-07	6.53810E-07	6.53810E-07	2.63	6.48478E-07	-0.62	1.69	1.70
2500	2500.2	1.09462E-07	1.09386E-07	8.81151E-07	2.83	8.73965E-07	-0.42	1.78	1.79
1300	1300.0	2.02114E-09	2.02141E-09	2.02240E-09	0.91	2.00594E-09	-0.47	0.51	0.52
1800	1800.5	5.96146E-08	5.94550E-08	5.94550E-08	1.58	5.89712E-08	-1.51	0.88	0.89
2200	2200.2	3.33867E-07	3.33655E-07	3.33655E-07	2.25	3.30938E-07	-1.57	1.45	1.46
2200	2199.4	3.34594E-07	3.35345E-07	3.35345E-07	2.25	3.32615E-07	-0.16	1.47	1.49

*the drift uncertainty was calculated from the semi-range of the maximum difference between the repeat measurements of the transfer Cu cell (±0.054 °C – see Table 7), treated as a type B uncertainty (divided by √3) and scaled as the ratio of the squares of the temperatures in kelvin.

17 APPENDIX 3 –THE PARTICIPANT RESULTS FOR THE CHINO THERMOMETER

Table 131 - NPL September 2014 calibration of the Chino thermometer

t_{nom}/ °C	t_{90}/ °C	Signal/ V	Signal corrected to t_{nom}/ V	Correction for drift/ °C	Signal corrected for drift/ V	U_{lab} (k = 2)/ °C	U_{lab} including drift* (k = 2)/ °C
960	960.2	0.004884	0.004869	0.00	0.004869	0.44	0.46
1100	1100.1	0.030232	0.030194	0.00	0.030194	0.48	0.50
1300	1300.1	0.233187	0.233020	0.00	0.233020	0.52	0.56
1500	1500.2	1.136419	1.135099	0.00	1.135099	0.60	0.66
1700	1700.0	4.004286	4.003375	0.00	4.003375	0.82	0.88
1800	1799.9	6.863404	6.865701	0.00	6.865701	0.81	0.89
2000	1999.7	1.744366	1.746495	0.00	1.746495	1.01	1.10
2200	2199.9	3.832734	3.833636	0.00	3.833636	1.11	1.22
2400	2400.0	7.478245	7.478360	0.00	7.478360	1.25	1.39
2500	2501.2	1.011939	1.008424	0.00	1.008424	1.36	1.51
2600	2600.4	1.332981	1.331524	0.00	1.331524	1.49	1.65
2800	2800.7	2.208773	2.205235	0.00	2.205235	1.50	1.70
2900	2900.1	2.770978	2.770156	0.00	2.770156	1.54	1.76
3000	3000.5	3.433269	3.429509	0.00	3.429509	1.69	1.92
1300	1299.6	0.232641	0.233421	0.00	0.233421	0.52	0.56
1700	1700.4	4.020079	4.010765	0.00	4.010765	0.82	0.88
2400	2400.6	7.495692	7.481470	0.00	7.481470	1.25	1.39

*the drift uncertainty was calculated from the semi-range of the maximum difference between the repeat measurements of the transfer Cu cell (±0.138 °C – see Table 8), treated as a type B uncertainty (divided by √3) and scaled as the ratio of the squares of the temperatures in kelvin.

Table 132 - NPL August 2015 calibration of the Chino thermometer

t_{nom}/ °C	t_{90}/ °C	Signal/ V	Signal corrected to t_{nom}/ V	Correction for drift/ °C	Signal corrected for drift/ V	dT from start/ °C	U_{lab} (k = 2)/ °C	U_{lab} including drift* (k = 2)/ °C
960	960.1	0.004898	0.004892	0.35	0.004868	-0.02	0.54	0.54
1100	1100.0	0.030325	0.030316	0.43	0.030163	-0.09	0.56	0.56
1300	1300.0	0.234278	0.234287	0.57	0.233100	-0.06	0.62	0.62
1500	1499.8	1.139356	1.140934	0.72	1.135153	0.01	0.68	0.69
1700	1699.9	4.026248	4.027437	0.89	4.007030	0.00	0.79	0.79
1800	1799.8	6.902311	6.908789	0.98	6.873782	0.23	0.87	0.87
2000	1999.7	1.756373	1.758333	1.18	1.749424	0.39	0.99	1.00
2200	2199.8	3.847725	3.851010	1.40	3.831497	-0.15	1.15	1.16
2400	2399.5	7.500751	7.511633	1.64	7.473572	-0.27	1.37	1.38
2500	2499.6	1.012343	1.013549	1.76	1.008413	0.00	1.50	1.51
2600	2599.3	1.335029	1.337403	1.89	1.330626	-0.25	1.61	1.62
2800	2799.7	2.208208	2.209809	2.16	2.198612	-1.28	1.63	1.64
2900	2900.3	2.765629	2.764027	2.30	2.750022	-3.31	2.60	2.61
3000	3000.7	3.431834	3.426634	2.45	3.409271	-2.86	2.81	2.82
960	960.0	0.004891	0.004892	0.35	0.004868	-0.02	0.54	0.54
2200	2199.6	3.835368	3.841418	1.40	3.821954	-0.84	1.71	1.71
3000	2999.7	3.418574	3.420457	2.45	3.403126	-3.72	3.00	3.01

*the drift uncertainty was calculated from the semi-range of the maximum difference between the repeat measurements of the transfer Cu cell (±0.031 °C – see Table 8), treated as a type B uncertainty (divided by √3) and scaled as the ratio of the squares of the temperatures in kelvin.

Table 133 - NPL October 2016 calibration of the Chino thermometer

t_{nom}/ °C	t_{90}/ °C	Signal/ V	Signal corrected to t_{nom}/ V	Correction for drift/ °C	Signal corrected for drift/ V	dT from start/ °C	U_{lab} (k = 2)/ °C	U_{lab} including drift* (k = 2)/ °C
960	960.0	0.004902	0.004904	0.44	0.004873	0.05	0.52	0.52
1100	1100.1	0.030456	0.030413	0.55	0.030217	0.06	0.54	0.55
1300	1300.2	0.235210	0.234722	0.72	0.233211	0.00	0.59	0.60
1500	1500.1	1.143690	1.143017	0.91	1.135661	0.07	0.66	0.67
1700	1700.1	4.039855	4.036797	1.13	4.010817	0.16	0.77	0.78
1800	1800.3	6.941869	6.931330	1.25	6.886722	0.59	0.91	0.92
2000	2000.2	1.763965	1.762499	1.50	1.751156	0.62	0.96	0.98
2200	2200.2	3.866531	3.863078	1.78	3.838216	0.33	1.09	1.11
2400	2400.2	7.540474	7.534667	2.08	7.486176	0.27	1.26	1.28
2500	2500.1	1.016269	1.016001	2.24	1.009463	0.36	1.35	1.37
2600	2600.2	1.342371	1.341560	2.40	1.332926	0.39	1.46	1.49
2800	2800.9	2.223123	2.218546	2.75	2.204268	-0.19	2.04	2.06
2900	2902.8	2.797914	2.780771	2.93	2.762874	-1.20	3.41	3.43
3000	3003.5	3.465452	3.440041	3.11	3.417901	-1.64	4.74	4.76
960	960.0	0.004902	0.004902	0.44	0.004870	0.01	0.52	0.52
1800	1800.0	6.916861	6.917411	1.25	6.872892	0.20	0.91	0.92
2600	2600.1	1.341554	1.341107	2.40	1.332476	0.27	1.46	1.49

*the drift uncertainty was calculated from the semi-range of the maximum difference between the repeat measurements of the transfer Cu cell (±0.053 °C – see Table 8), treated as a type B uncertainty (divided by √3) and scaled as the ratio of the squares of the temperatures in kelvin.

Table 134 - NPL January 2018 calibration of the Chino thermometer

t_{nom}/ °C	t_{90}/ °C	Signal/ V	Signal corrected to t_{nom}/ V	Correction for drift/ °C	Signal corrected for drift/ V	d*T* from start/ °C	U_{lab} (k = 2)/ °C	U_{lab} including drift* (k = 2)/ °C
960	960.2	0.004924	0.004910	0.51	0.004874	0.07	0.50	0.50
1100	1100.2	0.030503	0.030440	0.63	0.030215	0.06	0.59	0.59
1300	1300.2	0.235387	0.234945	0.83	0.233207	-0.01	0.76	0.76
1500	1500.1	1.144763	1.143647	1.05	1.135188	0.01	0.89	0.89
1700	1700.0	4.037321	4.038268	1.30	4.008400	0.06	1.02	1.03
1800	1800.3	6.932708	6.923693	1.44	6.872483	0.19	1.09	1.09
2000	2000.3	1.761622	1.759552	1.73	1.746538	0.01	1.27	1.28
2200	2200.4	3.865706	3.859855	2.04	3.831306	-0.17	1.53	1.54
2400	2400.3	7.527959	7.521109	2.39	7.465481	-0.62	1.90	1.90
2500	2500.3	1.014474	1.013697	2.57	1.006199	-0.77	2.18	2.18
2600	2600.4	1.340251	1.338858	2.76	1.328956	-0.72	2.18	2.19
2800	2800.6	2.217898	2.214914	3.16	2.198532	-1.30	2.92	2.92
960	960.1	0.004911	0.004907	0.51	0.004871	0.02	0.53	0.53
2000	2000.3	1.762150	1.759865	1.73	1.746848	0.05	1.42	1.42
2600	2600.5	1.340938	1.339139	2.76	1.329234	-0.64	2.21	2.22

*the drift uncertainty was calculated from the semi-range of the maximum difference between the repeat measurements of the transfer Cu cell (±0.025 °C – see Table 8), treated as a type B uncertainty (divided by √3) and scaled as the ratio of the squares of the temperatures in kelvin.

Table 135 - NPL January 2020 calibration of the Chino thermometer

t_{nom}/ °C	t_{90}/ °C	Signal/ V	Signal corrected to t_{nom}/ V	Correction for drift/ °C	Signal corrected for drift/ V	dT from start/ °C	U_{lab} (k = 2)/ °C	U_{lab} including drift* (k = 2)/ °C
960	960.4	0.004944	0.004916	0.58	0.004874	0.07	0.28	0.29
1100	1100.1	0.030508	0.030462	0.71	0.030206	0.03	0.34	0.35
1300	1300.3	0.235700	0.235144	0.94	0.233171	-0.02	0.48	0.49
1500	1499.7	1.141455	1.143972	1.19	1.134371	-0.09	0.55	0.57
1700	1700.3	4.047421	4.041299	1.48	4.007381	0.01	0.69	0.71
1800	1800.5	6.946337	6.930142	1.63	6.871978	0.18	0.81	0.83
2000	2000.4	1.763768	1.760766	1.96	1.745988	-0.07	0.85	0.87
2200	2200.5	3.869093	3.861882	2.32	3.829469	-0.30	1.01	1.03
2400	2400.7	7.543550	7.527838	2.71	7.464658	-0.66	1.19	1.22
2500	2500.5	1.016279	1.014774	2.92	1.006257	-0.75	1.29	1.31
2600	2600.8	1.343644	1.340885	3.13	1.329632	-0.53	1.45	1.48
2800	2800.5	2.225969	2.223350	3.58	2.204689	-0.11	1.53	1.56
2900	2900.5	2.795163	2.791952	3.82	2.768519	-0.27	1.66	1.70
3000	3001.1	3.465049	3.457494	4.06	3.428476	-0.15	2.13	2.16
960	960.0	0.004921	0.004918	0.58	0.004877	0.11	0.28	0.29
2000	2000.1	1.760900	1.759870	1.96	1.745100	-0.19	0.85	0.87
2600	2600.8	1.343592	1.340611	3.13	1.329360	-0.61	1.45	1.48

* Only one measurement of the transfer Cu cell had been carried out. Therefore, the drift uncertainty was calculated from the semi-range of the maximum difference of the other NPL transfer Cu cell repeat values (±0.056 °C), treated as a type B uncertainty (divided by √3) and scaled as the ratio of the squares of the temperatures in kelvin.

Table 136 - NMIJ calibration of the Chino thermometer

t_{nom}/ °C	t_{90}/ °C	Signal/ V	Signal corrected to t_{nom}/ V	Correction for drift/ °C	Signal corrected for drift/ V	dT from start/ °C	U_{lab} (k = 2)/ °C	U_{lab} including drift* (k = 2)/ °C
960	960	0.004878	0.004878	0.16	0.004867	-0.03	0.09	0.09
1100	1100	0.030260	0.030260	0.20	0.030190	-0.01	0.10	0.10
1300	1300	0.233621	0.233621	0.26	0.233086	-0.06	0.14	0.14
1500	1500	1.137595	1.137595	0.33	1.134986	-0.01	0.20	0.20
1700	1700	4.019227	4.019227	0.40	4.010009	0.13	0.27	0.27
1800	1800	6.895614	6.895614	0.45	6.879800	0.40	0.32	0.32
2000	2000	1.752170	1.752170	0.54	1.748152	0.22	0.41	0.41
2200	2200	3.844056	3.844056	0.63	3.835241	0.12	0.51	0.51
2400	2400	7.498681	7.498681	0.74	7.481484	0.07	0.63	0.63
2500	2500	1.011011	1.011011	0.80	1.008692	0.09	0.70	0.70
2600	2600	1.334073	1.334073	0.86	1.331014	-0.14	0.76	0.76
2800	2800	2.200710	2.200710	0.98	2.195663	-1.85	0.91	0.91
2900	2900	2.760612	2.760612	1.04	2.754281	-2.61	0.98	0.98
3000	3000	3.415490	3.415490	1.11	3.407657	-3.08	1.06	1.06

* the drift uncertainty was 0.00 °C because a component for drift had already been included in NMIJ’s uncertainty budget

Table 137 - NIM calibration of the Chino thermometer

t_{nom}/ °C	t_{90}/ °C	Signal/ V	Signal corrected to t_{nom}/ V	Correction for drift/ °C	Signal corrected for drift/ V	dT from start/ °C	U_{lab} (k = 2)/ °C	U_{lab} including drift* (k = 2)/ °C
960	960.1	0.004889	0.004881	0.31	0.004859	-0.14	0.35	0.36
1100	1100.1	0.030310	0.030261	0.39	0.030123	-0.20	0.42	0.43
1300	1300.1	0.233906	0.233794	0.51	0.232733	-0.23	0.48	0.49
1500	1499.8	1.137130	1.138654	0.64	1.133486	-0.20	0.57	0.58
1700	1700.0	4.024391	4.024214	0.80	4.005949	-0.05	0.65	0.68
1800	1799.9	6.902014	6.905478	0.88	6.874136	0.24	0.69	0.71
2000	1999.9	1.753514	1.754122	1.06	1.746161	-0.04	0.94	0.97
2200	2199.5	3.846295	3.853125	1.25	3.835637	0.14	1.04	1.07
2400	2400.1	7.545826	7.544104	1.47	7.509864	1.29	1.17	1.21
2500	2500.0	1.020424	1.020387	1.58	1.015756	2.53	1.24	1.29
2600	2600.2	1.349862	1.349315	1.69	1.343191	3.27	1.54	1.58
2800	2797.6	2.216890	2.229201	1.94	2.219083	2.68	2.11	2.16
2900	2893.9	2.762768	2.799757	2.06	2.787050	2.77	2.79	2.83

*the drift uncertainty was calculated from the semi-range of the maximum difference between the repeat measurements of the transfer Cu cell (±0.070 °C – see Table 8), treated as a type B uncertainty (divided by √3) and scaled as the ratio of the squares of the temperatures in kelvin.

Table 138 - KRISS calibration of the Chino thermometer

t_{nom}/ °C	t_{90}/ °C	Signal/ V	Signal corrected to t_{nom}/ V	Correction for drift/ °C	Signal corrected for drift/ V	dT from start/ °C	U_{lab} (k = 2)/ °C	U_{lab} including drift* (k = 2)/ °C
960	960.0	0.004894	0.004896	0.28	0.004876	0.10	0.14	0.14
1100	1100.1	0.030339	0.030319	0.35	0.030196	0.00	0.10	0.10
1300	1299.9	0.234213	0.234389	0.45	0.233438	0.10	0.16	0.16
1500	1500.1	1.141455	1.140872	0.58	1.136242	0.14	0.27	0.27
1700	1700.0	4.029208	4.030635	0.71	4.014277	0.32	0.50	0.50
1800	1799.9	6.910452	6.914453	0.79	6.886391	0.59	0.50	0.50
2000	1999.8	1.754983	1.756406	0.95	1.749278	0.37	0.68	0.69
2200	2199.5	3.846230	3.853329	1.12	3.837690	0.29	0.94	0.94
2400	2399.8	7.509362	7.514601	1.31	7.484104	0.18	1.13	1.13
2500	2499.8	1.012253	1.012716	1.41	1.008606	0.06	1.25	1.26
2600	2600.0	1.336068	1.336042	1.51	1.330620	-0.25	1.39	1.39
2800	2799.5	2.202190	2.204801	1.73	2.195853	-1.82	1.67	1.68
2900	2900.2	2.768724	2.767646	1.85	2.756414	-2.26	1.91	1.91
3000	3000.3	3.430994	3.428920	1.96	3.415004	-2.05	2.00	2.00

*the drift uncertainty was calculated from the semi-range of the maximum difference between the repeat measurements of the transfer Cu cell (±0.011 °C – see Table 8), treated as a type B uncertainty (divided by √3) and scaled as the ratio of the squares of the temperatures in kelvin.

Table 139 - NRC calibration of the Chino thermometer

t_{nom}/ °C	t_{90}/ °C	Signal/ V	Signal corrected to t_{nom}/ V	Correction for drift/ °C	Signal corrected for drift/ V	dT from start/ °C	U_{lab} (k = 2)/ °C	U_{lab} including drift* (k = 2)/ °C
960	960.1	0.004891	0.004885	0.40	0.004857	-0.17	0.53	0.53
1100	1100.1	0.030335	0.030313	0.50	0.030136	-0.16	0.58	0.58
1300	1300.0	0.234120	0.234173	0.65	0.232812	-0.20	0.70	0.70
1500	1499.9	1.139953	1.140563	0.83	1.133935	-0.15	0.86	0.86
1700	1700.0	4.031772	4.032116	1.02	4.008684	0.07	1.06	1.06
1800	1800.0	6.918775	6.919167	1.13	6.878957	0.37	1.17	1.17
2000	2000.0	1.758363	1.758378	1.36	1.748160	0.22	1.44	1.44
2200	2200.3	3.863201	3.859148	1.61	3.836721	0.22	1.76	1.76
2400	2400.2	7.532653	7.528057	1.88	7.484308	0.19	2.12	2.13
2500	2500.2	1.015405	1.014777	2.02	1.008879	0.16	2.31	2.32
2600	2600.4	1.340315	1.339029	2.17	1.331247	-0.08	2.52	2.53
2800	2800.4	2.210688	2.208849	2.48	2.196012	-1.78	2.98	2.99
2900	2900.4	2.775790	2.773319	2.64	2.757202	-2.13	3.18	3.19
3000	3000.3	3.440019	3.437695	2.81	3.417717	-1.66	3.44	3.45
960	960.0	0.004893	0.004891	0.40	0.004863	-0.09	0.53	0.53
1800	1800.0	6.920036	6.919217	1.13	6.879006	0.38	1.17	1.17
2400	2400.1	7.531823	7.528533	1.88	7.484782	0.21	2.12	2.13
2500	2500.2	1.015567	1.015061	2.02	1.009162	0.25	2.31	2.32
2800	2800.4	2.211451	2.209290	2.48	2.196451	-1.70	2.98	2.99
1300	1300.0	0.234212	0.234141	0.65	0.232781	-0.21	0.70	0.70
2200	2200.2	3.860966	3.858591	1.61	3.836168	0.18	1.76	1.76
1800	1800.0	6.915253	6.915965	1.13	6.875774	0.28	1.17	1.17
2800	2800.3	2.209730	2.208357	2.48	2.195524	-1.88	2.98	2.99

*the drift uncertainty was calculated from the semi-range of the maximum difference between the repeat measurements of the transfer Cu cell (±0.032 °C – see Table 8), treated as a type B uncertainty (divided by √3) and scaled as the ratio of the squares of the temperatures in kelvin.

Table 140 - NIST calibration of the Chino thermometer

t_{nom}/ °C	t_{90}/ °C	Signal/ V	Signal corrected to t_{nom}/ V	Correction for drift/ °C	Signal corrected for drift/ V	dT from start/ °C	U_{lab} (k = 2)/ °C	U_{lab} including drift* (k = 2)/ °C
960	959.5	0.004871	0.004908	0.44	0.004877	0.11	0.56	0.56
1100	1099.4	0.030208	0.030415	0.55	0.030220	0.07	0.58	0.58
1300	1299.2	0.232741	0.234491	0.72	0.232984	-0.11	0.64	0.64
1500	1498.9	1.134660	1.143113	0.91	1.135770	0.08	0.73	0.73
1700	1698.6	4.001952	4.034049	1.13	4.008135	0.05	0.85	0.85
1800	1798.5	6.865014	6.918796	1.25	6.874351	0.24	0.92	0.92
2000	1998.2	1.742812	1.756224	1.50	1.744942	-0.21	1.06	1.06
2200	2197.7	3.818181	3.849547	1.78	3.824819	-0.64	1.23	1.23
2400	2397.2	7.441337	7.506305	2.07	7.458087	-0.94	1.41	1.41
2500	2496.8	1.003353	1.012486	2.23	1.005982	-0.84	1.51	1.51
2600	2597.0	1.324944	1.335491	2.40	1.326912	-1.29	1.61	1.61
2800	2796.8	2.191031	2.207726	2.74	2.193545	-2.26	1.83	1.83
960	959.6	0.004873	0.004904	0.44	0.004873	0.05	0.56	0.56
1800	1798.6	6.862621	6.911393	1.25	6.866996	0.04	0.92	0.92
2800	2796.8	2.191373	2.207931	2.74	2.193748	-2.22	1.83	1.83

*the drift uncertainty was calculated from the semi-range of the maximum difference between the repeat measurements of the transfer Cu cell (±0.003 °C – see Table 8), treated as a type B uncertainty (divided by √3) and scaled as the ratio of the squares of the temperatures in kelvin.

Table 141 – LNE-Cnam calibration of the Chino thermometer

t_{nom}/ °C	t_{90}/ °C	Signal/ V	Signal corrected to t_{nom}/ V	Correction for drift/ °C	Signal corrected for drift/ V	dT from start/ °C	U_{lab} (k = 2)/ °C	U_{lab} including drift* (k = 2)/ °C
960	960	0.004909	0.004909	0.53	0.004872	0.03	0.10	0.10
1100	1100	0.030453	0.030453	0.66	0.030219	0.07	0.13	0.13
1300	1300	0.234983	0.234983	0.86	0.233171	-0.02	0.17	0.17
1500	1500	1.144184	1.144184	1.09	1.135364	0.03	0.21	0.21
1700	1700	4.042897	4.042897	1.36	4.011732	0.20	0.28	0.28
1800	1800	6.934256	6.934256	1.50	6.880803	0.43	0.31	0.31
2000	2000	1.760885	1.760885	1.80	1.747312	0.11	0.37	0.37
2200	2200	3.861853	3.861853	2.13	3.832084	-0.11	0.43	0.44
2400	2400	7.525369	7.525369	2.49	7.467360	-0.54	0.51	0.52
2600	2600	1.339278	1.339278	2.87	1.328954	-0.72	0.58	0.59
2800	2800	2.209100	2.209100	3.29	2.192071	-2.55	0.66	0.67
960	960	0.004909	0.004909	0.53	0.004871	0.02	0.10	0.10
1800	1800	6.929919	6.929919	1.50	6.876500	0.31	0.31	0.31
2800	2800	2.209403	2.209403	3.29	2.192372	-2.49	0.66	0.67

*the drift uncertainty was calculated from the semi-range of the maximum difference between the repeat measurements of the transfer Cu cell (±0.020 °C – see Table 8), treated as a type B uncertainty (divided by √3) and scaled as the ratio of the squares of the temperatures in kelvin.

Table 142 - PTB calibration of the Chino thermometer

t_{nom}/ °C	t_{90}/ °C	Signal/ V	Signal corrected to t_{nom}/ V	Correction for drift/ °C	Signal corrected for drift/ V	dT from start/ °C	U_{lab} (k = 2)/ °C	U_{lab} including drift* (k = 2)/ °C
960	960.1	0.004915	0.004910	0.52	0.004872	0.04	0.24	0.24
1100	1100.7	0.030677	0.030426	0.65	0.030195	0.00	0.35	0.35
1300	1300.9	0.236918	0.234920	0.85	0.233136	-0.04	0.47	0.47
1500	1500.9	1.153363	1.145960	1.08	1.137261	0.27	0.60	0.60
1700	1701.3	4.058751	4.028218	1.34	3.997642	-0.41	0.72	0.72
1800	1801.0	6.953396	6.916812	1.47	6.864309	-0.04	0.67	0.67
2000	2001.7	1.769183	1.756269	1.77	1.742937	-0.48	0.79	0.79
2200	2200.3	3.861221	3.857619	2.10	3.828337	-0.38	0.94	0.95
2400	2400.2	7.521867	7.518279	2.45	7.461211	-0.81	1.11	1.12
2500	2498.5	1.008691	1.013015	2.64	1.005326	-1.07	1.13	1.14
2600	2599.2	1.333572	1.336410	2.83	1.326265	-1.47	1.20	1.22
2800	2799.8	2.202104	2.203181	3.24	2.186457	-3.63	1.39	1.41
2900	2897.9	2.750393	2.762896	3.45	2.741923	-4.64	1.49	1.51
1100	1102.2	0.031261	0.030443	0.65	0.030212	0.05	0.35	0.35
1700	1700.6	4.048922	4.035490	1.34	4.004858	-0.10	0.72	0.72
2900	2898.3	2.753764	2.763863	3.45	2.742884	-4.48	1.49	1.51

*only one transfer Cu cell measurement was carried out by PTB. Therefore, the drift uncertainty was calculated from the semi-range of the difference between the LNE-Cnam and CEM measurements of the transfer Cu cell (±0.035 °C – see Table 7), treated as a type B uncertainty (divided by √3) and scaled as the ratio of the squares of the temperatures in kelvin.

Table 143 - CEM calibration of the Chino thermometer

t_{nom}/ °C	t_{90}/ °C	Signal/ V	Signal corrected to t_{nom}/ V	Correction for drift/ °C	Signal corrected for drift/ V	dT from start/ °C	U_{lab} (k = 2)/ °C	U_{lab} including drift* (k = 2)/ °C
960	959.9	0.004895	0.004906	0.47	0.004872	0.04	0.34	0.35
1100	1100.1	0.030484	0.030452	0.59	0.030243	0.14	0.40	0.41
1300	1300.1	0.235137	0.234905	0.77	0.233292	0.03	0.51	0.52
1500	1500.0	1.141637	1.141718	0.98	1.133876	-0.15	0.65	0.66
1700	1699.9	4.029275	4.031795	1.21	4.004105	-0.13	0.79	0.81
1800	1800.3	6.925203	6.915754	1.33	6.868256	0.07	0.87	0.89
2000	2000.8	1.762973	1.757161	1.60	1.745093	-0.19	1.04	1.07
2200	2200.1	3.867134	3.866154	1.90	3.839602	0.43	1.45	1.47
2400	2400.0	7.459411	7.458487	2.22	7.407262	-3.14	1.69	1.72
2500	2500.2	1.014453	1.013753	2.39	1.006790	-0.56	1.78	1.81
1300	1300.0	0.234567	0.234598	0.77	0.232987	-0.11	0.51	0.53
1800	1800.5	6.920693	6.902168	1.33	6.854763	-0.31	0.87	0.89
2200	2200.2	3.858230	3.855787	1.90	3.829305	-0.31	1.45	1.47
2200	2199.4	3.858105	3.866766	1.90	3.840209	0.47	1.47	1.50

*the drift uncertainty was calculated from the semi-range of the maximum difference between the repeat measurements of the transfer Cu cell (±0.070 °C – see Table 8), treated as a type B uncertainty (divided by √3) and scaled as the ratio of the squares of the temperatures in kelvin.

18 APPENDIX 4 - THE ANALYSIS OF THE THERMOMETER RESULTS USING THE WEIGHTED MEAN

1. Introduction

As mentioned previously, initially the full analysis of the thermometer calibration results was carried out according to the method described in the protocol (namely using the weighted mean with cut off), as follows, following the method described in [4]. For each transfer thermometer a reference value was calculated for each t_{nom} using the weighted mean with cut-off of all the participant results, including the average pilot results, at that $t_{nom.}$ The weight for each participant, including the pilot, was the inverse of the square of the standard measurement uncertainty for that participant at that t_{nom}. The cut-off values for the weights were the average of the uncertainty values of those participants with reported uncertainties smaller than or equal to the median uncertainty of all the participants.

The weighted mean, *y*, was calculated according to Equation A4:1:

$$y = \frac{x_1/u^2(x_1) + \cdots + x_N/u^2(x_N)}{1/u^2(x_1) + \cdots + 1/u^2(x_N)} \qquad \text{(A4:1)}$$

where x_1 through to x_N are the results from participants 1 through to *N* and $u\ (x_1)$ through to $u\ (x_N)$ are the associated standard uncertainties for participants 1 through to *N*, which includes an uncertainty component for the thermometer drift during the participant's measurements.

Since the participant uncertainties were expressed in terms of temperature, then the equivalent uncertainty in terms of thermometer output signal was calculated using the thermometer sensitivity at that temperature (see Equation 3 in Section 9.1) before calculating *y*.

The standard deviation (uncertainty) $u(y)$ associated with the weighted mean *y* was calculated according to Equation A4:2:

$$\frac{1}{u^2(y)} = \frac{1}{u^2(x_1)} + \cdots + \frac{1}{u^2(x_N)} \qquad \text{(A4:2)}$$

A consistency check of the results was carried out in the form of a chi-squared test by calculating the observed chi-squared value, χ^2_{obs}, according to Equation A4:3 and assigning the degrees of freedom, *v*, according to Equation A4:4.

$$\chi^2_{obs} = \frac{(x_1 - y)^2}{u^2(x_1)} + \cdots + \frac{(x_N - y)^2}{u^2(x_N)} \qquad \text{(A4:3)}$$

$$v = N - 1 \qquad \text{(A4:4)}$$

The consistency check was to be regarded as failing if

$$Pr\{\chi^2(v) > \chi^2_{obs}\} < 0.05 \qquad \text{(A4:5)}$$

where *Pr* denotes 'probability of'. The consistency check did not fail. Therefore, *y* was accepted as the reference value for that particular transfer thermometer with an associated standard uncertainty of $u(y)$.

2. Treatment of outliers

2.1 For the LP3

It was considered that there were no obvious outliers (with the exception of one of the PTB 2900 °C values, which was excluded from PTB's data – see comment below Table 129 in Appendix 2), because the results agreed within the participants' combined measurement uncertainties. All data was therefore included in the weighted mean.

2.2 For the Chino thermometer

All data was included in the weighted mean.

3. Additional uncertainty components

The additional uncertainty components, related to the stability of the transfer thermometers, were calculated as described in Section 10.4, and combined with the uncertainty of the weighted mean value to derive a total uncertainty for the reference value as shown in Table 144 and Table 145.

Table 144 - the uncertainty components for the reference value for the LP3

t_{nom} / °C	u_{drift} / °C	$u_{range\ ratio}$ / °C	$u_{ND\ filter}$ / °C	$u_{comparison}$ / °C	$u_{weighted\ mean}$ / °C	Totals	
						$u_{ref\ value}$ (*k* = 1)/ °C	$U_{ref\ value}$ (*k* = 2)/ °C
960	0.04	0.01	-	**0.04**	0.04	**0.06**	**0.12**
1100	0.05	0.01	-	**0.05**	0.05	**0.07**	**0.14**
1300	0.07	0.02	-	**0.07**	0.06	**0.09**	**0.18**
1500	0.09	-	-	**0.09**	0.08	**0.11**	**0.23**
1700	0.11	-	-	**0.11**	0.10	**0.14**	**0.28**
1800	0.12	-	-	**0.12**	0.11	**0.16**	**0.32**
2000	0.14	-	-	**0.14**	0.13	**0.19**	**0.39**
2200	0.17	-	-	**0.17**	0.16	**0.23**	**0.46**
2400	0.19	-	-	**0.19**	0.19	**0.27**	**0.54**
2500	0.21	-	0.16	**0.26**	0.23	**0.35**	**0.70**
2600	0.22	-	0.17	**0.28**	0.23	**0.36**	**0.72**
2800	0.26	-	0.19	**0.32**	0.27	**0.42**	**0.84**
2900	0.27	-	0.20	**0.34**	0.39	**0.52**	**1.04**
3000	0.29	-	0.22	**0.36**	0.52	**0.63**	**1.26**

Table 145 - the uncertainty components for the reference value for the Chino thermometer

t_{nom}/ °C	u_{drift} / °C	$u_{gain\ ratio}$ / °C	$u_{comparison}$ / °C	$u_{weighted\ mean}$ / °C	**Totals**	
					$u_{ref\ value}$ (*k* = 1)/ °C	$U_{ref\ value}$ (*k* = 2)/ °C
960	0.07	0.06	**0.09**	0.04	**0.10**	**0.20**
1100	0.08	0.06	**0.10**	0.05	**0.11**	**0.23**
1300	0.11	0.06	**0.12**	0.07	**0.14**	**0.28**
1500	0.14	0.06	**0.15**	0.08	**0.17**	**0.34**
1700	0.17	0.06	**0.18**	0.11	**0.21**	**0.42**
1800	0.19	0.06	**0.20**	0.11	**0.23**	**0.45**
2000	0.22	0.06	**0.23**	0.14	**0.27**	**0.54**
2200	0.27	0.06	**0.27**	0.17	**0.32**	**0.65**
2400	0.31	0.06	**0.32**	0.20	**0.38**	**0.75**
2500	0.33	0.06	**0.34**	0.25	**0.42**	**0.84**
2600	0.36	0.06	**0.36**	0.24	**0.43**	**0.87**
2800	0.41	0.06	**0.41**	0.28	**0.50**	**1.00**
2900	0.44	0.06	**0.44**	0.40	**0.60**	**1.20**
3000	0.46	0.06	**0.47**	0.54	**0.72**	**1.44**

4. Results using the weighted mean

For reference the results of the analysis using the weighted mean are given here.

Table 146 presents the data for the LP3, including the calculated cut off values for the uncertainties, the weighted mean value for each temperature calibration point, using the participant calibration results, and the uncertainty of the weighted mean value. The summaries of the participant calibration results with associated uncertainties are given in Table 147 to Table 160, along with the calculated differences from the weighted mean values and the total uncertainties, U_{total}. U_{total} includes the participant uncertainties, the uncertainties associated with the comparison (thermometer drift for example) and the uncertainty of the weighted mean. The results, i.e., differences from the weighted mean and associated uncertainties, are presented graphically in Figure 108 and Figure 109 for all data and in Figure 110 to Figure 129 for the individual participant data.

Table 161 presents the data for the Chino thermometer, including the calculated cut off values for the uncertainties and the weighted mean value for each temperature calibration point, using the participant calibration results, and the uncertainty of the weighted mean. The summaries of the participant calibration results with associated uncertainties are given in Table 162 to Table 175, along with the calculated difference from the weighted mean values and the total uncertainties, U_{total}. U_{total} includes the participant uncertainties, the uncertainties associated with the comparison (thermometer drift for example) and the uncertainty of the weighted mean. The results, i.e., differences from the weighted mean and measurement uncertainties, are presented graphically in Figure 130 and Figure 131 for all data and in Figure 132 to Figure 151 for the individual participant data.

Note: only the average of the NPL calibration results were used in the calculation of the weighted mean, but Tables and Figures giving the differences for each set the NPL calibration results from the weighted mean are given for completeness.

1. RESULTS FOR THE LP3 THERMOMETER WITH DIFFERENCES FROM THE WEIGHTED MEAN, PRESENTED IN TABLES AND FIGURES

Table 146 - determining the *U* cut off values and the weighted means for the LP3

t_{nom}/ °C	Median *U*/ A	Cut off *U* value/ A	Weighted mean/ A	Standard deviation of weighted mean/ A	$u_{weighted\ mean}$ (standard deviation)/ °C
960	1.6877E-13	1.0305E-13	4.19878E-11	2.4256E-14	0.04
1100	1.0998E-12	5.9651E-13	2.60598E-10	1.4246E-13	0.05
1300	8.4556E-12	4.5583E-12	2.01282E-09	1.0638E-12	0.06
1500	4.1354E-11	2.3125E-11	9.80160E-09	5.2272E-12	0.08
1700	1.4478E-10	8.5158E-11	3.46275E-08	1.8814E-11	0.10
1800	2.4955E-10	1.4797E-10	5.94027E-08	3.2702E-11	0.11
2000	5.4516E-10	3.8819E-10	1.51665E-07	8.6626E-11	0.13
2200	1.1727E-09	8.7078E-10	3.32755E-07	1.9519E-10	0.16
2400	2.3124E-09	1.7120E-09	6.49086E-07	3.8095E-10	0.19
2500	3.5066E-09	2.5578E-09	8.74575E-07	5.8880E-10	0.23
2600	4.2618E-09	2.9780E-09	1.15383E-06	7.1008E-10	0.23
2800	7.8645E-09	5.1029E-09	1.90329E-06	1.2217E-09	0.27
2900	1.1047E-08	7.4565E-09	2.38765E-06	2.0636E-09	0.39
3000	1.5450E-08	8.6976E-09	2.95756E-06	3.1621E-09	0.52

Table 147 – summary of NPL 2014 LP3 results and difference from weighted mean

t_{nom}/ °C	Average corrected Iph/ A	$U_{laboratory}$/ °C	Difference {Iph – weighted mean}/ A	Difference from weighted mean/ °C	$U_{ref\ value}$/ °C	U_{total}/ °C
960	4.20423E-11	0.21	5.4536E-14	0.09	0.12	0.24
1100	2.60645E-10	0.28	4.6971E-14	0.02	0.14	0.32
1300	2.01449E-09	0.34	1.6789E-12	0.09	0.18	0.38
1500	9.80653E-09	0.42	4.9291E-12	0.07	0.23	0.48
1700	3.46482E-08	0.56	2.0713E-11	0.11	0.28	0.63
1800	5.94331E-08	0.63	3.0351E-11	0.10	0.32	0.70
2000	1.51880E-07	0.75	2.1521E-10	0.33	0.39	0.84
2200	3.32830E-07	0.93	7.5523E-11	0.06	0.46	1.04
2400	6.49764E-07	1.12	6.7845E-10	0.34	0.54	1.24
2500	8.75072E-07	1.22	4.9689E-10	0.20	0.70	1.41
2600	1.15460E-06	1.35	7.6737E-10	0.25	0.72	1.53
2800	1.90660E-06	1.52	3.3112E-09	0.74	0.84	1.74
2900	2.39132E-06	1.49	3.6687E-09	0.70	1.04	1.83
3000	2.95811E-06	1.49	5.5124E-10	0.09	1.26	1.96

Table 148 – summary of NMIJ LP3 results and difference from weighted mean

t_{nom}/ °C	Average corrected Iph / A	$U_{laboratory}$ (inc. drift)/ °C	$U_{laboratory}$ / A	U to use in weighted mean / A	Difference {Iph – weighted mean} / A	Difference from weighted mean / °C	$U_{ref\ value}$/ °C	U_{total}/ °C
960	4.20018E-11	0.07	4.5126E-14	1.0305E-13	1.3982E-14	0.02	0.12	0.14
1100	2.60644E-10	0.09	2.7066E-13	5.9651E-13	4.5755E-14	0.01	0.14	0.17
1300	2.01316E-09	0.12	2.1905E-12	4.5583E-12	3.4492E-13	0.02	0.18	0.22
1500	9.80554E-09	0.17	1.1560E-11	2.3125E-11	3.9371E-12	0.06	0.23	0.28
1700	3.46502E-08	0.23	4.4342E-11	8.5158E-11	2.2684E-11	0.12	0.28	0.36
1800	5.94519E-08	0.26	7.8915E-11	1.4797E-10	4.9178E-11	0.16	0.32	0.41
2000	1.51782E-07	0.33	2.1506E-10	3.8819E-10	1.1641E-10	0.18	0.39	0.51
2200	3.33016E-07	0.41	4.9870E-10	8.7078E-10	2.6146E-10	0.22	0.46	0.62
2400	6.49658E-07	0.51	1.0197E-09	1.7120E-09	5.7212E-10	0.28	0.54	0.74
2500	8.75211E-07	0.56	1.4025E-09	2.5578E-09	6.3612E-10	0.25	0.70	0.90
2600	1.15490E-06	0.61	1.8867E-09	2.9780E-09	1.0723E-09	0.35	0.72	0.95
2800	1.90520E-06	0.72	3.2215E-09	5.1029E-09	1.9094E-09	0.43	0.84	1.12
2900	2.38995E-06	0.78	4.1041E-09	7.4565E-09	2.3045E-09	0.44	1.04	1.31
3000	2.95693E-06	0.84	5.1514E-09	8.6976E-09	-6.2603E-10	-0.10	1.26	1.53

Table 149 – summary of NIM LP3 results and difference from weighted mean

t_{nom}/ °C	Average corrected Iph/ A	$U_{laboratory}$ (inc. drift)/ °C	$U_{laboratory}$ / A	U to use in weighted mean / A	Difference {Iph – weighted mean}/ A	Difference from weighted mean / °C	$U_{ref\ value}$/ °C	U_{total}/ °C
960	4.195292E-11	0.28	1.6877E-13	1.6877E-13	-3.4860E-14	-0.06	0.12	0.30
1100	2.604755E-10	0.30	9.1546E-13	9.1546E-13	-1.2250E-13	-0.04	0.14	0.33
1300	2.012943E-09	0.34	6.1156E-12	6.1156E-12	1.2776E-13	0.01	0.18	0.39
1500	9.806294E-09	0.40	2.7867E-11	2.7867E-11	4.6953E-12	0.07	0.23	0.46
1700	3.465865E-08	0.49	9.5603E-11	9.5603E-11	3.1166E-11	0.16	0.28	0.56
1800	5.947180E-08	0.53	1.6155E-10	1.6155E-10	6.9089E-11	0.23	0.32	0.62
2000	1.518318E-07	0.75	4.9086E-10	4.9086E-10	1.6659E-10	0.26	0.39	0.85
2200	3.331113E-07	0.83	1.0044E-09	1.0044E-09	3.5634E-10	0.30	0.46	0.95
2400	6.498899E-07	0.95	1.9025E-09	1.9025E-09	8.0421E-10	0.40	0.54	1.09
2500	8.754525E-07	1.00	2.5146E-09	2.5578E-09	8.7730E-10	0.35	0.70	1.22
2600	1.155199E-06	1.33	4.1340E-09	4.1340E-09	1.3694E-09	0.44	0.72	1.52
2800	1.905392E-06	1.90	8.5028E-09	8.5028E-09	2.0986E-09	0.47	0.84	2.09
2900	2.393087E-06	2.61	1.3710E-08	1.3710E-08	5.4408E-09	1.04	1.04	2.81

Table 150 – summary of KRISS LP3 results and difference from weighted mean

t_{nom}/ °C	Average corrected Iph / A	$U_{laboratory}$ (inc. drift)/ °C	$U_{laboratory}$ / A	U to use in weighted mean / A	Difference {Iph – weighted mean}/ A	Difference from weighted mean / °C	$U_{ref\ value}$/ °C	U_{total}/ °C
960	4.19878E-11	0.15	8.8693E-14	1.0305E-13	4.4800E-18	0.00	0.12	0.19
1100	2.60648E-10	0.10	3.0441E-13	5.9651E-13	5.0183E-14	0.02	0.14	0.17
1300	2.01358E-09	0.16	2.9539E-12	4.5583E-12	7.6372E-13	0.04	0.18	0.25
1500	9.80505E-09	0.29	2.0234E-11	2.3125E-11	3.4512E-12	0.05	0.23	0.37
1700	3.46465E-08	0.44	8.6287E-11	8.6287E-11	1.9010E-11	0.10	0.28	0.52
1800	5.94351E-08	0.51	1.5561E-10	1.5561E-10	3.2343E-11	0.11	0.32	0.60
2000	1.51734E-07	0.69	4.5130E-10	4.5130E-10	6.9128E-11	0.11	0.39	0.79
2200	3.32893E-07	0.96	1.1546E-09	1.1546E-09	1.3783E-10	0.11	0.46	1.06
2400	6.49278E-07	1.14	2.2930E-09	2.2930E-09	1.9211E-10	0.10	0.54	1.26
2500	8.74053E-07	1.27	3.1910E-09	3.1910E-09	-5.2172E-10	-0.21	0.70	1.45
2600	1.15334E-06	1.42	4.3897E-09	4.3897E-09	-4.9203E-10	-0.16	0.72	1.60
2800	1.90247E-06	1.69	7.5329E-09	7.5329E-09	-8.2423E-10	-0.18	0.84	1.89
2900	2.38771E-06	1.93	1.0137E-08	1.0137E-08	6.4792E-11	0.01	1.04	2.20
3000	2.95208E-06	2.01	1.2244E-08	1.2244E-08	-5.4758E-09	-0.90	1.26	2.38

Table 151 – summary of NPL 2015 LP3 results and difference from weighted mean

t_{nom}/ °C	Average corrected Iph/ A	$U_{laboratory}$ (inc. drift)/ °C	Difference {Iph – weighted mean}/ A	Difference from weighted mean/ °C	$U_{ref\ value}$/ °C	U_{total}/ °C
960	4.19844E-11	0.33	-3.3879E-15	-0.01	0.12	0.35
1100	2.60591E-10	0.36	-6.5045E-15	0.00	0.14	0.38
1300	2.01336E-09	0.43	5.4315E-13	0.03	0.18	0.46
1500	9.80651E-09	0.51	4.9078E-12	0.07	0.23	0.56
1700	3.46400E-08	0.63	1.2557E-11	0.06	0.28	0.69
1800	5.94207E-08	0.72	1.7955E-11	0.06	0.32	0.79
2000	1.51747E-07	0.84	8.1730E-11	0.13	0.39	0.93
2200	3.32954E-07	1.05	1.9940E-10	0.17	0.46	1.15
2400	6.49324E-07	1.24	2.3798E-10	0.12	0.54	1.35
2500	8.74848E-07	1.37	2.7255E-10	0.11	0.70	1.54
2600	1.15413E-06	1.50	2.9941E-10	0.10	0.72	1.67
2800	1.90585E-06	1.36	2.5611E-09	0.57	0.84	1.61
2900	2.38998E-06	2.09	2.3323E-09	0.44	1.04	2.34
3000	2.95938E-06	3.09	1.8182E-09	0.30	1.26	3.35

Table 152 – summary of NRC LP3 results and difference from weighted mean

t_{nom}/ °C	Average corrected Iph / A	$U_{laboratory}$ (inc. drift)/ °C	$U_{laboratory}$ / A	U to use in weighted mean / A	Difference {Iph – weighted mean} / A	Difference from weighted mean / °C	$U_{ref\ value}$/ °C	U_{total}/ °C
960	4.192024E-11	0.53	3.2398E-13	3.2398E-13	-6.7540E-14	-0.11	0.12	0.54
1100	2.602356E-10	0.58	1.7759E-12	1.7759E-12	-3.6235E-13	-0.12	0.14	0.60
1300	2.010432E-09	0.70	1.2621E-11	1.2621E-11	-2.3829E-12	-0.13	0.18	0.73
1500	9.795616E-09	0.86	5.9478E-11	5.9478E-11	-5.9834E-12	-0.09	0.23	0.89
1700	3.462431E-08	1.06	2.0926E-10	2.0926E-10	-3.1825E-12	-0.02	0.28	1.10
1800	5.941848E-08	1.17	3.5907E-10	3.5907E-10	1.5773E-11	0.05	0.32	1.22
2000	1.517628E-07	1.44	9.3874E-10	9.3874E-10	9.7590E-11	0.15	0.39	1.49
2200	3.331135E-07	1.75	2.1151E-09	2.1151E-09	3.5854E-10	0.30	0.46	1.81
2400	6.499145E-07	2.13	4.2784E-09	4.2784E-09	8.2885E-10	0.41	0.54	2.19
2500	8.756975E-07	2.33	5.8613E-09	5.8613E-09	1.1223E-09	0.45	0.70	2.43
2600	1.155997E-06	2.54	7.8601E-09	7.8601E-09	2.1675E-09	0.70	0.72	2.64
2800	1.905962E-06	3.00	1.3385E-08	1.3385E-08	2.6688E-09	0.60	0.84	3.12
2900	2.392065E-06	3.20	1.6811E-08	1.6811E-08	4.4189E-09	0.84	1.04	3.37
3000	2.958604E-06	3.46	2.1132E-08	2.1132E-08	1.0468E-09	0.17	1.26	3.68

Table 153 – summary of NIST LP3 results and difference from weighted mean

t_{nom}/ °C	Average corrected Iph/ A	$U_{laboratory}$ (inc. drift)/ °C	$U_{laboratory}$ / A	U to use in weighted mean / A	Difference {Iph – weighted mean}/ A	Difference from weighted mean / °C	$U_{ref\ value}$/ °C	U_{total}/ °C
960	4.201880E-11	0.56	3.4276E-13	3.4276E-13	3.1019E-14	0.05	0.12	0.57
1100	2.604985E-10	0.58	1.7706E-12	1.7706E-12	-9.9445E-14	-0.03	0.14	0.60
1300	2.011025E-09	0.64	1.1479E-11	1.1479E-11	-1.7899E-12	-0.10	0.18	0.66
1500	9.807327E-09	0.74	5.0758E-11	5.0758E-11	5.7277E-12	0.08	0.23	0.77
1700	3.463611E-08	0.85	1.6801E-10	1.6801E-10	8.6232E-12	0.04	0.28	0.90
1800	5.940238E-08	0.92	2.8141E-10	2.8141E-10	-3.3135E-13	0.00	0.32	0.97
2000	1.516540E-07	1.07	6.9375E-10	6.9375E-10	-1.1271E-11	-0.02	0.39	1.14
2200	3.326185E-07	1.23	1.4864E-09	1.4864E-09	-1.3639E-10	-0.11	0.46	1.32
2400	6.486287E-07	1.42	2.8530E-09	2.8530E-09	-4.5699E-10	-0.23	0.54	1.52
2500	8.741593E-07	1.52	3.8222E-09	3.8222E-09	-4.1587E-10	-0.17	0.70	1.68
2600	1.153365E-06	1.62	5.0183E-09	5.0183E-09	-4.6453E-10	-0.15	0.72	1.78
2800	1.902701E-06	1.84	8.2166E-09	8.2166E-09	-5.9239E-10	-0.13	0.84	2.03

Table 154 – summary of NPL 2016 LP3 results and difference from weighted mean

t_{nom}/ °C	Average corrected Iph/ A	$U_{laboratory}$ (inc. drift)/ °C	Difference {Iph – weighted mean}/ A	Difference from weighted mean/ °C	$U_{ref\ value}$/ °C	U_{total}/ °C
960	4.205789E-11	0.33	7.0118E-14	0.11	0.12	0.35
1100	2.609640E-10	0.36	3.6604E-13	0.12	0.14	0.38
1300	2.015903E-09	0.42	3.0877E-12	0.17	0.18	0.46
1500	9.817708E-09	0.51	1.6109E-11	0.23	0.23	0.55
1700	3.467889E-08	0.63	5.1397E-11	0.26	0.28	0.69
1800	5.951530E-08	0.83	1.1259E-10	0.37	0.32	0.89
2000	1.521521E-07	0.85	4.8682E-10	0.75	0.39	0.93
2200	3.336445E-07	0.98	8.8954E-10	0.74	0.46	1.08
2400	6.507354E-07	1.15	1.6497E-09	0.82	0.54	1.27
2500	8.766061E-07	1.24	2.0309E-09	0.81	0.70	1.43
2600	1.156449E-06	1.36	2.6201E-09	0.85	0.72	1.55
2800	1.906921E-06	1.78	3.6274E-09	0.81	0.84	1.97
2900	2.389075E-06	3.34	1.4287E-09	0.27	1.04	3.50
3000	2.952821E-06	4.75	-4.7364E-09	-0.78	1.26	4.92

Table 155 – summary of NPL 2018 LP3 results and difference from weighted mean

t_{nom}/ °C	Average corrected Iph/ A	$U_{laboratory}$ (inc. drift)/ °C	Difference {Iph – weighted mean}/ A	Difference from weighted mean/ °C	$U_{ref\ value}$/ °C	U_{total}/ °C
960	4.204103E-11	0.47	5.3249E-14	0.09	0.12	0.48
1100	2.607875E-10	0.59	1.8948E-13	0.06	0.14	0.60
1300	2.012370E-09	0.76	-4.4466E-13	-0.02	0.18	0.78
1500	9.802582E-09	0.84	9.8345E-13	0.01	0.23	0.87
1700	3.461393E-08	0.99	-1.3560E-11	-0.07	0.28	1.03
1800	5.935389E-08	1.10	-4.8821E-11	-0.16	0.32	1.15
2000	1.516890E-07	1.34	2.3706E-11	0.04	0.39	1.39
2200	3.325026E-07	1.53	-2.5229E-10	-0.21	0.46	1.60
2400	6.482843E-07	1.80	-8.0135E-10	-0.40	0.54	1.88
2500	8.730915E-07	1.99	-1.4837E-09	-0.59	0.70	2.11
2600	1.152861E-06	2.15	-9.6831E-10	-0.31	0.72	2.27
2800	1.903420E-06	2.54	1.2657E-10	0.03	0.84	2.67

Table 156 – summary of LNE-Cnam LP3 results and difference from weighted mean

t_{nom}/ °C	Average corrected Iph / A	$U_{laboratory}$ (inc. drift)/ °C	$U_{laboratory}$ / A	U to use in weighted mean / A	Difference {Iph – weighted mean}/ A	Difference from weighted mean / °C	$U_{ref\ value}$/ °C	U_{total}/ °C
960	4.200249E-11	0.10	6.2351E-14	1.0305E-13	1.4711E-14	0.02	0.11	0.15
1100	2.605809E-10	0.13	3.9222E-13	5.9651E-13	-1.7124E-14	-0.01	0.13	0.19
1300	2.011813E-09	0.17	3.0760E-12	4.5583E-12	-1.0020E-12	-0.06	0.17	0.25
1500	9.797905E-09	0.21	1.4607E-11	2.3125E-11	-3.6941E-12	-0.05	0.22	0.31
1700	3.460111E-08	0.28	5.4778E-11	8.5158E-11	-2.6374E-11	-0.13	0.27	0.40
1800	5.935483E-08	0.31	9.4239E-11	1.4797E-10	-4.7879E-11	-0.16	0.30	0.44
2000	1.515169E-07	0.37	2.3856E-10	3.8819E-10	-1.4832E-10	-0.23	0.37	0.53
2200	3.323779E-07	0.44	5.2352E-10	8.7078E-10	-3.7705E-10	-0.31	0.44	0.64
2400	6.481529E-07	0.51	1.0323E-09	1.7120E-09	-9.3276E-10	-0.46	0.52	0.75
2500	-	-	-	-	-	-	-	-
2600	1.153293E-06	0.64	1.9672E-09	2.9780E-09	-5.3620E-10	-0.17	0.71	0.97
2800	1.902905E-06	0.72	3.1975E-09	5.1029E-09	-3.8871E-10	-0.09	0.82	1.11

Table 157 – summary of PTB LP3 results and difference from weighted mean

t_{nom}/ °C	Average corrected Iph / A	$U_{laboratory}$ (inc. drift)/ °C	$U_{laboratory}$ / A	U to use in weighted mean / A	Difference {Iph – weighted mean}/ A	Difference from weighted mean / °C	$U_{ref\ value}$/ °C	U_{total}/ °C
960	4.19539E-11	0.25	1.5032E-13	1.5032E-13	-3.3867E-14	-0.06	0.12	0.27
1100	2.60735E-10	0.36	1.0998E-12	1.0998E-12	1.3657E-13	0.04	0.14	0.39
1300	2.01568E-09	0.47	8.4556E-12	8.4556E-12	2.8642E-12	0.16	0.18	0.50
1500	9.79782E-09	0.60	4.1354E-11	4.1354E-11	-3.7820E-12	-0.05	0.23	0.64
1700	3.45794E-08	0.74	1.4478E-10	1.4478E-10	-4.8136E-11	-0.24	0.28	0.79
1800	5.93455E-08	0.82	2.4955E-10	2.4955E-10	-5.7176E-11	-0.19	0.32	0.88
2000	1.51449E-07	0.84	5.4516E-10	5.4516E-10	-2.1603E-10	-0.33	0.39	0.93
2200	3.32601E-07	0.97	1.1727E-09	1.1727E-09	-1.5434E-10	-0.13	0.46	1.08
2400	6.48145E-07	1.15	2.3124E-09	2.3124E-09	-9.4104E-10	-0.47	0.54	1.27
2500	8.72603E-07	1.24	3.1233E-09	3.1233E-09	-1.9722E-09	-0.78	0.70	1.43
2600	1.15110E-06	1.27	3.9239E-09	3.9239E-09	-2.7256E-09	-0.88	0.72	1.47
2800	1.89782E-06	1.45	6.4598E-09	6.4598E-09	-5.4754E-09	-1.23	0.84	1.68
2900†	2.37990E-06	1.55	8.1287E-09	8.1287E-09	-7.7471E-09	-1.48	1.04	1.88

† Only one 2900 °C measurement result was included in the weighted mean (see note below Table 129 in Appendix 2).

Table 158 – summary of CEM LP3 results and difference from weighted mean

t_{nom}/ °C	Average corrected Iph / A	$U_{laboratory}$ (inc. drift)/ °C	$U_{laboratory}$ / A	U to use in weighted mean / A	Difference {Iph – weighted mean}/ A	Difference from weighted mean / °C	$U_{ref\ value}$/ °C	U_{total}/ °C
960	4.192621E-11	0.34	2.0697E-13	2.0697E-13	-6.1571E-14	-0.10	0.12	0.36
1100	2.601557E-10	0.40	1.2331E-12	1.2331E-12	-4.4229E-13	-0.14	0.14	0.43
1300	2.008095E-09	0.51	9.2388E-12	9.2388E-12	-4.7201E-12	-0.26	0.18	0.55
1500	9.762228E-09	0.65	4.4733E-11	4.4733E-11	-3.9371E-11	-0.57	0.23	0.69
1700	3.449039E-08	0.80	1.5666E-10	1.5666E-10	-1.3709E-10	-0.70	0.28	0.85
1800	5.908776E-08	0.89	2.6978E-10	2.6978E-10	-3.1494E-10	-1.03	0.32	0.94
2000	1.512499E-07	1.06	6.8381E-10	6.8381E-10	-4.1533E-10	-0.64	0.39	1.12
2200	3.314114E-07	1.46	1.7518E-09	1.7518E-09	-1.3435E-09	-1.12	0.46	1.53
2400	6.484778E-07	1.70	3.4230E-09	3.4230E-09	-6.0788E-10	-0.30	0.54	1.79
2500	8.739647E-07	1.79	4.5136E-09	4.5136E-09	-6.1045E-10	-0.24	0.70	1.93

Table 159 – summary of NPL 2020 LP3 results and difference from weighted mean

t_{nom}/ °C	Average corrected Iph/ A	$U_{laboratory}$ (inc. drift)/ °C	Difference {Iph – weighted mean}/ A	Difference from weighted mean/ °C	$U_{ref\ value}$/ °C	U_{total}/ °C
960	4.223714E-11	0.28	2.4936E-13	0.41	0.12	0.30
1100	2.621771E-10	0.34	1.5791E-12	0.52	0.14	0.37
1300	2.025157E-09	0.49	1.2342E-11	0.69	0.18	0.52
1500	9.859289E-09	0.60	5.7690E-11	0.84	0.23	0.64
1700	3.483031E-08	0.69	2.0282E-10	1.03	0.28	0.75
1800	5.971986E-08	0.82	3.1715E-10	1.04	0.32	0.88
2000	1.524210E-07	0.88	7.5577E-10	1.16	0.39	0.96
2200	3.343491E-07	1.02	1.5942E-09	1.32	0.46	1.12
2400	6.514776E-07	1.20	2.3919E-09	1.19	0.54	1.31
2500	8.767742E-07	1.31	2.1990E-09	0.87	0.70	1.49
2600	1.156916E-06	1.45	3.0865E-09	1.00	0.72	1.62
2800	1.911196E-06	1.54	7.9029E-09	1.77	0.84	1.76
2900	2.397709E-06	1.67	1.0062E-08	1.92	1.04	1.98
3000	2.968182E-06	2.14	1.0625E-08	1.74	1.26	2.49

Table 160 – summary of the average of all the NPL calibrations of the LP3 and difference from weighted mean

t_{nom} / °C	**Average corrected Iph / A**	**Iph standard deviation / A**	**Average U_{NPL} (inc. drift) / A**	**Average U_{NPL} inc. drift & {std deviation/ $\sqrt{n}$} / A**	**Average U_{NPL} inc. drift & stdev)/ °C**	**U to use in weighted mean/ A**	**Difference {average Iph – weighted mean}/ A**	**Difference from weighted mean/ °C**	**$U_{ref\ value}$ / °C**	**U_{total} / °C**
960	4.207255E-11	9.61564E-14	1.9684E-13	2.1481E-13	0.35	2.1481E-13	8.4775E-14	0.14	0.12	0.37
1100	2.610330E-10	6.55649E-13	1.1838E-12	1.3211E-12	0.43	1.3211E-12	4.3502E-13	0.14	0.14	0.45
1300	2.016256E-09	5.14656E-12	8.7454E-12	9.8829E-12	0.55	9.8829E-12	3.4413E-12	0.19	0.18	0.58
1500	9.818523E-09	2.34782E-11	3.9667E-11	4.4883E-11	0.65	4.4883E-11	1.6924E-11	0.25	0.23	0.69
1700	3.468227E-08	8.59367E-11	1.3800E-10	1.5796E-10	0.80	1.5796E-10	5.4785E-11	0.28	0.28	0.85
1800	5.948855E-08	1.41457E-10	2.5122E-10	2.8129E-10	0.92	2.8129E-10	8.5845E-11	0.28	0.32	0.97
2000	1.519779E-07	3.0537E-10	6.0541E-10	6.6417E-10	1.02	6.6417E-10	3.1265E-10	0.48	0.39	1.09
2200	3.332562E-07	7.39167E-10	1.3294E-09	1.4847E-09	1.23	1.4847E-09	5.0127E-10	0.42	0.46	1.32
2400	6.499170E-07	1.23958E-09	2.6147E-09	2.8401E-09	1.41	2.8401E-09	8.3135E-10	0.41	0.54	1.51
2500	8.752783E-07	1.5009E-09	3.5903E-09	3.8331E-09	1.52	3.8331E-09	7.0314E-10	0.28	0.70	1.68
2600	1.154990E-06	1.67838E-09	4.8328E-09	5.0606E-09	1.63	5.0606E-09	1.1610E-09	0.38	0.72	1.79
2800	1.906799E-06	2.81508E-09	7.7996E-09	8.1960E-09	1.83	8.1960E-09	3.5058E-09	0.79	0.84	2.02
2900	2.392019E-06	3.90285E-09	1.1302E-08	1.1957E-08	2.27	1.1957E-08	4.3730E-09	0.83	1.04	2.51
3000	2.959621E-06	6.37395E-09	1.7533E-08	1.8656E-08	3.05	1.8656E-08	2.0644E-09	0.34	1.26	3.31

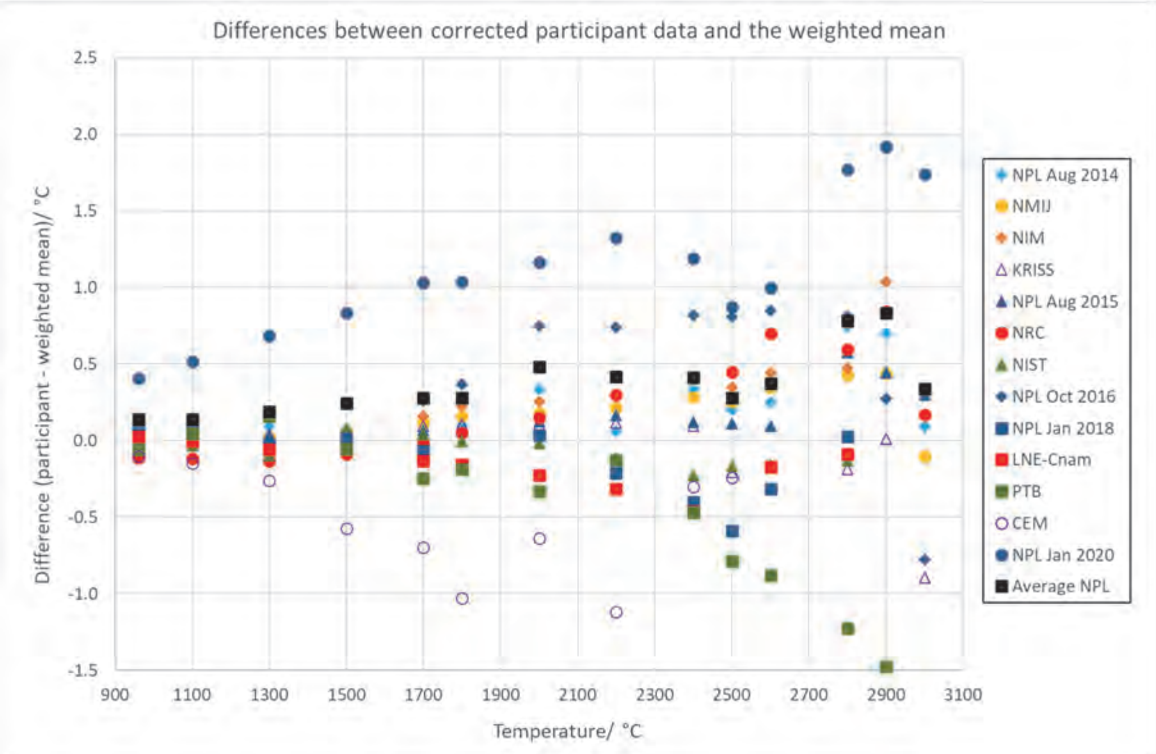

Figure 108 - Results of the comparison with the LP3, showing differences of each participant from the weighted mean value

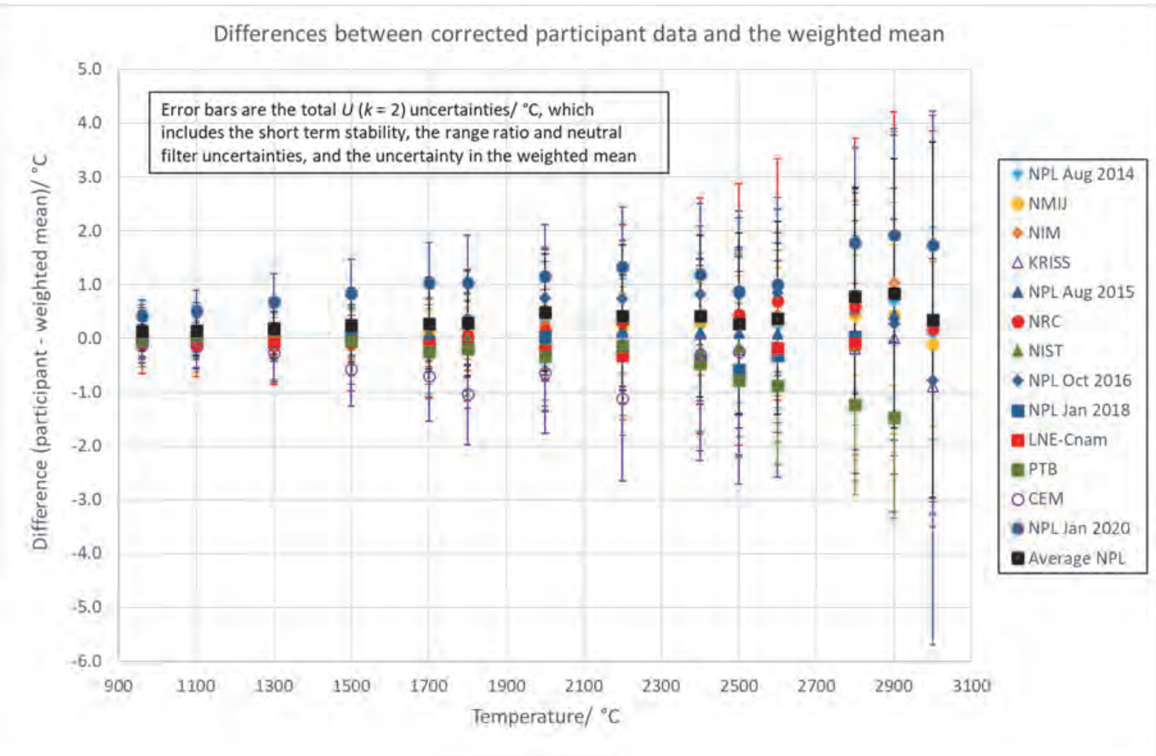

Figure 109 - Results of the comparison with the LP3, showing differences of each participant from the weighted mean value and the total, k = 2 uncertainties

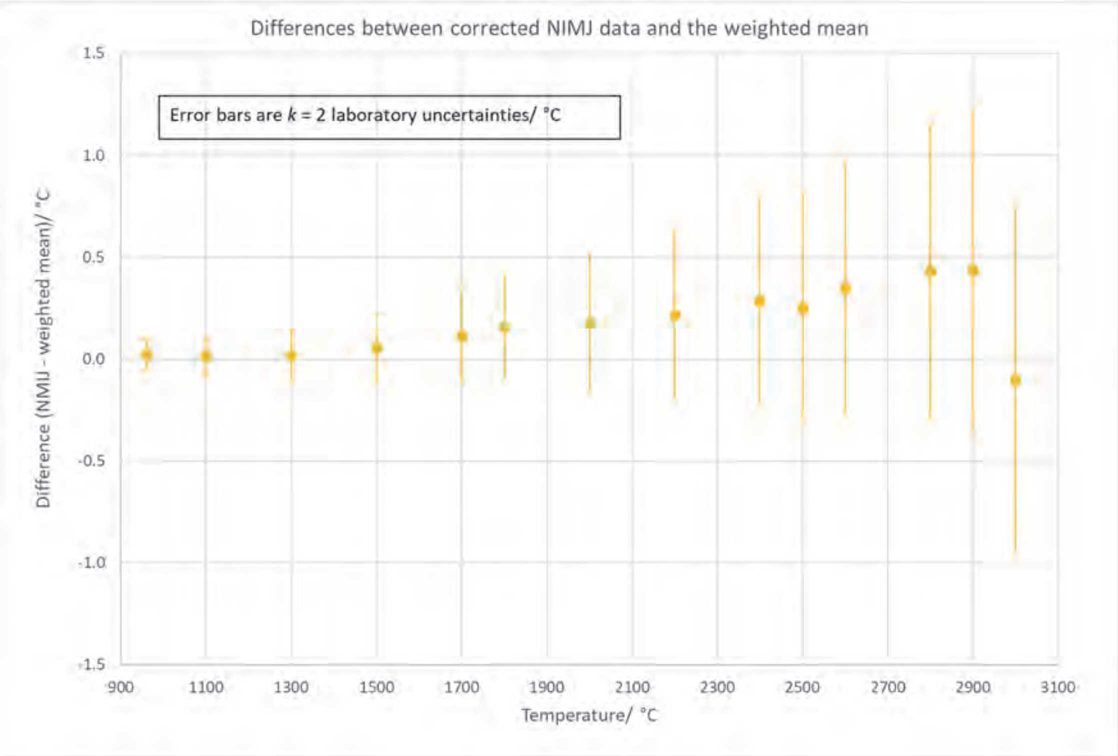

Figure 110 - difference between the NMIJ results and the weighted mean (*k* = 2 laboratory uncertainties)

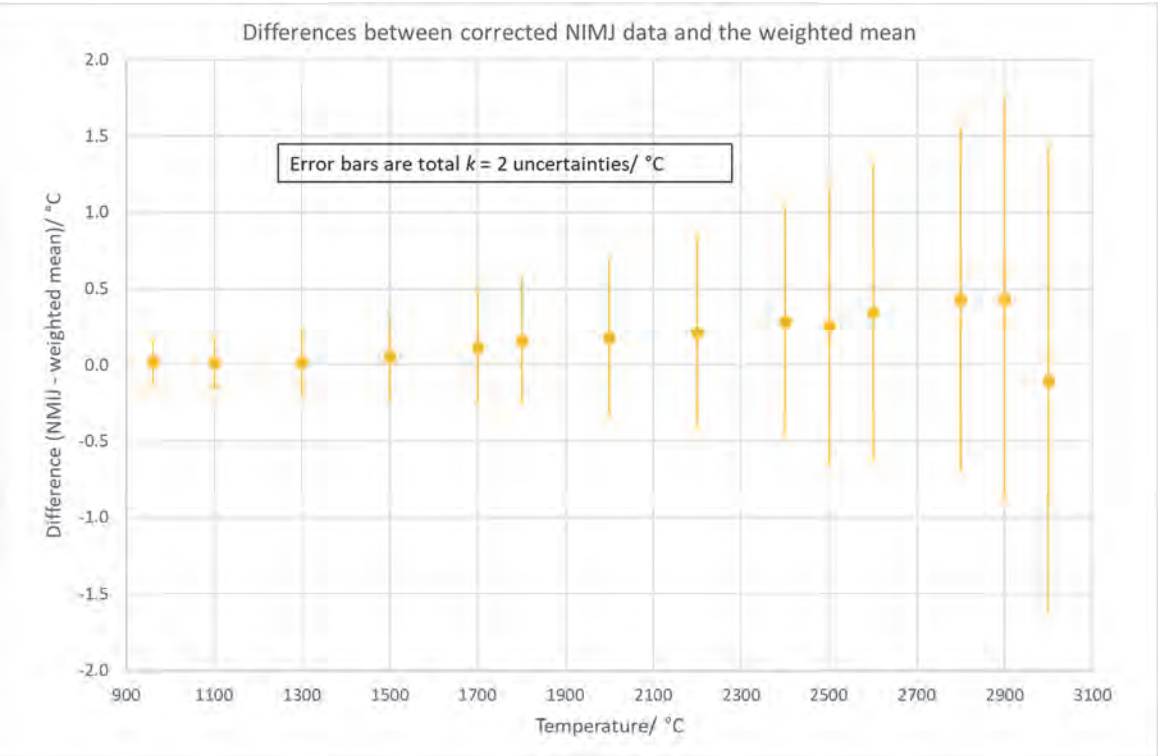

Figure 111 – difference between the NMIJ results and the weighted mean (*k* = 2 total uncertainties)

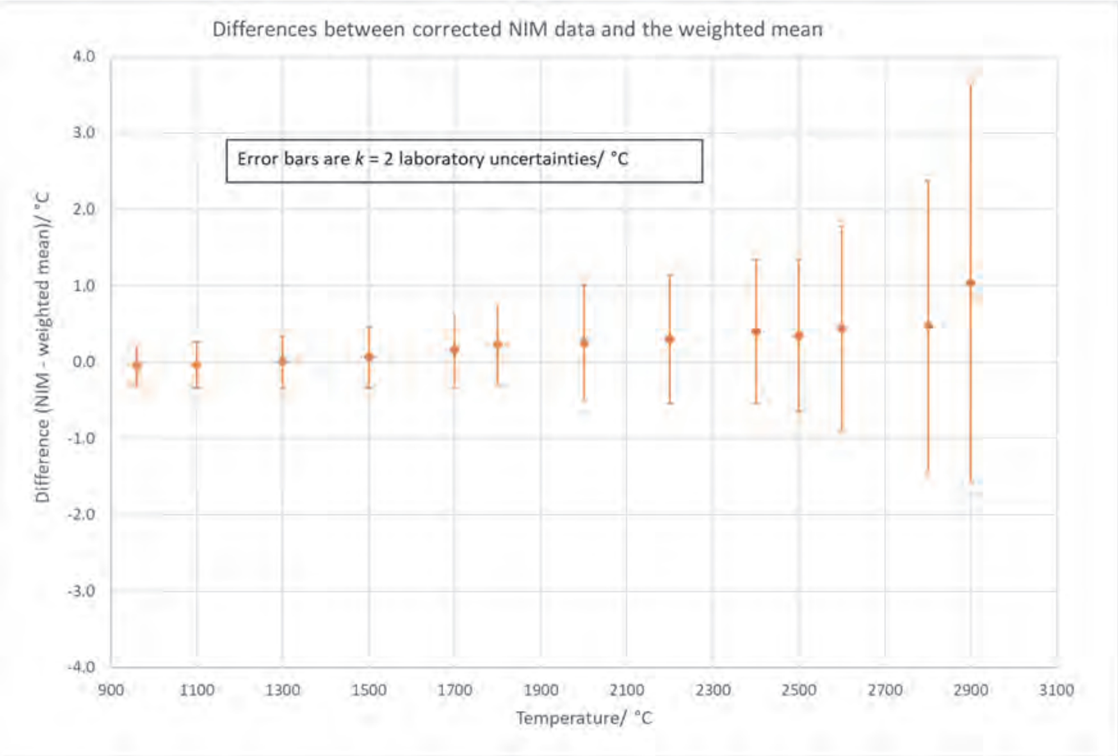

Figure 112 - difference between the NIM results and the weighted mean (*k* = 2 laboratory uncertainties)

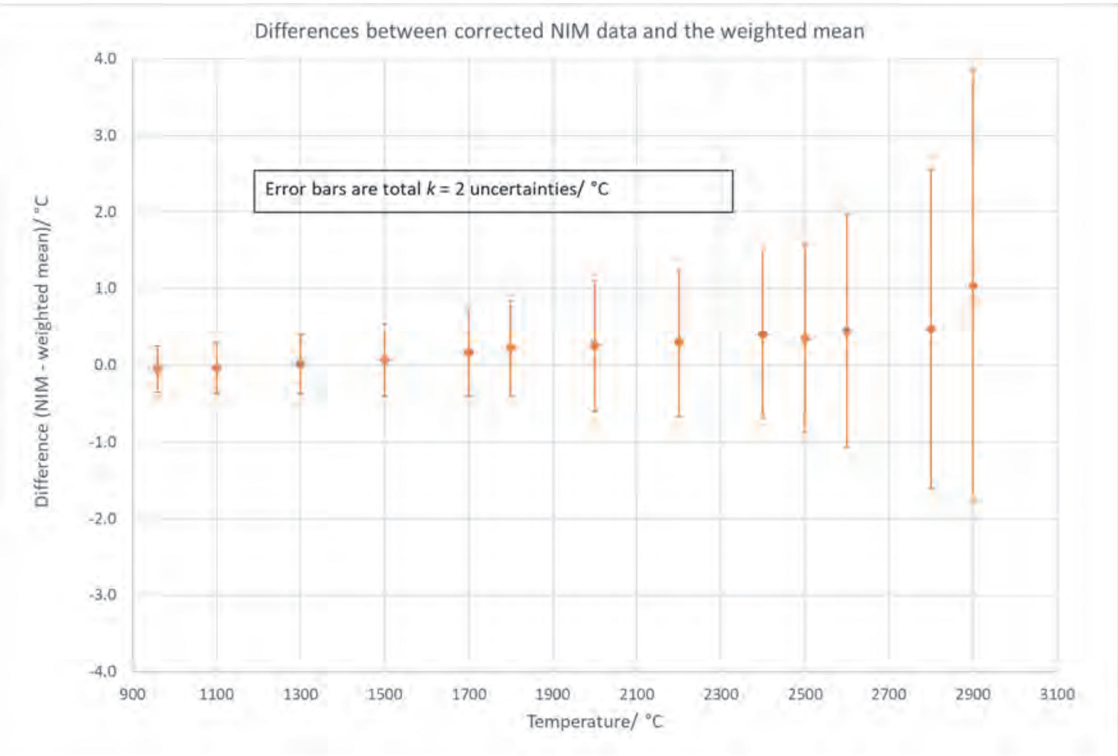

Figure 113 - difference between the NIM results and the weighted mean (*k* = 2 total uncertainties)

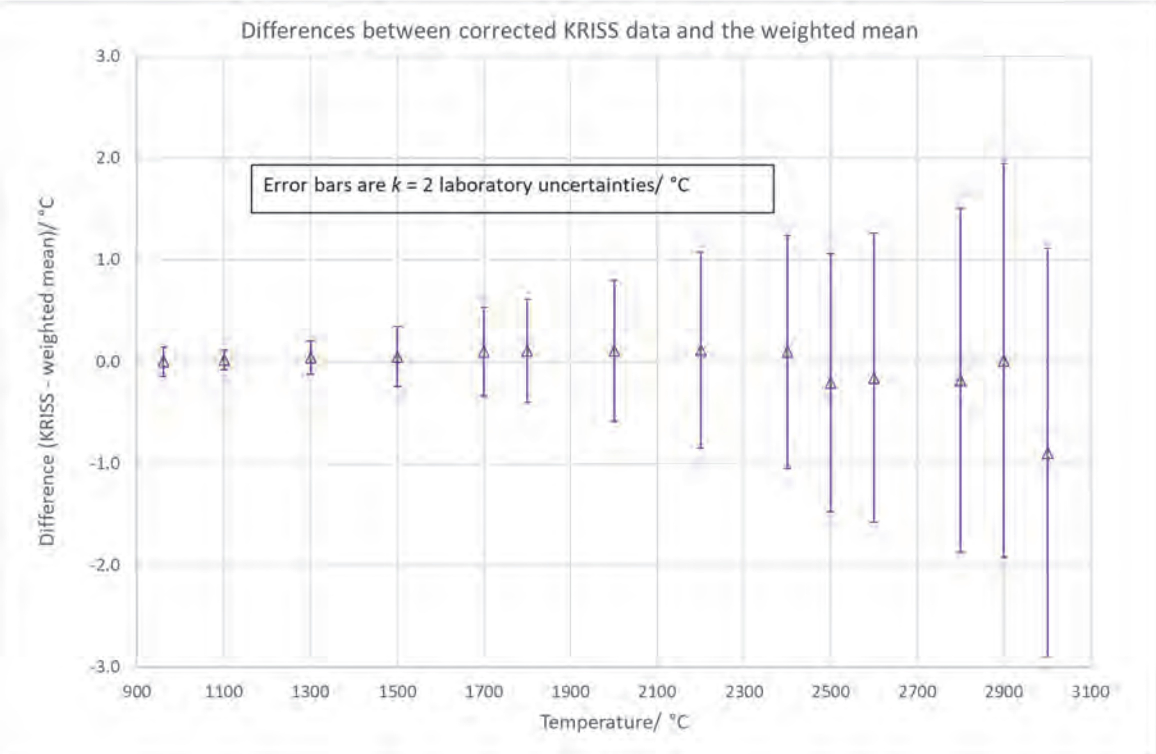

Figure 114 - difference between the KRISS results and the weighted mean (k = 2 laboratory uncertainties)

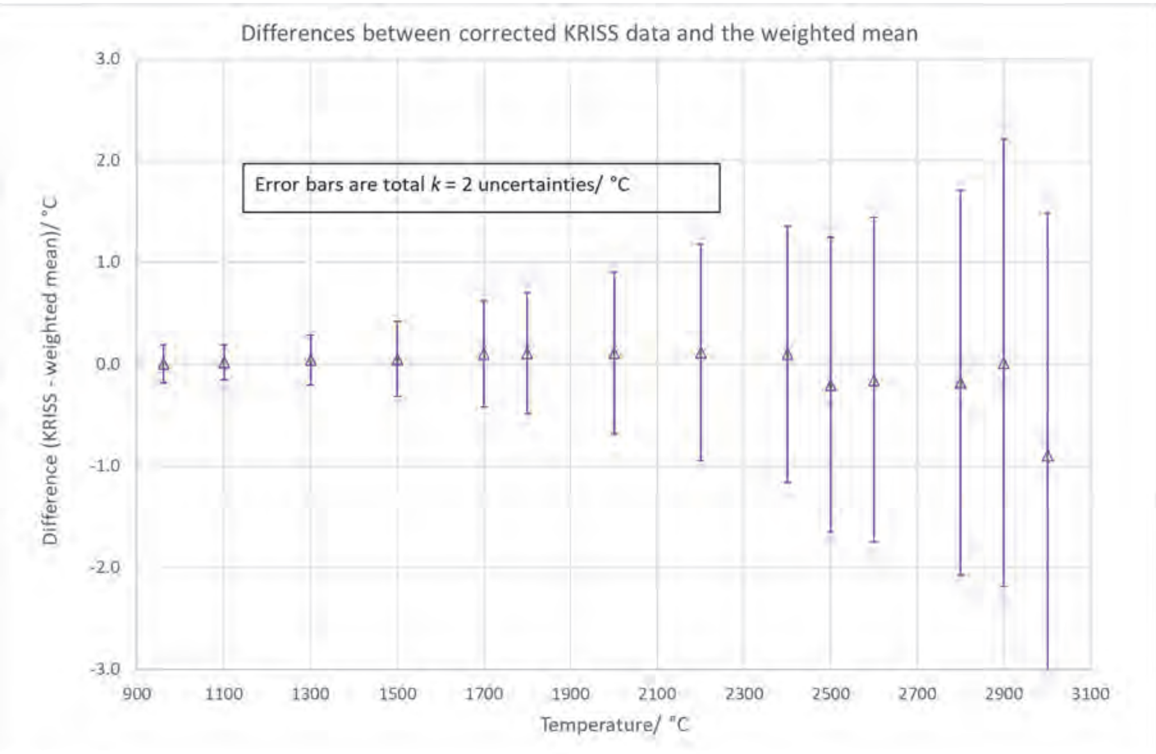

Figure 115 - difference between the KRISS results and the weighted mean (k = 2 total uncertainties)

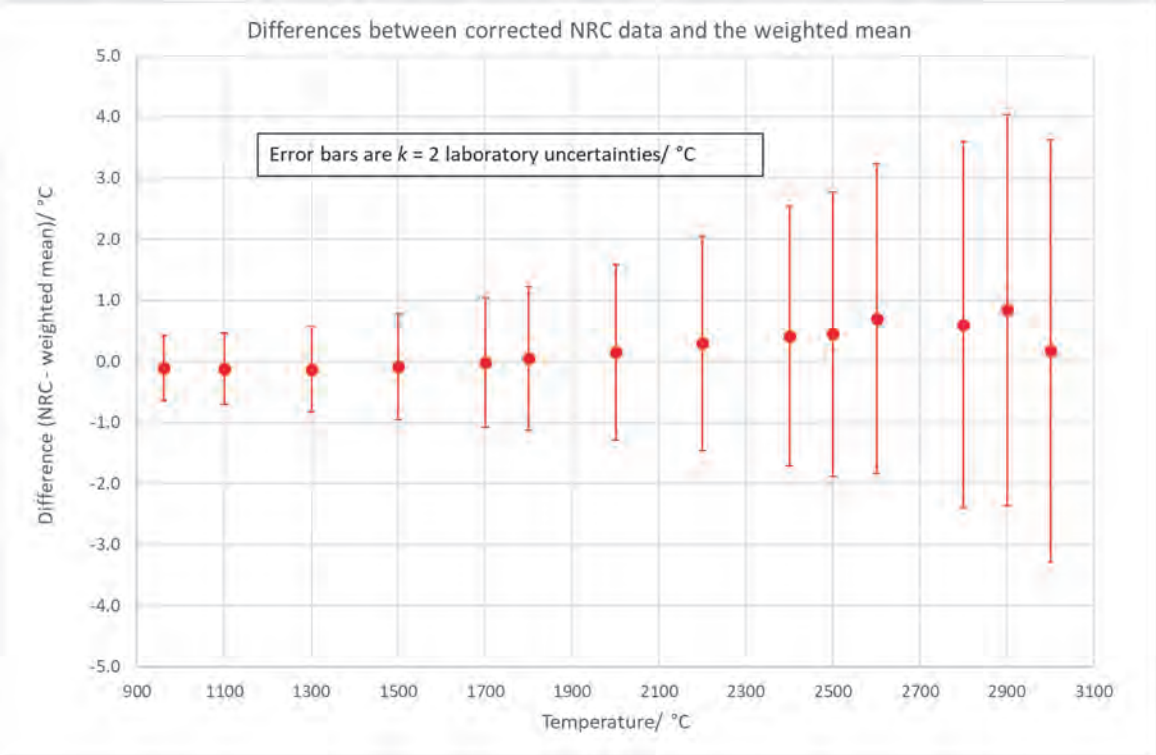

Figure 116 - difference between the NRC results and the weighted mean (*k* = 2 laboratory uncertainties)

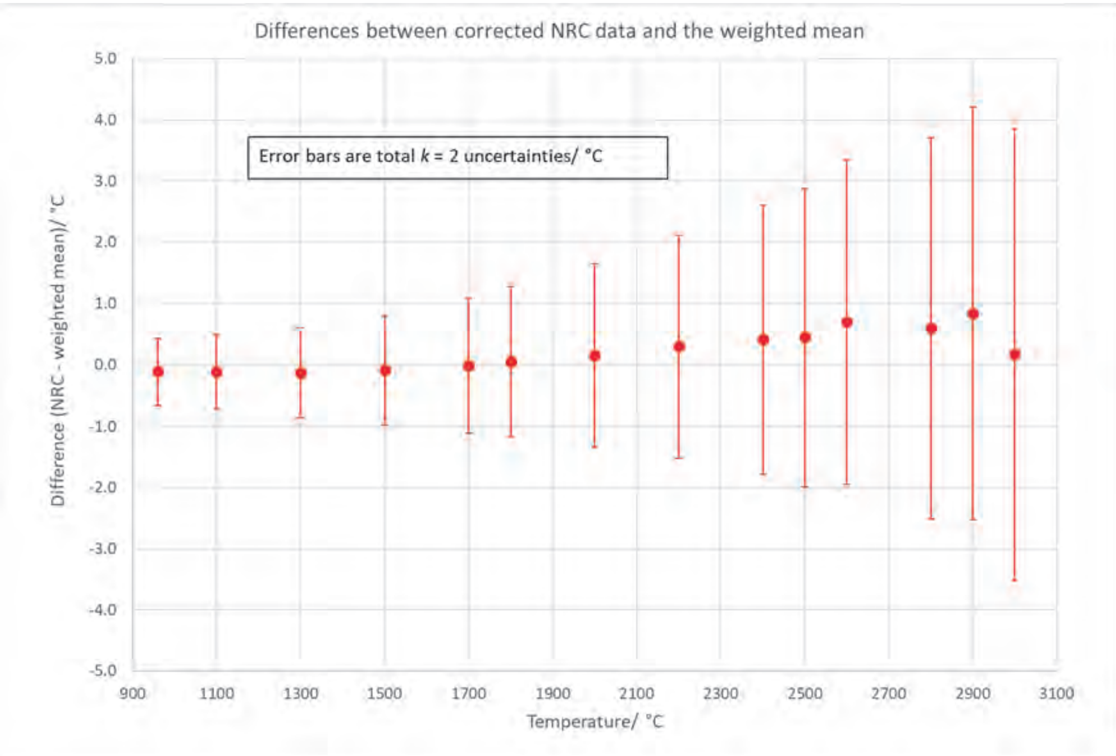

Figure 117 - difference between the NRC results and the weighted mean (*k* = 2 total uncertainties)

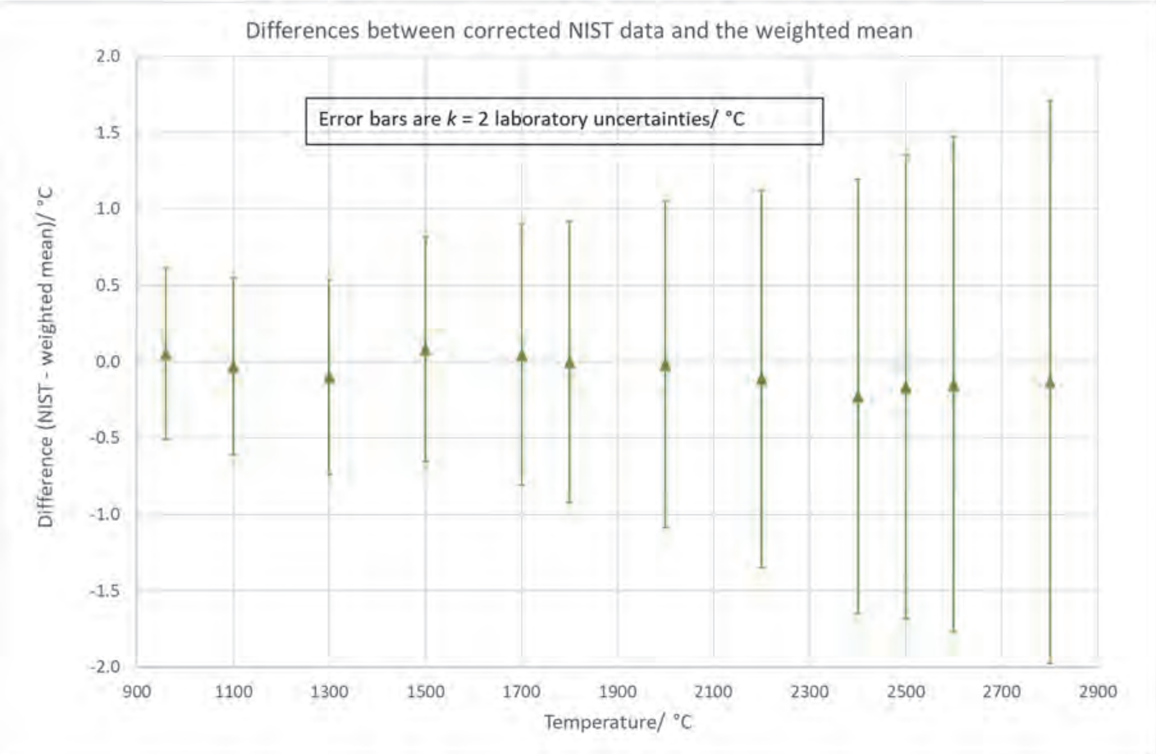

Figure 118 - difference between the NIST results and the weighted mean (*k* = 2 laboratory uncertainties)

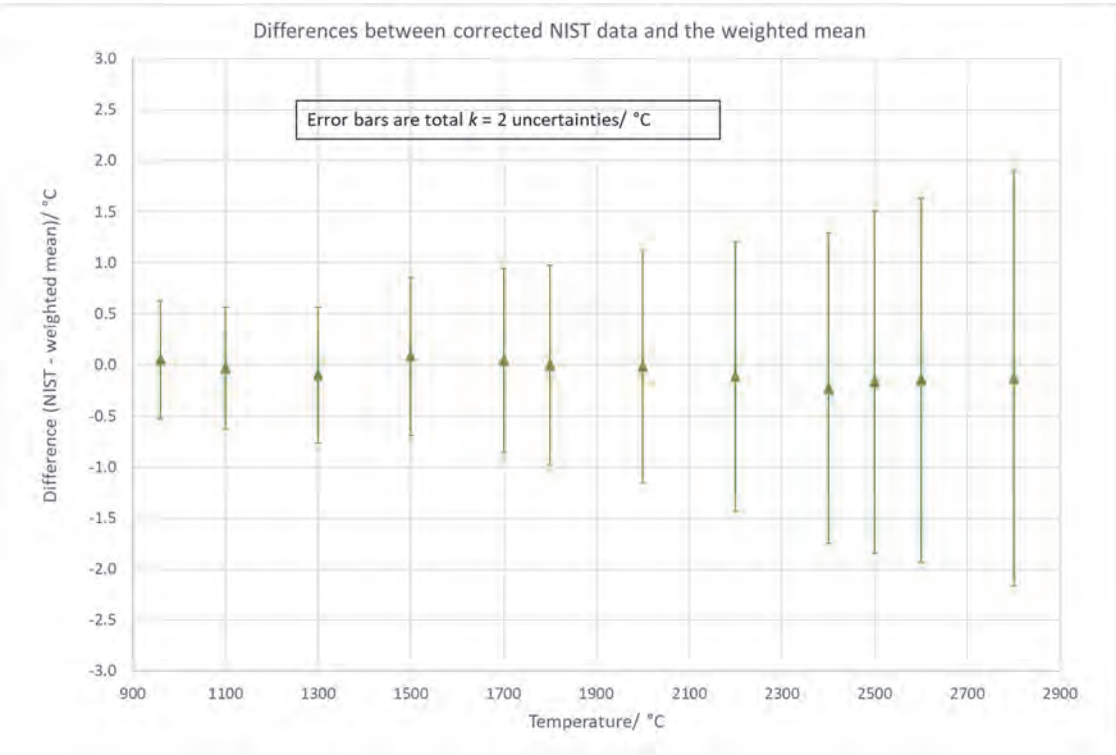

Figure 119 - difference between the NIST results and the weighted mean (*k* = 2 total uncertainties)

Figure 120 - difference between the LNE-Cnam results and the weighted mean (*k* = 2 laboratory uncertainties)

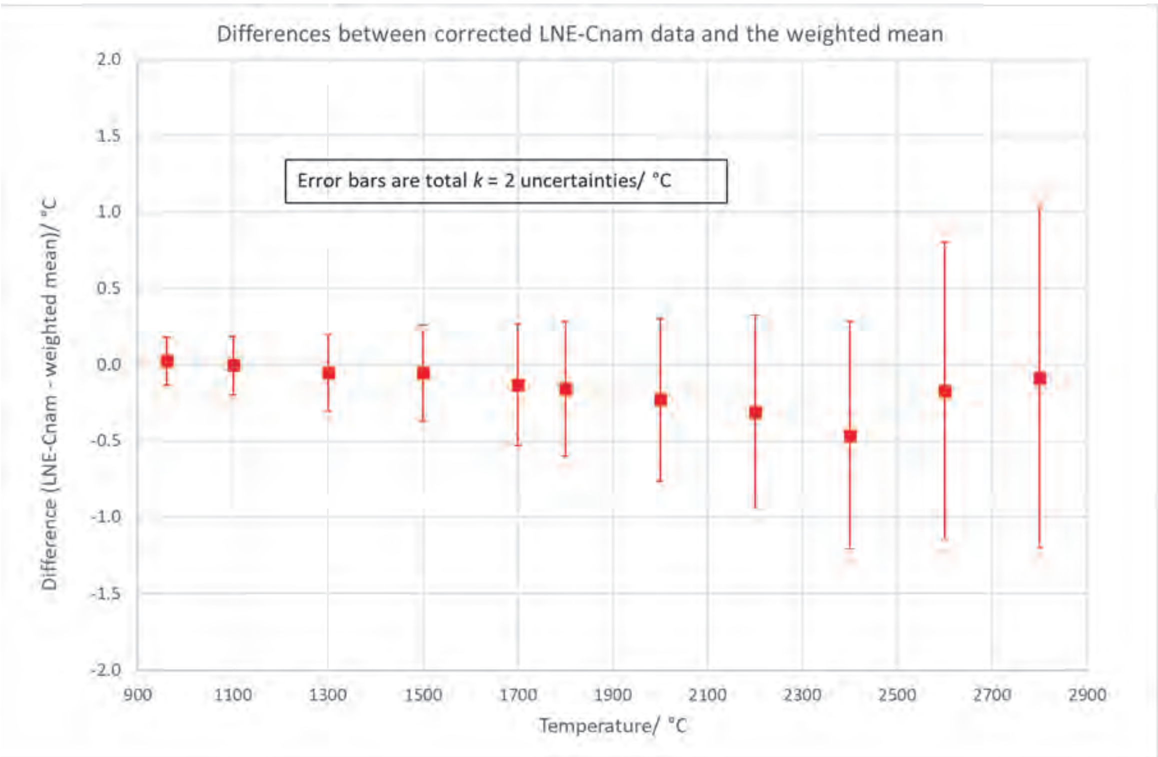

Figure 121 - difference between the LNE-Cnam results and the weighted mean (*k* = 2 total uncertainties)

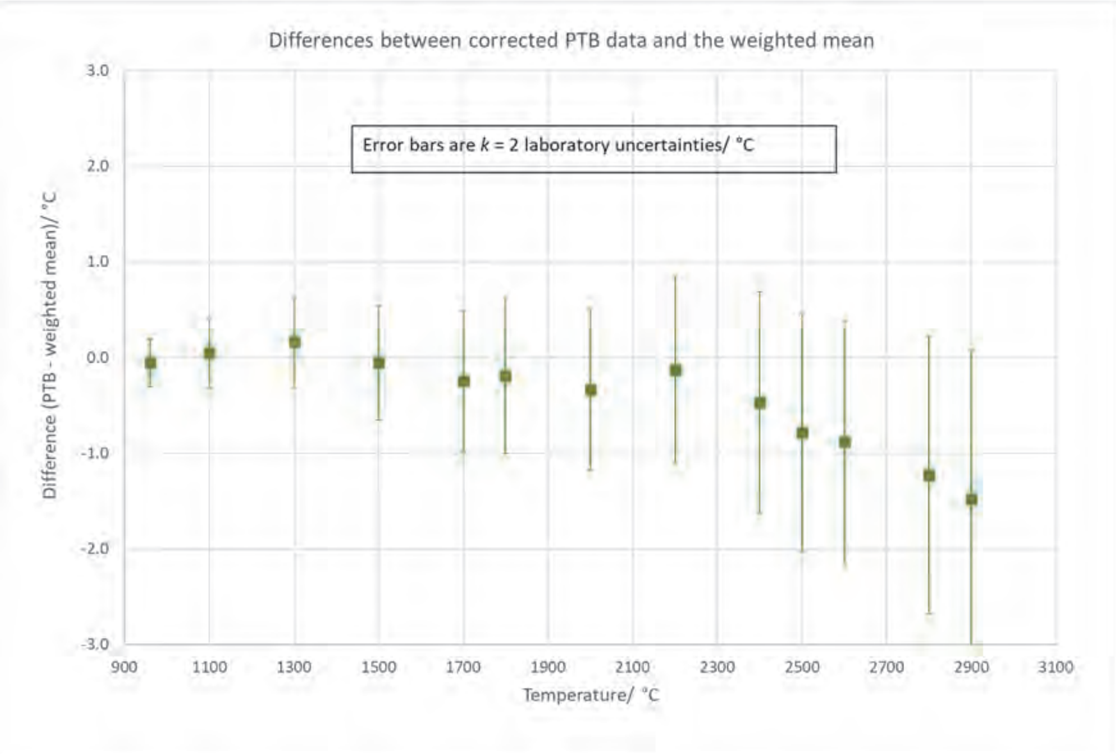

Figure 122 - difference between the PTB results and the weighted mean (*k* = 2 laboratory uncertainties)

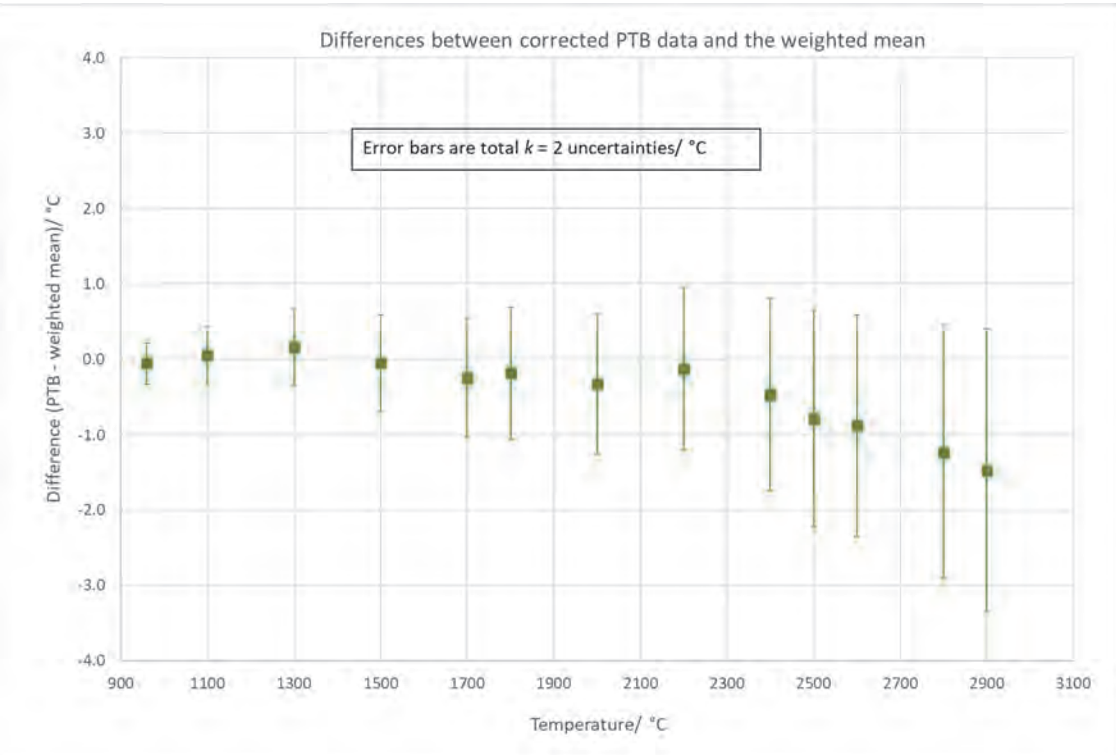

Figure 123 - difference between the PTB results and the weighted mean (*k* = 2 total uncertainties)

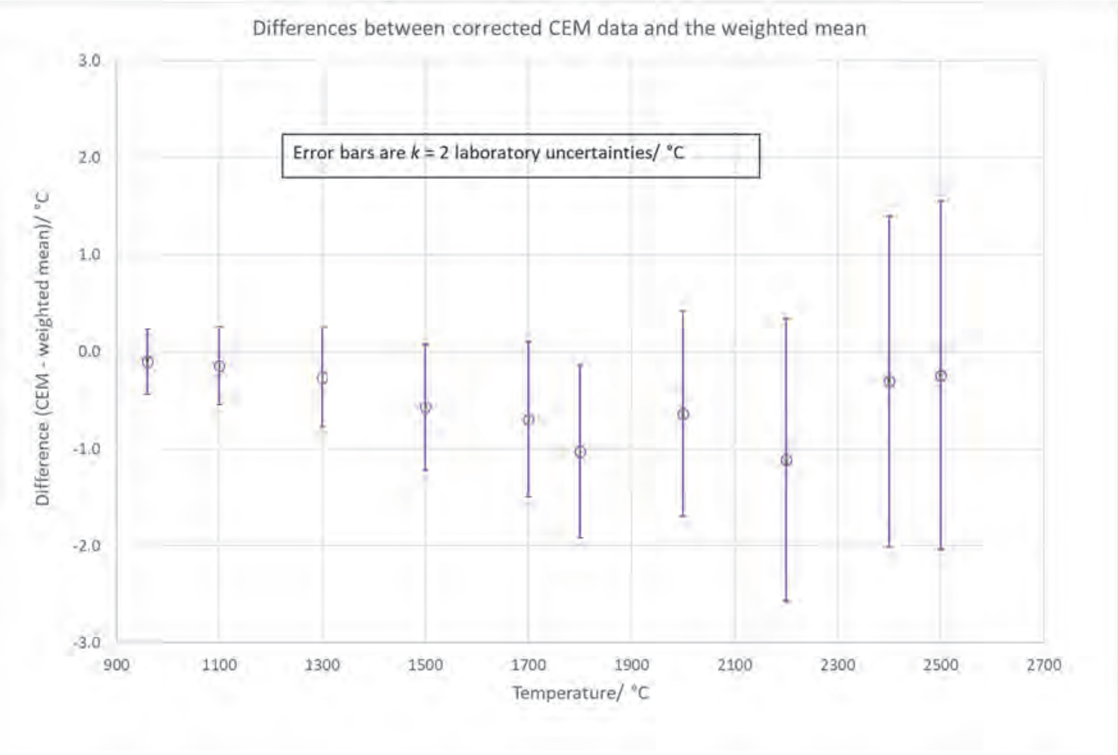

Figure 124 - difference between the CEM results and the weighted mean (*k* = 2 laboratory uncertainties)

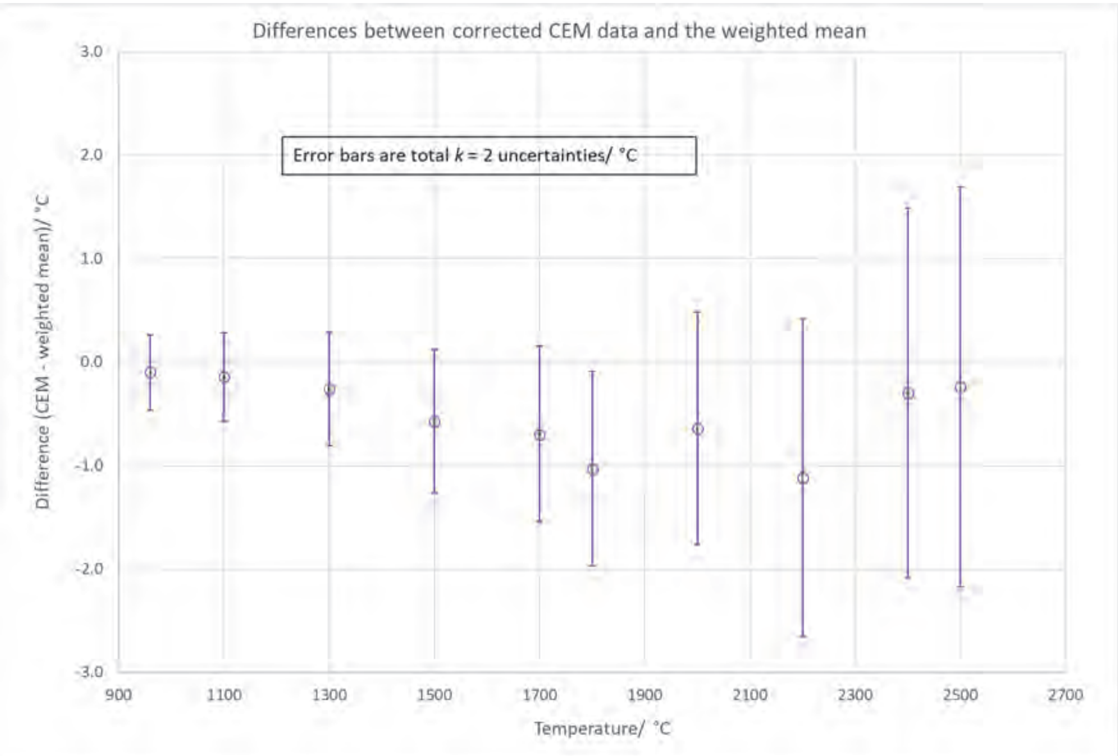

Figure 125 - difference between the CEM results and the weighted mean (*k* = 2 total uncertainties)

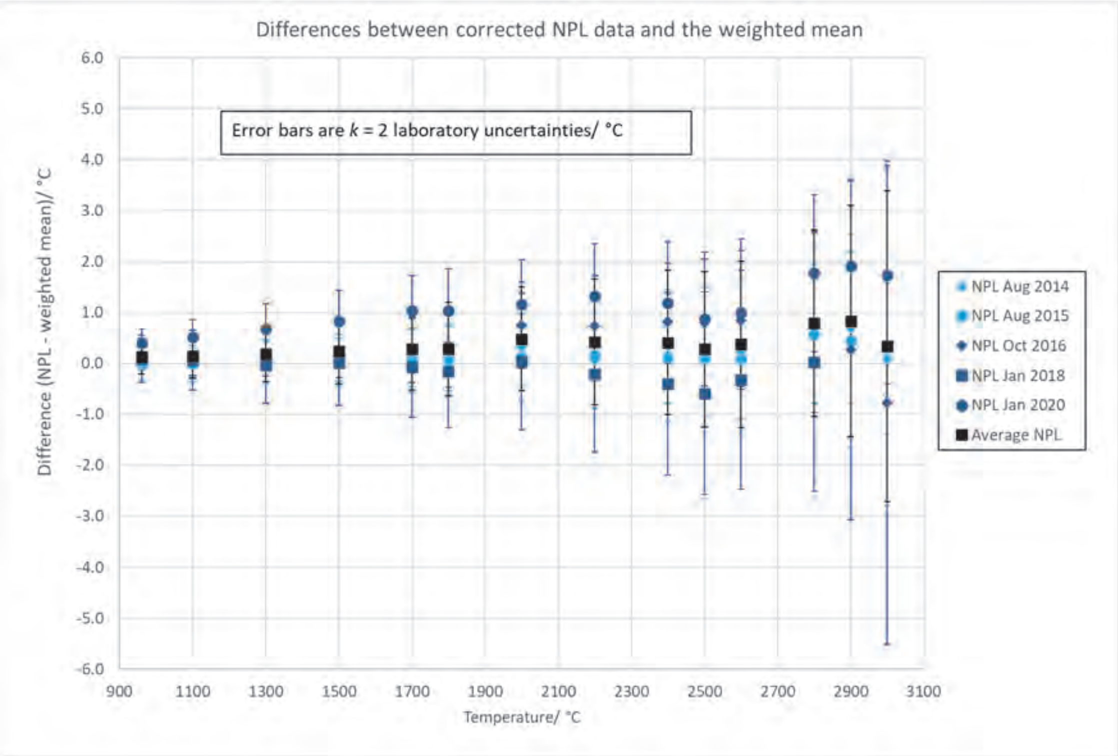

Figure 126 - difference between the NPL results and the weighted mean (*k* = 2 laboratory uncertainties)

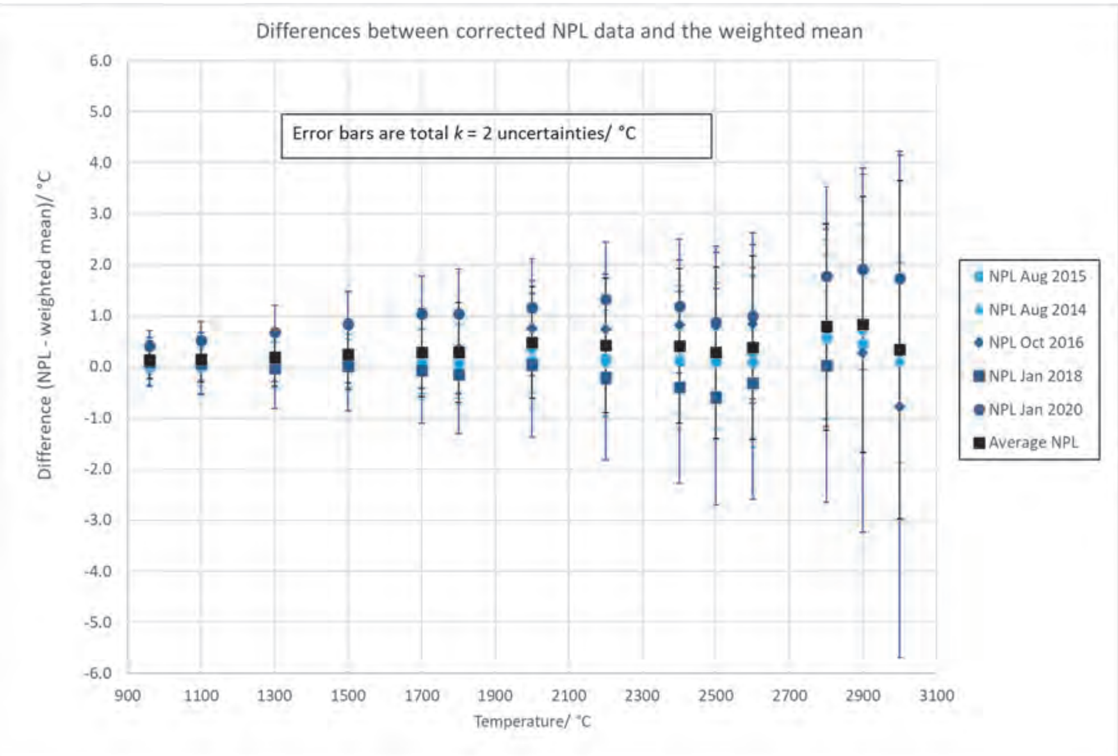

Figure 127 - difference between the NPL results and the weighted mean (*k* = 2 total uncertainties)

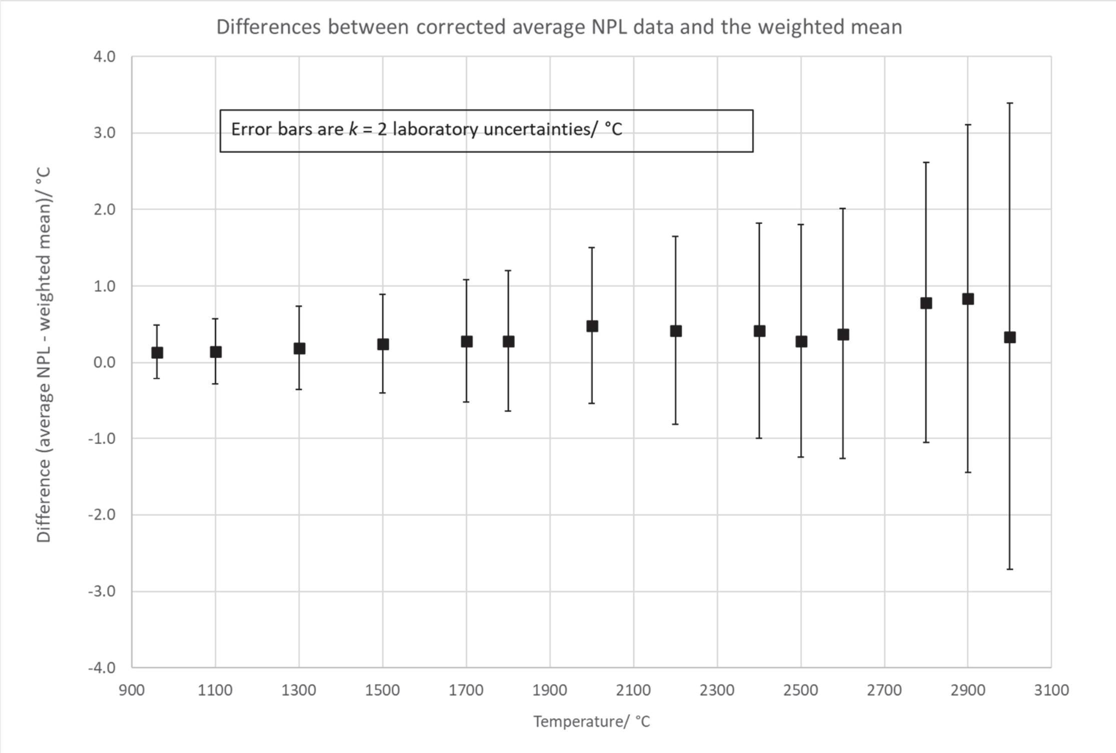

Figure 128 - difference between the average NPL results and the weighted mean (*k* = 2 laboratory uncertainties)

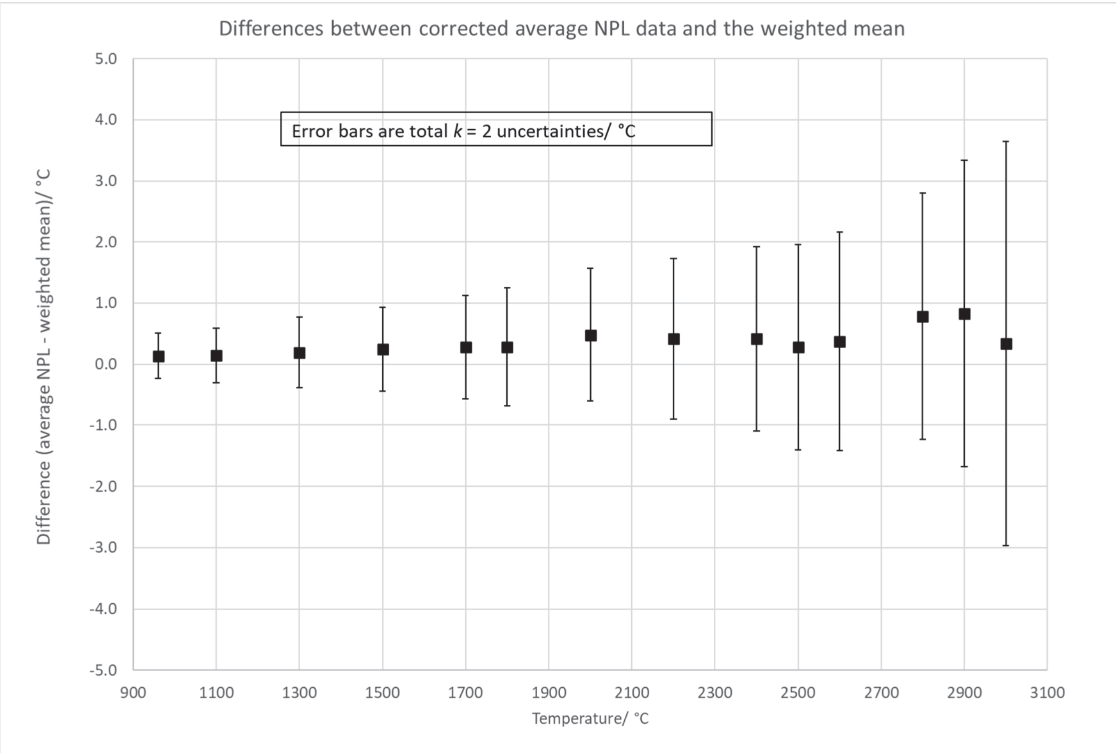

Figure 129 - difference between the average NPL results and the weighted mean (*k* = 2 total uncertainties)

2. RESULTS FOR THE CHINO THERMOMETER WITH DIFFERENCES FROM THE WEIGHTED MEAN, PRESENTED IN TABLES AND FIGURES

Table 161 - determining the *U* cut off values and the weighted means for the Chino thermometer

t_{nom}/ °C	Median *U*/ V	Cut off *U* value/ V	Weighted mean/ V	Standard deviation of weighted mean/ V	$u_{weighted\ mean}$ (standard deviation)/ °C
960	0.000025	0.000013	0.004871	0.000003	0.04
1100	0.000145	0.000078	0.030198	0.000019	0.05
1300	0.001017	0.000598	0.233151	0.000139	0.07
1500	0.004817	0.002988	1.135309	0.000678	0.08
1700	0.016472	0.011222	4.009205	0.002458	0.11
1800	0.025251	0.017825	6.876491	0.003924	0.11
2000	0.007258	0.004833	1.746901	0.001052	0.14
2200	0.014880	0.010862	3.833127	0.002392	0.17
2400	0.028258	0.021396	7.473033	0.004680	0.20
2500	0.004067	0.003184	1.008571	0.000714	0.25
2600	0.005327	0.003530	1.330478	0.000840	0.24
2800	0.009021	0.005985	2.195270	0.001439	0.28
2900	0.014331	0.008877	2.754722	0.002448	0.40
3000	0.018793	0.010814	3.412178	0.003828	0.54

Table 162 – summary of NPL 2014 Chino thermometer results and difference from weighted mean

t_{nom}/ °C	Average corrected signal/ V	$U_{laboratory}$/ °C	Difference {signal – weighted mean}/ V	Difference from weighted mean/ °C	$U_{ref\ value}$/ °C	U_{total}/ °C
960	0.004869	0.46	-0.000001	-0.02	0.20	0.50
1100	0.030194	0.50	-0.000004	-0.01	0.23	0.55
1300	0.233220	0.56	0.000069	0.03	0.28	0.63
1500	1.135099	0.66	-0.000210	-0.03	0.34	0.74
1700	4.007070	0.88	-0.002135	-0.09	0.42	0.98
1800	6.865701	0.89	-0.010790	-0.30	0.45	1.00
2000	1.746495	1.10	-0.000405	-0.05	0.54	1.23
2200	3.833636	1.22	0.000508	0.04	0.65	1.38
2400	7.479915	1.39	0.006881	0.30	0.75	1.58
2500	1.008424	1.51	-0.000147	-0.05	0.84	1.73
2600	1.331524	1.65	0.001046	0.29	0.87	1.86
2800	2.205235	1.70	0.009965	1.94	1.00	1.97
2900	2.770156	1.76	0.015434	2.55	1.20	2.13
3000	3.429509	1.92	0.017331	2.46	1.44	2.40

Table 163 – summary of NMIJ Chino thermometer results and difference from weighted mean

t_{nom}/ °C	Average corrected signal/ V	$U_{laboratory}$ (inc. drift)/ °C	$U_{laboratory}$ / V	U to use in weighted mean / V	Difference {signal – weighted mean}/ V	Difference from weighted mean / °C	$U_{ref\ value}$/ °C	U_{total}/ °C
960	0.004867	0.09	0.000006	0.000013	-0.000003	-0.05	0.20	0.22
1100	0.030190	0.10	0.000037	0.000078	-0.000008	-0.02	0.23	0.25
1300	0.233086	0.14	0.000302	0.000598	-0.000066	-0.03	0.28	0.32
1500	1.134986	0.20	0.001616	0.002988	-0.000323	-0.04	0.34	0.40
1700	4.010009	0.27	0.006263	0.011222	0.000804	0.04	0.42	0.50
1800	6.879800	0.32	0.011201	0.017825	0.003309	0.09	0.45	0.55
2000	1.748152	0.41	0.003063	0.004833	0.001251	0.17	0.54	0.68
2200	3.835241	0.51	0.007146	0.010862	0.002114	0.15	0.65	0.83
2400	7.481484	0.63	0.014675	0.021396	0.008450	0.37	0.75	0.98
2500	1.008692	0.70	0.002024	0.003184	0.000121	0.04	0.84	1.09
2600	1.331014	0.76	0.002729	0.003530	0.000536	0.15	0.87	1.16
2800	2.195663	0.91	0.004671	0.005985	0.000393	0.08	1.00	1.35
2900	2.754281	0.98	0.005958	0.008877	-0.000441	-0.07	1.20	1.55
3000	3.407657	1.06	0.007486	0.010814	-0.004521	-0.64	1.44	1.79

Table 164 – summary of NIM Chino thermometer results and difference from weighted mean

t_{nom}/ °C	Average corrected signal/ V	$U_{laboratory}$ (inc. drift)/ °C	$U_{laboratory}$ / V	U to use in weighted mean / V	Difference {signal – weighted mean}/ V	Difference from weighted mean / °C	$U_{ref\ value}$/ °C	U_{total}/ °C
960	0.004859	0.36	0.000026	0.000026	-0.000012	-0.16	0.20	0.41
1100	0.030123	0.43	0.000153	0.000153	-0.000075	-0.21	0.23	0.49
1300	0.232733	0.49	0.001017	0.001017	-0.000418	-0.20	0.28	0.56
1500	1.133486	0.58	0.004646	0.004646	-0.001823	-0.23	0.34	0.68
1700	4.005949	0.68	0.015400	0.015400	-0.003255	-0.14	0.42	0.80
1800	6.874136	0.71	0.025251	0.025251	-0.002354	-0.07	0.45	0.84
2000	1.746161	0.97	0.007258	0.007258	-0.000740	-0.10	0.54	1.11
2200	3.835637	1.07	0.014880	0.014880	0.002510	0.18	0.65	1.25
2400	7.509864	1.21	0.028258	0.028258	0.036830	1.59	0.75	1.43
2500	1.015756	1.29	0.003760	0.003760	0.007185	2.48	0.84	1.54
2600	1.343191	1.58	0.005700	0.005700	0.012714	3.56	0.87	1.80
2800	2.219083	2.16	0.011215	0.011215	0.023813	4.63	1.00	2.38
2900	2.787050	2.83	0.017325	0.017325	0.032328	5.34	1.20	3.07

Table 165 – summary of KRISS Chino thermometer results and difference from weighted mean

t_{nom}/ °C	Average corrected signal/ V	$U_{laboratory}$ (inc. drift)/ °C	$U_{laboratory}$ / V	U to use in weighted mean / V	Difference {signal – weighted mean}/ V	Difference from weighted mean / °C	$U_{ref\ value}$/ °C	U_{total}/ °C
960	0.004876	0.14	0.000010	0.000013	0.000005	0.07	0.20	0.25
1100	0.030196	0.10	0.000036	0.000078	-0.000002	-0.01	0.23	0.25
1300	0.233438	0.16	0.000326	0.000598	0.000286	0.14	0.28	0.32
1500	1.136242	0.27	0.002153	0.002988	0.000933	0.12	0.34	0.44
1700	4.014277	0.50	0.011516	0.011516	0.005072	0.22	0.42	0.66
1800	6.886391	0.50	0.017732	0.017825	0.009901	0.28	0.45	0.67
2000	1.749278	0.69	0.005134	0.005134	0.002377	0.32	0.54	0.87
2200	3.837690	0.94	0.013066	0.013066	0.004563	0.33	0.65	1.14
2400	7.484104	1.13	0.026162	0.026162	0.011071	0.48	0.75	1.36
2500	1.008606	1.26	0.003644	0.003644	0.000035	0.01	0.84	1.51
2600	1.330620	1.39	0.004955	0.004955	0.000142	0.04	0.87	1.64
2800	2.195853	1.68	0.008621	0.008621	0.000583	0.11	1.00	1.95
2900	2.756414	1.91	0.011594	0.011594	0.001692	0.28	1.20	2.26
3000	3.415004	2.00	0.014141	0.014141	0.002826	0.40	1.44	2.46

Table 166 – summary of NPL 2015 Chino thermometer results and difference from weighted mean

t_{nom}/ °C	Average corrected signal/ V	$U_{laboratory}$ (inc. drift)/ °C	Difference {signal – weighted mean}/ V	Difference from weighted mean/ °C	$U_{ref\ value}$/ °C	U_{total}/ °C
960	0.004868	0.54	-0.000003	-0.04	0.20	0.58
1100	0.030163	0.56	-0.000035	-0.10	0.23	0.61
1300	0.233100	0.62	-0.000052	-0.02	0.28	0.68
1500	1.135153	0.69	-0.000156	-0.02	0.34	0.77
1700	4.007030	0.79	-0.002175	-0.10	0.42	0.90
1800	6.873782	0.87	-0.002709	-0.08	0.45	0.98
2000	1.749424	1.00	0.002523	0.34	0.54	1.14
2200	3.826725	1.44	-0.006402	-0.46	0.65	1.58
2400	7.473572	1.38	0.000538	0.02	0.75	1.57
2500	1.008413	1.51	-0.000158	-0.05	0.84	1.73
2600	1.330626	1.62	0.000149	0.04	0.87	1.83
2800	2.198612	1.64	0.003342	0.65	1.00	1.92
2900	2.750022	2.61	-0.004700	-0.78	1.20	2.87
3000	3.406198	2.91	-0.005979	-0.85	1.44	3.25

Table 167 – summary of NRC Chino thermometer results and difference from weighted mean

t_{nom}/ °C	Average corrected signal/ V	$U_{laboratory}$ (inc. drift)/ °C	$U_{laboratory}$ / V	U to use in weighted mean / V	Difference {signal – weighted mean}/ V	Difference from weighted mean / °C	$U_{ref\ value}$/ °C	U_{total}/ °C
960	0.004860	0.53	0.000038	0.000038	-0.000011	-0.15	0.20	0.57
1100	0.030136	0.58	0.000206	0.000206	-0.000062	-0.17	0.23	0.62
1300	0.232796	0.70	0.001461	0.001461	-0.000355	-0.17	0.28	0.76
1500	1.133935	0.86	0.006885	0.006885	-0.001374	-0.17	0.34	0.93
1700	4.008684	1.06	0.024228	0.024228	-0.000521	-0.02	0.42	1.14
1800	6.877912	1.17	0.041563	0.041563	0.001422	0.04	0.45	1.26
2000	1.748160	1.44	0.010813	0.010813	0.001259	0.17	0.54	1.54
2200	3.836444	1.76	0.024498	0.024498	0.003317	0.24	0.65	1.88
2400	7.484545	2.13	0.049271	0.049271	0.011512	0.50	0.75	2.25
2500	1.009021	2.32	0.006725	0.006725	0.000450	0.15	0.84	2.46
2600	1.331247	2.53	0.009016	0.009016	0.000769	0.22	0.87	2.67
2800	2.195996	2.99	0.015371	0.015371	0.000726	0.14	1.00	3.15
2900	2.757202	3.19	0.019316	0.019316	0.002480	0.41	1.20	3.40
3000	3.417717	3.45	0.024341	0.024341	0.005540	0.79	1.44	3.73

Table 168 – summary of NIST Chino thermometer results and difference from weighted mean

t_{nom}/ °C	Average corrected signal/ V	$U_{laboratory}$ (inc. drift)/ °C	$U_{laboratory}$ / V	U to use in weighted mean / V	Difference {signal – weighted mean} / V	Difference from weighted mean / °C	$U_{ref\ value}$/ °C	U_{total}/ °C
960	0.004875	0.56	0.000040	0.000040	0.000004	0.06	0.20	0.59
1100	0.030220	0.58	0.000205	0.000205	0.000021	0.06	0.23	0.62
1300	0.232984	0.64	0.001326	0.001326	-0.000167	-0.08	0.28	0.70
1500	1.135770	0.73	0.005856	0.005856	0.000461	0.06	0.34	0.81
1700	4.008135	0.85	0.019357	0.019357	-0.001070	-0.05	0.42	0.95
1800	6.870674	0.92	0.032399	0.032399	-0.005817	-0.16	0.45	1.02
2000	1.744942	1.06	0.007943	0.007943	-0.001959	-0.26	0.54	1.19
2200	3.824819	1.23	0.017004	0.017004	-0.008308	-0.60	0.65	1.39
2400	7.458087	1.41	0.032629	0.032629	-0.014947	-0.65	0.75	1.60
2500	1.005982	1.51	0.004375	0.004375	-0.002589	-0.89	0.84	1.73
2600	1.326912	1.61	0.005742	0.005742	-0.003566	-1.00	0.87	1.83
2800	2.193646	1.83	0.009421	0.009421	-0.001624	-0.32	1.00	2.09

Table 169 – summary of NPL 2016 Chino thermometer results and difference from weighted mean

t_{nom}/ °C	Average corrected signal/ V	$U_{laboratory}$ (inc. drift)/ °C	Difference {signal – weighted mean}/ V	Difference from weighted mean/ °C	$U_{ref\ value}$/ °C	U_{total}/ °C
960	0.004871	0.52	0.000001	0.01	0.20	0.56
1100	0.030217	0.55	0.000019	0.05	0.23	0.59
1300	0.233211	0.60	0.000060	0.03	0.28	0.66
1500	1.135661	0.67	0.000352	0.04	0.34	0.75
1700	4.010817	0.78	0.001612	0.07	0.42	0.88
1800	6.879807	0.92	0.003316	0.09	0.45	1.02
2000	1.751156	0.98	0.004255	0.57	0.54	1.12
2200	3.838216	1.11	0.005089	0.37	0.65	1.28
2400	7.486176	1.28	0.013142	0.57	0.75	1.48
2500	1.009463	1.37	0.000891	0.31	0.84	1.61
2600	1.332701	1.49	0.002223	0.62	0.87	1.72
2800	2.204268	2.06	0.008998	1.75	1.00	2.29
2900	2.762874	3.43	0.008152	1.35	1.20	3.63
3000	3.417901	4.76	0.005724	0.81	1.44	4.97

Table 170 – summary of NPL 2018 Chino thermometer results and difference from weighted mean

t_{nom}/ °C	Average corrected signal/ V	$U_{laboratory}$ (inc. drift)/ °C	Difference {signal – weighted mean}/ V	Difference from weighted mean/ °C	$U_{ref\ value}$/ °C	U_{total}/ °C
960	0.004872	0.51	0.000002	0.02	0.20	0.55
1100	0.030215	0.59	0.000017	0.05	0.23	0.63
1300	0.233207	0.76	0.000056	0.03	0.28	0.81
1500	1.135188	0.89	-0.000121	-0.02	0.34	0.95
1700	4.008400	1.03	-0.000805	-0.04	0.42	1.11
1800	6.872483	1.09	-0.004008	-0.11	0.45	1.18
2000	1.746693	1.35	-0.000208	-0.03	0.54	1.45
2200	3.831306	1.54	-0.001821	-0.13	0.65	1.67
2400	7.465481	1.90	-0.007553	-0.33	0.75	2.05
2500	1.006199	2.18	-0.002372	-0.82	0.84	2.34
2600	1.329095	2.20	-0.001382	-0.39	0.87	2.37
2800	2.198532	2.92	0.003262	0.63	1.00	3.09

Table 171 – summary of LNE-Cnam Chino thermometer results and difference from weighted mean

t_{nom}/ °C	Average corrected signal/ V	$U_{laboratory}$ (inc. drift)/ °C	$U_{laboratory}$ / V	U to use in weighted mean / V	Difference {signal – weighted mean} / V	Difference from weighted mean / °C	$U_{ref\ value}$/ °C	U_{total}/ °C
960	0.004871	0.10	0.000007	0.000013	0.000001	0.01	0.20	0.23
1100	0.030219	0.13	0.000046	0.000078	0.000021	0.06	0.23	0.26
1300	0.233171	0.17	0.000358	0.000598	0.000020	0.01	0.28	0.33
1500	1.135364	0.21	0.001708	0.002988	0.000055	0.01	0.34	0.41
1700	4.011732	0.28	0.006459	0.011222	0.002528	0.11	0.42	0.51
1800	6.878651	0.31	0.011111	0.017825	0.002161	0.06	0.45	0.55
2000	1.747312	0.37	0.002784	0.004833	0.000411	0.05	0.54	0.66
2200	3.832084	0.44	0.006073	0.010862	-0.001044	-0.08	0.65	0.78
2400	7.467360	0.52	0.011940	0.021396	-0.005674	-0.25	0.75	0.91
2500	-	-	-	-	-	-	-	-
2600	1.328954	0.59	0.002107	0.003530	-0.001524	-0.43	0.87	1.05
2800	2.192222	0.67	0.003437	0.005985	-0.003049	-0.59	1.00	1.20

Table 172 – summary of PTB Chino thermometer results and difference from weighted mean

t_{nom}/ °C	Average corrected signal/ V	$U_{laboratory}$ (inc. drift)/ °C	$U_{laboratory}$ / V	U to use in weighted mean / V	Difference {signal – weighted mean} / V	Difference from weighted mean / °C	$U_{ref\ value}$/ °C	U_{total}/ °C
960	0.004872	0.24	0.000017	0.000017	0.000002	0.02	0.20	0.31
1100	0.030203	0.35	0.000125	0.000125	0.000005	0.01	0.23	0.42
1300	0.233136	0.47	0.000989	0.000989	-0.000015	-0.01	0.28	0.55
1500	1.137261	0.60	0.004817	0.004817	0.001952	0.24	0.34	0.69
1700	4.001250	0.72	0.016472	0.016472	-0.007955	-0.35	0.42	0.84
1800	6.864309	0.67	0.023829	0.023829	-0.012182	-0.34	0.45	0.81
2000	1.742937	0.79	0.005924	0.005924	-0.003963	-0.53	0.54	0.96
2200	3.828337	0.95	0.013144	0.013144	-0.004790	-0.35	0.65	1.15
2400	7.461211	1.12	0.025944	0.025944	-0.011823	-0.51	0.75	1.35
2500	1.005326	1.14	0.003308	0.003308	-0.003245	-1.12	0.84	1.42
2600	1.326265	1.22	0.004329	0.004329	-0.004212	-1.18	0.87	1.49
2800	2.186457	1.41	0.007210	0.007210	-0.008813	-1.71	1.00	1.73
2900	2.742404	1.51	0.009080	0.009080	-0.012318	-2.03	1.20	1.92

Table 173 – summary of CEM Chino thermometer results and difference from weighted mean

t_{nom}/ °C	Average corrected signal/ V	$U_{laboratory}$ (inc. drift)/ °C	$U_{laboratory}$ / V	U to use in weighted mean / V	Difference {signal – weighted mean} / V	Difference from weighted mean / °C	$U_{ref\ value}$/ °C	U_{total}/ °C
960	0.004872	0.35	0.000025	0.000025	0.000002	0.02	0.20	0.40
1100	0.030243	0.41	0.000145	0.000145	0.000045	0.13	0.23	0.47
1300	0.233139	0.52	0.001093	0.001093	-0.000012	-0.01	0.28	0.60
1500	1.133876	0.66	0.005268	0.005268	-0.001433	-0.18	0.34	0.74
1700	4.004105	0.81	0.018430	0.018430	-0.005100	-0.22	0.42	0.91
1800	6.861510	0.89	0.031553	0.031553	-0.014981	-0.42	0.45	1.00
2000	1.745093	1.07	0.007983	0.007983	-0.001807	-0.24	0.54	1.20
2200	3.836372	1.48	0.020560	0.020560	0.003245	0.23	0.65	1.62
2400	7.407262	1.72	0.039435	0.039435	-0.065772	-2.84	0.75	1.88
2500	1.006790	1.81	0.005246	0.005246	-0.001781	-0.61	0.84	1.99

Table 174 – summary of NPL 2020 Chino thermometer results and difference from weighted mean

t_{nom}/ °C	Average corrected signal/ V	$U_{laboratory}$ (inc. drift)/ °C	Difference {signal – weighted mean}/ V	Difference from weighted mean/ °C	$U_{ref\ value}$/ °C	U_{total}/ °C
960	0.004876	0.29	0.000005	0.07	0.20	0.35
1100	0.030206	0.35	0.000008	0.02	0.23	0.42
1300	0.233171	0.49	0.000019	0.01	0.28	0.57
1500	1.134371	0.57	-0.000938	-0.12	0.34	0.66
1700	4.007381	0.71	-0.001824	-0.08	0.42	0.82
1800	6.871978	0.83	-0.004512	-0.13	0.45	0.94
2000	1.745544	0.87	-0.001357	-0.18	0.54	1.03
2200	3.829469	1.03	-0.003658	-0.26	0.65	1.22
2400	7.464658	1.22	-0.008376	-0.36	0.75	1.43
2500	1.006257	1.31	-0.002314	-0.80	0.84	1.56
2600	1.329496	1.48	-0.000982	-0.28	0.87	1.72
2800	2.204689	1.56	0.009419	1.83	1.00	1.86
2900	2.768519	1.70	0.013797	2.28	1.20	2.08
3000	3.428476	2.16	0.016298	2.31	1.44	2.60

Table 175 – average of all the NPL calibrations of the Chino thermometer and difference from weighted mean

t_{nom}/ °C	Average corrected signal/ V	Signal standard deviation/ V	Average U_{NPL}/ V	Average U_{NPL} with {std deviation/ √n} /V	Average U_{NPL} inc. drift & stdev)/ °C	U to use in weighted mean/ V	Difference {average signal – weighted mean} / V	Difference from weighted mean/ °C	$U_{ref\ value}$/ °C	U_{total}/ °C
960	0.004871	0.000003	0.000033	0.000033	0.47	0.000033	0.000001	0.01	0.20	0.51
1100	0.030199	0.000022	0.000181	0.000182	0.51	0.000182	0.000001	0.00	0.23	0.56
1300	0.233182	0.000050	0.001263	0.001264	0.61	0.001264	0.000030	0.01	0.28	0.67
1500	1.135095	0.000463	0.005542	0.005557	0.70	0.005557	-0.000215	-0.03	0.34	0.78
1700	4.008140	0.001596	0.019081	0.019134	0.84	0.019134	-0.001065	-0.05	0.42	0.94
1800	6.872750	0.005030	0.032555	0.032864	0.93	0.032864	-0.003740	-0.11	0.45	1.03
2000	1.747862	0.002340	0.007938	0.008209	1.10	0.008209	0.000962	0.13	0.54	1.22
2200	3.831870	0.004357	0.017575	0.018002	1.30	0.018002	-0.001257	-0.09	0.65	1.45
2400	7.473960	0.009264	0.033194	0.034213	1.48	0.034213	0.000927	0.04	0.75	1.66
2500	1.007751	0.001454	0.004577	0.004758	1.64	0.004758	-0.000820	-0.28	0.84	1.84
2600	1.330688	0.001476	0.006024	0.006167	1.73	0.006167	0.000211	0.06	0.87	1.93
2800	2.202267	0.003391	0.010206	0.010647	2.06	0.010647	0.006997	1.36	1.00	2.29
2900	2.762893	0.009130	0.014420	0.017067	2.81	0.017067	0.008171	1.35	1.20	3.05
3000	3.420521	0.010894	0.020761	0.023446	3.32	0.023446	0.008343	1.18	1.44	3.61

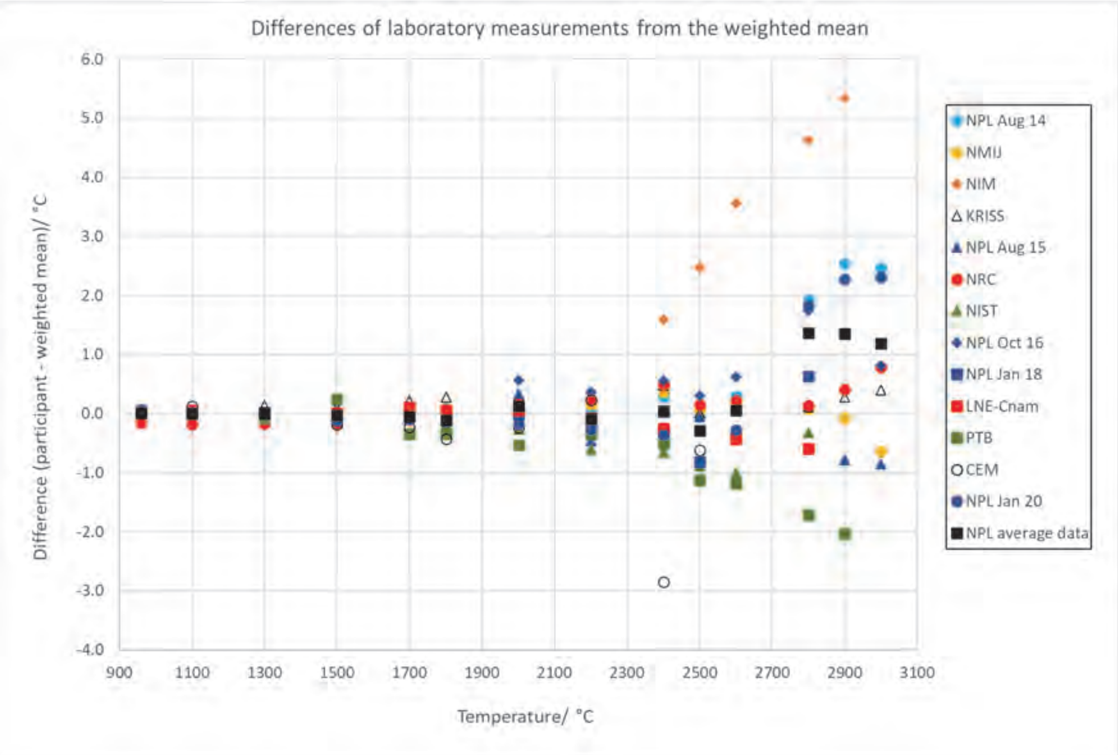

Figure 130 - Results of the comparison with the Chino thermometer, showing differences of each participant from the weighted mean value

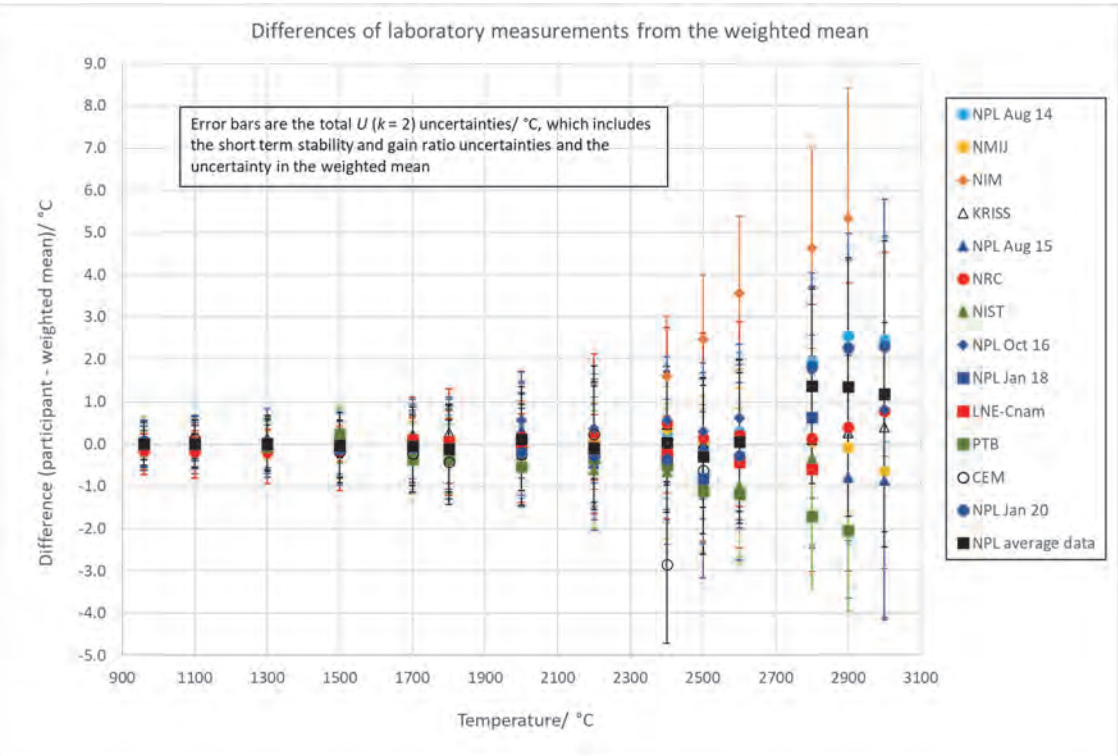

Figure 131 - Results of the comparison with the Chino thermometer, showing differences of each participant from the weighted mean value and the total, *k* = 2 uncertainties

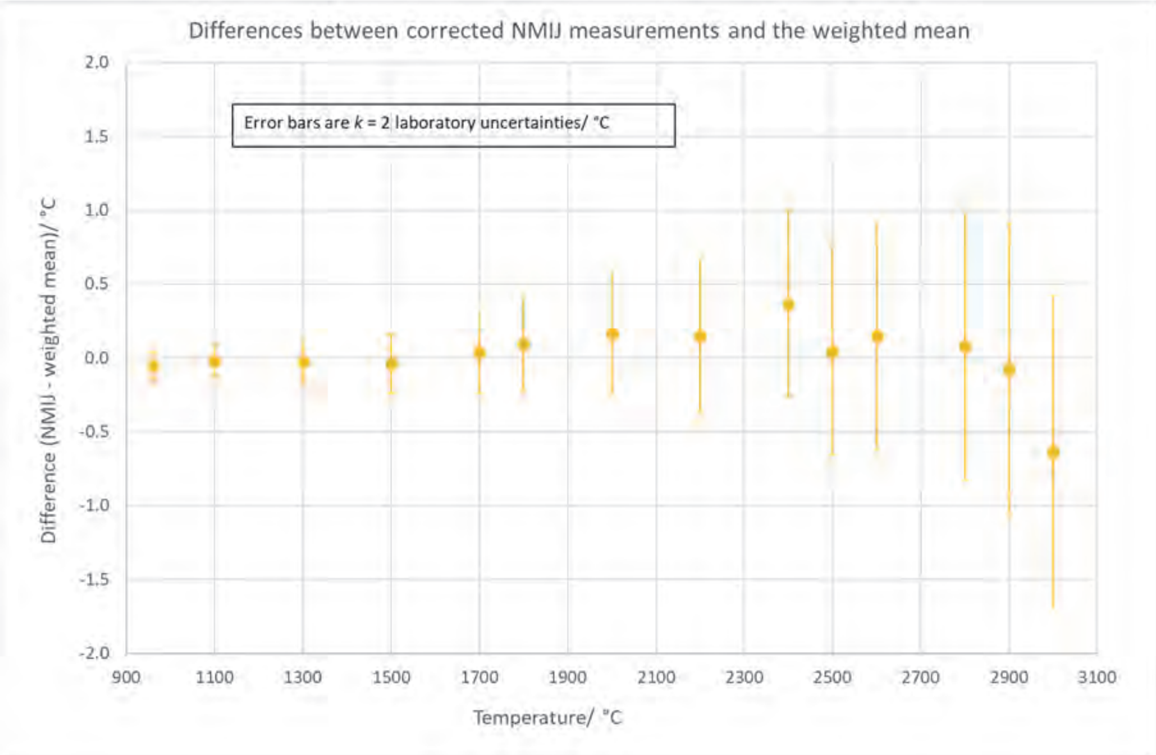

Figure 132 - difference between the NMIJ results and the weighted mean (*k* = 2 laboratory uncertainties)

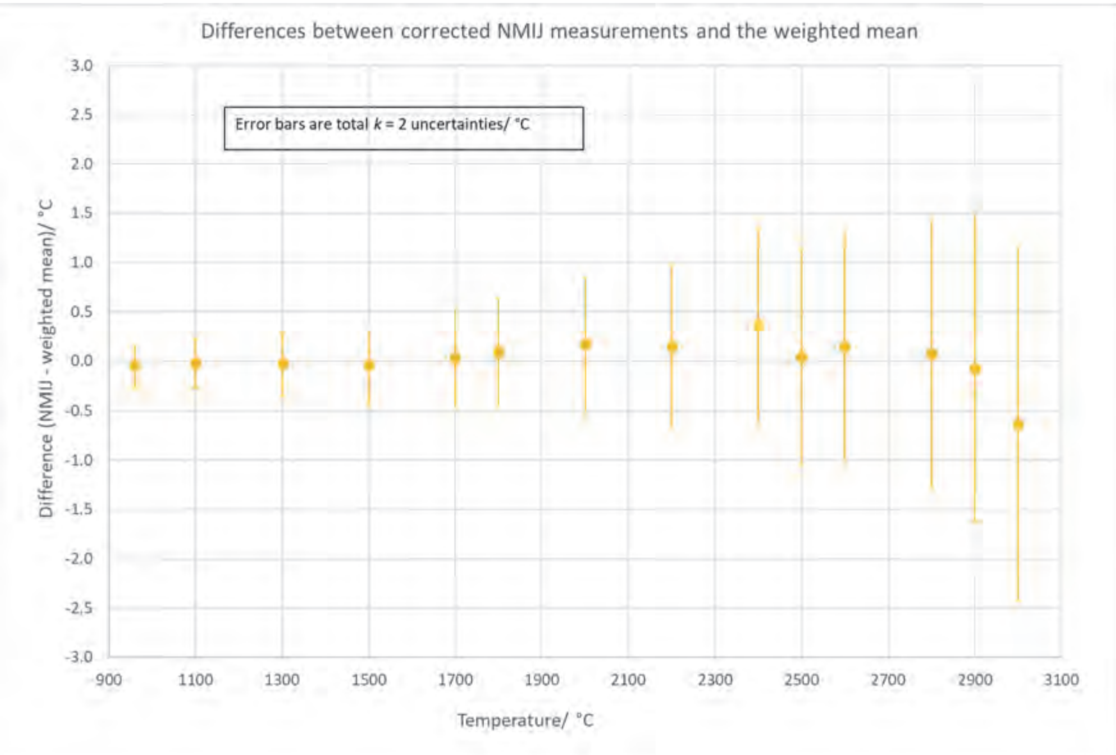

Figure 133 - difference between the NMIJ results and the weighted mean (*k* = 2 total uncertainties)

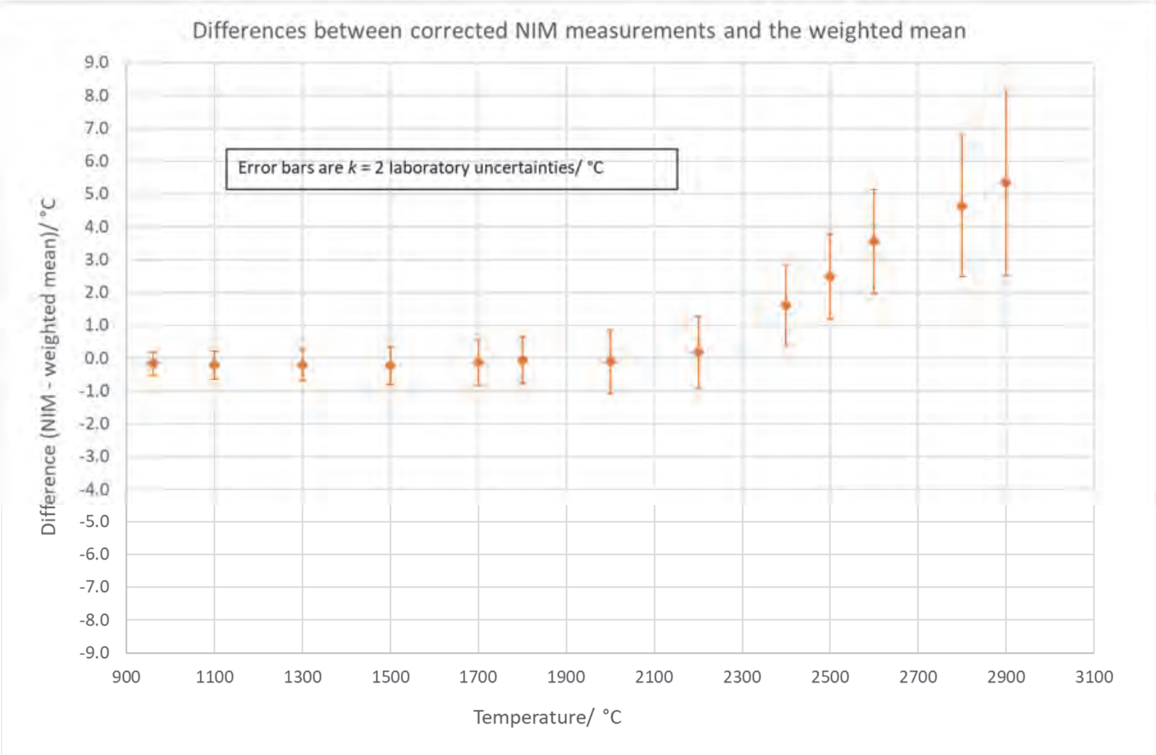

Figure 134 - difference between the NIM results and the weighted mean (*k* = 2 laboratory uncertainties)

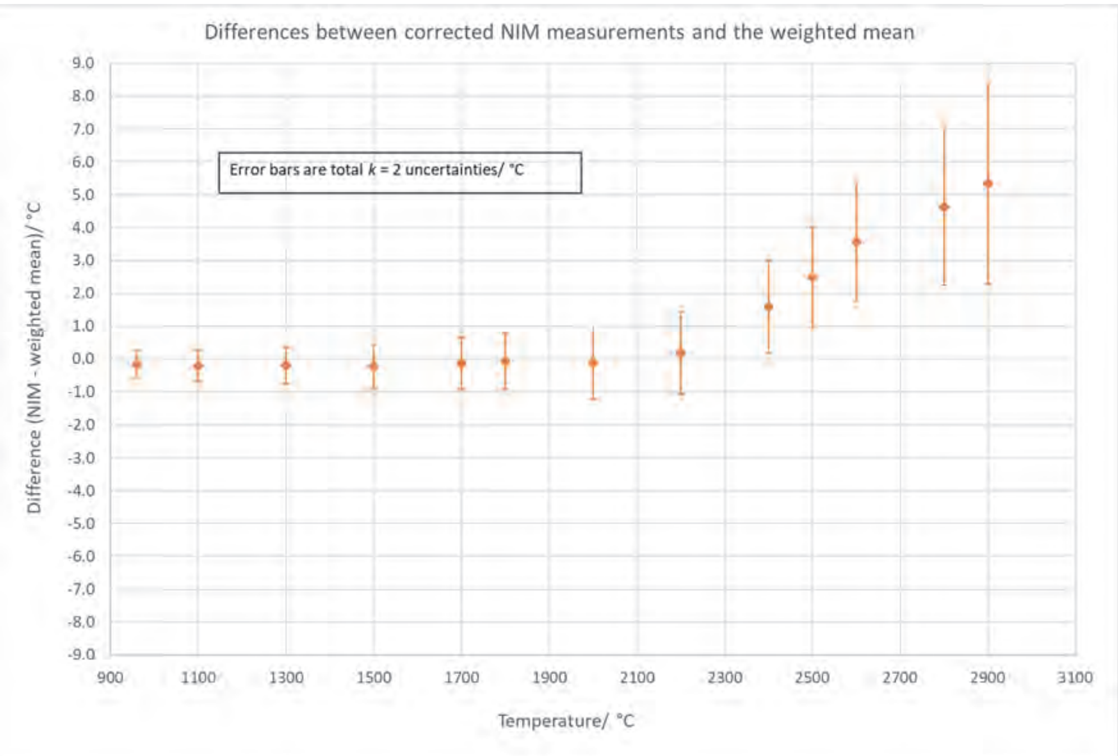

Figure 135 - difference between the NIM results and the weighted mean (*k* = 2 total uncertainties)

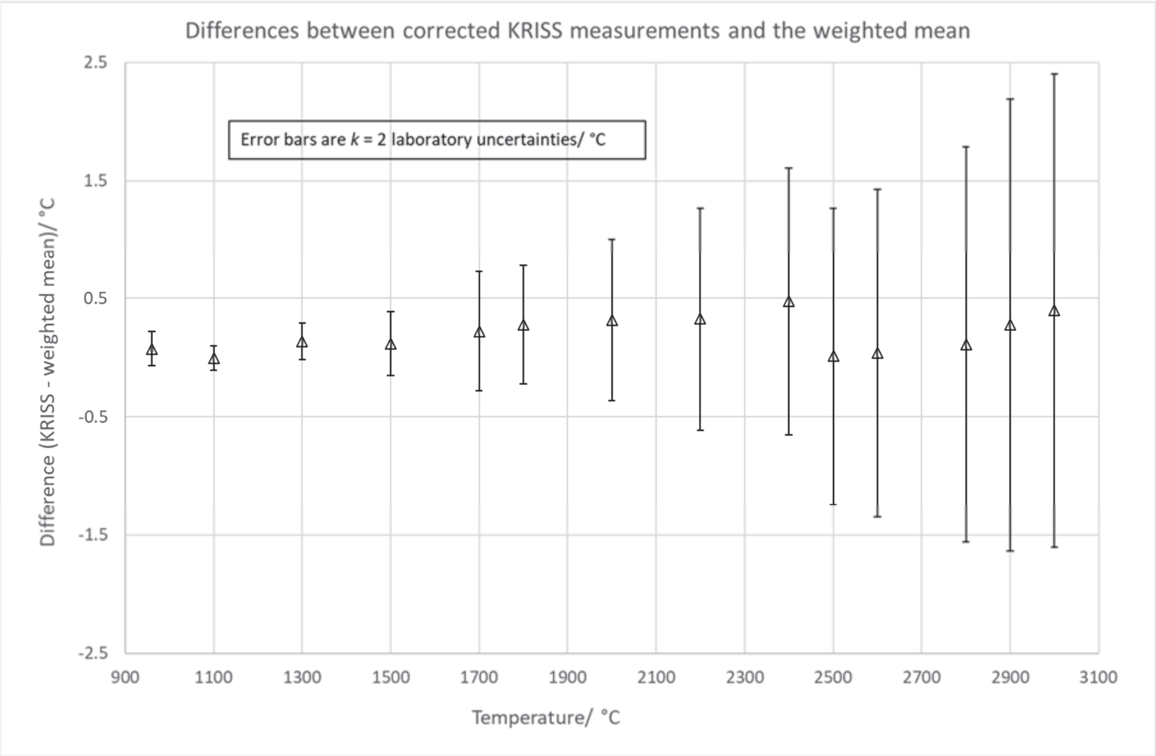

Figure 136 - difference between the KRISS results and the weighted mean (*k* = 2 laboratory uncertainties)

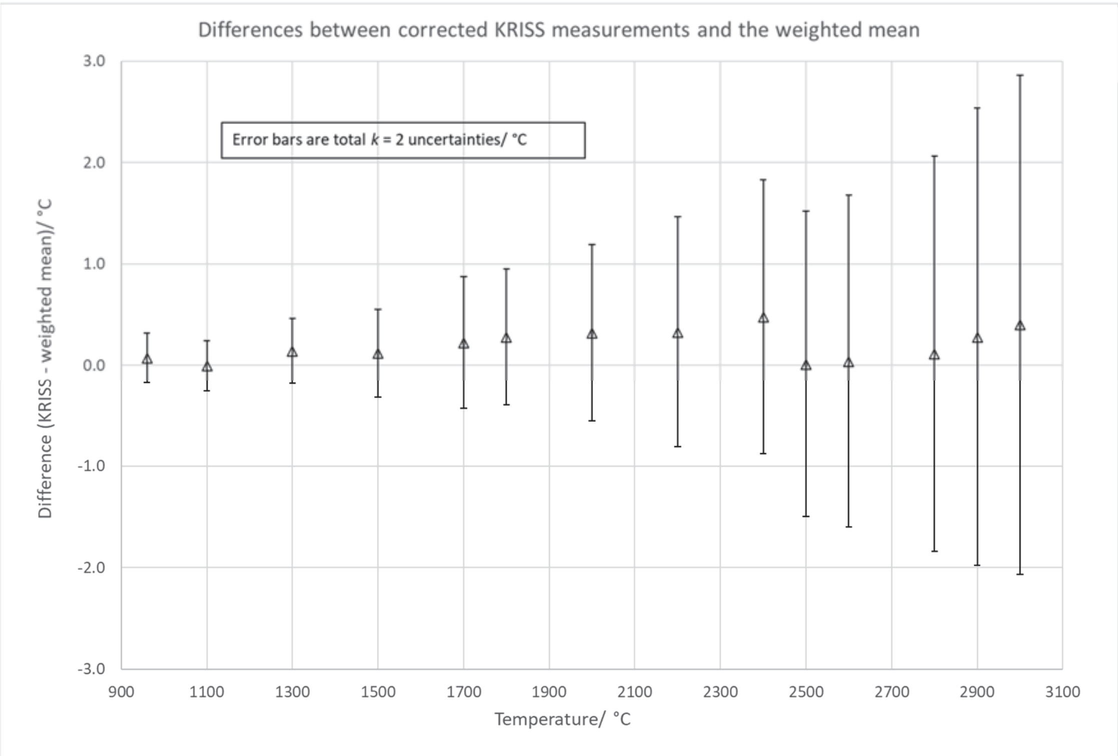

Figure 137 - difference between the KRISS results and the weighted mean (*k* = 2 total uncertainties)

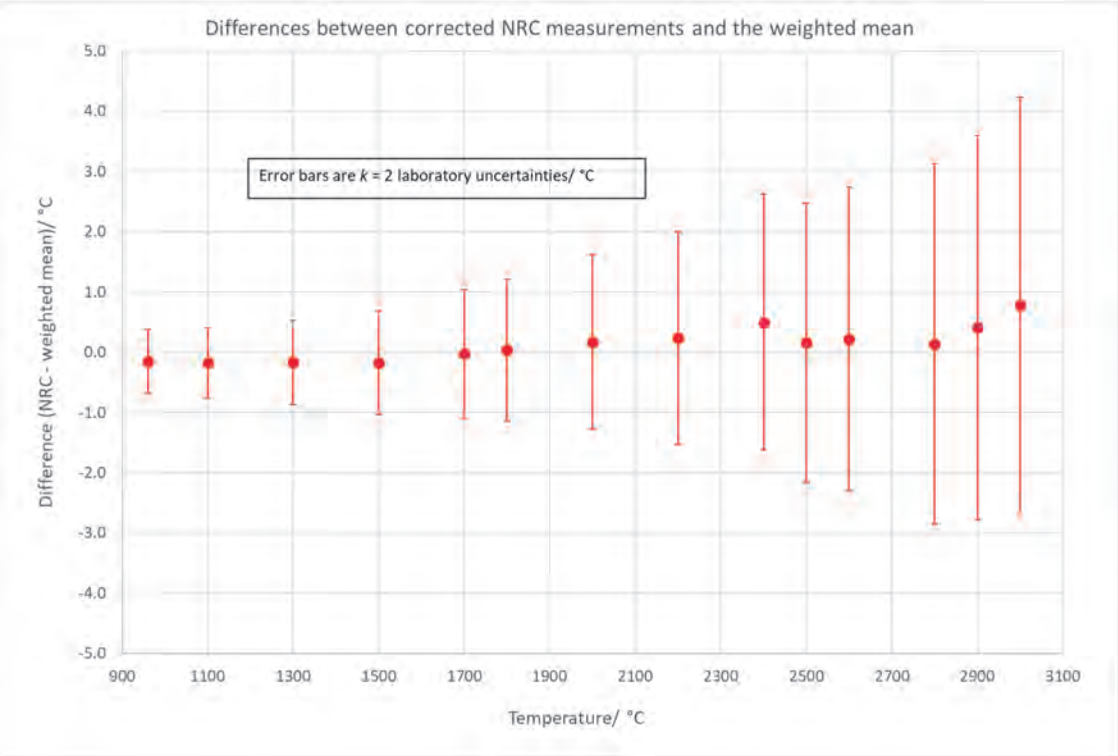

Figure 138 - difference between the NRC results and the weighted mean (*k* = 2 laboratory uncertainties)

Figure 139 - difference between the NRC results and the weighted mean (*k* = 2 total uncertainties)

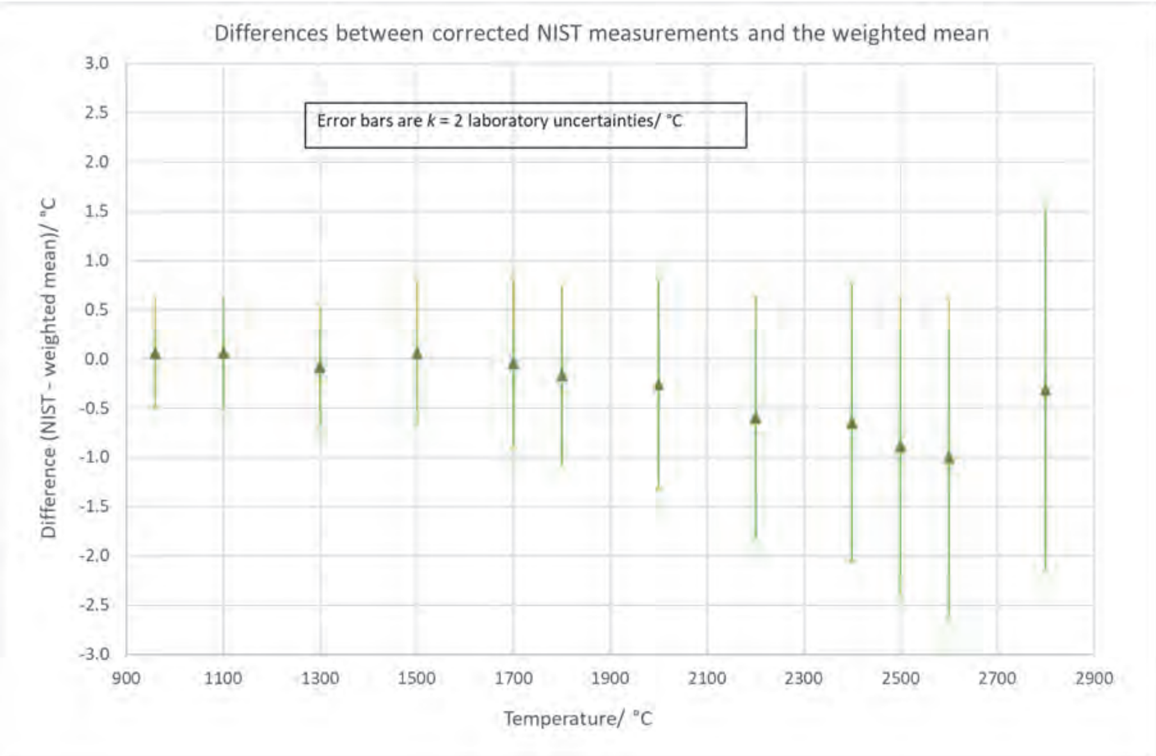

Figure 140 - difference between the NIST results and the weighted mean (*k* = 2 laboratory uncertainties)

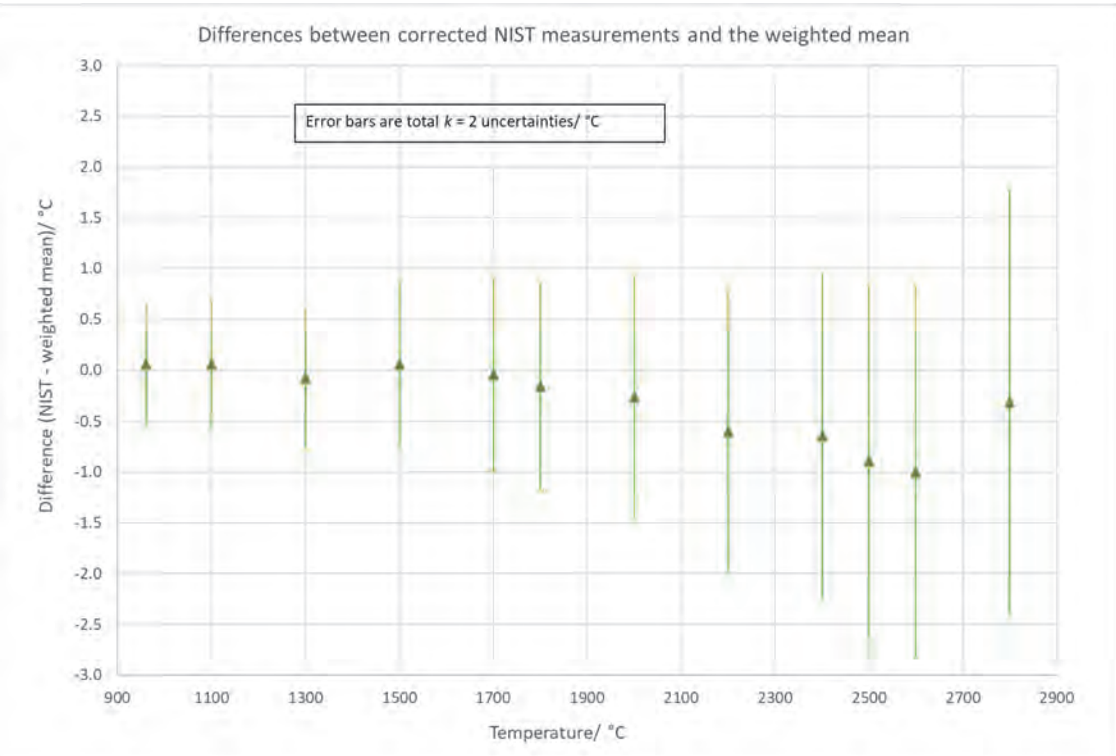

Figure 141 - difference between the NIST results and the weighted mean (*k* = 2 total uncertainties)

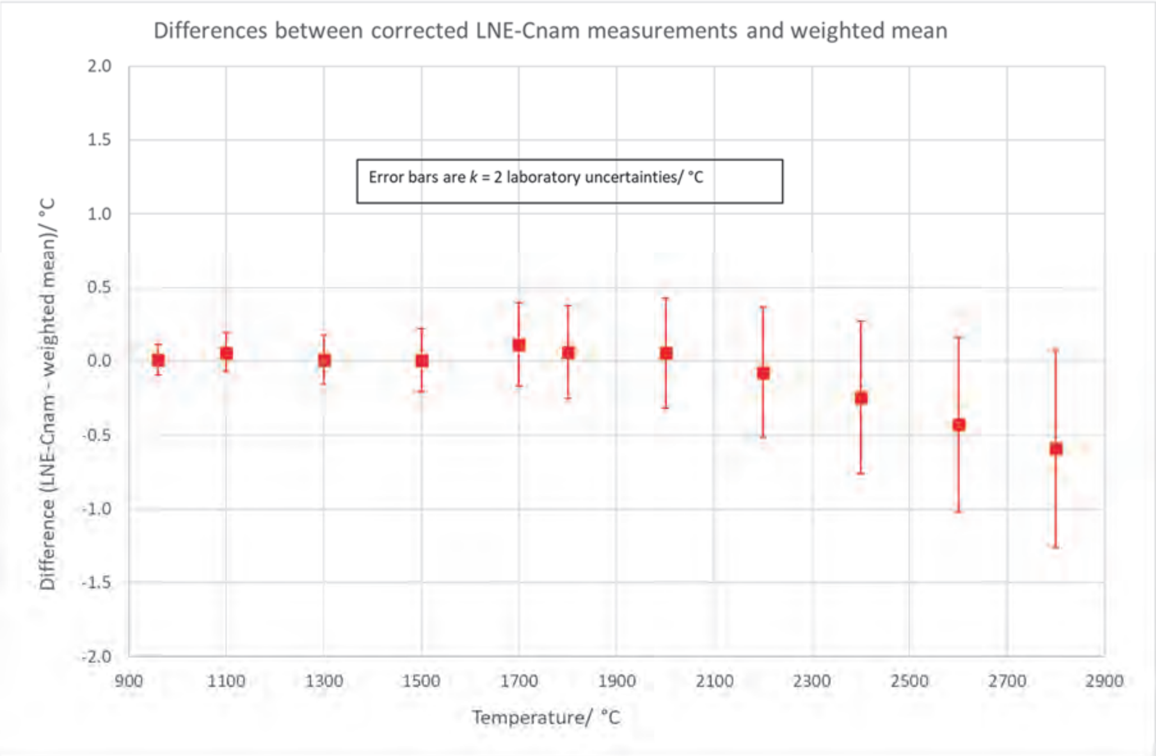

Figure 142 - difference between the LNE-Cnam results and the weighted mean (*k* = 2 laboratory uncertainties)

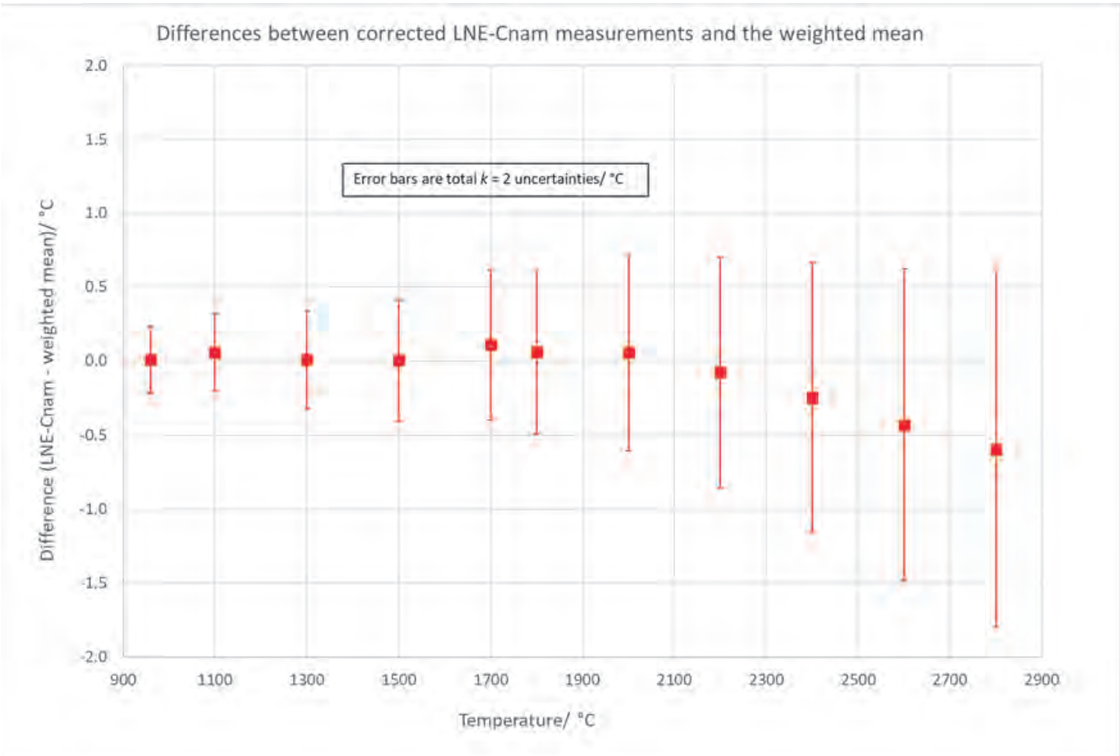

Figure 143 - difference between the LNE-Cnam results and the weighted mean (*k* = 2 total uncertainties)

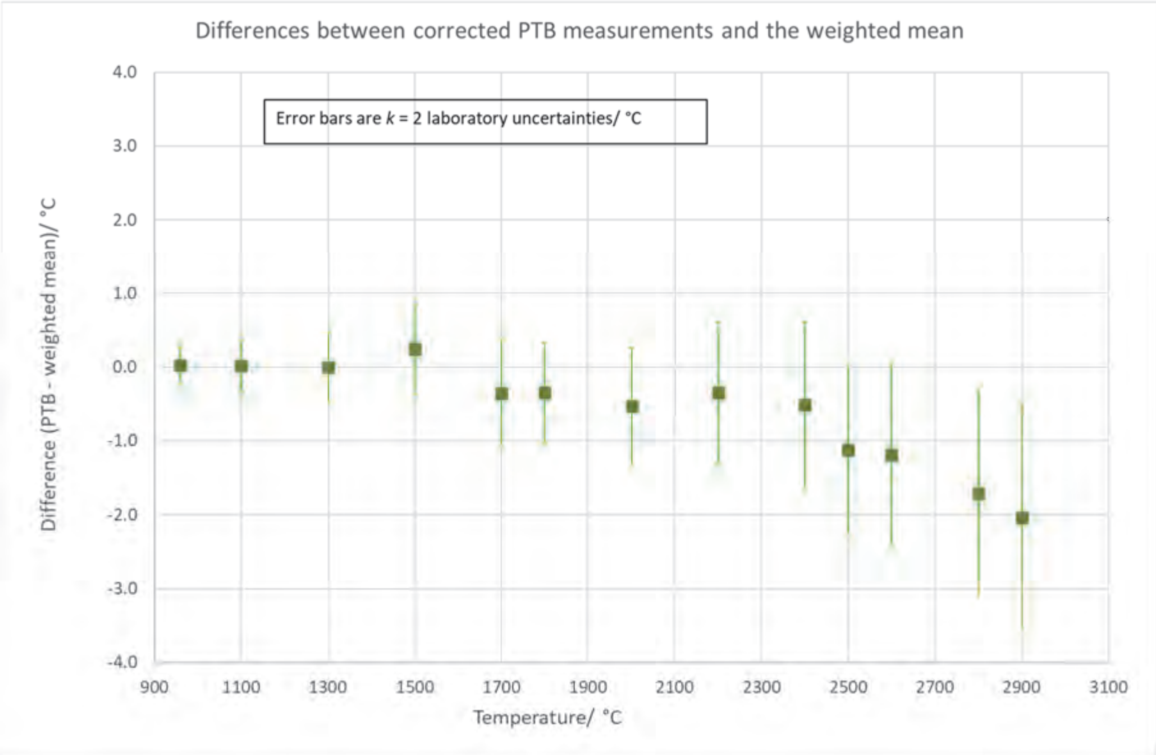

Figure 144 - difference between the PTB results and the weighted mean (*k* = 2 laboratory uncertainties)

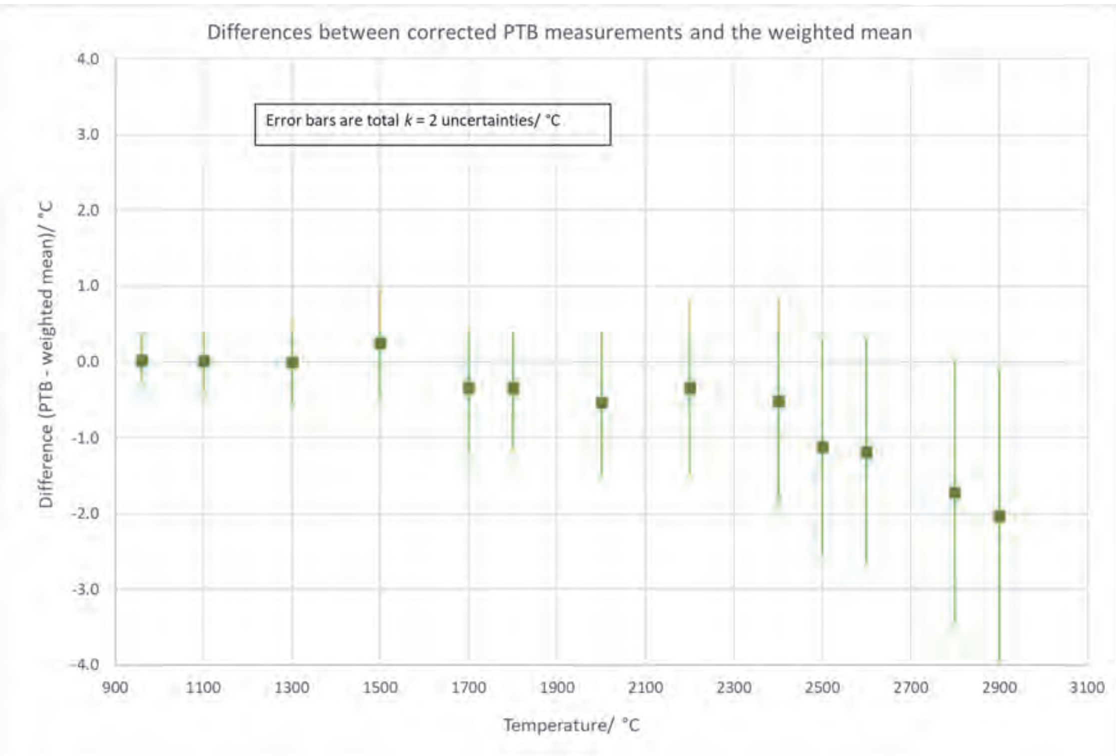

Figure 145 - difference between the PTB results and the weighted mean (*k* = 2 total uncertainties)

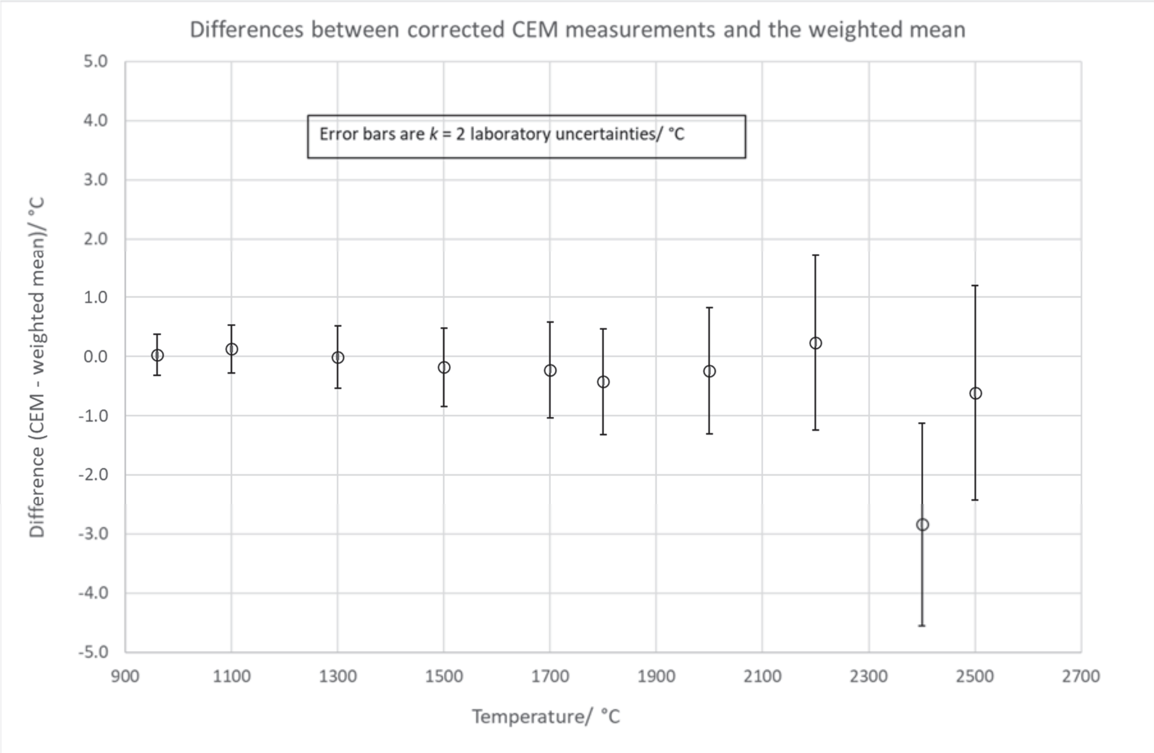

Figure 146 - difference between the CEM results and the weighted mean (*k* = 2 laboratory uncertainties)

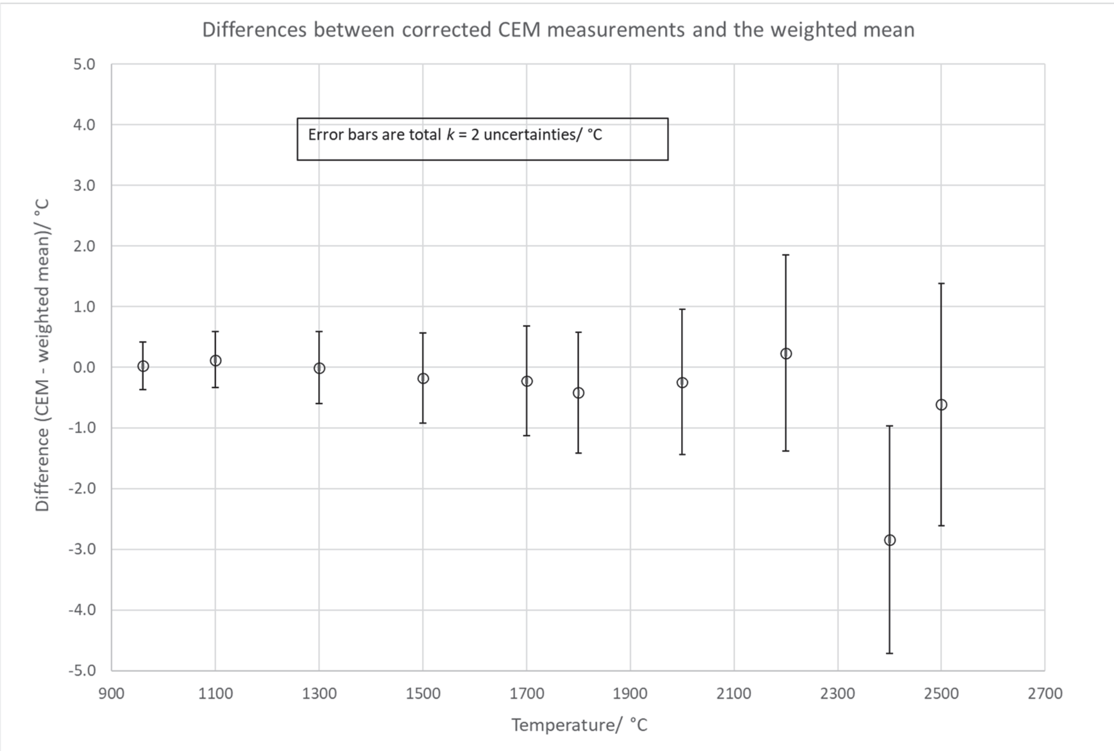

Figure 147 - difference between the CEM results and the weighted mean (*k* = 2 total uncertainties)

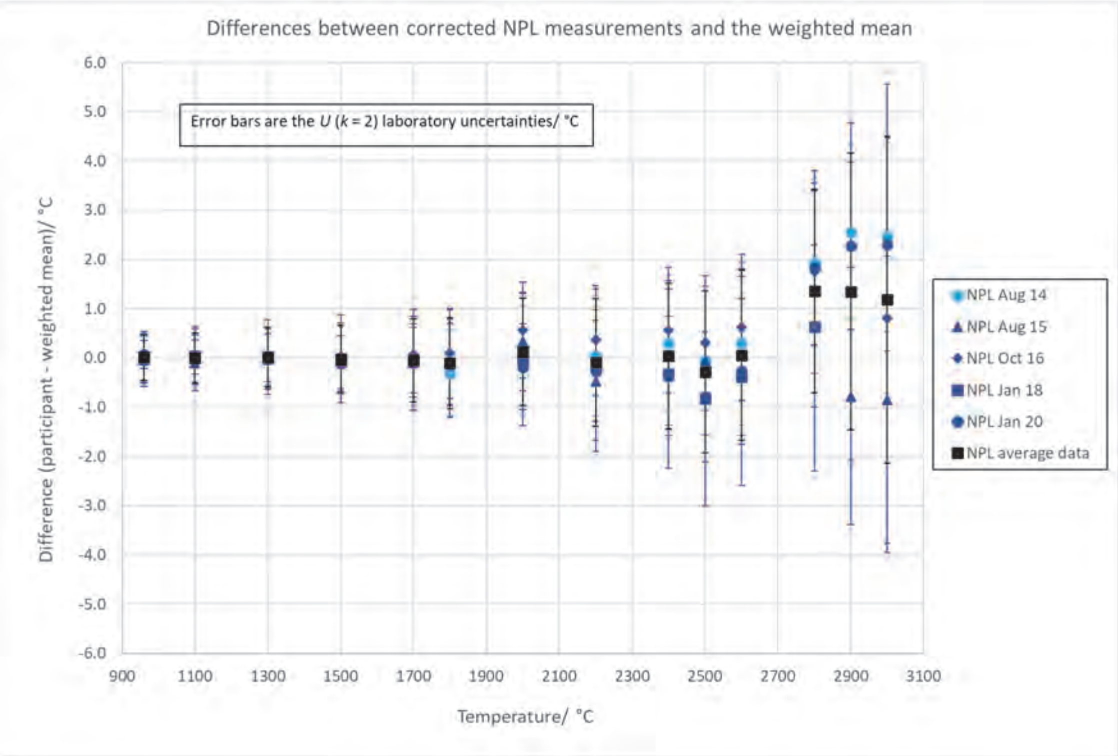

Figure 148 - difference between the NPL results and the weighted mean (*k* = 2 total uncertainties)

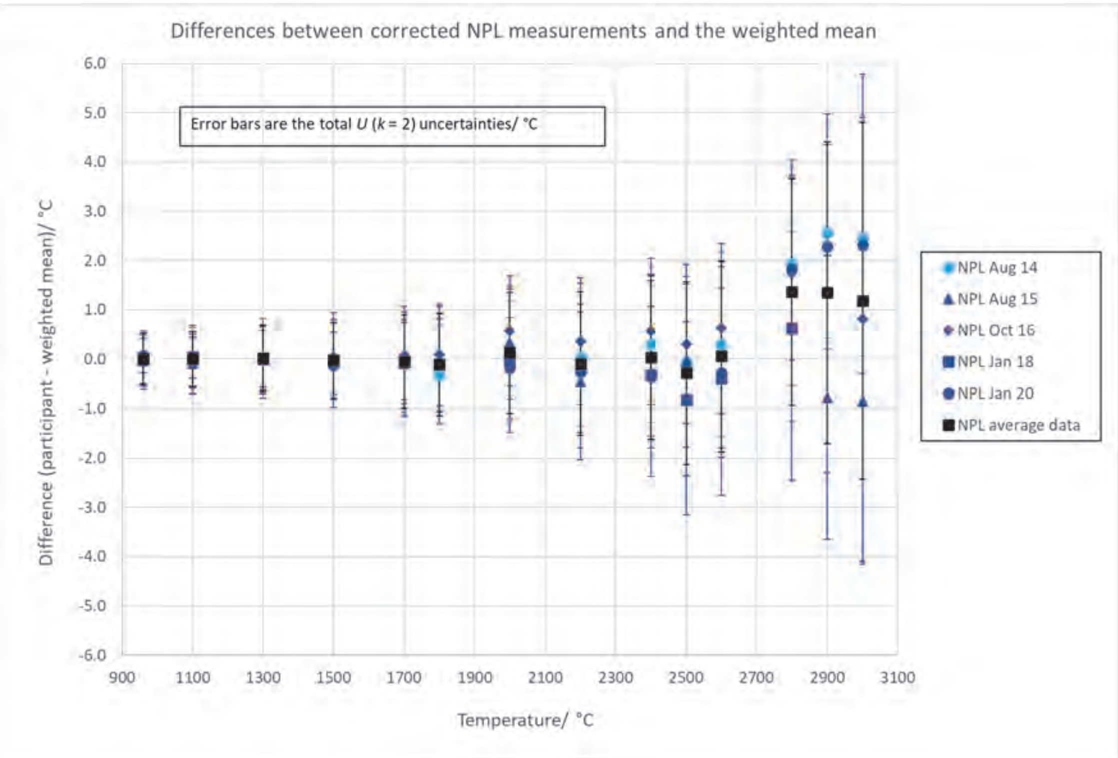

Figure 149 - difference between the NPL results and the weighted mean (k = 2 laboratory uncertainties)

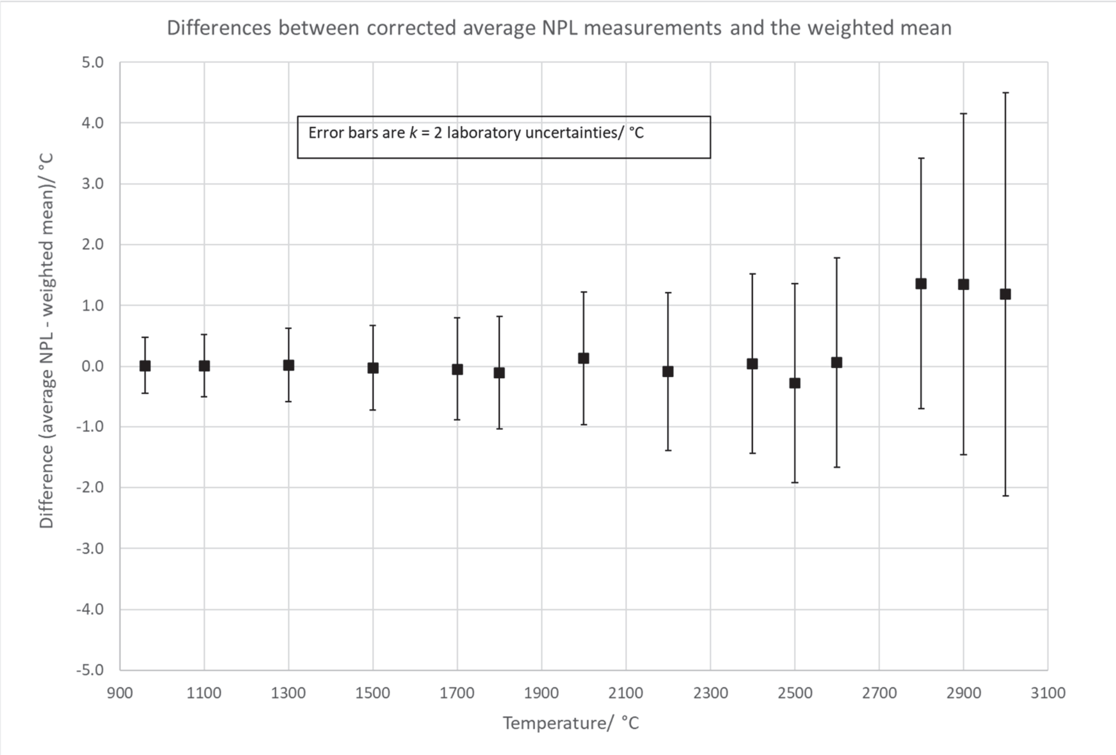

Figure 150 - difference between the average NPL results and the weighted mean (*k* = 2 laboratory uncertainties)

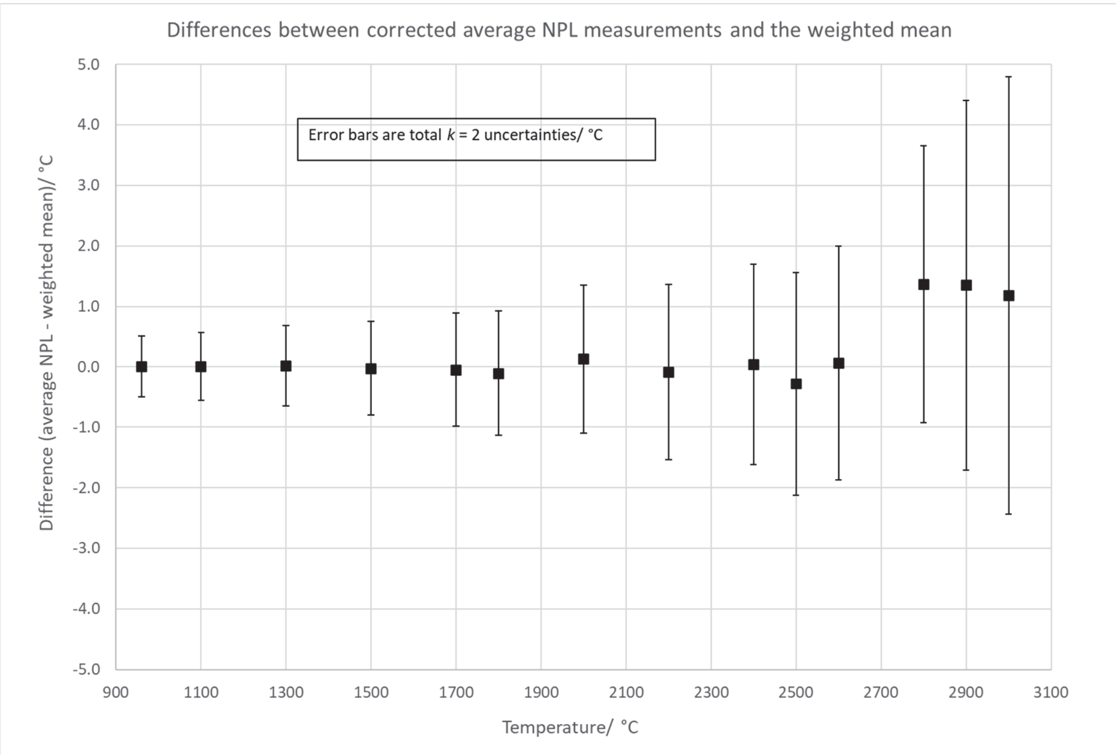

Figure 151 - difference between the average NPL results and the weighted mean (*k* = 2 total uncertainties)