For Publication in *Metrologia* Vol. 39 Issue 1

Summary of Comparison of Realizations of the ITS-90 over the Range 83.8058 K to 933.473 K: CCT Key Comparison 3

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Abstract

This is a summary of the Comité Consultatif de Thermométrie (CCT) Key Comparison 3, i.e., the comparison of realizations of the fixed points of the International Temperature Scale of 1990 (ITS-90) over the range from 83.8058 K to 933.473 K. The differences in the realizations of the various fixed points in this range of the ITS-90 and the uncertainties of those differences are given for the 15 standards laboratories participating in the comparison.

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1. INTRODUCTION

This is a summary of the key comparison of the realizations of the International Temperature Scale of 1990 (ITS-90) [1, 2] at the defining fixed-point temperatures over the range from 83.8058 K (triple point of Ar) to 933.473 K (freezing point of Al) that was conducted under the auspices of the Comité Consultatif de Thermométrie (CCT). See the full version of the final report to the CCT [3] for complete details of the comparison. The BIPM key comparison database KCDB (http://kcdb.bipm.fr/BIPM-KCDB/) and the NIST International Comparisons Database ICDB (http://icdb.nist.gov/) also give the results of this comparison, but without details. Fifteen national metrology institutes were involved in this comparison. NIST was the coordinating laboratory for this comparison and there were two sub-coordinating laboratories; NML for the Asia/Pacific area participants and PTB for some of the European participants. Artifacts that were circulated among the participating laboratories were one, and in some cases two, standard platinum resistance thermometers (SPRTs), a sealed gallium triple-point cell, and a sealed cadmium freezing-point cell. With the exception of a very-long SPRT that went from NML to NRLM, the SPRTs and the fixed-point cells were supplied by NIST.

2. LABORATORIES PARTICIPATING IN CCT KEY COMPARISON 3

The laboratories participating in CCT Key Comparison 3 (KC 3) are shown in Figure 1, with the various comparison loops indicated. The SPRTs on which a participant made measurements are indicated also in Figure 1. The laboratories performing comparisons directly with NIST (those in the NIST loop) were NML, PTB, NMi/VSL, NRC and IMGC. The laboratories performing comparisons directly with NML (those in the NML loop) were MSL, NRLM (now known as NMIJ), KRISS and NIM. The laboratories performing comparisons directly with PTB (those in the PTB loop) were VNIIM, BNM-INM, SMU, NPL and BIPM.

3. DEVICES USED IN THE COMPARISON

In preparation for the comparison, NIST evaluated the SPRTs to be used by the participants of the comparison and, additionally, constructed and evaluated the Ga and Cd transfer fixed-point cells.

3.1. SPRTs

After the SPRTs to be used in the comparison had been selected and had been annealed at 950 K until their resistance at the triple point of water (TPW) following anneals was repeatable to the equivalent of < 0.2 mK, they underwent three complete calibrations. For those calibrations, all of the defining fixed points throughout the range from 83.8058 K to 933.473 K were used, as was the Cd freezing point. For the three calibrations, the range of values of W {[$W \equiv R(T_{FP})/R(273.16\ K)$], where $R(T_{FP})$ is the resistance of the SPRT at a fixed-point temperature T_{FP} and $R(273.16\ K)$ is its resistance at the TPW}, was no greater than the equivalent of 0.35 mK at any of the fixed points. Over the three calibrations, the range of values of $R(273.16\ K)$, obtained soon after measurements of the SPRT at the T_{FP} , was no greater than the equivalent of 0.68 mK. The resistances of the SPRTs at the TPW obtained during their annealing and calibrations, as measured at NIST before and after the other participants of the comparison and also as reported by the participants, are shown in Figures 1 through 7 of the full report [3]. Two things are of note concerning those results. One is that the R(273.16 K) values for most SPRTs change over time, i.e., that there are apparent or real changes in the value from laboratory to laboratory. Another is that the range of values obtained for a given SPRT during its calibrations, after annealing, generally was different for the different laboratories. In certain cases, some of these types of behavior are attributed to changes incurred during transport of the SPRT. Also, the value of the realized ohm may be slightly different in the different laboratories and the absolute value of R(273.16 K) will reflect that difference. The remaining behavior, however, is related in some way to the techniques used by the participants, including those used by NIST (see the full report to the CCT for details [3]).

3.2. Transfer Cells

3.2.1. Gallium Cells

It is well known that the temperature of the TPW, determined in cells prepared with water from different sources and/or purified by different methods, has the potential of exhibiting fairly large differences (as large as 0.25 mK) due to isotopic composition [4, 5]. Since the isotopic composition of Ga samples from widely-different sources and of different purities is essentially independent of sample [6, 7], a Ga cell was circulated among the participating laboratories to try to determine how closely the triple-point/melting-point temperatures of the various participants' Ga cells agree, independently of other sources of measurement uncertainty, and also how well the various realizations of the melting-point temperatures of the participants' Ga cells agree. This was an effort to ascertain if Ga might be a better reference point than the TPW for SPRT resistance ratios.

The NIST reference cell against which the Ga transfer cells were compared contains 99.999 99_5% pure Ga. The Ga transfer cells used in the comparison contained Ga of 99.999 99+% purity in a Teflon crucible of the usual NIST design [8]. The NIST reference Ga cell and the transfer Ga cells were triple-point cells.

The triple-point temperatures of the cells at the completion of the comparisons were unchanged from their original values, indicating that the transfer cells had not become contaminated during the key comparison.

3.2.2. Cadmium Cells

Since the Cd freezing-point temperature (594.219 K) is a convenient value for it to be used as a check on the measurement process of calibrating SPRTs over the range from either 83.8058 K or 273.15 K to 692.677 K, 933.473 K or 1234.93 K, and as a means of determining the non-uniqueness at that point, a NIST Cd cell was circulated among the participating laboratories to try to ascertain how closely the freezing-point temperatures of the various participants' Cd cells agree, independently of other sources of measurement uncertainty, and also to try to ascertain how well the realizations of the Cd point agree. Unfortunately, only seven participants possessed Cd fixed-point cells.

The NIST laboratory reference cell and the four Cd cells that were used in the comparison contained 99.999 99% pure Cd. These cells were constructed at the same time (all of the same lot) before the key comparison began. Upon their return from the participants, the four transfer cells were directly compared with the Cd reference cell and the W values of the transfer cells were found to be unchanged from those before measurements by the participants to within the repeatability of measurements at NIST, i.e., to within 0.03 mK (k = 2).

4. RESULTS OF COMPARISONS

4.1. Results of Measurements at Fixed-Points

Although the comparison was designed to cover the range from 83.8058 K to 933.473 K, not all of the participants had the capability to make comparisons over the entire range. The data in Tables 1, 2 and 3 are for the fixed points used by a given participant. The uncertainties result from those reported by the participants for each SPRT circulated among the given set of participants but were adjusted for the number of W values obtained from different freezes (or melts, as appropriate) at each fixed point (see Section 4.2). When a participant sent the results to NIST in electronic form, the values of W (not rounded to eight decimal places) in the electronic file were used in calculating the mean value given in the tables. As a result, the mean values given in Tables 1, 2 and 3 may differ by the equivalent of about 0.01 mK from the values of the mean as calculated directly from the W values given in the full report [3]. The range of the values of W, in equivalent temperature for each of the fixed points, that were obtained by each of the participants is given also in Tables 1, 2 and 3. It is interesting to compare these values with the uncertainties. The complete uncertainty budgets, as reported by the participants and which led to the expanded uncertainty values in the results, are given in Appendix IV of the full report to the CCT [3]. An abbreviated version of those uncertainty tables is given in this paper as Appendix I, and it contains the uncertainty values used in the analyses, adjusted for purposes of comparison to the basis of a single freeze or melt .

As can be seen in Tables 2 and 3 for NML, PTB, BNM-INM, SMU, NPL and BIPM, comparison measurements were made in each of those laboratories with at least two SPRTs that were also used in measurements at NIST. As can be additionally seen from the data presented in those tables, the pertinent pair-wise differences in realizations in those laboratories, as obtained with the different SPRTs, sometimes differ from one another. Since the participants sent the results of their measurements on both SPRTs to NIST (the coordinator), the averages of the differences obtained with the different SPRTs were used in all subsequent calculations of pair-wise differences.

The pair-wise temperature differences and their associated uncertainties, as given in Tables 4 through 11, were calculated by two paths. Those paths are indicated by the terms ‘direct’ and ‘inclusive’, and yield results that are indicated in the tables by ‘dir.’ and ‘inc.’, respectively.

The ‘direct’ differences are the temperature differences between the realizations of a pair of laboratories that were obtained using the shortest available path linking those laboratories. In some cases, this means that the laboratories are compared using measurements made on the same SPRT or SPRTs. Where necessary, however, NIST or NML serves as an intermediary, linking the measurements of the other two laboratories.

In some cases, direct differences may not use all of the data reported by one or the other of the laboratories of the pair or of the intermediate laboratory (if any). This situation often arises in cases in which both laboratories of the pair made measurements on one SPRT but in which one or both members also made measurements on another SPRT not used by the other laboratory. Examples of this case are provided by the temperature differences between SMU and BNM-INM, VNIIM and NPL, SMU and VNIIM, VNIIM and BNM-INM, and NPL and BNM-INM.

The ‘inclusive’ differences are those in which all of the data obtained by the pair of laboratories involved are used in the calculations of their pair-wise temperature differences. In inclusive differences, whether or not there is a direct linkage between the laboratories, NIST (and possibly also NML) may be used as an intermediary so that the temperature differences and their associated uncertainties can be computed using all relevant data. NIST was selected as the intermediate laboratory for these differences because, overall, that results in a minimum number of intermediate laboratories in the pair-wise differences. If NML and PTB had been included as intermediate laboratories, the pair-wise differences would have been somewhat different but the uncertainties would have been only slightly different.

To further illustrate the computation of the direct and inclusive differences, a typical example is given here for one pair of laboratories. The details of the computations of all of the temperature differences, direct and inclusive, are given in Tables 6-20 in the full report [3]. The example here focuses on the temperature difference between MSL and NML, which is representative of the situations in which different direct and inclusive temperature differences could be computed. The direct difference between these laboratories is computed using data collected with SPRT 1032 and is given by

$$\Delta T_{\mathrm{MSL-NML}} = \frac{(\overline{W}_{\mathrm{MSL,1032}} - \overline{W}_{\mathrm{NML,1032}})}{\mathrm{d}W_{\mathrm{r}} / \mathrm{d}T} \quad , \tag{1}$$

where $\overline{W}_{\mathrm{Lab,SPRT}}$ is the mean resistance ratio obtained for a given SPRT by the participant and where W_{r} is the relevant ITS-90 reference function [1, 2].

As a sub-coordinating laboratory, NML also made measurements using SPRT 4386, while MSL did not have an opportunity to do so. Those additional data from NML give additional information on NML's realization of the ITS-90. Those data can be used in calculating $\Delta T_{\mathrm{MSL-NML}}$ if data from NIST (as the intermediate laboratory) are used, giving the inclusive difference

$$\Delta T_{\mathrm{MSL-NML}} = \frac{(\overline{W}_{\mathrm{MSL,1032}} - \overline{W}_{\mathrm{NIST,1032}}) - ((\overline{W}_{\mathrm{NML,1032}} - \overline{W}_{\mathrm{NIST,1032}})/2 + (\overline{W}_{\mathrm{NML,4386}} - \overline{W}_{\mathrm{NIST,4386}})/2)}{\mathrm{d}W_{\mathrm{r}} / \mathrm{d}T} \, . \tag{2}$$

When pair-wise temperature differences obtained from calculations using the direct and inclusive paths are different, then one or the other path may provide the better precision. Because the direct differences use measurements only from the shortest path between the laboratories, they will tend to provide more precise estimates of the temperature differences when the uncertainties of the intermediate laboratories (when needed) are large relative to the uncertainties of the pair of laboratories. Due to the increased averaging of results across different SPRTs, inclusive differences will tend to be more precise in cases in which the intermediate laboratories have relatively low uncertainty.

Comparison of direct and inclusive differences also can provide further insight into the differences between laboratories. Direct differences can provide temperature differences as observed for a single SPRT. This can be useful as a check for interactions between particular thermometers and a laboratory's measurement procedures. Two laboratories may agree closely with one another when the results are averaged across different thermometers because one or both may have results that are systematically higher for some thermometers and systematically lower for others. Of course, this type of interaction between thermometers and measurement procedures can be detected only when one laboratory is compared with another using at least two SPRTs. This is observable in some of the pairs of direct and inclusive comparisons in this study, summarized for each of the fixed points Al, Zn, Cd, Sn, In, Ga, Hg and Ar in Tables 4 through 11, respectively.

Significant interactions between thermometers and laboratories could arise from a variety of causes. Some possible causes include thermometer instability, inadequate immersion, particular measurement methods, measurement equipment and laboratory conditions. In any specific case, however, the actual cause of an interaction can really only be determined by study of the underlying physics of the problem and further experimentation, the logical follow-ups to a key comparison.

An upper bound on each laboratory's individual contribution to the total uncertainties of the bilateral temperature differences at each fixed point is also given in Tables 4 through 11, denoted as an expanded uncertainty U_L at the 95% confidence level. The details of how these approximations were obtained are given at the end of Section 4.2.

4.2 Data Analysis for Comparison of Realizations at Fixed Points

This section describes the procedures used in the analysis of the CCT KC 3 data. As previously described, each laboratory participating in the comparison provided resistance ratios, denoted *W*, measured in their own fixed-point cells with transfer thermometers provided by NIST (by NML in the case of NRLM) for some or all of the eight fixed points included in the comparison. Some participants measured each fixed point in only a single freeze or melt, while others used multiple freezes or melts at each point. Similarly, some participants used only one transfer SPRT while others made measurements with two transfer SPRTs. Uncertainties, computed from the comparison data directly, or based on additional measurements with the fixed-point cells and a check thermometer, also were provided by each participant.

Differences of mean resistance ratios for each fixed point were computed from the *W* values for a given transfer SPRT for every pair of laboratories making measurements with that SPRT and then converted into the equivalent temperature differences using values of dW_r/dT, where W_r is the relevant ITS-90 reference function [1, 2]. Both direct and inclusive temperature differences, as described in Section 4.1, were computed.

The information provided as part of the uncertainty of the measurements at each fixed point by each participant included the repeatability, or standard uncertainty, of a single resistance ratio for multiple freezes or melts, and the standard uncertainties for any other sources of variation affecting the measurements. Some of the sources of uncertainty typically included, in addition to the resistance-ratio repeatability, were impurities in fixed-point cell composition, hydrostatic-head errors, SPRT self-heating errors, etc. The specific sources of uncertainty and their associated uncertainty values can be found for each laboratory in Appendix IV of the full report to the CCT [3].

The freeze-to-freeze repeatability reported by each laboratory is denoted S_A. In addition to S_A , the other information needed to assess the level of uncertainty associated with each laboratory's mean resistance ratio includes the number of freezes or melts, denoted *n*, reported for computation of mean temperature differences and the degrees of freedom associated with S_A, denoted DF_A. The uncertainty due to sources of variability other than resistance-ratio repeatability were combined by root-sum-of-squares and are denoted by S_B. In some cases, degrees of freedom were explicitly given for each source of uncertainty included in S_B. When this was done, the degrees of freedom associated with S_B were obtained by using the Welch-Satterthwaite formula as described in the *ISO Guide to the Expression of Uncertainty in Measurement* [9]. If the degrees of freedom were not given explicitly for a particular component included in S_B, then that component of S_B was assumed to have an infinite number of degrees of freedom. The degrees of freedom associated with S_B are denoted by DF_B.

The various sources of uncertainty, other than freeze-to-freeze repeatability summarized in the term S_A, are taken to be components of uncertainty that affect a set of measurements made with a specific fixed-point cell in a specific measurement system in the same way. That is, the effects of these sources of variability do not vary in any practical sense from freeze to freeze.

As mentioned in Section 4.1, uncertainties are reported in Tables 1, 2, and 3 for the mean resistance ratio, $\overline{W}$, obtained by each laboratory for each transfer thermometer measured. These values typically differ from the summary values reported by each laboratory (and given in Appendix IV of the full report [3]) because the laboratories were not required to summarize their uncertainties for each thermometer in a standardized format. Therefore, when the uncertainties were summarized for inclusion in Tables 1, 2, and 3, they were all converted, as necessary, to a common format. In the format used in Tables 1, 2, and 3, the combined standard uncertainty of $\overline{W}$ for each thermometer is related to the final uncertainties calculated for the temperature differences between laboratories given in Tables 4 through 11 of this report. The relationship between the components of uncertainty reported by the laboratories and the combined standard uncertainty of $\overline{W}$, $u_c(\overline{W})$, expressed in mK, is given by

$$u_{\mathrm{c}}(\overline{W}) = \sqrt{\frac{S_{\mathrm{A}}^2}{n} + S_{\mathrm{B}}^2} \quad . \tag{3}$$

Numerical examples, which illustrate the computations described in the paragraph above, can be found in the full report [3].

In addition to the uncertainties reported by each laboratory for the data they collected for this key comparison, uncertainties for possible changes in each transfer thermometer over the course of the comparison were computed also and included for each temperature difference. Because they affect only differences in measurements made with the transfer thermometers over time, these SPRT uncertainty components are included only in the uncertainties of the temperature differences between laboratories, and not in the uncertainties of the measurements made in a single laboratory.

These additional uncertainties were computed by first computing the difference in W observed at NIST (or at NML for SPRT 040) at each fixed point, using data taken before each thermometer was sent to a sub-coordinating laboratory, or to another laboratory in the NIST loop of the comparison (see Fig. 1), and after its return. If there were no evidence of change in the 'before' and 'after' W values for the thermometer at a particular fixed point, based on a t test (95% confidence interval), the additional uncertainty component for that fixed point was set to zero. If the t test indicated that a change was likely to have occurred, the absolute difference between the before and after W values was converted to a Type B uncertainty based on a uniform distribution by dividing the half-width of the interval defined by the 'before' and 'after' travel difference by $\sqrt{3}$. The degrees of freedom for this uncertainty were approximated using the methods described in [9].

The formula for the t-test used to determine whether or not a change in the SPRT had occurred is

$$\frac{(\overline{W}_{\mathrm{After}} - \overline{W}_{\mathrm{Before}})}{\mathrm{d}W_{\mathrm{r}} / \mathrm{d}T} \pm t(0.975, DF_{\mathrm{A}}) S_{\mathrm{A}} \sqrt{\frac{1}{n_{\mathrm{After}}} + \frac{1}{n_{\mathrm{Before}}}} \quad . \tag{4}$$

In this equation, $\overline{W}_{\text{Before}}$ is the mean resistance ratio measured at NIST before the thermometer traveled to the sub-coordinating laboratory or to another laboratory in the NIST loop of the comparison (see Fig. 1); $\overline{W}_{\text{After}}$ is the mean resistance ratio measured at NIST after the thermometer returned from the sub-coordinating laboratory or from another laboratory in the NIST loop of the comparison; $t(0.975, DF_{\text{A}})$ is the 95% expansion factor from the t distribution for a two-sided interval and the degrees of freedom of NIST's freeze-to-freeze repeatability, S_{A}; n_{Before} is the number of measurements made at NIST before the thermometer traveled; and n_{After} is the number of measurements made at NIST after the thermometer traveled. A numerical example of the t-test can be found in the full report [3].

Whenever the confidence interval for the difference in SPRT response before and after the SPRT traveled indicated that a significant change occurred during travel, then an uncertainty term for the difference was calculated [9] as shown in Eq. (5).

$$u_{\text{SPRT}} = \frac{\left|\overline{W}_{\text{After}} - \overline{W}_{\text{Before}}\right|}{2\sqrt{3}(\text{d}W_{\text{r}} / \text{d}T)}. \qquad (5)$$

The degrees of freedom for this uncertainty were obtained by using formula G.3 in [9], substituting an estimate of the standard deviation of the absolute value of the difference of two normal random variables and the absolute temperature difference into the general terms given in the equation listed in the *Guide to the Expression of Uncertainty in Measurement* [9]. This is equivalent to the use of u_{SPRT} and its uncertainty in the formula since the scaling factor, $2\sqrt{3}$, cancels out of formula G.3. The formula for the estimate of the variance of the absolute difference of two normal random variables, which is given in the full report, was obtained from the *Handbook of the Normal Distribution* [10].

In the two cases in which the shipment of the transfer thermometers easily allowed, or necessitated, the treatment of each SPRT as two effectively-different thermometers, the estimation of the uncertainty for potential thermometer changes was computed separately for each effectively-different thermometer, if possible. Accordingly, SPRTs 1098A and 1098B have different uncertainties for potential thermometer changes during the course of the comparisons. There were no intermediate measurements at NIST for SPRTs 1030A and 1030B, however, so the uncertainties for them are based on before and after measurements that include the change in SPRT 1030 leading to its treatment as two separate thermometers (see full report [3]). As a result, the uncertainties given for SPRTs 1030A and 1030B are conservative estimates of u_{SPRT}.

The uncertainties quantifying potential changes in the transfer thermometers during the course of the comparisons, and their associated degrees of freedom, are given in Table VI.1 in Appendix VI of the full report [3] and in Table II.1 in Appendix II of this paper.

Focusing now on the computation of the temperature differences between laboratories and their uncertainties, derivation of the appropriate combined standard uncertainty from the formulas used to compute the temperature differences between laboratories yields the following results.

For a direct comparison between two laboratories in the same comparison loop, or between a given laboratory and NIST, using a single transfer thermometer

$$\Delta T_{\text{Lab1}-\text{Lab2}} = \frac{\overline{W}_{\text{Lab1}} - \overline{W}_{\text{Lab2}}}{\mathrm{d}W_{\text{r}} / \mathrm{d}T}, \tag{6}$$

which then leads to the uncertainty formula,

$$u_{\text{c}}(\Delta T_{\text{Lab1}-\text{Lab2}}) = \sqrt{\frac{S^2_{\text{A}_{\text{Lab1}}}}{n_{\text{Lab1}}} + S^2_{B_{Lab1}} + \frac{S^2_{\text{A}_{\text{Lab2}}}}{n_{\text{Lab2}}} + S^2_{\text{B}_{\text{Lab2}}} + u^2_{\text{SPRT}}}\ . \tag{7}$$

In Eq. (7) for the uncertainty of such a direct comparison between laboratories with a single transfer thermometer, multiple freezes reduce the uncertainty in resistance-ratio repeatability, but not the uncertainty from the sources that are summarized in S_{B}. This is because in S_{B} all of the resistance ratios are affected by those sources of uncertainty in exactly the same, unknown way. The term $\mathrm{d}W_{\text{r}}/\mathrm{d}T$ does not appear in the uncertainty formula because the conversion to temperature units is implicit in the definition of S_{A} and S_{B}.

For a direct comparison between two laboratories in the same comparison loop, or between a given laboratory and NIST, using two transfer thermometers

$$\Delta T_{\text{Lab1}-\text{Lab2}} = \frac{\frac{1}{2}(\overline{W}_{\text{Lab1, SPRT1}} - \overline{W}_{\text{Lab2, SPRT1}}) + \frac{1}{2}(\overline{W}_{\text{Lab1, SPRT2}} - \overline{W}_{\text{Lab2, SPRT2}})}{\mathrm{d}W_{\text{r}} / \mathrm{d}T}, \tag{8}$$

which yields the uncertainty formula,

$$u_{\text{c}}(\Delta T_{\text{Lab1}-\text{Lab2}}) = \sqrt{\frac{S^2_{\text{A}_{\text{Lab1}}}}{4n_{\text{Lab1,SPRT1}}} + \frac{S^2_{\text{A}_{\text{Lab2}}}}{4n_{\text{Lab2,SPRT1}}} + S^2_{\text{B}_{\text{Lab1}}} + \frac{S^2_{\text{A}_{\text{Lab1}}}}{4n_{\text{Lab1,SPRT2}}} + \frac{S^2_{\text{A}_{\text{Lab2}}}}{4n_{\text{Lab2,SPRT2}}} + S^2_{\text{B}_{\text{Lab2}}} + \frac{u^2_{\text{SPRT1}}}{4} + \frac{u^2_{\text{SPRT2}}}{4}}\ . \tag{9}$$

In this uncertainty formula, as in Eq. (7), the averaging of data from multiple freezes reduces the amount of uncertainty arising from sources of random uncertainty. The averaging of temperature differences measured with different SPRTs also reduces the amount of random uncertainty from potential changes in the SPRT over time but does not affect the amount of uncertainty from the sources summarized in S_{B}, which often tend to dominate the total uncertainty. Averaging the results from two thermometers for laboratories 1 and 2 is the source of the number 4 in the denominators of the S_{A} and u_{SPRT} terms.

For a direct comparison of the temperature difference between two laboratories with NIST serving as an intermediary, with the exceptions noted above for NRLM,

$$\Delta T_{\text{Lab1}-\text{Lab2}} = (\Delta T_{\text{Lab1}-\text{NIST}} - \Delta T_{\text{Lab2}-\text{NIST}}), \tag{10}$$

which leads to the uncertainty

$$u_c(\Delta T_{\text{Lab1-Lab2}}) = \sqrt{u_c^2(\Delta T_{\text{Lab1-NIST}}) + u_c^2(\Delta T_{\text{NIST-Lab2}}) - 2S_{\text{B}_{\text{NIST}}}^2} \; . \tag{11}$$

In this uncertainty formula, the variances of the temperature differences between each laboratory and NIST are first combined and then adjusted so that the term S_{B}, which affects all of the measurements made using the NIST measurement system and fixed-point cells in the same, but unknown, way is not included in the uncertainty. This term can, and in fact should, be eliminated from this uncertainty because the effects from the sources of uncertainty in the NIST measurements included in $S_{\text{B}_{\text{NIST}}}$ cancel out in these comparison computations involving NIST as an intermediary.

The equations above for typical direct comparisons with NIST as an intermediary could be used to describe the direct comparisons between NRLM and the other laboratories whose measurements were coordinated by NML by substituting NML for NIST in the subscripts. For direct comparisons between NRLM and laboratories whose measurements were coordinated by PTB or NIST, the temperature difference is computed by

$$\Delta T_{\text{Lab1-NRLM}} = (\Delta T_{\text{Lab1-NIST}} - \Delta T_{\text{NML-NIST}} - \Delta T_{\text{NRLM-NML}}) \; , \tag{12}$$

which leads to the uncertainty

$$u_c(\Delta T_{\text{Lab1-NRLM}}) = \sqrt{u_c^2(\Delta T_{\text{Lab1-NIST}}) + u_c^2(\Delta T_{\text{NIST-NML}}) + u_c^2(\Delta T_{\text{NML-NRLM}}) - 2S_{\text{B}_{\text{NIST}}}^2 - 2S_{\text{B}_{\text{NML}}}^2} \; . \tag{13}$$

Finally, to complete the uncertainty analysis, expanded uncertainties were computed for all of the different types of temperature differences and uncertainties described above. The usual methods for computing expanded uncertainties described in the *ISO Guide* [9] were not used, however. This is because in a few cases the results obtained by computing the expanded uncertainties using the ISO procedures exhibited paradoxical behavior relative to physical intuition. Due to the nature of statistical confidence intervals, it is possible for the expanded uncertainty from a direct comparison between two laboratories, say Lab 1 and NIST, to be larger than the expanded uncertainty of a comparison between Lab 1 and Lab 2 constructed from the direct comparison between Lab 1 and NIST and Lab 2 and NIST. Confidence intervals computed using the Welch-Satterthwaite formula to approximate the degrees of freedom of the uncertainty are prone to this in particular, although not exclusively. This is considered by some, including the majority of the authors of the full report of the CCT KC 3 [3], to be a limitation of the ISO procedures. More information on behavior and interpretation of expanded uncertainties computed using the Welch-Satterthwaite formula can be found in the full report [3] and in [11, 12, 13]. The alternative approach to the computation of expanded uncertainties that was used instead is described next.

In the alternative approach to the computation of expanded uncertainties that was chosen, the first two steps in the computation are essentially the same as the ISO method, i.e., the standard uncertainty for each type of comparison described above was algebraically expanded into independent terms in each uncertainty and the terms were collected. Then the effective degrees of freedom for all of the terms associated with data of each laboratory were computed using the Welch-Satterthwaite formula and expanded uncertainties were computed for each laboratory's contribution to the total uncertainty using coverage factors obtained from the t distribution and the effective degrees of freedom. The effective degrees of freedom and coverage factor for each laboratory's uncertainty are given by the formulas

$$DF_{\text{Lab}} = \frac{\left(\dfrac{S^2_{\text{A}_{\text{Lab1}}}}{n_{\text{Lab1}}} + S^2_{\text{B}_{\text{Lab1}}} \right)^2}{\dfrac{S^4_{\text{A}_{\text{Lab1}}}}{n^2_{\text{Lab1}} DF_{\text{A}}} + \dfrac{S^4_{\text{B}_{\text{Lab1}}}}{DF_{\text{B}}}} \tag{14}$$

and

$$k_{\text{Lab}} = t_{0.975,\ DF_{\text{Lab}}} . \tag{15}$$

Coverage factors for the uncertainty attributed to the use of each SPRT (denoted k_{SPRT}) were also computed as shown in Eq. (15) using the effective degrees of freedom found in Table II.1 in Appendix II and described in the full report [3]. Finally, these expanded uncertainties were combined by root-sum-of-squares to obtain the final expanded uncertainty.

For a direct comparison of the fixed-point temperatures at two laboratories, of the same comparison loop or between a given laboratory and NIST, of the type

$$\Delta T_{\text{Lab1}-\text{Lab2}} = \frac{\overline{W}_{\text{Lab1}} - \overline{W}_{\text{Lab2}}}{\text{d}W_{\text{r}} / \text{d}T} \quad , \tag{16}$$

in which each laboratory used the same transfer thermometer, this results in the expanded uncertainty

$$U(\Delta T_{\text{Lab1}-\text{Lab2}}) = \sqrt{k^2_{\text{Lab1}} \left(\frac{S^2_{\text{A}_{\text{Lab1}}}}{n_{\text{Lab1}}} + S^2_{\text{B}_{\text{Lab1}}} \right) + k^2_{\text{Lab2}} \left(\frac{S^2_{\text{A}_{\text{Lab2}}}}{n_{\text{Lab2}}} + S^2_{\text{B}_{\text{Lab2}}} \right) + k^2_{\text{SPRT1}} u^2_{SPRT1}} \quad . \tag{17}$$

For an inclusive comparison of the temperature at two laboratories of the type

$$\Delta T_{\text{Lab1}-\text{Lab2}} = (\Delta T_{\text{Lab1}-\text{NIST}} - \Delta T_{\text{Lab2}-\text{NIST}}) \quad , \tag{18}$$

in which each laboratory used a different transfer thermometer, this results in the expanded uncertainty

$$U(\Delta T_{Lab1-Lab2}) = \sqrt{k^2_{\text{Lab1}} \left(\frac{S^2_{A_{Lab1}}}{n_{\text{Lab1}}} + S^2_{B_{Lab1}} \right) + k^2_{\text{NIST}} \left(\frac{S^2_{\text{A}_{\text{NIST}}}}{n_{\text{NIST}_1}} + \frac{S^2_{\text{A}_{\text{NIST}}}}{n_{\text{NIST}_2}} \right) + k^2_{\text{Lab2}} \left(\frac{S^2_{A_{Lab2}}}{n_{\text{Lab2}}} + S^2_{B_{Lab2}} \right) + k^2_{\text{SPRT1}} u^2_{SPRT1} + k^2_{\text{SPRT2}} u^2_{SPRT2}} \ . \tag{19}$$

Note that in Eq. (19), the coverage factor for NIST is based only on the random portion of the uncertainty, S_A, because that is the only portion of the uncertainty that affects the temperature difference in the cases in which NIST serves as an intermediary.

The expanded uncertainties for all of the other types of comparisons between laboratories described above were obtained analogously.

While the alternative method for computing expanded uncertainties used here is not in line with the methods described in [9], it always results in larger expanded uncertainty intervals than the ISO methods and is therefore more conservative than the procedures outlined there. When the degrees of freedom associated with each of the components of uncertainty in u_c are large, the alternative method will be only slightly conservative. When the number of the degrees of freedom for one or more of the uncertainty components in u_c is small, however, it can become extremely conservative. Of course, one of the primary advantages of using this alternative method is the fact that both the standard uncertainties and expanded uncertainties are ordered according to physical intuition.

The results of the data analysis are given in Tables 6 through 28 of the full report [3] and summarized in Tables 4 through 11 of this article. Please note that the description of the data analysis given above provides the general procedures followed for each comparison. In some cases, the data for a particular comparison had to be handled slightly differently than was done in the general case described above.

An upper bound on each laboratory's individual contribution to the total uncertainties of the bilateral temperature differences at each fixed point is also given in Tables 4 through 11, denoted as an expanded uncertainty U_L at the 95% confidence level. This value serves as an approximation that shows how much uncertainty each laboratory contributed to the uncertainty of the bilateral comparisons at each fixed point across all other laboratories. The value of this uncertainty bound was obtained for each laboratory by extracting the expanded uncertainty components associated with that laboratory from the bilateral comparisons with all other laboratories and taking the maximum of the uncertainty contributions as an approximation to the individual values.

While these approximate uncertainties are closely related to the uncertainties of the bilateral differences and provide a bound on each laboratory's contribution to the uncertainty of the bilateral differences, it is important to remember that these are only approximations taken over multiple bilateral temperature differences. These uncertainties also account for each laboratory individually, not for the difference between laboratories. If these values are combined, the resulting uncertainty estimate will not account for the uncertainty due to any intermediate laboratories or the components of uncertainty associated with the SPRTs themselves. If the approximations for intermediate laboratories are explicitly included in a combined uncertainty estimated from the approximate uncertainty values, the resulting value will not account for the covariance between the intermediate laboratory's measurements.

4.3. Results of Direct and Indirect Comparisons of Ga Cells

As stated in Section 3.2.1, a Ga transfer cell was sent to each participant to ascertain how closely the temperatures of all the participating laboratories' Ga cells agreed, as determined by either "direct" or "indirect" comparisons, with the transfer cell. The direct comparisons were those in which the two cells were measured simultaneously in nearly identical furnaces at the same liquid-solid ratio and the indirect comparisons were those in which the cells were compared sequentially in the same furnace rather than simultaneously. The results are presented in Tables 12a and 12b, respectively.

These differences may be compared with the differences, also given in Tables 12a and 12b, obtained from the realizations of the Ga melting point as indicated by the calibrations of the circulating SPRTs, indicated in Tables 12a and 12b as bilateral (these latter being identical to those in Table 9).

The data analysis for the direct and indirect comparisons of the Ga cells was handled similarly to the analysis of the ITS-90 realizations described in Section 4.2. For the direct comparisons, paired differences of the *W* values, converted to terms of temperature, were averaged to determine the differences between the cells. The paired differences were used also to determine the repeatability of the measurements since the paired results should be less variable than non-paired results. The other sources of uncertainty included in the direct comparisons included hydrostatic-head effects, SPRT self-heating effects, immersion effects, and effects arising from the choice of plateau values. All other sources of uncertainty reported by the participants will not affect the direct comparisons because each will affect the results in the same way and therefore will cancel.

For indirect comparisons, the mean *W* values were computed for each cell and then the difference of the means, expressed in terms of temperature, was used to determine the difference between the cells. When more than one thermometer was used, the results were averaged to get the best-possible estimate of the difference between the cells. The sources of uncertainty included when assessing the variability of these mean temperature differences included all sources reported by the laboratories except for effects due to impurities in the samples. For the indirect comparisons, the values of measurement repeatability reported by the participants were used, rather than the values computed from the comparison data. This was done because the participant-reported measurement-repeatability values were often based on more degrees of freedom and over a wider range of environmental conditions than the repeatability estimates from the comparison data alone.

For both types of comparisons, the number of freezes used to compute the mean differences in the cells was used in the uncertainty calculations. Also, as in the comparison of the ITS-90 realizations, expanded uncertainties for the differences between fixed-point cells were obtained for each laboratory's contribution to the comparison and then those expanded uncertainties were combined by root-sum-of-squares. The same method for obtaining expanded uncertainties as described in Section 4.2 applies to the analysis when used for direct or indirect comparison of fixed-point cells.

4.4. Results of Direct and Indirect Comparisons of Cd Cells

Direct or indirect comparisons were made also with the Cd transfer cell. The results are presented in Table 13a and Table 13b, respectively. These differences may be compared with the differences, also given in Tables 13a and 13b, obtained from the realizations of the Cd freezing point as indicated by the calibrations of the circulating SPRTs, indicated in Tables 13a and 13b as bilateral (these latter being identical to those in Table 6).

The data-analysis methods used for the comparison of Cd fixed-point cells are analogous to the methods used for comparison of Ga cells described in Section 4.3.

4.5. Immersion Results Provided by the Participants

Proper immersion of SPRTs in fixed-point cells is essential for accurate realizations of those cells' fixed-point temperatures. The full report to the CCT of the key comparison [3] contains the immersion results provided by the participants and it should be consulted for details.

5. DISCUSSION

The best method for comparing the temperatures of fixed-point cells is by a direct, i.e., simultaneous, comparison of the cells, with the cells located in nearly identical furnaces and with measurements made on the samples at the same liquid/solid ratio. This method eliminates most systematic errors.

The best method for comparison of realizations of the ITS-90 by laboratories is to compare not only the temperatures of fixed-point cells by a direct comparison in each laboratory, but also to compare realizations of those fixed points through the calibrations of one or more SPRTs at those points in the respective laboratories, since the latter procedure includes most systematic errors present in the measurements made in each of the laboratories. This best method for comparison of realizations of the ITS-90, however, is not a practical method for key comparisons because of the amount of time and the cost that would be involved and it was not the method used for the CCT KC 3.

The protocol of the CCT KC 3, which used parts of both methods described above, appears to be a good compromise for comparing the realizations of the ITS-90 by the National Metrology Institutes participating. In fact, it is believed that the CCT KC 3 represents the best global comparison to date of realizations of the ITS-90 over the range of the comparison.

It was expected, at least by the authors from the coordinating laboratory, that the agreement among the laboratories of the Ga fixed-point temperature would be to within 0.02 mK, but certainly no worse than 0.05 mK. As can be seen from the results of the direct and indirect comparisons presented in Table 12a and Table 12b, respectively, however, the results are disappointing and obviously did not meet expectations.

The Cd freezing-point temperature is a good secondary fixed point that can be used as a check point to evaluate the quality of calibrations of SPRTs from either 83.8058 K or 273.15 K through 692.677 K, 933.473 K or 1234.93 K, and has been used by some laboratories for that purpose. As can be seen from the results of the direct and indirect comparisons, presented in Table 13a and Table 13b, respectively, and from the differences between those and those from realizations also presented in Table 13a and Table 13b, the agreement of the temperatures of the participants' cells was rather poor. Unfortunately, it was discovered that only seven participants had Cd fixed-point cells of their own. Thus, it was decided not to address the non-uniqueness issue in the full report [3] since so many of the participants had little or no experience in using the Cd cell and, consequently, had no estimate of the uncertainty in the realization of its freezing point.

Perhaps some of the disagreement of the results of realizations of all of the fixed points is related to inadequate immersion of the SPRTs in the fixed-point cells. That may have caused increased, but unknown, errors in the participants' measurements and, also, may have led to a participant having an increased spread of values at a given fixed point.

The participants decided that key-comparison reference values (KCRVs) would not be given for this key comparison. The reasons for and against KCRVs are presented in the full report to the CCT [3] and the reader is referred to that report for details.

Based on things that occurred during this KC 3 comparison, it is recommended that those planning comparisons similar to KC 3 should be aware of several potential problems that may be encountered during the course of their comparison: (1) unless artifacts are hand-carried, breakage during shipment is likely, (2) if sealed cells are involved, they may develop leaks, (3) difficulties with transportation documents and in dealing with Customs are likely, and (4) problems of compatibility of artifacts with a participant's laboratory equipment may be encountered.

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Table 1. This table is for the NIST comparison loop, but it does not include results from comparisons between NIST and the sub-coordinators (see Fig. 1). It gives the average value of $W(T_{90})$, the range of the $W(T_{90})$ expressed in mK, the number of measurements (n) made, and the uncertainty of the measurements at the fixed points for each participant for the SPRT indicated.

Hart Model 5681, s/n 1094

	NIST avg. $W(T_{90})$	range $W(T_{90})$ / mK	n	u_c (k=1) / mK	**VSL** avg. $W(T_{90})$	range $W(T_{90})$ / mK	n	u_c (k=1) / mK
Al	3.375 732 56	0.41	4	0.21	3.375 731 25		1	0.77
Zn	2.568 747 52	0.43	4	0.13	2.568 746 43		1	0.48
Cd	2.219 019 53	0.50	4	0.07	2.219 015 43		1	
Sn	1.892 712 29	0.28	4	0.06	1.892 710 70		1	0.37
In	1.609 746 41	0.25	4	0.04	1.609 741 78		1	0.33
Ga	1.118 129 76	0.02	4	0.01	1.118 128 87		1	0.21
Hg	0.844 151 47	0.03	4	0.04	0.844 151 64		1	0.20
Ar	0.215 910 58	0.03	4	0.03	0.215 910 32		1	0.33

Hart Model 5681, s/n 1098

	NIST (1098A) avg. $W(T_{90})$	range $W(T_{90})$ / mK	n	u_c (k=1) / mK	**NRC** (1098A) avg. $W(T_{90})$	range $W(T_{90})$ / mK	n	u_c (k=1) / mK
Al	3.375 747 12	0.47	4	0.21	3.375 753 30		1	0.53
Zn	2.568 758 04	0.63	4	0.13	2.568 754 00		1	0.14
Cd	2.219 023 55	0.33	4	0.07	2.219 020 11		1	0.19
Sn	1.892 712 69	0.28	4	0.06	1.892 707 68		1	0.38
In	1.609 745 17	0.29	4	0.04	1.609 741 25		1	0.13
Ga	1.118 128 27	0.06	4	0.01	1.118 127 72		1	0.12
Hg	0.844 151 59	0.05	4	0.04	0.844 152 46		1	0.08
Ar	0.215 909 22	0.10	4	0.03	0.215 909 68		1	0.15

	NIST (1098B) avg. $W(T_{90})$	range $W(T_{90})$ / mK	n	u_c (k=1) / mK	**IMGC** (1098B) avg. $W(T_{90})$	range $W(T_{90})$ / mK	n	u_c (k=1) / mK
Al	3.375 747 56	0.04	2	0.25	3.375 739 99	2.77	3	0.49
Zn	2.568 759 10	0.04	2	0.16	2.568 754 54		1	0.42
Cd	2.219 024 40	0.11	2	0.09	2.219 019 11		1	0.32
Sn	1.892 713 55	0.14	2	0.09	1.892 713 07		1	0.21
In	1.609 745 74	0.08	2	0.04	1.609 744 75		1	0.31
Ga	1.118 128 35	0.04	2	0.02	1.118 128 69		1	0.06
Hg	0.844 151 53	0.01	2	0.05	0.844 151 19		1	0.13
Ar	0.215 909 28	0.07	2	0.04	0.215 912 46		1	0.23

Table 2. This table is for the NML comparison loop (see Fig. 1). It gives the average value of $W(T_{90})$, the range of the $W(T_{90})$ expressed in mK, the number of measurements (n) made, and the uncertainty of the measurements at the fixed points for each participant for the SPRT indicated.

Rosemount Model 162CE, s/n 4386

	NIST avg. $W(T_{90})$	range $W(T_{90})$ / mK	n	u_c (k=1) / mK	**NML** avg. $W(T_{90})$	range $W(T_{90})$ / mK	n	u_c (k=1) / mK
Al	3.375 674 05	0.51	4	0.21	3.375 671 26	2.96	4	0.43
Zn	2.568 703 63	0.28	4	0.13	2.568 701 29	1.21	5	0.21
Cd	2.218 980 47	0.49	4	0.07	2.218 974 91	1.41	5	0.18
Sn	1.892 681 25	0.17	4	0.06	1.892 676 09	0.94	5	0.15
In	1.609 724 44	0.18	4	0.04	1.609 716 06	0.80	5	0.41
Ga	1.118 124 62	0.07	4	0.01	1.118 123 46	0.90	5	0.13
Hg	0.844 159 29	0.11	4	0.04	0.844 158 14	0.20	5	0.13
Ar	0.215 953 56	0.12	4	0.03	0.215 941 86	1.81	4	0.49

	KRISS avg. $W(T_{90})$	range $W(T_{90})$ / mK	n	u_c (k=1) / mK	**NIM** avg. $W(T_{90})$	range $W(T_{90})$ / mK	n	u_c (k=1) / mK
Al	3.375 661 60		1	1.11	3.375 663 92	0.01	2	1.39
Zn	2.568 700 00		1	0.63	2.568 704 79	0.10	2	0.56
Cd					2.218 985 09	0.26	2	0.86
Sn	1.892 679 30		1	0.46	1.892 676 88	0.23	2	1.59
In	1.609 729 50		1	0.38	1.609 718 33	0.09	2	0.46
Ga	1.118 124 60		1	0.20	1.118 122 28	0.22	2	0.28
Hg	0.844 161 30		1	0.21	0.844 160 13	0.06	2	0.23
Ar					0.215 952 54		1	0.28

Hart Model 5681, s/n 1032

	NIST avg. $W(T_{90})$	range $W(T_{90})$ / mK	n	u_c (k=1) / mK	**NML** avg. $W(T_{90})$	range $W(T_{90})$ / mK	n	u_c (k=1) / mK
Al	3.375 711 84	0.62	4	0.21				
Zn	2.568 743 16	0.32	4	0.13	2.568 741 40	2.17	2	0.24
Cd	2.219 014 25	0.59	4	0.07	2.219 011 08	0.67	2	0.20
Sn	1.892 706 86	0.55	4	0.06	1.892 703 57	0.62	2	0.16
In	1.609 741 29	0.38	4	0.04	1.609 737 15	0.42	2	0.42
Ga	1.118 127 59	0.18	4	0.01	1.118 127 46	0.30	2	0.13
Hg	0.844 151 65	0.09	4	0.04	0.844 152 43		1	0.13
Ar	0.215 913 88	0.07	4	0.03	0.215 904 58		1	0.49

Table 2. Cont'd.

Hart Model 5681, s/n 1032 (continued)

	MSL			
	avg. $W(T_{90})$	range $W(T_{90})$ / mK	n	u_c (k=1) / mK
Al				
Zn	2.568 740 53		1	1.01
Cd				
Sn	1.892 703 74		1	0.47
In	1.609 739 76		1	0.39
Ga	1.118 128 26	0.02	2	0.18
Hg	0.844 152 71		1	0.19
Ar				

Isotech Model 670, s/n 040

	NML				NRLM			
	avg. $W(T_{90})$	range $W(T_{90})$ / mK	n	u_c (k=1) / mK	avg. $W(T_{90})$	range $W(T_{90})$ / mK	n	u_c (k=1) / mK
Al	3.375 581 10	4.61	2	0.50	3.375 578 61	2.34	4	0.95
Zn	2.568 653 91	1.77	2	0.24	2.568 647 44	0.42	4	0.88
Cd	2.218 939 38	1.09	2	0.20				
Sn	1.892 650 93	0.62	2	0.16	1.892 650 69	0.37	4	0.38
In	1.609 699 57	0.26	2	0.42	1.609 702 03	0.37	3	0.45
Ga	1.118 120 89	0.01	2	0.13	1.118 120 06	0.03	3	0.11
Hg	0.844 161 75	0.01	2	0.13	0.844 161 52		1	0.30
Ar								

Table 3. This table is for the PTB comparison loop (see Fig. 1). It gives the average value of $W(T_{90})$, the range of the $W(T_{90})$ expressed in mK, the number of measurements (n) made, and the uncertainty of the measurements at the fixed points for each participant for the SPRT indicated.

Rosemount Model 162CE, s/n 4385

	NIST				PTB			
	avg. $W(T_{90})$	range $W(T_{90})$ / mK	n	u_c (k=1) / mK	avg. $W(T_{90})$	range $W(T_{90})$ / mK	n	u_c (k=1) / mK
Al	3.375 679 15	0.48	4	0.21	3.375 692 83	0.62	4	0.84
Zn	2.568 710 12	0.31	4	0.13	2.568 714 64	0.34	5	0.64
Cd	2.218 987 11	0.46	4	0.07				
Sn	1.892 685 74	0.24	4	0.06	1.892 686 64	0.35	5	0.44
In	1.609 727 92	0.24	4	0.04	1.609 723 74	0.71	5	0.57
Ga	1.118 124 99	0.06	4	0.01	1.118 124 16	0.15	5	0.12
Hg	0.844 157 56	0.11	4	0.04	0.844 157 80	0.37	5	0.14
Ar	0.215 947 09	0.09	4	0.03	0.215 945 82	0.37	5	0.28

	VNIIM				BNM			
	avg. $W(T_{90})$	range $W(T_{90})$ / mK	n	u_c (k=1) / mK	avg. $W(T_{90})$	range $W(T_{90})$ / mK	n	u_c (k=1) / mK
Al	3.375 678 20	0.38	3	0.54	3.375 693 08	0.17	3	1.12
Zn	2.568 710 20	0.54	3	0.54	2.568 719 35	1.58	3	0.52
Cd	2.218 988 54	0.49	3	0.53				
Sn	1.892 686 50	0.41	3	0.28	1.892 685 51	0.32	3	0.48
In	1.609 728 36	0.09	3	0.29	1.609 724 31	0.34	2	0.32
Ga	1.118 125 03	0.07	3	0.08	1.118 123 65	0.08	3	0.15
Hg					0.844 156 18		1	0.29
Ar					0.215 947 01		1	0.31

	SMU				NPL			
	avg. $W(T_{90})$	range $W(T_{90})$ / mK	n	u_c (k=1) / mK	avg. $W(T_{90})$	range $W(T_{90})$ / mK	n	u_c (k=1) / mK
Al	3.375 691 17	2.25	3	0.47				
Zn	2.568 717 97	1.43	3	0.41	2.568 719 60	0.97	2	0.44
Cd								
Sn	1.892 687 27	0.22	3	0.45	1.892 683 05	1.37	2	0.36
In					1.609 722 05	0.18	2	0.34
Ga	1.118 124 37	0.13	3	0.10	1.118 123 10		1	0.22
Hg					0.844 158 45	0.12	2	0.20
Ar					0.215 943 20	0.37	2	0.36

Table 3. Cont'd.

Rosemount Model 162CE, s/n 4385 (continued)

	BIPM avg. $W(T_{90})$	range $W(T_{90})$ / mK	n	u_c (k=1) / mK
Al				
Zn				
Cd				
Sn				
In				
Ga	1.118 123 20	0.00	2	0.08
Hg				
Ar				

Hart Model 5681, s/n 1030

	NIST (1030A)				**NIST** (1030B)			
	avg. $W(T_{90})$	range $W(T_{90})$ / mK	n	u_c (k=1) / mK	avg. $W(T_{90})$	range $W(T_{90})$ / mK	n	u_c (k=1) / mK
Al	3.375 761 50	0.35	3	0.23	3.375 764 15	0.30	2	0.25
Zn	2.568 771 37	0.23	3	0.14	2.568 772 97	0.22	2	0.16
Cd	2.219 031 68	0.29	3	0.08	2.219 033 18	0.21	2	0.09
Sn	1.892 716 03	0.09	3	0.07	1.892 717 23	0.07	2	0.09
In	1.609 745 91	0.18	3	0.04	1.609 747 03	0.01	2	0.04
Ga	1.118 127 72	0.04	3	0.02	1.118 127 72	0.00	2	0.02
Hg	0.844 151 02	0.09	3	0.04	0.844 151 19	0.02	2	0.05
Ar	0.215 908 39	0.07	3	0.03	0.215 908 09	0.03	2	0.04

	PTB (1030A)				**PTB** (1030B)			
	avg. $W(T_{90})$	range $W(T_{90})$ / mK	n	u_c (k=1) / mK	avg. $W(T_{90})$	range $W(T_{90})$ / mK	n	u_c (k=1) / mK
Al	3.375 760 93	0.31	3	0.85	3.375 761 10		1	0.88
Zn	2.568 763 17	1.34	3	0.65	2.568 764 20		1	0.66
Cd								
Sn	1.892 715 83	0.67	3	0.44	1.892 718 80		1	0.46
In	1.609 746 07	0.42	3	0.57	1.609 747 50		1	0.59
Ga	1.118 129 00	0.25	3	0.12	1.118 129 70		1	0.13
Hg	0.844 151 43	0.22	3	0.14	0.844 149 90		1	0.15
Ar	0.215 907 20	0.55	3	0.28	0.215 907 60		1	0.31

Table 3. Cont'd.

Hart Model 5681, s/n 1030 (continued)

	BNM (1030A) avg. $W(T_{90})$	range $W(T_{90})$ / mK	n	u_c (k=1) / mK	**SMU** (1030B) avg. $W(T_{90})$	range $W(T_{90})$ / mK	n	u_c (k=1) / mK
Al	3.375 762 55	0.08	2	1.12	3.375 759 47	4.59	3	0.47
Zn	2.568 762 04	1.16	3	0.52	2.568 761 80	0.40	3	0.41
Cd								
Sn	1.892 712 54	0.93	3	0.48	1.892 714 73	1.27	3	0.45
In	1.609 744 72	0.32	2	0.32				
Ga	1.118 128 85	0.12	4	0.15	1.118 128 67	0.03	3	0.10
Hg	0.844 149 44		1	0.29				
Ar	0.215 905 47		1	0.31				

	NPL (1030B) avg. $W(T_{90})$	range $W(T_{90})$ / mK	n	u_c (k=1) / mK	**BIPM** (1030B) avg. $W(T_{90})$	range $W(T_{90})$ / mK	n	u_c (k=1) / mK
Al								
Zn	2.568 762 50	0.29	2	0.44				
Cd								
Sn	1.892 717 93	0.75	3	0.36				
In	1.609 747 70	0.05	2	0.34				
Ga	1.118 128 30		1	0.22	1.118 128 80	0.02	2	0.08
Hg	0.844 151 15	0.17	2	0.20				
Ar	0.215 903 23	0.37	3	0.35				

Table 4. Summary of differences of realizations and of their expanded uncertainties U (95 %) between laboratories for Al, where ΔT/mK = column – row. U is expressed in mK. For information on why dir. and inc. values are different, see Section 4.1. An upper bound on each laboratory's individual contribution to the total uncertainties of the bilateral temperature differences is denoted by U_L (95%).

	BIPM		BNM		IMGC		KRISS		MSL		NIM		NIST		NML		NPL		NRC		NRLM		PTB		SMU		VNIIM		VSL		
	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	
BIPM																															**ΔT**
																															U
BNM					-4.69	-4.69	-6.21	-6.21			-5.49	-5.49	-2.33	-2.33	-3.20	-3.20			-0.41	-0.41	-3.98	-3.98	-0.29	-1.29	-0.60	-1.19	-4.64	-2.63	-2.74	-2.74	**ΔT**
					2.46	2.46	3.36	3.36			3.76	3.76	2.25	2.25	2.40	2.40			2.48	2.48	4.13	4.13	2.76	2.78	2.43	2.41	2.61	2.63	2.72	2.72	***U***
IMGC			4.69	4.69			-1.52	-1.52			-0.80	-0.80	2.36	2.36	1.49	1.49			4.29	4.29	0.72	0.72	3.40	3.40	3.50	3.50	2.06	2.06	1.95	1.95	**ΔT**
			2.46	2.46			2.73	2.73			3.21	3.21	1.10	1.10	1.38	1.38			1.49	1.49	3.64	3.64	1.98	1.98	1.41	1.41	1.78	1.78	1.88	1.88	***U***
KRISS			6.21	6.21	1.52	1.52					0.72	0.72	3.88	3.88	3.01	3.01			5.81	5.81	2.24	2.24	4.92	4.92	5.02	5.02	3.58	3.58	3.47	3.47	**ΔT**
			3.36	3.36	2.73	2.73					3.92	3.92	2.54	2.54	2.65	2.65			2.75	2.75	4.28	4.28	3.03	3.03	2.69	2.69	2.90	2.90	2.96	2.96	***U***
MSL																															**ΔT**
																															U
NIM			5.49	5.49	0.80	0.80	-0.72	-0.72					3.16	3.16	2.29	2.29			5.08	5.08	1.51	1.51	4.20	4.20	4.30	4.30	2.86	2.86	2.75	2.75	**ΔT**
			3.76	3.76	3.21	3.21	3.92	3.92					3.04	3.04	3.13	3.13			3.22	3.22	4.60	4.60	3.46	3.46	3.17	3.17	3.35	3.35	3.41	3.41	***U***
NIST			2.33	2.33	-2.36	-2.36	-3.88	-3.88			-3.16	-3.16			-0.87	-0.87			1.93	1.93	-1.64	-1.64	1.04	1.04	1.14	1.14	-0.29	-0.29	-0.41	-0.41	**ΔT**
			2.25	2.25	1.10	1.10	2.54	2.54			3.04	3.04			0.95	0.95			1.13	1.13	3.50	3.50	1.71	1.71	0.99	0.99	1.47	1.47	1.59	1.59	***U***
NML			3.20	3.20	-1.49	-1.49	-3.01	-3.01			-2.29	-2.29	0.87	0.87					2.80	2.80	-0.77	-0.77	1.91	1.91	2.01	2.01	0.57	0.57	0.46	0.46	**ΔT**
			2.40	2.40	1.38	1.38	2.65	2.65			3.13	3.13	0.95	0.95					1.41	1.41	3.50	3.50	1.90	1.90	1.30	1.30	1.69	1.69	1.80	1.80	***U***
NPL																															**ΔT**
																															U
NRC			0.41	0.41	-4.29	-4.29	-5.81	-5.81			-5.08	-5.08	-1.93	-1.93	-2.80	-2.80					-3.57	-3.57	-0.88	-0.88	-0.78	-0.78	-2.22	-2.22	-2.33	-2.33	**ΔT**
			2.48	2.48	1.49	1.49	2.75	2.75			3.22	3.22	1.13	1.13	1.41	1.41					3.65	3.65	2.00	2.00	1.44	1.44	1.80	1.80	1.90	1.90	***U***
NRLM			3.98	3.98	-0.72	-0.72	-2.24	-2.24			-1.51	-1.51	1.64	1.64	0.77	0.77			3.57	3.57			2.69	2.69	2.78	2.78	1.35	1.35	1.23	1.23	**ΔT**
			4.13	4.13	3.64	3.64	4.28	4.28			4.60	4.60	3.50	3.50	3.50	3.50			3.65	3.65			3.87	3.87	3.61	3.61	3.76	3.76	3.81	3.81	***U***
PTB			0.29	1.29	-3.40	-3.40	-4.92	-4.92			-4.20	-4.20	-1.04	-1.04	-1.91	-1.91			0.88	0.88	-2.69	-2.69			-0.51	0.10	-4.56	-1.34	-1.45	-1.45	**ΔT**
			2.76	2.78	1.98	1.98	3.03	3.03			3.46	3.46	1.71	1.71	1.90	1.90			2.00	2.00	3.87	3.87			1.89	1.91	2.17	2.20	2.29	2.29	***U***
SMU			0.60	1.19	-3.50	-3.50	-5.02	-5.02			-4.30	-4.30	-1.14	-1.14	-2.01	-2.01			0.78	0.78	-2.78	-2.78	0.51	-0.10			-4.04	-1.44	-1.55	-1.55	**ΔT**
			2.43	2.41	1.41	1.41	2.69	2.69			3.17	3.17	0.99	0.99	1.30	1.30			1.44	1.44	3.61	3.61	1.89	1.91			1.74	1.69	1.82	1.82	***U***
VNIIM			4.64	2.63	-2.06	-2.06	-3.58	-3.58			-2.86	-2.86	0.29	0.29	-0.57	-0.57			2.22	2.22	-1.35	-1.35	4.56	1.34	4.04	1.44			-0.11	-0.11	**ΔT**
			2.61	2.63	1.78	1.78	2.90	2.90			3.35	3.35	1.47	1.47	1.69	1.69			1.80	1.80	3.76	3.76	2.17	2.20	1.74	1.69			2.12	2.12	***U***
VSL			2.74	2.74	-1.95	-1.95	-3.47	-3.47			-2.75	-2.75	0.41	0.41	-0.46	-0.46			2.33	2.33	-1.23	-1.23	1.45	1.45	1.55	1.55	0.11	0.11			**ΔT**
			2.72	2.72	1.88	1.88	2.96	2.96			3.41	3.41	1.59	1.59	1.80	1.80			1.90	1.90	3.81	3.81	2.29	2.29	1.82	1.82	2.12	2.12			***U***
U_L (95%)			2.20		0.98		2.51				3.02		0.50		0.98				1.05		1.92		1.73		1.03		1.40		1.53		

Table 5. Summary of differences of realizations and of their expanded uncertainties U (95 %) between laboratories for Zn, where ΔT/mK = column – row. U is expressed in mK. For information on why dir. and inc. values are different, see Section 4.1. An upper bound on each laboratory's individual contribution to the total uncertainties of the bilateral temperature differences is denoted by U_{L} (95%).

	BIPM		**BNM**		**IMGC**		**KRISS**		**MSL**		**NIM**		**NIST**		**NML**		**NPL**		**NRC**		**NRLM**		**PTB**		**SMU**		**VNIIM**		**VSL**		
	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	
BIPM																															**Δ*T***
																															U
BNM					-1.29	-1.29	-1.02	-1.02	-0.74	-0.74	0.34	0.34	0.01	0.01	-0.57	-0.57	0.07	-0.13	-1.14	-1.14	-2.42	-2.42	-0.51	-1.17	-0.39	-0.46	-2.61	0.04	-0.30	-0.30	**Δ*T***
					1.33	1.33	1.67	1.67	5.51	5.51	1.54	1.54	1.01	1.01	1.07	1.07	1.35	1.32	1.14	1.14	2.29	2.29	1.59	1.61	1.33	1.26	1.75	1.72	1.38	1.38	***U***
IMGC			1.29	1.29			0.26	0.26	0.55	0.55	1.63	1.63	1.30	1.30	0.72	0.72	1.16	1.16	0.15	0.15	-1.13	-1.13	0.12	0.12	0.83	0.83	1.33	1.33	0.99	0.99	**Δ*T***
			1.33	1.33			1.61	1.61	5.50	5.50	1.47	1.47	0.91	0.91	0.98	0.98	1.25	1.25	1.04	1.04	2.25	2.25	1.55	1.55	1.19	1.19	1.67	1.67	1.31	1.31	***U***
KRISS			1.02	1.02	-0.26	-0.26			0.29	0.29	1.37	1.37	1.04	1.04	0.37	0.45	0.90	0.90	-0.12	-0.12	-1.48	-1.40	-0.15	-0.15	0.56	0.56	1.06	1.06	0.73	0.73	**Δ*T***
			1.67	1.67	1.61	1.61			5.59	5.59	1.77	1.77	1.36	1.36	1.40	1.40	1.61	1.61	1.47	1.47	2.46	2.46	1.86	1.86	1.57	1.57	1.96	1.96	1.66	1.66	***U***
MSL			0.74	0.74	-0.55	-0.55	-0.29	-0.29			1.08	1.08	0.75	0.75	0.25	0.17	0.61	0.61	-0.40	-0.40	-1.60	-1.68	-0.43	-0.43	0.28	0.28	0.78	0.78	0.44	0.44	**Δ*T***
			5.51	5.51	5.50	5.50	5.59	5.59			5.55	5.55	5.43	5.43	5.44	5.44	5.49	5.49	5.45	5.45	5.81	5.80	5.57	5.57	5.48	5.48	5.61	5.61	5.51	5.51	***U***
NIM			-0.34	-0.34	-1.63	-1.63	-1.37	-1.37	-1.08	-1.08			-0.33	-0.33	-1.00	-0.92	-0.47	-0.47	-1.48	-1.48	-2.85	-2.77	-1.52	-1.52	-0.81	-0.81	-0.31	-0.31	-0.64	-0.64	**Δ*T***
			1.54	1.54	1.47	1.47	1.77	1.77	5.55	5.55			1.19	1.19	1.23	1.24	1.47	1.47	1.31	1.31	2.37	2.37	1.74	1.74	1.42	1.42	1.84	1.84	1.52	1.52	***U***
NIST			-0.01	-0.01	-1.30	-1.30	-1.04	-1.04	-0.75	-0.75	0.33	0.33			-0.59	-0.59	-0.14	-0.14	-1.15	-1.15	-2.44	-2.44	-1.19	-1.19	-0.47	-0.47	0.02	0.02	-0.31	-0.31	**Δ*T***
			1.01	1.01	0.91	0.91	1.36	1.36	5.43	5.43	1.19	1.19			0.46	0.46	0.90	0.90	0.61	0.61	2.08	2.08	1.29	1.29	0.82	0.82	1.43	1.43	0.98	0.98	***U***
NML			0.57	0.57	-0.72	-0.72	-0.37	-0.45	-0.25	-0.17	1.00	0.92	0.59	0.59			0.45	0.45	-0.57	-0.57	-1.85	-1.85	-0.60	-0.60	0.11	0.11	0.61	0.61	0.28	0.28	**Δ*T***
			1.07	1.07	0.98	0.98	1.40	1.40	5.44	5.44	1.23	1.24	0.46	0.46			0.98	0.98	0.71	0.71	2.09	2.09	1.35	1.35	0.90	0.90	1.48	1.48	1.05	1.05	***U***
NPL			-0.07	0.13	-1.16	-1.16	-0.90	-0.90	-0.61	-0.61	0.47	0.47	0.14	0.14	-0.45	-0.45			-1.01	-1.01	-2.29	-2.29	-0.47	-1.04	-0.33	-0.33	-2.69	0.17	-0.17	-0.17	**Δ*T***
			1.35	1.32	1.25	1.25	1.61	1.61	5.49	5.49	1.47	1.47	0.90	0.90	0.98	0.98			1.05	1.05	2.25	2.25	1.53	1.54	1.16	1.16	1.65	1.66	1.31	1.31	***U***
NRC			1.14	1.14	-0.15	-0.15	0.12	0.12	0.40	0.40	1.48	1.48	1.15	1.15	0.57	0.57	1.01	1.01			-1.28	-1.28	-0.03	-0.03	0.68	0.68	1.18	1.18	0.84	0.84	**Δ*T***
			1.14	1.14	1.04	1.04	1.47	1.47	5.45	5.45	1.31	1.31	0.61	0.61	0.71	0.71	1.05	1.05			2.15	2.15	1.40	1.40	0.98	0.98	1.53	1.53	1.12	1.12	***U***
NRLM			2.42	2.42	1.13	1.13	1.48	1.40	1.60	1.68	2.85	2.77	2.44	2.44	1.85	1.85	2.29	2.29	1.28	1.28			1.25	1.25	1.96	1.96	2.46	2.46	2.12	2.12	**Δ*T***
			2.29	2.29	2.25	2.25	2.46	2.46	5.81	5.80	2.37	2.37	2.08	2.08	2.09	2.09	2.25	2.25	2.15	2.15			2.43	2.43	2.22	2.22	2.51	2.51	2.28	2.28	***U***
PTB			0.51	1.17	-0.12	-0.12	0.15	0.15	0.43	0.43	1.52	1.52	1.19	1.19	0.60	0.60	0.47	1.04	0.03	0.03	-1.25	-1.25			0.13	0.71	-1.27	1.21	0.87	0.87	**Δ*T***
			1.59	1.61	1.55	1.55	1.86	1.86	5.57	5.57	1.74	1.74	1.29	1.29	1.35	1.35	1.53	1.54	1.40	1.40	2.43	2.43			1.49	1.50	1.89	1.91	1.60	1.60	***U***
SMU			0.39	0.46	-0.83	-0.83	-0.56	-0.56	-0.28	-0.28	0.81	0.81	0.47	0.47	-0.11	-0.11	0.33	0.33	-0.68	-0.68	-1.96	-1.96	-0.13	-0.71			-2.22	0.50	0.16	0.16	**Δ*T***
			1.33	1.26	1.19	1.19	1.57	1.57	5.48	5.48	1.42	1.42	0.82	0.82	0.90	0.90	1.16	1.16	0.98	0.98	2.22	2.22	1.49	1.50			1.64	1.62	1.25	1.25	***U***
VNIIM			2.61	-0.04	-1.33	-1.33	-1.06	-1.06	-0.78	-0.78	0.31	0.31	-0.02	-0.02	-0.61	-0.61	2.69	-0.17	-1.18	-1.18	-2.46	-2.46	1.27	-1.21	2.22	-0.50			-0.33	-0.33	**Δ*T***
			1.75	1.72	1.67	1.67	1.96	1.96	5.61	5.61	1.84	1.84	1.43	1.43	1.48	1.48	1.65	1.66	1.53	1.53	2.51	2.51	1.89	1.91	1.64	1.62			1.71	1.71	***U***
VSL			0.30	0.30	-0.99	-0.99	-0.73	-0.73	-0.44	-0.44	0.64	0.64	0.31	0.31	-0.28	-0.28	0.17	0.17	-0.84	-0.84	-2.12	-2.12	-0.87	-0.87	-0.16	-0.16	0.33	0.33			**Δ*T***
			1.38	1.38	1.31	1.31	1.66	1.66	5.51	5.51	1.52	1.52	0.98	0.98	1.05	1.05	1.31	1.31	1.12	1.12	2.28	2.28	1.60	1.60	1.25	1.25	1.71	1.71			***U***
U_{L} (95%)			1.04		0.85		1.34		5.42		1.16		0.32		0.47		0.86		0.27		1.73		1.26		0.83		1.41		0.95		

Table 6. Summary of differences of realizations and of their expanded uncertainties U (95 %) between laboratories for Cd, where ΔT/mK = column – row. U is expressed in mK. For information on why dir. and inc. values are different, see Section 4.1. An upper bound on each laboratory's individual contribution to the total uncertainties of the bilateral temperature differences is denoted by U_L (95%).

	BIPM		BNM		IMGC		KRISS		MSL		NIM		NIST		NML		NPL		NRC		NRLM		PTB		SMU		VNIIM		VSL		
	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	
BIPM																															ΔT
																															U
BNM																															ΔT
																															U
IMGC											2.75	2.75	1.47	1.47	0.26	0.26			0.51	0.51							1.87	1.87			ΔT
											2.07	2.07	0.66	0.66	0.77	0.77			0.77	0.77							1.60	1.60			U
KRISS																															ΔT
																															U
MSL																															ΔT
																															U
NIM					-2.75	-2.75							-1.28	-1.28	-2.83	-2.49			-2.24	-2.24							-0.89	-0.89			ΔT
					2.07	2.07							1.96	1.96	1.99	2.00			2.01	2.01							2.44	2.44			U
NIST					-1.47	-1.47					1.28	1.28			-1.21	-1.21			-0.95	-0.95							0.40	0.40			ΔT
					0.66	0.66					1.96	1.96			0.41	0.41			0.42	0.42							1.46	1.46			U
NML					-0.26	-0.26					2.83	2.49	1.21	1.21					0.26	0.26							1.61	1.61			ΔT
					0.77	0.77					1.99	2.00	0.41	0.41					0.58	0.58							1.51	1.51			U
NPL																															ΔT
																															U
NRC					-0.51	-0.51					2.24	2.24	0.95	0.95	-0.26	-0.26											1.35	1.35			ΔT
					0.77	0.77					2.01	2.01	0.42	0.42	0.58	0.58											1.51	1.51			U
NRLM																															ΔT
																															U
PTB																															ΔT
																															U
SMU																															ΔT
																															U
VNIIM					-1.87	-1.87					0.89	0.89	-0.40	-0.40	-1.61	-1.61			-1.35	-1.35											ΔT
					1.60	1.60					2.44	2.44	1.46	1.46	1.51	1.51			1.51	1.51											U
VSL																															ΔT
																															U
U_L (95%)					0.63						1.96		0.18		0.40				0.40								1.42				

Table 7. Summary of differences of realizations and of their expanded uncertainties U (95 %) between laboratories for Sn, where ΔT/mK = column – row. U is expressed in mK. For information on why dir. and inc. values are different, see Section 4.1. An upper bound on each laboratory's individual contribution to the total uncertainties of the bilateral temperature differences is denoted by U_L (95%).

	BIPM		BNM		IMGC		KRISS		MSL		NIM		NIST		NML		NPL		NRC		NRLM		PTB		SMU		VNIIM		VSL		
	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	
BIPM																															**Δ*T***
																															U
BNM					0.37	0.37	-0.02	-0.02	-0.34	-0.34	-0.68	-0.68	0.50	0.50	-0.64	-0.64	-0.66	0.23	-0.85	-0.85	-0.70	-0.70	0.60	0.71	0.47	0.37	0.27	0.71	0.07	0.07	**Δ*T***
					1.04	1.04	1.39	1.39	1.51	1.51	5.73	5.73	0.94	0.94	1.00	1.00	1.19	1.18	1.21	1.21	1.28	1.28	1.26	1.27	1.32	1.27	1.18	1.17	1.19	1.19	***U***
IMGC			-0.37	-0.37			-0.40	-0.40	-0.71	-0.71	-1.05	-1.05	0.13	0.13	-1.01	-1.01	-0.14	-0.14	-1.22	-1.22	-1.07	-1.07	0.33	0.33	0.00	0.00	0.33	0.33	-0.30	-0.30	**Δ*T***
			1.04	1.04			1.12	1.12	1.26	1.26	5.67	5.67	0.44	0.44	0.57	0.57	0.84	0.84	0.88	0.88	0.98	0.98	0.97	0.97	0.97	0.97	0.84	0.84	0.86	0.86	***U***
KRISS			0.02	0.02	0.40	0.40			-0.31	-0.31	-0.65	-0.65	0.53	0.53	-0.86	-0.61	0.26	0.26	-0.82	-0.82	-0.93	-0.68	0.73	0.73	0.39	0.39	0.73	0.73	0.10	0.10	**Δ*T***
			1.39	1.39	1.12	1.12			1.56	1.56	5.74	5.74	1.03	1.03	1.06	1.08	1.25	1.25	1.28	1.28	1.33	1.34	1.34	1.34	1.34	1.34	1.25	1.25	1.26	1.26	***U***
MSL			0.34	0.34	0.71	0.71	0.31	0.31			-0.34	-0.34	0.84	0.84	-0.05	-0.30	0.57	0.57	-0.51	-0.51	-0.11	-0.36	1.04	1.04	0.71	0.71	1.04	1.04	0.41	0.41	**Δ*T***
			1.51	1.51	1.26	1.26	1.56	1.56			5.77	5.77	1.18	1.18	1.22	1.23	1.38	1.38	1.41	1.41	1.46	1.47	1.46	1.46	1.46	1.46	1.38	1.38	1.39	1.39	***U***
NIM			0.68	0.68	1.05	1.05	0.65	0.65	0.34	0.34			1.18	1.18	-0.21	0.04	0.91	0.91	-0.17	-0.17	-0.27	-0.02	1.38	1.38	1.05	1.05	1.38	1.38	0.75	0.75	**Δ*T***
			5.73	5.73	5.67	5.67	5.74	5.74	5.77	5.77			5.65	5.65	5.66	5.66	5.70	5.70	5.70	5.70	5.71	5.72	5.72	5.72	5.72	5.72	5.70	5.70	5.70	5.70	***U***
NIST			-0.50	-0.50	-0.13	-0.13	-0.53	-0.53	-0.84	-0.84	-1.18	-1.18			-1.14	-1.14	-0.27	-0.27	-1.35	-1.35	-1.20	-1.20	0.20	0.20	-0.13	-0.13	0.20	0.20	-0.43	-0.43	**Δ*T***
			0.94	0.94	0.44	0.44	1.03	1.03	1.18	1.18	5.65	5.65			0.36	0.36	0.72	0.72	0.76	0.76	0.88	0.88	0.86	0.86	0.86	0.86	0.71	0.71	0.74	0.74	***U***
NML			0.64	0.64	1.01	1.01	0.86	0.61	0.05	0.30	0.21	-0.04	1.14	1.14			0.87	0.87	-0.21	-0.21	-0.06	-0.06	1.34	1.34	1.01	1.01	1.34	1.34	0.71	0.71	**Δ*T***
			1.00	1.00	0.57	0.57	1.06	1.08	1.22	1.23	5.66	5.66	0.36	0.36			0.80	0.80	0.84	0.84	0.90	0.90	0.93	0.93	0.93	0.93	0.79	0.79	0.82	0.82	***U***
NPL			0.66	-0.23	0.14	0.14	-0.26	-0.26	-0.57	-0.57	-0.91	-0.91	0.27	0.27	-0.87	-0.87			-1.08	-1.08	-0.93	-0.93	0.60	0.47	0.14	0.14	0.93	0.47	-0.16	-0.16	**Δ*T***
			1.19	1.18	0.84	0.84	1.25	1.25	1.38	1.38	5.70	5.70	0.72	0.72	0.80	0.80			1.05	1.05	1.13	1.13	1.11	1.11	1.10	1.10	1.00	1.00	1.03	1.03	***U***
NRC			0.85	0.85	1.22	1.22	0.82	0.82	0.51	0.51	0.17	0.17	1.35	1.35	0.21	0.21	1.08	1.08			0.15	0.15	1.55	1.55	1.22	1.22	1.55	1.55	0.92	0.92	**Δ*T***
			1.21	1.21	0.88	0.88	1.28	1.28	1.41	1.41	5.70	5.70	0.76	0.76	0.84	0.84	1.05	1.05			1.16	1.16	1.15	1.15	1.15	1.15	1.04	1.04	1.06	1.06	***U***
NRLM			0.70	0.70	1.07	1.07	0.93	0.68	0.11	0.36	0.27	0.02	1.20	1.20	0.06	0.06	0.93	0.93	-0.15	-0.15			1.41	1.41	1.07	1.07	1.41	1.41	0.77	0.77	**Δ*T***
			1.28	1.28	0.98	0.98	1.33	1.34	1.46	1.47	5.71	5.72	0.88	0.88	0.90	0.90	1.13	1.13	1.16	1.16			1.23	1.23	1.23	1.23	1.13	1.13	1.15	1.15	***U***
PTB			-0.60	-0.71	-0.33	-0.33	-0.73	-0.73	-1.04	-1.04	-1.38	-1.38	-0.20	-0.20	-1.34	-1.34	-0.60	-0.47	-1.55	-1.55	-1.41	-1.41			-0.46	-0.34	-0.04	0.00	-0.63	-0.63	**Δ*T***
			1.26	1.27	0.97	0.97	1.34	1.34	1.46	1.46	5.72	5.72	0.86	0.86	0.93	0.93	1.11	1.11	1.15	1.15	1.23	1.23			1.21	1.21	1.10	1.11	1.14	1.14	***U***
SMU			-0.47	-0.37	0.00	0.00	-0.39	-0.39	-0.71	-0.71	-1.05	-1.05	0.13	0.13	-1.01	-1.01	-0.14	-0.14	-1.22	-1.22	-1.07	-1.07	0.46	0.34			-0.21	0.34	-0.30	-0.30	**Δ*T***
			1.32	1.27	0.97	0.97	1.34	1.34	1.46	1.46	5.72	5.72	0.86	0.86	0.93	0.93	1.10	1.10	1.15	1.15	1.23	1.23	1.21	1.21			1.15	1.11	1.14	1.14	***U***
VNIIM			-0.27	-0.71	-0.33	-0.33	-0.73	-0.73	-1.04	-1.04	-1.38	-1.38	-0.20	-0.20	-1.34	-1.34	-0.93	-0.47	-1.55	-1.55	-1.41	-1.41	0.04	0.00	0.21	-0.34			-0.63	-0.63	**Δ*T***
			1.18	1.17	0.84	0.84	1.25	1.25	1.38	1.38	5.70	5.70	0.71	0.71	0.79	0.79	1.00	1.00	1.04	1.04	1.13	1.13	1.10	1.11	1.15	1.11			1.02	1.02	***U***
VSL			-0.07	-0.07	0.30	0.30	-0.10	-0.10	-0.41	-0.41	-0.75	-0.75	0.43	0.43	-0.71	-0.71	0.16	0.16	-0.92	-0.92	-0.77	-0.77	0.63	0.63	0.30	0.30	0.63	0.63			**Δ*T***
			1.19	1.19	0.86	0.86	1.26	1.26	1.39	1.39	5.70	5.70	0.74	0.74	0.82	0.82	1.03	1.03	1.06	1.06	1.15	1.15	1.14	1.14	1.14	1.14	1.02	1.02			***U***
U_L (95%)			0.95		0.41		1.02		1.13		5.65		0.17		0.32		0.71		0.75		0.75		0.86		0.91		0.70		0.73		

Table 8. Summary of differences of realizations and of their expanded uncertainties U (95 %) between laboratories for In, where ΔT/mK = column – row. U is expressed in mK. For information on why dir. and inc. values are different, see Section 4.1. An upper bound on each laboratory's individual contribution to the total uncertainties of the bilateral temperature differences is denoted by U_L (95%).

	BIPM		BNM		IMGC		KRISS		MSL		NIM		NIST		NML		NPL		NRC		NRLM		PTB		SMU		VNIIM		VSL		
	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	
BIPM																															**ΔT**
																															U
BNM					0.37	0.37	1.96	1.96	0.23	0.23	-0.98	-0.98	0.63	0.63	-1.01	-1.01	-0.59	-0.05	-0.40	-0.40	-0.37	-0.37	0.10	0.32			1.07	0.75	-0.58	-0.58	**ΔT**
					0.89	0.89	0.98	0.98	1.06	1.06	1.13	1.13	0.64	0.64	1.04	1.04	0.93	0.92	0.71	0.71	1.15	1.15	1.28	1.28			0.95	0.96	0.92	0.92	***U***
IMGC			-0.37	-0.37			1.59	1.59	-0.14	-0.14	-1.35	-1.35	0.26	0.26	-1.39	-1.39	-0.42	-0.42	-0.77	-0.77	-0.74	-0.74	-0.05	-0.05			0.38	0.38	-0.96	-0.96	**ΔT**
			0.89	0.89			0.97	0.97	1.06	1.06	1.13	1.13	0.63	0.63	1.03	1.03	0.91	0.91	0.70	0.70	1.14	1.14	1.28	1.28			0.95	0.95	0.91	0.91	***U***
KRISS			-1.96	-1.96	-1.59	-1.59			-1.73	-1.73	-2.94	-2.94	-1.33	-1.33	-3.54	-2.98	-2.02	-2.02	-2.36	-2.36	-2.89	-2.33	-1.64	-1.64			-1.22	-1.22	-2.55	-2.55	**ΔT**
			0.98	0.98	0.97	0.97			1.13	1.13	1.20	1.20	0.75	0.75	1.11	1.11	1.00	1.00	0.81	0.81	1.21	1.21	1.34	1.34			1.03	1.03	1.00	1.00	***U***
MSL			-0.23	-0.23	0.14	0.14	1.73	1.73			-1.21	-1.21	0.40	0.40	-0.69	-1.25	-0.28	-0.28	-0.63	-0.63	-0.04	-0.60	0.09	0.09			0.52	0.52	-0.81	-0.81	**ΔT**
			1.06	1.06	1.06	1.06	1.13	1.13			1.27	1.27	0.85	0.85	1.18	1.18	1.08	1.08	0.91	0.91	1.28	1.28	1.40	1.40			1.11	1.11	1.08	1.08	***U***
NIM			0.98	0.98	1.35	1.35	2.94	2.94	1.21	1.21			1.61	1.61	-0.60	-0.04	0.92	0.92	0.58	0.58	0.05	0.61	1.30	1.30			1.72	1.72	0.39	0.39	**ΔT**
			1.13	1.13	1.13	1.13	1.20	1.20	1.27	1.27			0.94	0.94	1.24	1.25	1.15	1.15	0.99	0.99	1.34	1.34	1.46	1.46			1.18	1.18	1.15	1.15	***U***
NIST			-0.63	-0.63	-0.26	-0.26	1.33	1.33	-0.40	-0.40	-1.61	-1.61			-1.65	-1.65	-0.68	-0.68	-1.03	-1.03	-1.00	-1.00	-0.31	-0.31			0.11	0.11	-1.22	-1.22	**ΔT**
			0.64	0.64	0.63	0.63	0.75	0.75	0.85	0.85	0.94	0.94			0.82	0.82	0.67	0.67	0.32	0.32	0.96	0.96	1.12	1.12			0.72	0.72	0.67	0.67	***U***
NML			1.01	1.01	1.39	1.39	3.54	2.98	0.69	1.25	0.60	0.04	1.65	1.65			0.96	0.96	0.62	0.62	0.65	0.65	1.34	1.34			1.76	1.76	0.43	0.43	**ΔT**
			1.04	1.04	1.03	1.03	1.11	1.11	1.18	1.18	1.24	1.25	0.82	0.82			1.06	1.06	0.88	0.88	1.26	1.26	1.38	1.38			1.09	1.09	1.06	1.06	***U***
NPL			0.59	0.05	0.42	0.42	2.02	2.02	0.28	0.28	-0.92	-0.92	0.68	0.68	-0.96	-0.96			-0.35	-0.35	-0.32	-0.32	0.20	0.37			1.66	0.80	-0.53	-0.53	**ΔT**
			0.93	0.92	0.91	0.91	1.00	1.00	1.08	1.08	1.15	1.15	0.67	0.67	1.06	1.06			0.74	0.74	1.17	1.17	1.30	1.30			0.98	0.98	0.94	0.94	***U***
NRC			0.40	0.40	0.77	0.77	2.36	2.36	0.63	0.63	-0.58	-0.58	1.03	1.03	-0.62	-0.62	0.35	0.35			0.03	0.03	0.72	0.72			1.15	1.15	-0.18	-0.18	**ΔT**
			0.71	0.71	0.70	0.70	0.81	0.81	0.91	0.91	0.99	0.99	0.32	0.32	0.88	0.88	0.74	0.74			1.01	1.01	1.16	1.16			0.78	0.78	0.73	0.73	***U***
NRLM			0.37	0.37	0.74	0.74	2.89	2.33	0.04	0.60	-0.05	-0.61	1.00	1.00	-0.65	-0.65	0.32	0.32	-0.03	-0.03			0.69	0.69			1.12	1.12	-0.22	-0.22	**ΔT**
			1.15	1.15	1.14	1.14	1.21	1.21	1.28	1.28	1.34	1.34	0.96	0.96	1.26	1.26	1.17	1.17	1.01	1.01			1.47	1.47			1.20	1.20	1.17	1.17	***U***
PTB			-0.10	-0.32	0.05	0.05	1.64	1.64	-0.09	-0.09	-1.30	-1.30	0.31	0.31	-1.34	-1.34	-0.20	-0.37	-0.72	-0.72	-0.69	-0.69					1.21	0.43	-0.91	-0.91	**ΔT**
			1.28	1.28	1.28	1.28	1.34	1.34	1.40	1.40	1.46	1.46	1.12	1.12	1.38	1.38	1.30	1.30	1.16	1.16	1.47	1.47					1.32	1.32	1.30	1.30	***U***
SMU																															**ΔT**
																															U
VNIIM			-1.07	-0.75	-0.38	-0.38	1.22	1.22	-0.52	-0.52	-1.72	-1.72	-0.11	-0.11	-1.76	-1.76	-1.66	-0.80	-1.15	-1.15	-1.12	-1.12	-1.21	-0.43					-1.33	-1.33	**ΔT**
			0.95	0.96	0.95	0.95	1.03	1.03	1.11	1.11	1.18	1.18	0.72	0.72	1.09	1.09	0.98	0.98	0.78	0.78	1.20	1.20	1.32	1.32					0.97	0.97	***U***
VSL			0.58	0.58	0.96	0.96	2.55	2.55	0.81	0.81	-0.39	-0.39	1.22	1.22	-0.43	-0.43	0.53	0.53	0.18	0.18	0.22	0.22	0.91	0.91			1.33	1.33			**ΔT**
			0.92	0.92	0.91	0.91	1.00	1.00	1.08	1.08	1.15	1.15	0.67	0.67	1.06	1.06	0.94	0.94	0.73	0.73	1.17	1.17	1.30	1.30			0.97	0.97			***U***
U_L (95%)			0.64		0.62		0.74		0.83		0.94		0.08		0.82		0.67		0.27		0.93		1.12				0.70		0.65		

Table 9. Summary of differences of realizations and of their expanded uncertainties U (95 %) between laboratories for Ga, where ΔT/mK = column – row. U is expressed in mK. For information on why dir. and inc. values are different, see Section 4.1. An upper bound on each laboratory's individual contribution to the total uncertainties of the bilateral temperature differences is denoted by U_L (95%).

	BIPM		BNM		IMGC		KRISS		MSL		NIM		NIST		NML		NPL		NRC		NRLM		PTB		SMU		VNIIM		VSL		
	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	
BIPM			0.11	0.06	0.18	0.18	0.09	0.09	0.26	0.26	-0.50	-0.50	0.09	0.09	-0.07	-0.07	-0.08	-0.08	-0.05	-0.05	-0.28	-0.28	0.24	0.30	0.13	0.13	0.46	0.10	-0.13	-0.13	ΔT
			0.34	0.33	0.20	0.20	0.48	0.48	0.39	0.39	0.59	0.59	0.16	0.16	0.30	0.30	0.45	0.45	0.31	0.31	0.27	0.27	0.29	0.29	0.24	0.24	0.25	0.24	0.44	0.44	U
BNM	-0.11	-0.06			0.11	0.11	0.02	0.02	0.20	0.20	-0.56	-0.56	0.03	0.03	-0.14	-0.14	-0.14	-0.14	-0.11	-0.11	-0.34	-0.34	0.08	0.23	0.18	0.07	0.35	0.04	-0.20	-0.20	ΔT
	0.34	0.33			0.32	0.32	0.54	0.54	0.46	0.46	0.64	0.64	0.29	0.29	0.39	0.39	0.54	0.51	0.40	0.40	0.37	0.37	0.38	0.38	0.35	0.35	0.34	0.34	0.50	0.50	U
IMGC	-0.18	-0.18	-0.11	-0.11			-0.09	-0.09	0.08	0.08	-0.68	-0.68	-0.09	-0.09	-0.25	-0.25	-0.25	-0.25	-0.23	-0.23	-0.46	-0.46	0.12	0.12	-0.05	-0.05	-0.08	-0.08	-0.31	-0.31	ΔT
	0.20	0.20	0.32	0.32			0.47	0.47	0.38	0.38	0.59	0.59	0.13	0.13	0.29	0.29	0.44	0.44	0.30	0.30	0.26	0.26	0.27	0.27	0.23	0.23	0.23	0.23	0.43	0.43	U
KRISS	-0.09	-0.09	-0.02	-0.02	0.09	0.09			0.17	0.17	-0.59	-0.59	0.00	0.00	-0.29	-0.16	-0.16	-0.16	-0.13	-0.13	-0.50	-0.37	0.21	0.21	0.04	0.04	0.01	0.01	-0.22	-0.22	ΔT
	0.48	0.48	0.54	0.54	0.47	0.47			0.58	0.58	0.73	0.73	0.46	0.46	0.52	0.52	0.62	0.62	0.53	0.53	0.51	0.51	0.52	0.52	0.50	0.50	0.49	0.49	0.62	0.62	U
MSL	-0.26	-0.26	-0.20	-0.20	-0.08	-0.08	-0.17	-0.17			-0.76	-0.76	-0.17	-0.17	-0.20	-0.33	-0.34	-0.34	-0.31	-0.31	-0.41	-0.54	0.03	0.03	-0.13	-0.13	-0.16	-0.16	-0.40	-0.40	ΔT
	0.39	0.39	0.46	0.46	0.38	0.38	0.58	0.58			0.68	0.68	0.36	0.36	0.44	0.44	0.55	0.55	0.45	0.45	0.42	0.42	0.43	0.43	0.41	0.41	0.40	0.40	0.55	0.55	U
NIM	0.50	0.50	0.56	0.56	0.68	0.68	0.59	0.59	0.76	0.76			0.59	0.59	0.30	0.43	0.43	0.43	0.45	0.45	0.09	0.22	0.80	0.80	0.63	0.63	0.60	0.60	0.37	0.37	ΔT
	0.59	0.59	0.64	0.64	0.59	0.59	0.73	0.73	0.68	0.68			0.57	0.57	0.62	0.63	0.71	0.71	0.63	0.63	0.61	0.61	0.62	0.62	0.60	0.60	0.60	0.60	0.70	0.70	U
NIST	-0.09	-0.09	-0.03	-0.03	0.09	0.09	0.00	0.00	0.17	0.17	-0.59	-0.59			-0.16	-0.16	-0.17	-0.17	-0.14	-0.14	-0.37	-0.37	0.20	0.20	0.04	0.04	0.01	0.01	-0.23	-0.23	ΔT
	0.16	0.16	0.29	0.29	0.13	0.13	0.46	0.46	0.36	0.36	0.57	0.57			0.26	0.26	0.42	0.42	0.27	0.27	0.22	0.22	0.24	0.24	0.19	0.19	0.19	0.19	0.41	0.41	U
NML	0.07	0.07	0.14	0.14	0.25	0.25	0.29	0.16	0.20	0.33	-0.30	-0.43	0.16	0.16			0.00	0.00	0.02	0.02	-0.21	-0.21	0.37	0.37	0.20	0.20	0.17	0.17	-0.06	-0.06	ΔT
	0.30	0.30	0.39	0.39	0.29	0.29	0.52	0.52	0.44	0.44	0.62	0.63	0.26	0.26			0.49	0.49	0.37	0.37	0.33	0.33	0.35	0.35	0.32	0.32	0.32	0.32	0.48	0.48	U
NPL	0.08	0.08	0.14	0.14	0.25	0.25	0.16	0.16	0.34	0.34	-0.43	-0.43	0.17	0.17	0.00	0.00			0.03	0.03	-0.21	-0.21	0.31	0.37	0.21	0.21	0.49	0.18	-0.06	-0.06	ΔT
	0.45	0.45	0.54	0.51	0.44	0.44	0.62	0.62	0.55	0.55	0.71	0.71	0.42	0.42	0.49	0.49			0.50	0.50	0.48	0.48	0.48	0.48	0.46	0.46	0.49	0.46	0.59	0.59	U
NRC	0.05	0.05	0.11	0.11	0.23	0.23	0.13	0.13	0.31	0.31	-0.45	-0.45	0.14	0.14	-0.02	-0.02	-0.03	-0.03			-0.23	-0.23	0.34	0.34	0.18	0.18	0.15	0.15	-0.09	-0.09	ΔT
	0.31	0.31	0.40	0.40	0.30	0.30	0.53	0.53	0.45	0.45	0.63	0.63	0.27	0.27	0.37	0.37	0.50	0.50			0.35	0.35	0.36	0.36	0.33	0.33	0.32	0.32	0.49	0.49	U
NRLM	0.28	0.28	0.34	0.34	0.46	0.46	0.50	0.37	0.41	0.54	-0.09	-0.22	0.37	0.37	0.21	0.21	0.21	0.21	0.23	0.23			0.58	0.58	0.41	0.41	0.38	0.38	0.15	0.15	ΔT
	0.27	0.27	0.37	0.37	0.26	0.26	0.51	0.51	0.42	0.42	0.61	0.61	0.22	0.22	0.33	0.33	0.48	0.48	0.35	0.35			0.33	0.33	0.29	0.29	0.29	0.29	0.47	0.47	U
PTB	-0.24	-0.30	-0.08	-0.23	-0.12	-0.12	-0.21	-0.21	-0.03	-0.03	-0.80	-0.80	-0.20	-0.20	-0.37	-0.37	-0.31	-0.37	-0.34	-0.34	-0.58	-0.58			-0.10	-0.16	0.22	-0.20	-0.43	-0.43	ΔT
	0.29	0.29	0.38	0.38	0.27	0.27	0.52	0.52	0.43	0.43	0.62	0.62	0.24	0.24	0.35	0.35	0.48	0.48	0.36	0.36	0.33	0.33			0.31	0.31	0.30	0.30	0.48	0.48	U
SMU	-0.13	-0.13	-0.18	-0.07	0.05	0.05	-0.04	-0.04	0.13	0.13	-0.63	-0.63	-0.04	-0.04	-0.20	-0.20	-0.21	-0.21	-0.18	-0.18	-0.41	-0.41	0.10	0.16			0.17	-0.03	-0.27	-0.27	ΔT
	0.24	0.24	0.35	0.35	0.23	0.23	0.50	0.50	0.41	0.41	0.60	0.60	0.19	0.19	0.32	0.32	0.46	0.46	0.33	0.33	0.29	0.29	0.31	0.31			0.27	0.26	0.45	0.45	U
VNIIM	-0.46	-0.10	-0.35	-0.04	0.08	0.08	-0.01	-0.01	0.16	0.16	-0.60	-0.60	-0.01	-0.01	-0.17	-0.17	-0.49	-0.18	-0.15	-0.15	-0.38	-0.38	-0.22	0.20	-0.17	0.03			-0.23	-0.23	ΔT
	0.25	0.24	0.34	0.34	0.23	0.23	0.49	0.49	0.40	0.40	0.60	0.60	0.19	0.19	0.32	0.32	0.49	0.46	0.32	0.32	0.29	0.29	0.30	0.30	0.27	0.26			0.45	0.45	U
VSL	0.13	0.13	0.20	0.20	0.31	0.31	0.22	0.22	0.40	0.40	-0.37	-0.37	0.23	0.23	0.06	0.06	0.06	0.06	0.09	0.09	-0.15	-0.15	0.43	0.43	0.27	0.27	0.23	0.23			ΔT
	0.44	0.44	0.50	0.50	0.43	0.43	0.62	0.62	0.55	0.55	0.70	0.70	0.41	0.41	0.48	0.48	0.59	0.59	0.49	0.49	0.47	0.47	0.48	0.48	0.45	0.45	0.45	0.45			U
U_L (95%)	0.16		0.29		0.13		0.46		0.35		0.57		0.03		0.25		0.45		0.27		0.21		0.24		0.19		0.18		0.41		

Table 10. Summary of differences of realizations and of their expanded uncertainties U (95 %) between laboratories for Hg, where ΔT/mK = column – row. U is expressed in mK. For information on why dir. and inc. values are different, see Section 4.1. An upper bound on each laboratory's individual contribution to the total uncertainties of the bilateral temperature differences is denoted by U_L (95%).

	BIPM		BNM		IMGC		KRISS		MSL		NIM		NIST		NML		NPL		NRC		NRLM		PTB		SMU		VNIIM		VSL		
	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	
BIPM																															**ΔT**
																															U
BNM					0.29	0.29	0.87	0.87	0.63	0.63	0.58	0.58	0.37	0.37	0.32	0.32	0.57	0.48	0.59	0.59	0.27	0.27	0.45	0.32					0.41	0.41	**ΔT**
					0.62	0.62	0.73	0.73	0.70	0.70	0.76	0.76	0.57	0.57	0.62	0.62	0.69	0.68	0.59	0.59	0.81	0.81	0.63	0.63					0.70	0.70	**U**
IMGC			-0.29	-0.29			0.59	0.59	0.35	0.35	0.29	0.29	0.09	0.09	0.04	0.04	0.19	0.19	0.30	0.30	-0.02	-0.02	0.03	0.03					0.13	0.13	**ΔT**
			0.62	0.62			0.54	0.54	0.49	0.49	0.57	0.57	0.27	0.27	0.37	0.37	0.46	0.46	0.31	0.31	0.64	0.64	0.39	0.39					0.49	0.49	**U**
KRISS			-0.87	-0.87	-0.59	-0.59			-0.24	-0.24	-0.29	-0.29	-0.50	-0.50	-0.79	-0.55	-0.40	-0.40	-0.28	-0.28	-0.85	-0.61	-0.56	-0.56					-0.46	-0.46	**ΔT**
			0.73	0.73	0.54	0.54			0.62	0.62	0.68	0.68	0.47	0.47	0.52	0.53	0.60	0.60	0.50	0.50	0.74	0.74	0.54	0.54					0.62	0.62	**U**
MSL			-0.63	-0.63	-0.35	-0.35	0.24	0.24			-0.06	-0.06	-0.26	-0.26	-0.07	-0.31	-0.16	-0.16	-0.05	-0.05	-0.13	-0.37	-0.32	-0.32					-0.22	-0.22	**ΔT**
			0.70	0.70	0.49	0.49	0.62	0.62			0.65	0.65	0.41	0.41	0.47	0.47	0.55	0.55	0.44	0.44	0.71	0.71	0.50	0.50					0.58	0.58	**U**
NIM			-0.58	-0.58	-0.29	-0.29	0.29	0.29	0.06	0.06			-0.21	-0.21	-0.50	-0.26	-0.10	-0.10	0.01	0.01	-0.55	-0.31	-0.26	-0.26					-0.17	-0.17	**ΔT**
			0.76	0.76	0.57	0.57	0.68	0.68	0.65	0.65			0.51	0.51	0.56	0.56	0.63	0.63	0.53	0.53	0.77	0.77	0.58	0.58					0.65	0.65	**U**
NIST			-0.37	-0.37	-0.09	-0.09	0.50	0.50	0.26	0.26	0.21	0.21			-0.05	-0.05	0.11	0.11	0.22	0.22	-0.10	-0.10	-0.05	-0.05					0.04	0.04	**ΔT**
			0.57	0.57	0.27	0.27	0.47	0.47	0.41	0.41	0.51	0.51			0.25	0.25	0.37	0.37	0.17	0.17	0.59	0.59	0.28	0.28					0.41	0.41	**U**
NML			-0.32	-0.32	-0.04	-0.04	0.79	0.55	0.07	0.31	0.50	0.26	0.05	0.05			0.15	0.15	0.26	0.26	-0.06	-0.06	-0.01	-0.01					0.09	0.09	**ΔT**
			0.62	0.62	0.37	0.37	0.52	0.53	0.47	0.47	0.56	0.56	0.25	0.25			0.45	0.45	0.30	0.30	0.63	0.63	0.38	0.38					0.48	0.48	**U**
NPL			-0.57	-0.48	-0.19	-0.19	0.40	0.40	0.16	0.16	0.10	0.10	-0.11	-0.11	-0.15	-0.15			0.11	0.11	-0.21	-0.21	-0.24	-0.16					-0.06	-0.06	**ΔT**
			0.69	0.68	0.46	0.46	0.60	0.60	0.55	0.55	0.63	0.63	0.37	0.37	0.45	0.45			0.41	0.41	0.69	0.69	0.46	0.46					0.55	0.55	**U**
NRC			-0.59	-0.59	-0.30	-0.30	0.28	0.28	0.05	0.05	-0.01	-0.01	-0.22	-0.22	-0.26	-0.26	-0.11	-0.11			-0.32	-0.32	-0.27	-0.27					-0.17	-0.17	**ΔT**
			0.59	0.59	0.31	0.31	0.50	0.50	0.44	0.44	0.53	0.53	0.17	0.17	0.30	0.30	0.41	0.41			0.61	0.61	0.33	0.33					0.44	0.44	**U**
NRLM			-0.27	-0.27	0.02	0.02	0.85	0.61	0.13	0.37	0.55	0.31	0.10	0.10	0.06	0.06	0.21	0.21	0.32	0.32			0.05	0.05					0.15	0.15	**ΔT**
			0.81	0.81	0.64	0.64	0.74	0.74	0.71	0.71	0.77	0.77	0.59	0.59	0.63	0.63	0.69	0.69	0.61	0.61			0.65	0.65					0.71	0.71	**U**
PTB			-0.45	-0.32	-0.03	-0.03	0.56	0.56	0.32	0.32	0.26	0.26	0.05	0.05	0.01	0.01	0.24	0.16	0.27	0.27	-0.05	-0.05							0.10	0.10	**ΔT**
			0.63	0.63	0.39	0.39	0.54	0.54	0.50	0.50	0.58	0.58	0.28	0.28	0.38	0.38	0.46	0.46	0.33	0.33	0.65	0.65							0.50	0.50	**U**
SMU																															**ΔT**
																															U
VNIIM																															**ΔT**
																															U
VSL			-0.41	-0.41	-0.13	-0.13	0.46	0.46	0.22	0.22	0.17	0.17	-0.04	-0.04	-0.09	-0.09	0.06	0.06	0.17	0.17	-0.15	-0.15	-0.10	-0.10							**ΔT**
			0.70	0.70	0.49	0.49	0.62	0.62	0.58	0.58	0.65	0.65	0.41	0.41	0.48	0.48	0.55	0.55	0.44	0.44	0.71	0.71	0.50	0.50							**U**
U_L (95%)			0.57		0.25		0.46		0.40		0.50		0.10		0.25		0.39		0.15		0.58		0.28						0.40		

Table 11. Summary of differences of realizations and of their expanded uncertainties U (95 %) between laboratories for Ar, where ΔT/mK = column – row. U is expressed in mK. For information on why dir. and inc. values are different, see Section 4.1. An upper bound on each laboratory's individual contribution to the total uncertainties of the bilateral temperature differences is denoted by U_L (95%).

	BIPM		BNM		IMGC		KRISS		MSL		NIM		NIST		NML		NPL		NRC		NRLM		PTB		SMU		VNIIM		VSL		
	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	dir.	inc.	
BIPM																															**ΔT**
																															U
BNM					1.08	1.08					0.11	0.11	0.35	0.35	-2.07	-2.07	-0.88	-0.66	0.45	0.45			0.06	0.12					0.29	0.29	**ΔT**
					0.78	0.78					0.88	0.88	0.58	0.58	1.12	1.12	0.94	0.89	0.65	0.65			0.79	0.79					0.87	0.87	**U**
IMGC			-1.08	-1.08							-0.97	-0.97	-0.73	-0.73	-3.15	-3.15	-1.74	-1.74	-0.63	-0.63			-0.96	-0.96					-0.79	-0.79	**ΔT**
			0.78	0.78							0.84	0.84	0.52	0.52	1.10	1.10	0.85	0.85	0.60	0.60			0.75	0.75					0.84	0.84	**U**
KRISS																															**ΔT**
																															U
MSL																															**ΔT**
																															U
NIM			-0.11	-0.11	0.97	0.97							0.24	0.24	-2.46	-2.18	-0.77	-0.77	0.34	0.34			0.01	0.01					0.18	0.18	**ΔT**
			0.88	0.88	0.84	0.84							0.66	0.66	1.17	1.17	0.95	0.95	0.73	0.73			0.86	0.86					0.93	0.93	**U**
NIST			-0.35	-0.35	0.73	0.73					-0.24	-0.24			-2.42	-2.42	-1.01	-1.01	0.10	0.10			-0.23	-0.23					-0.06	-0.06	**ΔT**
			0.58	0.58	0.52	0.52					0.66	0.66			0.97	0.97	0.68	0.68	0.31	0.31			0.55	0.55					0.66	0.66	**U**
NML			2.07	2.07	3.15	3.15					2.46	2.18	2.42	2.42			1.41	1.41	2.52	2.52			2.19	2.19					2.36	2.36	**ΔT**
			1.12	1.12	1.10	1.10					1.17	1.17	0.97	0.97			1.18	1.18	1.01	1.01			1.11	1.11					1.17	1.17	**U**
NPL			0.88	0.66	1.74	1.74					0.77	0.77	1.01	1.01	-1.41	-1.41			1.11	1.11			0.80	0.78					0.95	0.95	**ΔT**
			0.94	0.89	0.85	0.85					0.95	0.95	0.68	0.68	1.18	1.18			0.74	0.74			0.87	0.87					0.94	0.94	**U**
NRC			-0.45	-0.45	0.63	0.63					-0.34	-0.34	-0.10	-0.10	-2.52	-2.52	-1.11	-1.11					-0.33	-0.33					-0.16	-0.16	**ΔT**
			0.65	0.65	0.60	0.60					0.73	0.73	0.31	0.31	1.01	1.01	0.74	0.74					0.62	0.62					0.72	0.72	**U**
NRLM																															**ΔT**
																															U
PTB			-0.06	-0.12	0.96	0.96					-0.01	-0.01	0.23	0.23	-2.19	-2.19	-0.80	-0.78	0.33	0.33									0.17	0.17	**ΔT**
			0.79	0.79	0.75	0.75					0.86	0.86	0.55	0.55	1.11	1.11	0.87	0.87	0.62	0.62									0.85	0.85	**U**
SMU																															**ΔT**
																															U
VNIIM																															**ΔT**
																															U
VSL			-0.29	-0.29	0.79	0.79					-0.18	-0.18	0.06	0.06	-2.36	-2.36	-0.95	-0.95	0.16	0.16			-0.17	-0.17							**ΔT**
			0.87	0.87	0.84	0.84					0.93	0.93	0.66	0.66	1.17	1.17	0.94	0.94	0.72	0.72			0.85	0.85							**U**
U_L (95%)			0.61		0.52						0.66		0.07		0.96		0.72		0.30				0.55						0.65		

Table 12a. Direct and bilateral comparison results for the gallium melting point. See Section 4.3.

	Direct Comparison (Lab X - NIST)			Bilateral Differences (Lab X - NIST)		
	ΔT / mK	u_c (k=1) / mK	U (95%) / mK	ΔT / mK	u_c (k=1) / mK	U (95%) / mK
IMGC	0.00	0.04	0.12	0.09	0.06	0.13
NPL	-0.04	0.12	0.24	-0.17	0.21	0.42
NRC	-0.17	0.11	0.25	-0.14	0.13	0.27
VNIIM	0.09	0.02	0.04	0.01	0.08	0.19
VSL	0.25	0.06	0.12	-0.23	0.21	0.41

Table 12b. Indirect and bilateral comparison results for the gallium melting point. See Section 4.3.

	Indirect Comparison (Lab X - NIST)			Bilateral Differences (Lab X - NIST)		
	ΔT / mK	u_c (k=1) / mK	U (95%) / mK	ΔT / mK	u_c (k=1) / mK	U (95%) / mK
BIPM	-0.03	0.08	0.16	-0.09	0.08	0.16
BNM	0.00	0.14	0.28	-0.03	0.15	0.29
KRISS	-0.27	0.29	0.64	0.00	0.20	0.46
MSL	0.15	0.16	0.32	0.17	0.18	0.36
NIM	0.96	0.23	0.48	-0.59	0.28	0.57
NML	0.09	0.08	0.16	-0.16	0.13	0.26
NRLM	1.16	0.11	0.21	-0.37	0.11	0.22
PTB	0.07	0.11	0.21	0.20	0.12	0.24
SMU	0.06	0.10	0.19	0.04	0.10	0.19

Table 13a. Direct and bilateral comparison results for the cadmium freezing point. See Section 4.4.

	Direct Comparison (Lab X - NIST)			Bilateral Differences (Lab X - NIST)		
	ΔT / mK	u_c (k=1) / mK	U (95%) / mK	ΔT / mK	u_c (k=1) / mK	U (95%) / mK
IMGC	-0.01	0.07	0.16	-1.47	0.33	0.66
NRC	-0.11	0.15	0.34	-0.95	0.21	0.42
VNIIM	0.01	0.31	1.30	0.40	0.54	1.46
VSL	-0.89	0.06	0.12	-1.14	NA	NA

Table 13b. Indirect and bilateral comparison results for the cadmium freezing point. See Section 4.4.

	Indirect Comparison (Lab X - NIST)			Bilateral Differences (Lab X - NIST)		
	ΔT / mK	u_c (k=1) / mK	U (95%) / mK	ΔT / mK	u_c (k=1) / mK	U (95%) / mK
NIM	0.12	1.10	2.70	1.28	0.87	1.96
NML	-0.37	0.18	0.36	-1.21	0.20	0.41

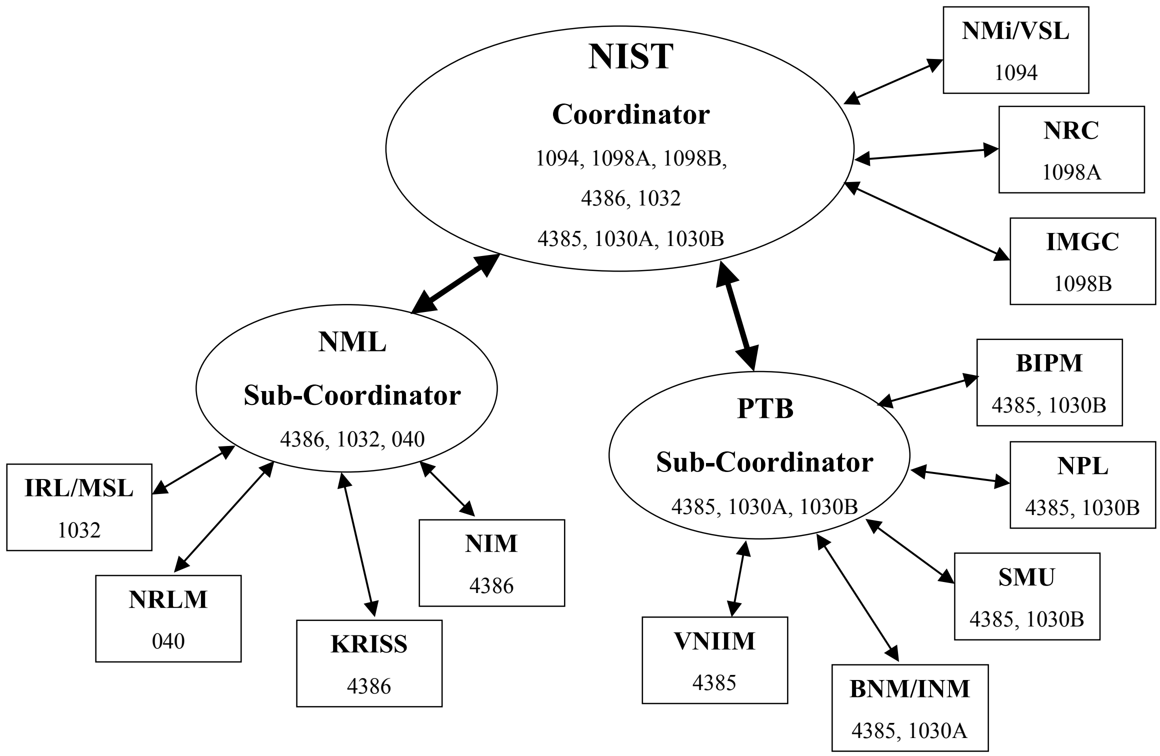

Figure 1. Comparison loops for the coordinator and sub-coordinators. The numbers associated with a given participant are the serial numbers of the SPRTs measured by that participant.

Appendix I

Table I.1. Standard uncertainties for a single measurement (n = 1) for the fixed points used for the various participants.

		Al FP	Zn FP	Cd FP	Sn FP	In FP	Ga FP	Hg TP	Ar TP
BIPM	Type A (k=1, n=1) / mK						**0.05**		
	deg. freedom						9		
	Type B (k=1) / mK						**0.07**		
	deg. freedom						Inf		
	u_c (k=1, n=1), mK						**0.09**		
	deg. freedom						72.92		
	k for (95%)						1.99		
	U (95%, n=1) / mK						**0.18**		
BNM	Type A (k=1, n=1) / mK	**0.10**	**0.46**		**0.27**	**0.10**	**0.04**	**0.05**	**0.13**
	deg. freedom	5	5		5	5	5	5	5
	Type B (k=1) / mK	**1.12**	**0.45**		**0.46**	**0.32**	**0.15**	**0.28**	**0.28**
	deg. freedom	Inf	Inf		Inf	Inf	Inf	Inf	Inf
	u_c (k=1, n=1), mK	**1.12**	**0.64**		**0.53**	**0.33**	**0.15**	**0.29**	**0.31**
	deg. freedom	79935.37	19.14		75.78	605.00	1051.25	5580.61	155.51
	k for (95%)	1.96	2.09		1.99	1.96	1.96	1.96	1.98
	U (95%, n=1) / mK	**2.20**	**1.35**		**1.06**	**0.65**	**0.30**	**0.57**	**0.61**
IMGC	Type A (k=1, n=1) / mK	**0.47**	**0.27**	**0.15**	**0.10**	**0.15**	**0.05**	**0.04**	**0.19**
	deg. freedom	8	7	8	7	6	11	11	4
	Type B (k=1) / mK	**0.41**	**0.32**	**0.29**	**0.18**	**0.28**	**0.03**	**0.12**	**0.13**
	deg. freedom	Inf	Inf	Inf	Inf	Inf	Inf	Inf	Inf
	u_c (k=1, n=1), mK	**0.62**	**0.42**	**0.32**	**0.21**	**0.31**	**0.06**	**0.13**	**0.23**
	deg. freedom	24.99	40.42	181.17	140.93	117.81	18.00	976.96	9.07
	k for (95%)	2.06	2.02	1.97	1.98	1.98	2.10	1.96	2.26
	U (95%, n=1) / mK	**1.28**	**0.85**	**0.63**	**0.41**	**0.62**	**0.13**	**0.25**	**0.52**
KRISS	Type A (k=1, n=1) / mK	**1.00**	**0.50**		**0.40**	**0.20**	**0.20**	**0.20**	
	deg. freedom	6	6		6	9	9	9	
	Type B (k=1) / mK	**0.48**	**0.38**		**0.23**	**0.32**	**0.04**	**0.06**	
	deg. freedom	Inf	Inf		Inf	Inf	Inf	Inf	
	u_c (k=1, n=1), mK	**1.11**	**0.63**		**0.46**	**0.38**	**0.20**	**0.21**	
	deg. freedom	9.11	14.82		10.49	112.03	9.81	10.52	
	k for (95%)	2.26	2.13		2.21	1.98	2.23	2.21	
	U (95%, n=1) / mK	**2.51**	**1.34**		**1.02**	**0.74**	**0.46**	**0.46**	
MSL	Type A (k=1, n=1) / mK		**0.89**		**0.35**	**0.20**	**0.01**	**0.09**	
	deg. freedom		1		2	1	3	1	
	Type B (k=1) / mK		**0.47**		**0.31**	**0.33**	**0.18**	**0.17**	
	deg. freedom		Inf		Inf	Inf	Inf	Inf	
	u_c (k=1, n=1), mK		**1.01**		**0.47**	**0.39**	**0.18**	**0.19**	
	deg. freedom		1.63		6.41	14.23	289715.30	21.25	
	k for (95%)		5.39		2.41	2.14	1.96	2.08	
	U (95%, n=1) / mK		**5.42**		**1.13**	**0.83**	**0.35**	**0.40**	

Table I.1 (cont'd.). Standard uncertainties for a single measurement ($n = 1$) for the fixed points used for the various participants.

		Al FP	Zn FP	Cd FP	Sn FP	In FP	Ga FP	Hg TP	Ar TP
NIM	Type A (k=1, n=1) / mK	**1.70**	**0.57**	**1.05**	**0.57**	**0.42**	**0.17**	**0.26**	**0.26**
	deg. freedom	7	7	5	7	7	7	6	6
	Type B (k=1) / mK	**0.70**	**0.39**	**0.44**	**1.54**	**0.34**	**0.25**	**0.14**	**0.11**
	deg. freedom	262	25	34	2	33	29	43	30
	u_c (k=1, n=1), mK	**1.84**	**0.69**	**1.14**	**1.64**	**0.55**	**0.31**	**0.30**	**0.28**
	deg. freedom	9.62	14.39	6.85	2.84	17.67	33.15	9.64	8.03
	k for (95%)	2.24	2.14	2.37	3.29	2.10	2.03	2.24	2.30
	U (95%, n=1) / mK	**4.12**	**1.47**	**2.71**	**5.39**	**1.15**	**0.62**	**0.67**	**0.66**
NIST	Type A (k=1, n=1) / mK	**0.28**	**0.18**	**0.12**	**0.12**	**0.04**	**0.02**	**0.07**	**0.03**
	deg. freedom	129	405	35	301	83	287	259	265
	Type B (k=1) / mK	**0.16**	**0.10**	**0.03**	**0.02**	**0.03**	**0.01**	**0.01**	**0.03**
	deg. freedom	Inf	Inf	Inf	Inf	Inf	Inf	Inf	Inf
	u_c (k=1, n=1), mK	**0.32**	**0.21**	**0.12**	**0.12**	**0.05**	**0.02**	**0.07**	**0.04**
	deg. freedom	227.00	693.58	39.51	317.95	202.64	448.44	269.68	1060.00
	k for (95%)	1.97	1.96	2.02	1.97	1.97	1.97	1.97	1.96
	U (95%, n=1) / mK	**0.64**	**0.40**	**0.25**	**0.24**	**0.10**	**0.04**	**0.14**	**0.08**
NML	Type A (k=1, n=1) / mK	**0.50**	**0.21**	**0.15**	**0.09**	**0.06**	**0.04**	**0.02**	**0.01**
	deg. freedom	120	180	180	180	180	180	180	120
	Type B (k=1) / mK	**0.35**	**0.18**	**0.17**	**0.15**	**0.41**	**0.13**	**0.13**	**0.49**
	deg. freedom	120	180	180	180	180	180	180	120
	u_c (k=1, n=1), mK	**0.61**	**0.28**	**0.23**	**0.17**	**0.42**	**0.13**	**0.13**	**0.49**
	deg. freedom	216.62	354.42	355.79	298.66	186.97	208.12	191.10	120.04
	k for (95%)	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.98
	U (95%, n=1) / mK	**1.20**	**0.55**	**0.45**	**0.34**	**0.82**	**0.26**	**0.25**	**0.96**
NPL	Type A (k=1, n=1) / mK		**0.11**		**0.13**	**0.13**	**0.10**	**0.11**	**0.22**
	deg. freedom		8		8	8	2	3	4
	Type B (k=1) / mK		**0.43**		**0.35**	**0.33**	**0.20**	**0.18**	**0.33**
	deg. freedom		Inf		Inf	Inf	Inf	Inf	Inf
	u_c (k=1, n=1), mK		**0.44**		**0.37**	**0.35**	**0.22**	**0.21**	**0.40**
	deg. freedom		2120.57		544.30	443.28	50.00	43.37	43.76
	k for (95%)		1.96		1.96	1.97	2.01	2.02	2.02
	U (95%, n=1) / mK		**0.87**		**0.73**	**0.70**	**0.45**	**0.42**	**0.80**
NRC	Type A (k=1, n=1) / mK	**0.30**	**0.05**	**0.15**	**0.17**	**0.10**	**0.11**	**0.06**	**0.04**
	deg. freedom	8	9	9	9	9	9	9	9
	Type B (k=1) / mK	**0.43**	**0.13**	**0.12**	**0.34**	**0.09**	**0.06**	**0.05**	**0.15**
	deg. freedom	Inf	Inf	Inf	Inf	Inf	Inf	Inf	Inf
	u_c (k=1, n=1), mK	**0.53**	**0.14**	**0.19**	**0.38**	**0.13**	**0.13**	**0.08**	**0.15**
	deg. freedom	76.76	522.25	25.18	231.87	27.32	15.01	32.81	1281.76
	k for (95%)	1.99	1.96	2.06	1.97	2.05	2.13	2.03	1.96
	U (95%, n=1) / mK	**1.05**	**0.27**	**0.40**	**0.75**	**0.27**	**0.27**	**0.15**	**0.30**

Table I.1 (cont'd.). Standard uncertainties for a single measurement ($n = 1$) for the fixed points used for the various participants

		Al FP	Zn FP	Cd FP	Sn FP	In FP	Ga FP	Hg TP	Ar TP
NRLM	Type A (k=1, n=1) / mK	**1.01**	**0.28**		**0.17**	**0.42**	**0.02**	**0.15**	
	deg. freedom	3	3		3	2	Inf	Inf	
	Type B (k=1) / mK	**0.80**	**0.87**		**0.37**	**0.38**	**0.11**	**0.26**	
	deg. freedom	Inf	Inf		Inf	Inf	Inf	Inf	
	u_c (k=1, n=1), mK	**1.29**	**0.92**		**0.41**	**0.57**	**0.11**	**0.30**	
	deg. freedom	7.94	342.15		106.59	6.60	Inf	Inf	
	k for (95%)	2.31	1.97		1.98	2.39	1.96	1.96	
	U (95%, n=1) / mK	**2.97**	**1.80**		**0.81**	**1.36**	**0.21**	**0.58**	
PTB	Type A (k=1, n=1) / mK	**0.30**	**0.15**		**0.15**	**0.20**	**0.05**	**0.05**	**0.15**
	deg. freedom	49	149		149	49	199	49	49
	Type B (k=1) / mK	**0.83**	**0.64**		**0.43**	**0.56**	**0.12**	**0.14**	**0.27**
	deg. freedom	Inf	Inf		Inf	Inf	Inf	Inf	Inf
	u_c (k=1, n=1), mK	**0.88**	**0.66**		**0.46**	**0.59**	**0.13**	**0.15**	**0.31**
	deg. freedom	3670.07	54952.79		12660.15	3829.13	9093.82	3829.13	880.90
	k for (95%)	1.96	1.96		1.96	1.96	1.96	1.96	1.96
	U (95%, n=1) / mK	**1.73**	**1.29**		**0.89**	**1.17**	**0.25**	**0.29**	**0.61**
SMU	Type A (k=1, n=1) / mK	**0.52**	**0.35**		**0.35**		**0.05**		
	deg. freedom	2	2		2		2		
	Type B (k=1) / mK	**0.36**	**0.36**		**0.41**		**0.09**		
	deg. freedom	Inf	Inf		Inf		Inf		
	u_c (k=1, n=1), mK	**0.63**	**0.50**		**0.53**		**0.11**		
	deg. freedom	4.44	8.52		11.22		35.81		
	k for (95%)	2.67	2.28		2.20		2.03		
	U (95%, n=1) / mK	**1.69**	**1.14**		**1.17**		**0.22**		
VNIIM	Type A (k=1, n=1) / mK	**0.89**	**0.89**	**0.89**	**0.45**	**0.45**	**0.11**		
	deg. freedom	4	4	4	4	4	4		
	Type B (k=1) / mK	**0.17**	**0.15**	**0.11**	**0.10**	**0.13**	**0.04**		
	deg. freedom	Inf	Inf	Inf	Inf	Inf	Inf		
	u_c (k=1, n=1), mK	**0.91**	**0.91**	**0.90**	**0.46**	**0.47**	**0.12**		
	deg. freedom	4.29	4.23	4.12	4.41	4.70	5.09		
	k for (95%)	2.70	2.72	2.74	2.68	2.62	2.56		
	U (95%, n=1) / mK	**2.46**	**2.47**	**2.47**	**1.23**	**1.22**	**0.30**		
VSL	Type A (k=1, n=1) / mK	**0.65**	**0.34**		**0.31**	**0.29**	**0.12**	**0.18**	**0.32**
	deg. freedom	64	52		118	42	92	128	64
	Type B (k=1) / mK	**0.42**	**0.34**		**0.20**	**0.15**	**0.17**	**0.10**	**0.07**
	deg. freedom	Inf	Inf		Inf	Inf	Inf	Inf	Inf
	u_c (k=1, n=1), mK	**0.77**	**0.48**		**0.37**	**0.33**	**0.21**	**0.20**	**0.33**
	deg. freedom	129.14	205.57		239.48	66.36	979.51	211.17	70.74
	k for (95%)	1.98	1.97		1.97	2.00	1.96	1.97	1.99
	U (95%, n=1) / mK	**1.53**	**0.95**		**0.73**	**0.65**	**0.41**	**0.40**	**0.65**

Appendix II

Table II.1. Standard uncertainties quantifying potential changes in SPRTs (listed in column 1) that were used in KC 3. The associated degrees of freedom (*DF*) are given also.

		Al	Zn	Cd	Sn	In	Ga	Hg	Ar
1030A	u_{SPRT} / mK	**0.239**	**0.133**	**0.121**	**0.094**	**0.085**	**0.000**	**0.000**	**0.020**
	DF_{SPRT}	5.254	3.948	7.304	4.421	32.621	NA	NA	3.168
1030B	u_{SPRT} / mK	**0.239**	**0.133**	**0.121**	**0.094**	**0.085**	**0.000**	**0.000**	**0.020**
	DF_{SPRT}	5.254	3.948	7.304	4.421	32.621	NA	NA	3.168
1032	u_{SPRT} / mK	**0.000**	**0.000**	**0.124**	**0.128**	**0.085**	**0.048**	**0.000**	**0.000**
	DF_{SPRT}	NA	NA	4.793	5.129	20.093	26.104	NA	NA
1094	u_{SPRT} / mK	**0.000**	**0.000**	**0.114**	**0.000**	**0.057**	**0.000**	**0.000**	**0.000**
	DF_{SPRT}	NA	NA	4.063	NA	9.281	NA	NA	NA
1098A	u_{SPRT} / mK	**0.000**	**0.125**	**0.000**	**0.000**	**0.073**	**0.000**	**0.000**	**0.000**
	DF_{SPRT}	NA	2.290	NA	NA	14.977	NA	NA	NA
1098B	u_{SPRT} / mK	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**
	DF_{SPRT}	NA	NA	NA	NA	NA	NA	NA	NA
4385	u_{SPRT} / mK	**0.000**	**0.000**	**0.101**	**0.000**	**0.062**	**0.016**	**0.000**	**0.000**
	DF_{SPRT}	NA	NA	3.224	NA	10.689	2.900	NA	NA
4386	u_{SPRT} / mK	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.027**
	DF_{SPRT}	NA	NA	NA	NA	NA	NA	NA	3.733
040	u_{SPRT} / mK	**1.332**	**0.510**	**0.314**	**0.179**	**0.074**	**0.000**	**0.000**	**0.000**
	DF_{SPRT}	21.591	17.800	12.701	11.591	4.948	NA	NA	NA