Final Report

4 September 2006

Report to the CCT on Key Comparison EUROMET. T-K3 (EUROMET Project 552)

Comparison of the realisations of the ITS-90 from 83,805 8 K to 692,677 K

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***LNE-INM/CNAM since 1 January 2005**

Contents

1.Introduction

EUROMET. Project 552 was initiated by EUROMET during its meeting in March 2000. It was defined as the comparison of the European local realisation of ITS-90 from the triple point of Ar (83,805 8 K) to the freezing point of Zinc (692,677 K) using long-stem SPRTs. This project was intended to be the Regional Key comparison corresponding to CCT-K3.

All the participants have globally agreed the version 3 of the technical protocol during the EUROMET meeting in March 2001. Nevertheless, in order to take into account the suggestions coming from some participating laboratories an “amendment to the technical protocol” was established in April 2001. The technical protocol together with the amendment has been sent to the participating laboratories and to the CCT-WG7 chairman on May 2001. These documents received the approval of all the participants. The EUROMET project 552 was agreed by the CCT-WG7 as a Regional Key comparison corresponding to CCT-K3 and was named EUROMET.T-K3.

The comparison involved the 6 NMIs previously involved in CIPM key comparison CCT-K3 (BNM-INM/CNAM, SMU, IMGC, NMi-VSL, NPL, PTB) and 18 European national laboratories. The comparison was divided in five different loops coordinated by a co-pilot chosen among the laboratories having participated to the CCT-K3 comparison. BNM-INM/CNAM played the role of pilot in establishing the link between the five loops.

Summary of the Work programme and the Calibration protocol:

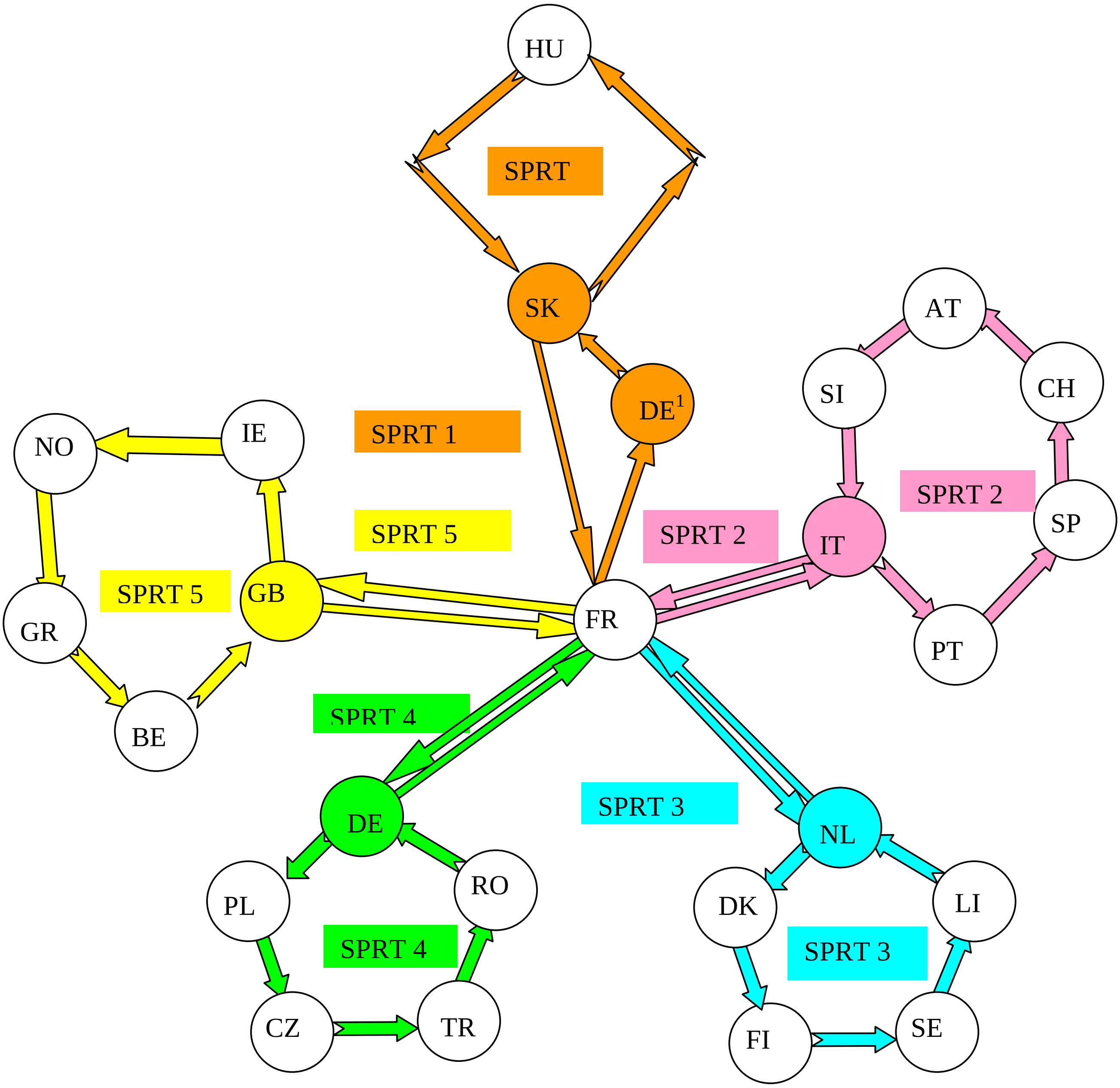
Work programme

1. The Co-pilots calibrated two SPRTs according to the protocol and hand-carried one to BNM-INM/CNAM for the linking calibration
2. On the return of the thermometer, the Co-pilot checked it before taking it to the first laboratory in its loop. If the result of the check showed a lack of stability of the first SPRT , the second SPRT was hand-carried to BNM-INM/CNAM for calibration.
3. The participants in each loop calibrated the thermometer and took it to the next laboratory
4. The Co-pilot carried out a final calibration.

Calibration protocol

After initial measurements of R(tpw) and successful annealing treatment, each calibration consisted of three measurements of R(t) at each fixed point, in separate realisations. Each measurement was followed by a measurement of R(tpw). The order of fixed points was Zn, Sn, In, Ga, Hg, Ar, but if a fixed point was not available, it was omitted. Values of W(t), and the average values, were calculated. The results were reported to the Co-pilot and BNM-INM/CNAM, with uncertainty budgets and other specified data.

1.1 Scheme of the organization of the comparison



[1] : only for measurements at Hg and In fixed points (see the Protocol Appendix A)

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2. Protocol

The Protocol of the EUROMET Project 552 (cf Appendix A) has been sent to the co-pilots, to all participants and to the CCT-WG 7. In order to take into account the comments of the participants the Protocol has been completed by one “Amendment” (cf Appendix). All participants have approved them (Protocol + amendment) before the measurements began. The EUROMET project 552 has been accepted by the CCT-WG7 as the regional KC corresponding to CCT-K3 with the name “EUROMET.T-K3”.

Due to different reasons (technical or otherwise) it was not possible to follow the provisional time schedule. The corrected schedule of comparisons is shown below. It takes into account the delay of some laboratories in the sending of their report.

Loop 1 (co-pilot SMU, participant: BNM-INM/CNAM, OMH)
From March 2003 to July 2004

Loop 2 (co-pilot IMGC, participants: BNM-INM/CNAM, CEM, METAS, BEV, MIRS/FE-LMK, IPQ)
From January 2001 to August 2004

Loop 3: (co-pilot NMI-VSL, participants: BNM-INM/CNAM, MIKES, DTI, SP, VMT/PFI)
From January 2001 to January 2004

Loop 4: (co-pilot PTB, participants: BNM-INM/CNAM, GUM, CMI, INM, UME)
From January 2001 to November 2003

Loop 5: (co-pilot NPL, participants: BNM-INM/CNAM, JV, EIM, SMD, NML)
From September 2003 to October 2004

3. Devices used in the comparison

In preparation for the comparison the co-pilots selected and calibrated two SPRTs.
One of these SPRTs was sent to BNM-INM/CNAM for calibration.

BNM-INM/CNAM received the 5 circulating SPRTs on Spring 2001 and calibrated them from June 2001 to January 2002. A BNM-INM/CNAM thermometer was included in this calibration run (only for Ga, In, Sn and Zn fixed points).

Table 1 : List of the SPRT included in the first calibration run by BNM-INM/CNAM

Co-pilot or Pilot	Circulating SPRT
PTB	YSI 8167 – 25 n° H99S4807
NMI-VSL	Tinsley 5187 n° 274686
NPL	Tinsley 5187 n° 275079
IMGC	Hart scientific 5681 n° 1283
SMU	Hart scientific 5681 n° 1256
BNM-INM/CNAM	Leeds & Northrup n° 1825320

The SPRTs were returned to the co-pilots. Then, the co-pilots determined again the reduced resistance values at Ga and Zinc points in order to check the SPRT stability.

The stability tests didn't show significant instabilities for the thermometers provided by PTB, NMI-VSL and IMGC. Consequently, the circulation of the SPRTs started in the corresponding loops on the beginning of 2002.

Unfortunately, substantial differences were observed at the zinc point for the SPRT furnished by SMU and at the zinc and tin points for the SPRT supplied by NPL (temperature changes as large as 2 mK). So, after discussions between these co-pilots and the BNM-INM/CNAM, it was decided to use the second SPRT calibrated by NPL and SMU.

Due to practical difficulties BNM-INM/CNAM received NPL's new SPRT on December 2002 and the SMU's SPRT on May 2003. In order to limit the delay of the comparison, these new SPRTs were calibrated in two different runs. The BNM-INM/CNAM 1825320 thermometer was included in these calibration runs (only for Ga, In, Sn and Zn fixed points).

Table 2 : List of the SPRTs included in the second calibration run by BNM-INM/CNAM (December 2003 to February 2003)

Co-pilot or Pilot	Circulating SPRT
NPL	Tinsley 5187 n° 269586
BNM-INM/CNAM	Leeds & Northrup n° 1825320

Table 3 : List of the SPRTs included in the third calibration run by BNM-INM/CNAM (June 2003 to September 2003).

Co-pilot or Pilot	Circulating SPRT
SMU	ISOTECH 670 n° 036
BNM-INM/CNAM	Leeds & Northrup n° 1825320

By reading tables 9 and 5, one can note that the stability of the SPRTs Tinsley 269586 and ISOTECH 036 was validated at the time of the stability tests.

At the time of KC3 SMU was not able to perform measurements neither at the point of Mercury nor the point of Indium. Therefore in order to have at least two laboratories having participated to KC3 in the loop managed by SMU it was necessary to include a complementary laboratory. This complementary laboratory performed only measurements at the Indium and Mercury points on thermometers delivered by SMU. PTB agreed to take in charge this additional task and calibrated the SMU SPRT Hart scientific 5681 n° 1256.
As the results (see below) between PTB and SMU were consistent and in order to avoid:

- additional work to PTB
- more delay in the comparison

the SPRT ISOTECH 670 n° 036 was not sent to PTB for calibration at the Mercury and Indium points.

4. Laboratory report

Appendix B shows the typical parameters of the devices used in this comparison by the participants:

- bridge
- standard resistor
- fixed point cells
- immersion depth of the middle of the SPRT sensing element
- bath or furnace
- typical duration of the melting and/or freezing plateau

5. Loop results

The comparison was carried out in five loops as described section 1.1. Tables 4 to 9 present the *W* values given by the participants at the different fixed points. The plots in Figures 1 to 28 show the comparison results for the different loops.

The values of the uncertainties reported in Tables 4 to 9 and in Figure 1 to 28 correspond to the expanded (*k*=2) uncertainties U_{Labij} given by the participants. All the information about the uncertainty budgets are presented in chapter 6 and in Appendices A and C.

Loop 1 – Co-pilot SMU

Table 4: Loop 1. Comparison between the PTB and SMU calibrations at the Hg and In fixed point

SPRT Hart scientific 5681 n° 1256

Point	PTB		SMU		$W_{SMU} - W_{PTB}$	$T_{SMU} - T_{PTB}$	$U_{(T_{SMU} - T_{PTB})}$
	W	*U* mK	*W*	*U* mK		mK	mK
Hg	0,8441580	0,27	0,8441567	0,70	- 0,0000013	- 0,33	0,75
In	1,6097235	0,86	1,6097256	0,95	+ 0,0000021	+ 0,55	1,28

The expanded uncertainty on $T_{SMU} - T_{PTB}$ is calculated using the following formula:

$$U_{(T_{PTB}-T_{SMU})} = 2\sqrt{\left(u^2_{T_{PTB}} + u^2_{T_{SMU}}\right)}$$

Table 4 shows that the PTB and SMU results for SPRT calibration at Hg and In are consistent.

Table 5: Loop 1. Calibration of the SPRT ISOTECH 670 n° 036

Point	*W (SMU)*	*U (SMU)* mK	*W (BNM-INM /CNAM)*	*U (BNM-INM) /CNAM)* mK	*W (OMH)*	*U (OMH)* mK	*W (SMU)*	*U (SMU)* mK
Hg	0,8441601	0,70	0,8441592	0,58	0,8441590	0,43	0,8441615	0,70
Ga	1,1181234	0,22	1,1181228	0,24	1,1181220	0,48	1,1181219	0,22
In	1,6097122	0,95	1,6097127	0,78			1,6097117	0,95
Sn	1,8926712	0,92	1,8926691	0,74	1,8926697	1,58	1,8926680	0,92
Zn	2,5686862	0,86	2,5686857	1,16	2,5686859	2,17	2,5686835	0,86

Figure 1 : Results of SPRT ISOTECH 670 n° 036 calibration – Hg

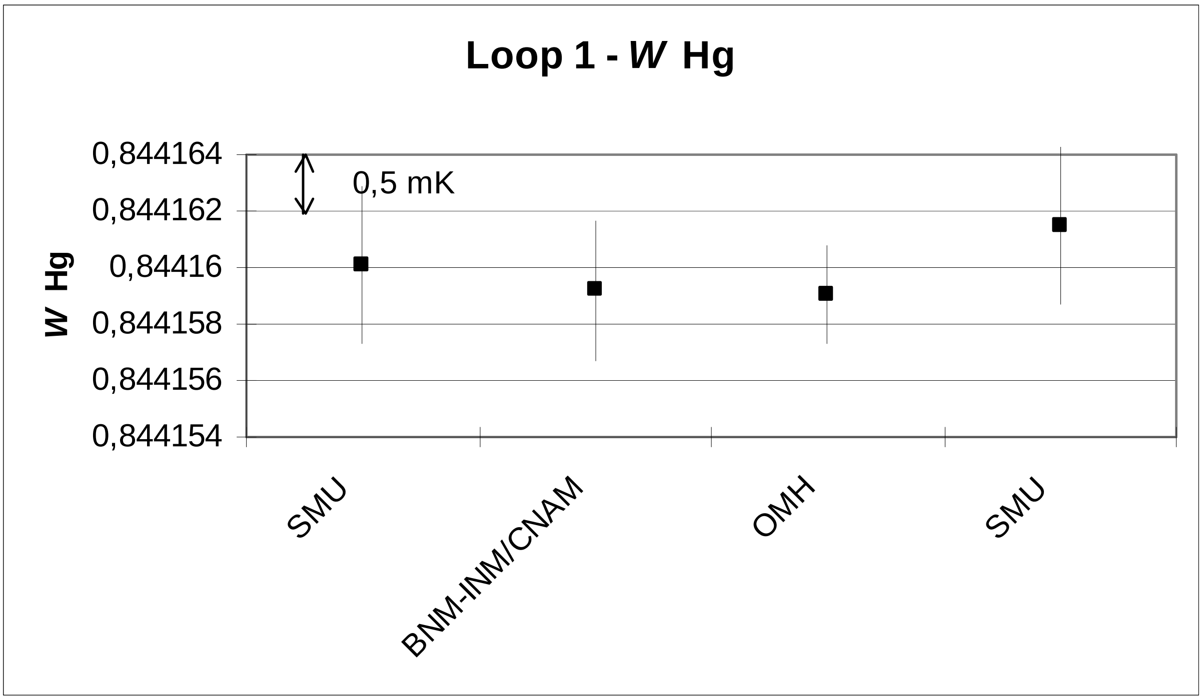


Figure 2 : Results of SPRT ISOTECH 670 n° 036 calibration – Ga

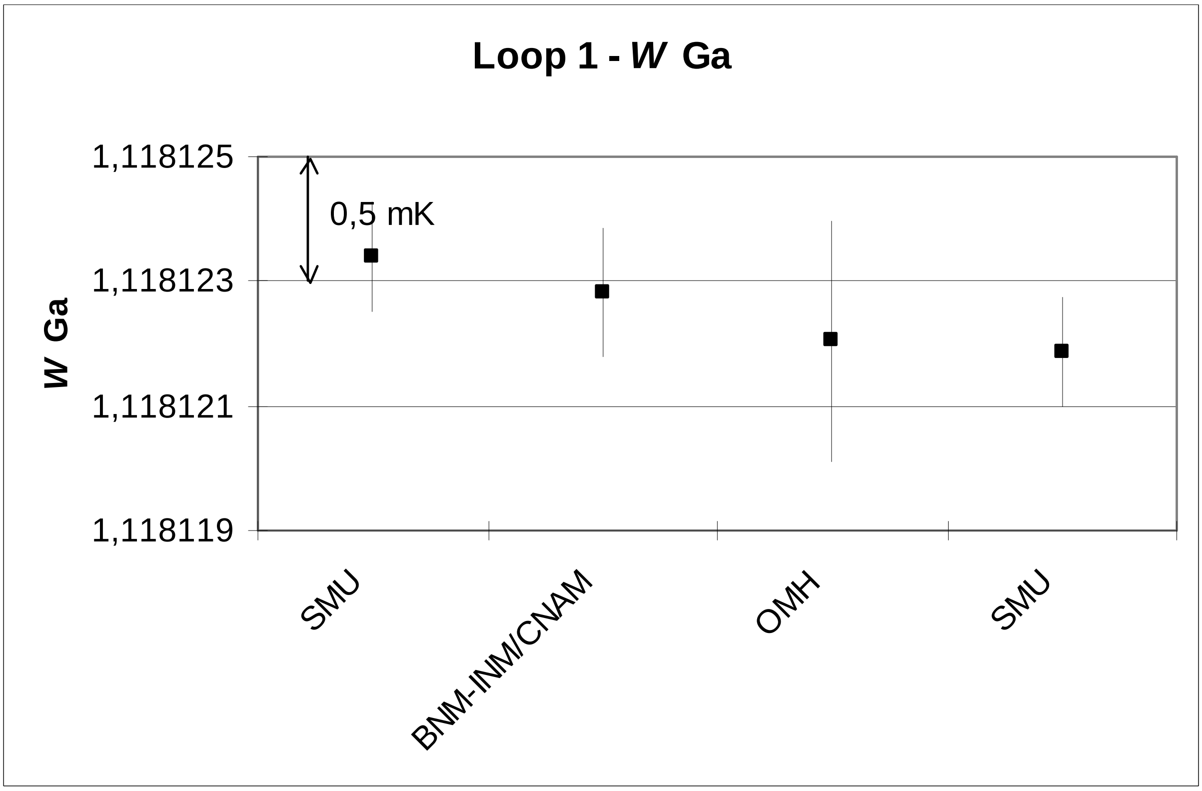


Figure 3 : Results of SPRT ISOTECH 670 n° 036 calibration – In

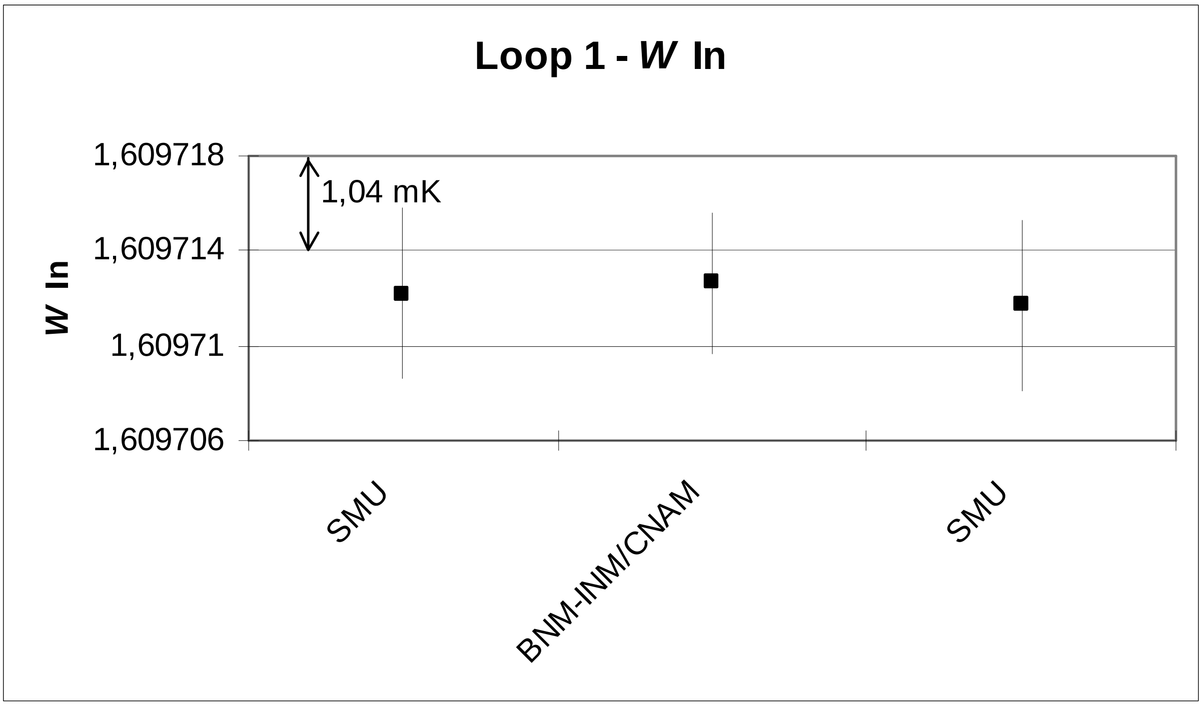


Figure 4 : Results of SPRT ISOTECH 670 n° 036 calibration – Sn

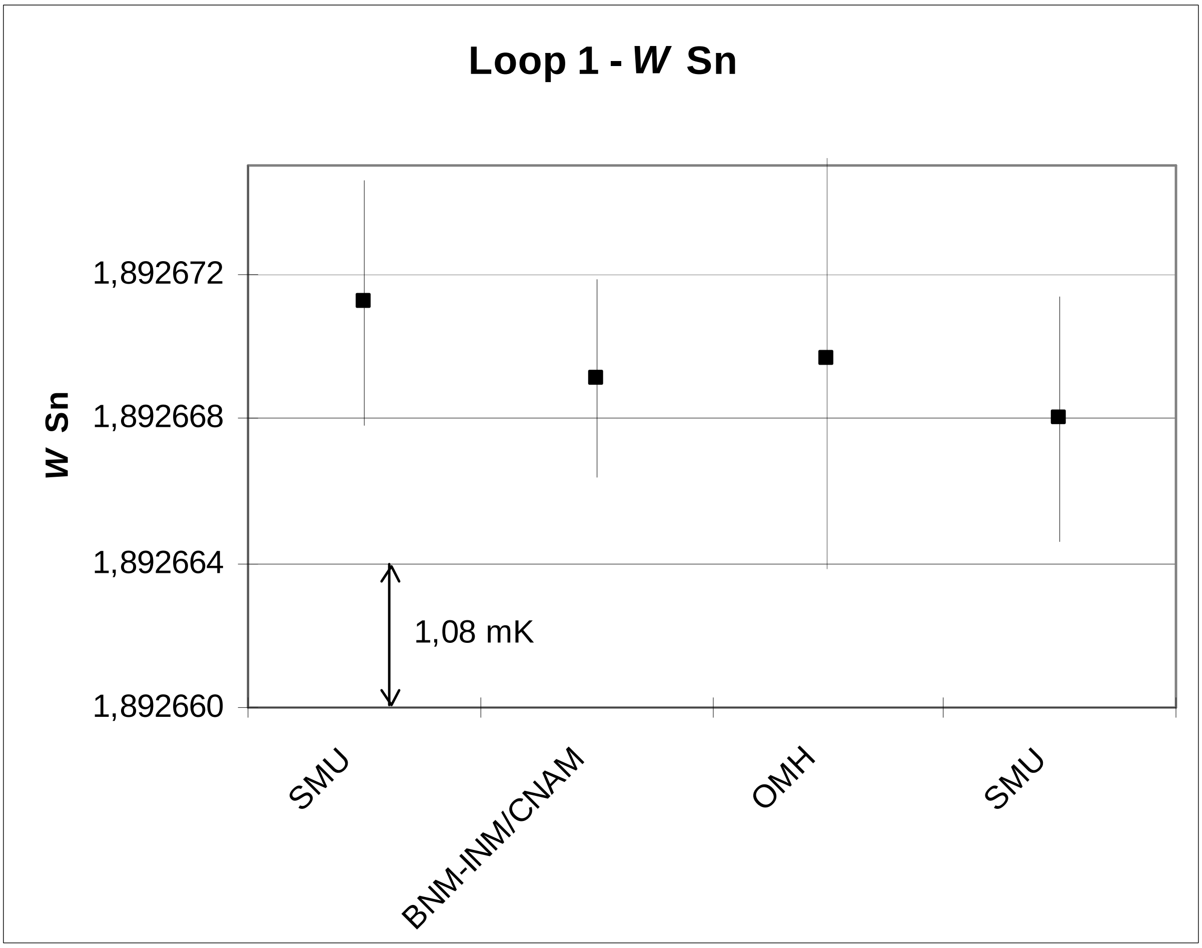
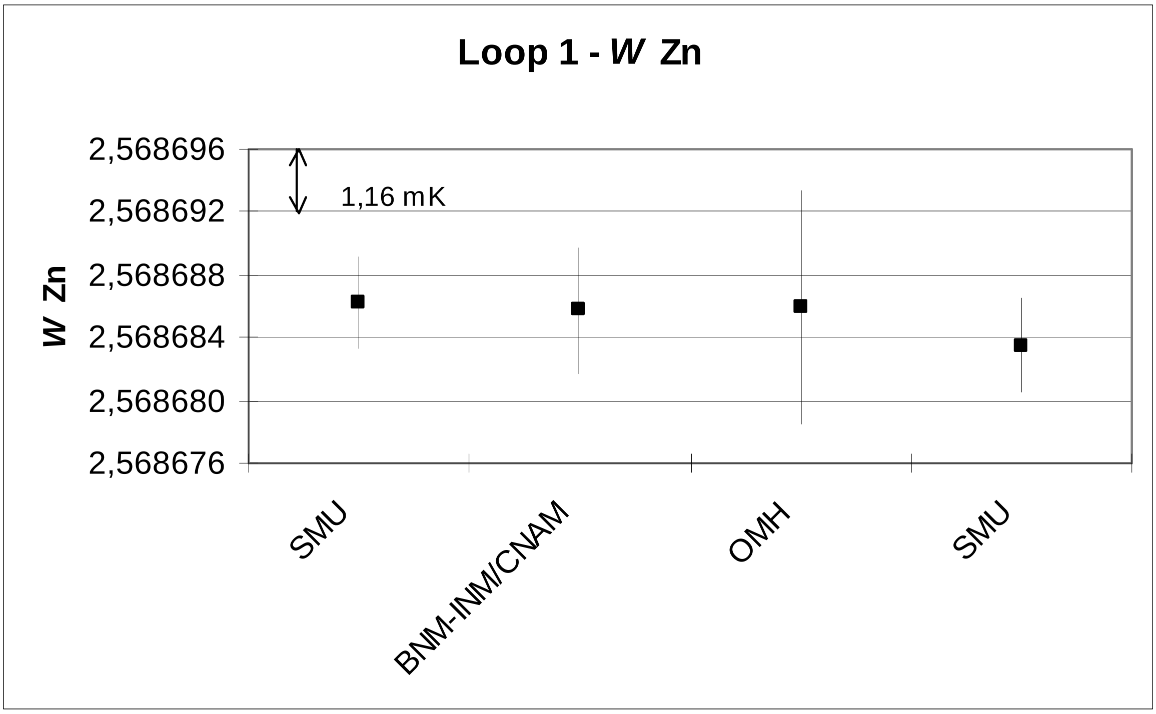


Figure 5 : Results of SPRT ISOTECH 670 n° 036 calibration - Zn



Loop 2 – Co-pilot IMGC

Table 6: Loop 2. Calibration of the SPRT Hart scientific 5681 n° 1283

Point	*W (IMGC)*	*U (IMGC)* mK	*W (BNM-INM /CNAM)*	*U (BNM-INM /CNAM)* mK	*W (CEM)*	*U (CEM)* mK
Ar	0,2159237	0,46	0,2159235	0,68	0,2159205	0,94
Hg	0,8441552	0,26	0,8441545	0,58	0,8441547	0,46
Ga	1,1181249	0,17	1,1181253	0,40	1,1181264	0,48
In	1,6097294	0,63	1,6097285	0,73	1,6097297	1,20
Sn	1,8926895	0,73	1,8926904	0,81	1,8926924	1,30
Zn	2,5687150	1,23	2,5687216	1,34	2,5687197	1,78

Point	*W (METAS)*	*U (METAS)* mK	*W (BEV)*	*U (BEV)* mK	*W (MIRS/FE-LMK)*	*U (MIRS/FE-LMK)* mK
Ar	0,2159216	0,85			0,2159228	0,84
Hg	0,8441553	0,44	0,8441519	1,04	0,8441548	0,62
Ga	1,1181257	0,66	1,1181240	1,02	1,1181262	0,46
In	1,6097306	1,08	1,6097306	1,10	1,6097306	1,37
Sn	1,8926927	0,9	1,8926939	1,26	1,8926918	0,98
Zn	2,5687196	1,52	2,5687219	1,48	2,5687176	2,03

Point	*W (IPQ)*	*U (IPQ)* mK	*W (IMGC)*	*U (IMGC)* mK
Ar	0,2159220	0,88	0,2159247	0,46
Hg	0,8441547	0,63	0,8441548	0,26
Ga	1,1181251	0,81	1,1181255	0,17
In	1,6097326	2,00	1,6097285	0,63
Sn	1,8926941	1,32	1,8926912	0,73
Zn	2,5687253	1,58	2,5687194	1,23

Figure 6 : Results of SPRT Hart scientific 5681 n° 1283 calibration – Ar

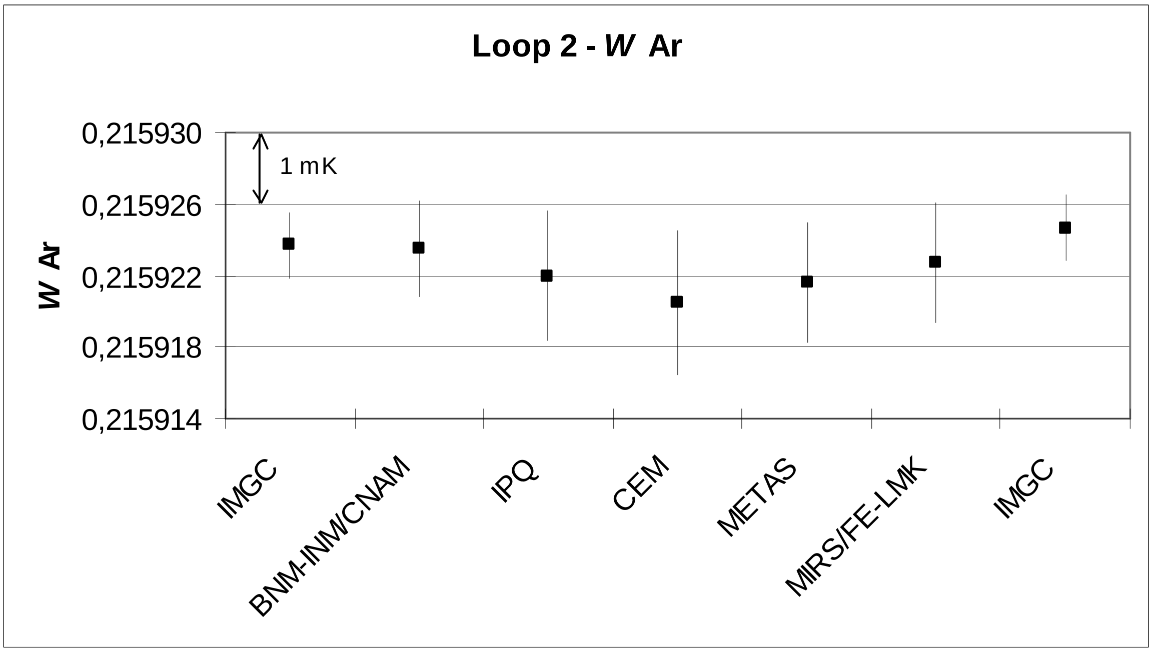


Figure 7 : Results of SPRT Hart scientific 5681 n° 1283 calibration - Hg

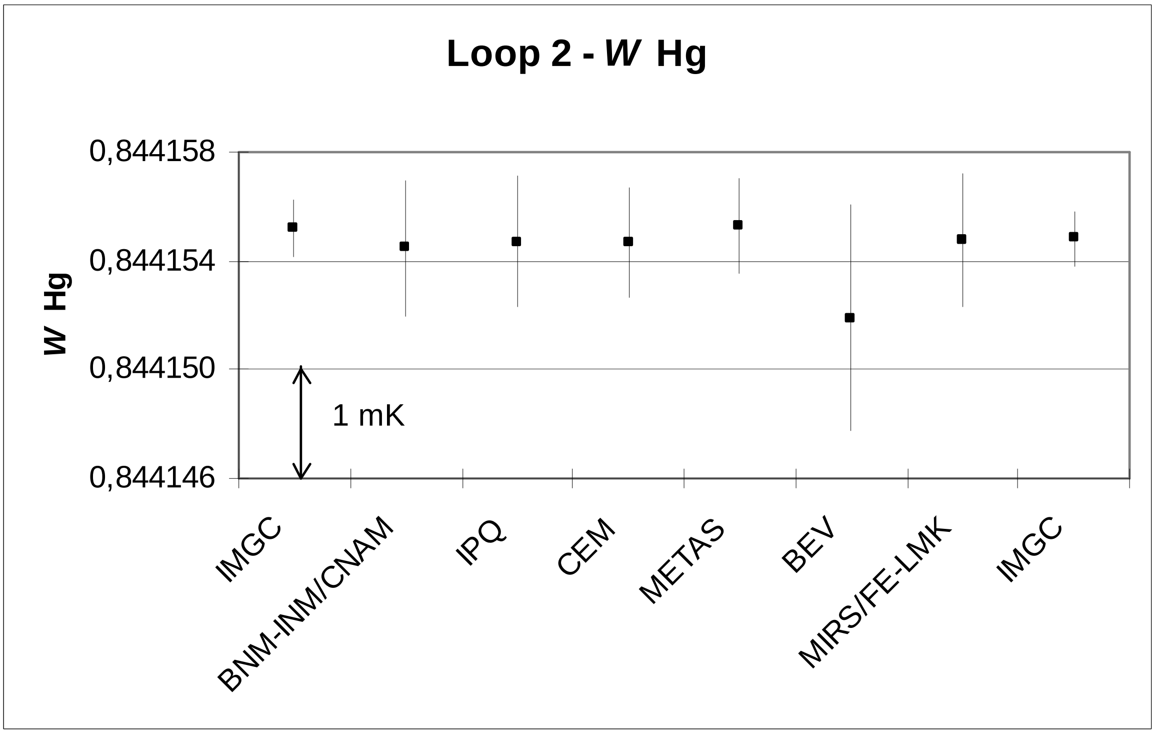


Figure 8 : Results of SPRT Hart scientific 5681 n° 1283 calibration - Ga

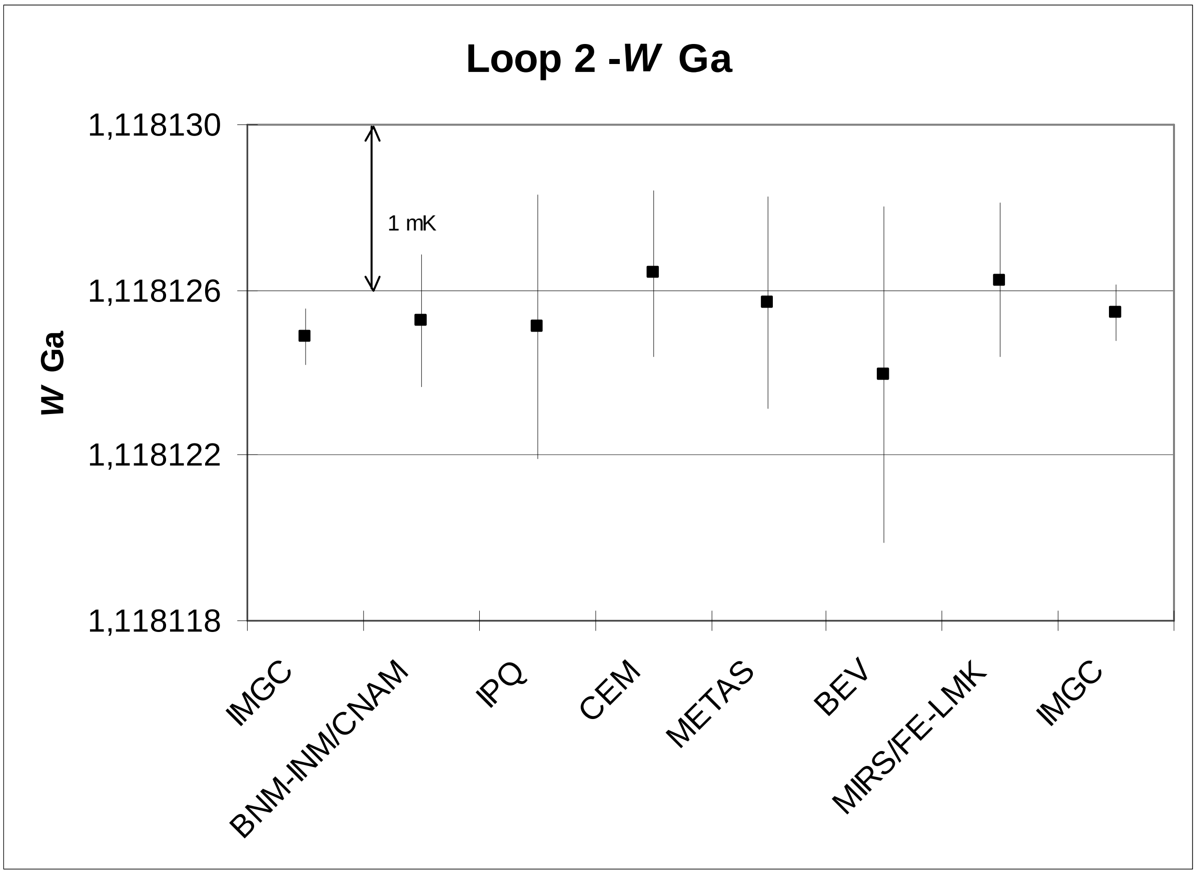


Figure 9 : Results of SPRT Hart scientific 5681 n° 1283 calibration - In

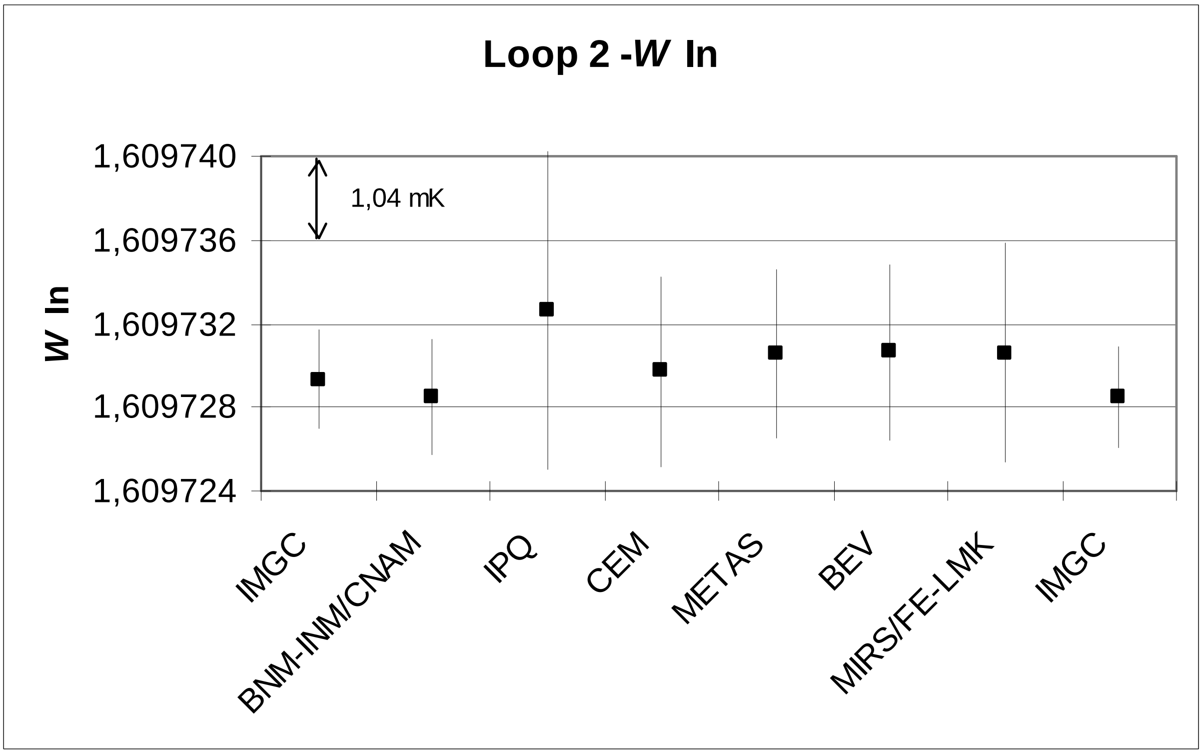


Figure 10 : Results of SPRT Hart scientific 5681 n° 1283 calibration - Sn

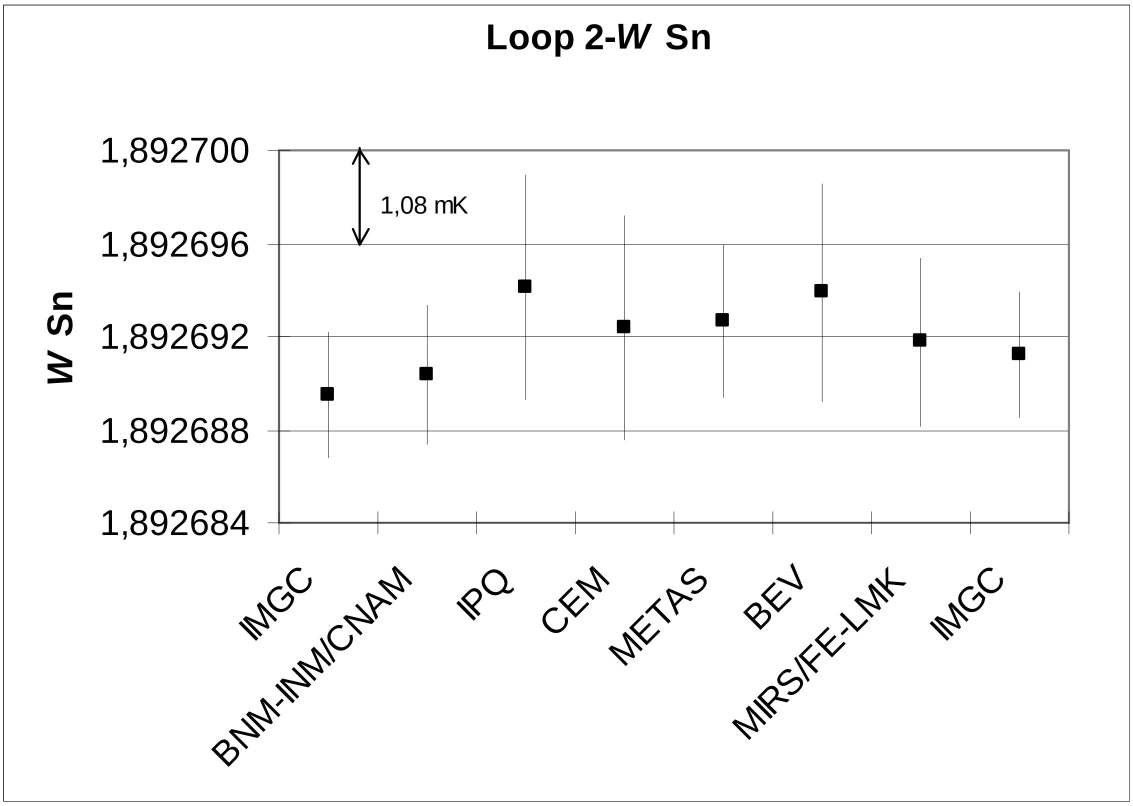
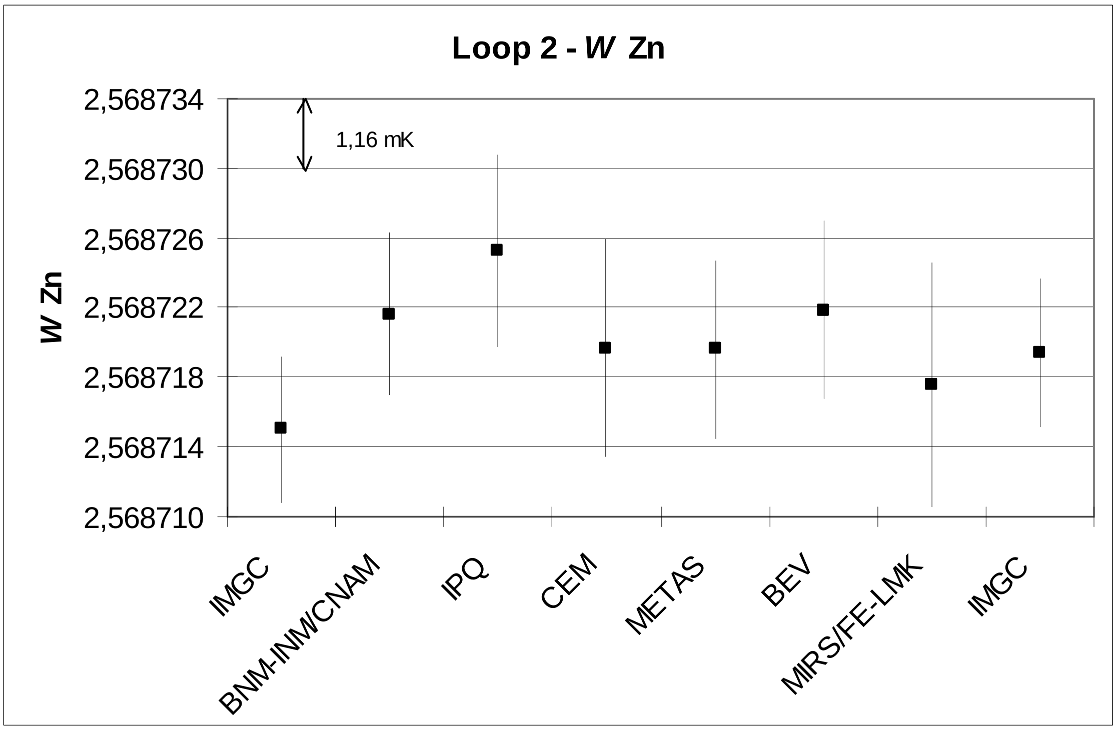


Figure 11 : Results of SPRT Hart scientific 5681 n° 1283 calibration – Zn



Loop 3 – Co-pilot NMi-VSL

Table 7: Loop 3. Calibration of the SPRT Tinsley 5187 n° 274686

Point	*W (NMI-VSL)*	*U (NMI-VSL)* mK	*W (BNM-INM /CNAM)*	*U (BNM-INM /CNAM)* mK	*W (DTI)*	*U (DTI)* mK	*W (MIKES)*	*U (MIKES)* mK
Ar	0,2159873	0,31	0,2159873	0,68			0,2159855	1,06
Hg	0,8441655	0,29	0,8441645	0,58	0,8441761	3,06	0,8441656	0,75
Ga	1,1181173	0,32	1,1181174	0,30	1,1181172	0,58	1,1181178	0,64
In	1,6096869	0,46	1,6096879	0,87	1,6096874	2,12	1,6096879	1,97
Sn	1,8926337	0,66	1,8926323	0,76	1,8926306	1,89	1,8926302	1,20
Zn	2,5686178	0,9	2,5686217	1,31	2,5686193	1,95	2,5686194	1,50

Point	*W (SP)*	*U (SP)* mK	*W (VMT/PFI)*	*U (VMT/PFI)* mK	*W (NMI-VSL)*	*U (NMI-VSL)* mK
Ar	0,2159881	0,85			0,2159862	0,30
Hg	0,8441657	0,80	0,8441652	0,56	0,8441663	0,23
Ga	1,1181186	0,53	1,1181170	0,51	1,1181168	0,32
In	1,6096896	1,21			1,6096866	0,39
Sn	1,8926318	1,05	1,8926322	1,52	1,8926321	0,54
Zn	2,5686173	1,35	2,5686175	1,66	2,5686141	0,79

Figure 12 : Results of SPRT Tinsley 5187 n° 274686 calibration – Ar

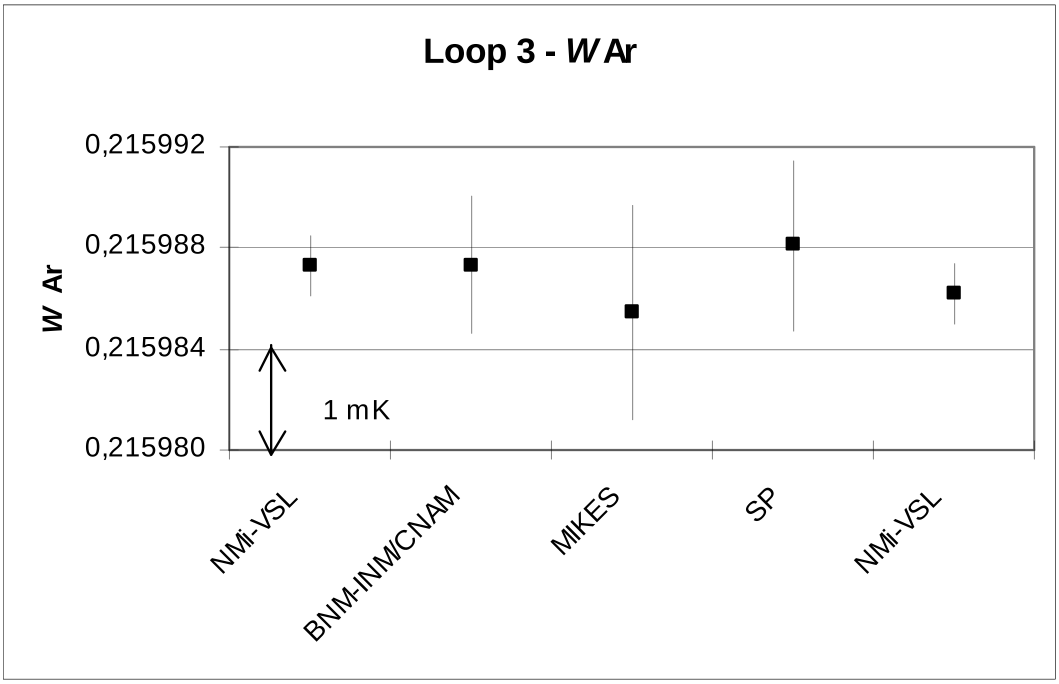


Figure 13 : Results of SPRT Tinsley 5187 n° 274686 calibration – Hg

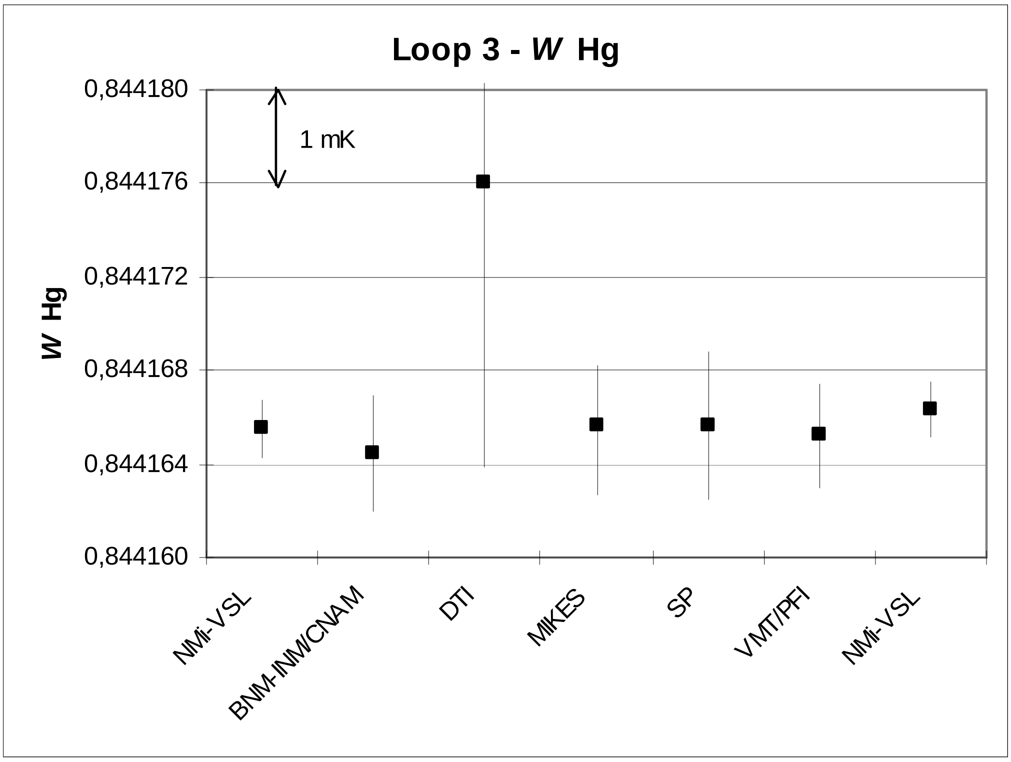


Figure 14 : Results of SPRT Tinsley 5187 n° 274686 calibration – Ga

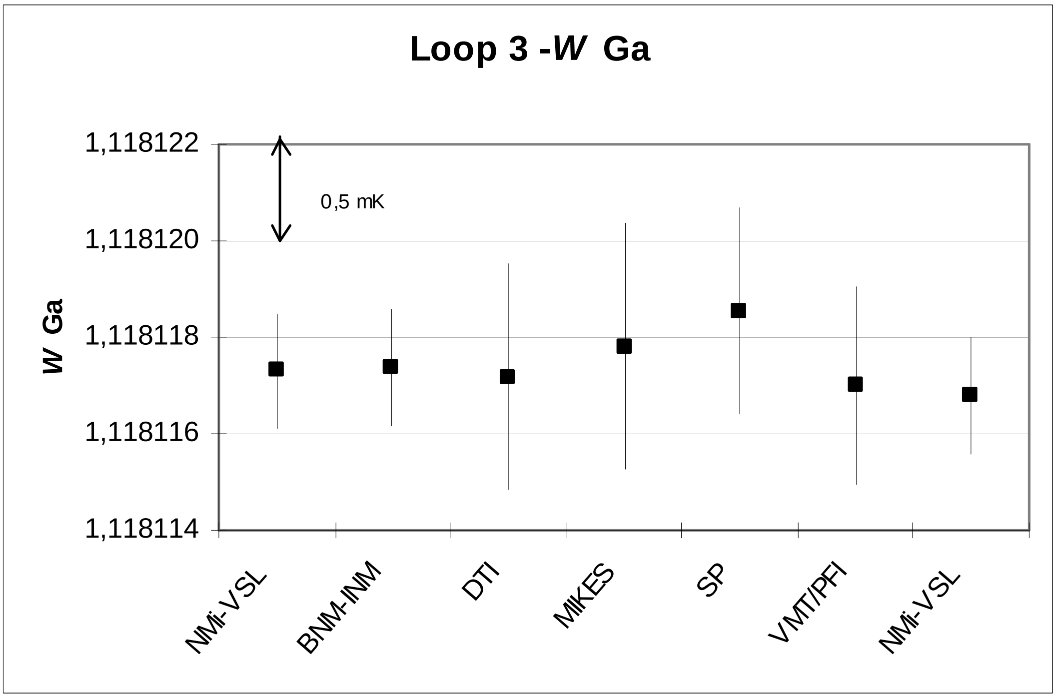


Figure 15 : Results of SPRT Tinsley 5187 n° 274686 calibration – In

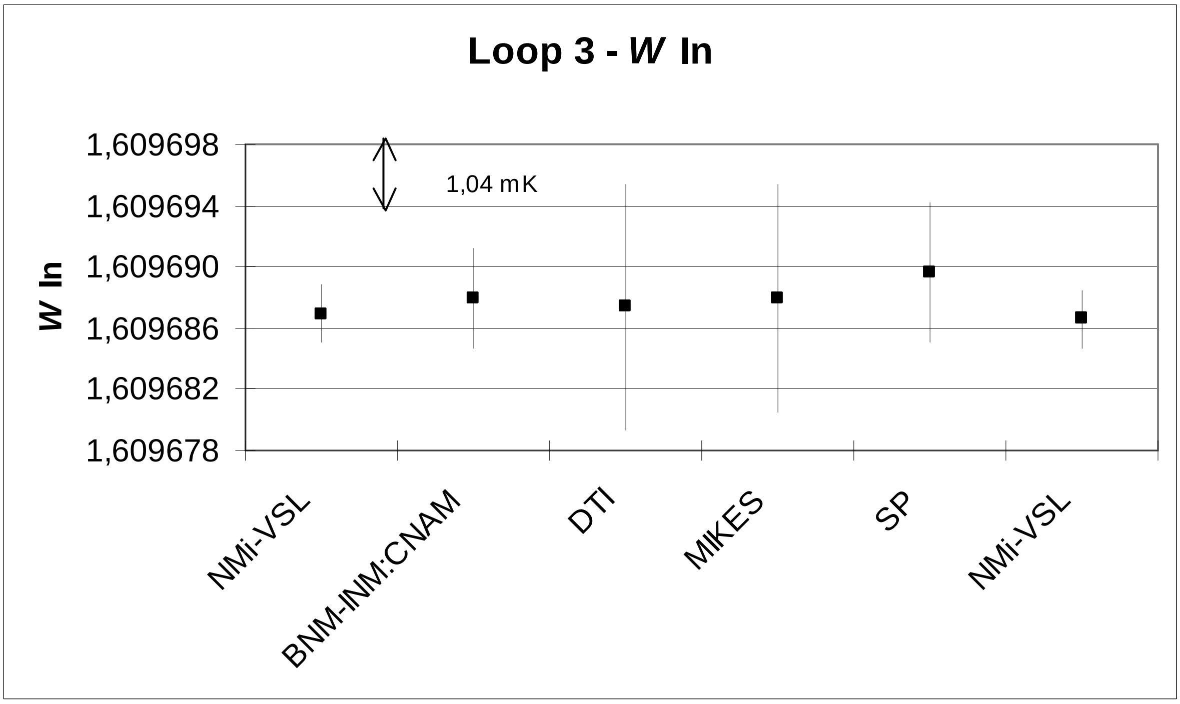


Figure 16 : Results of SPRT Tinsley 5187 n° 274686 calibration – Sn

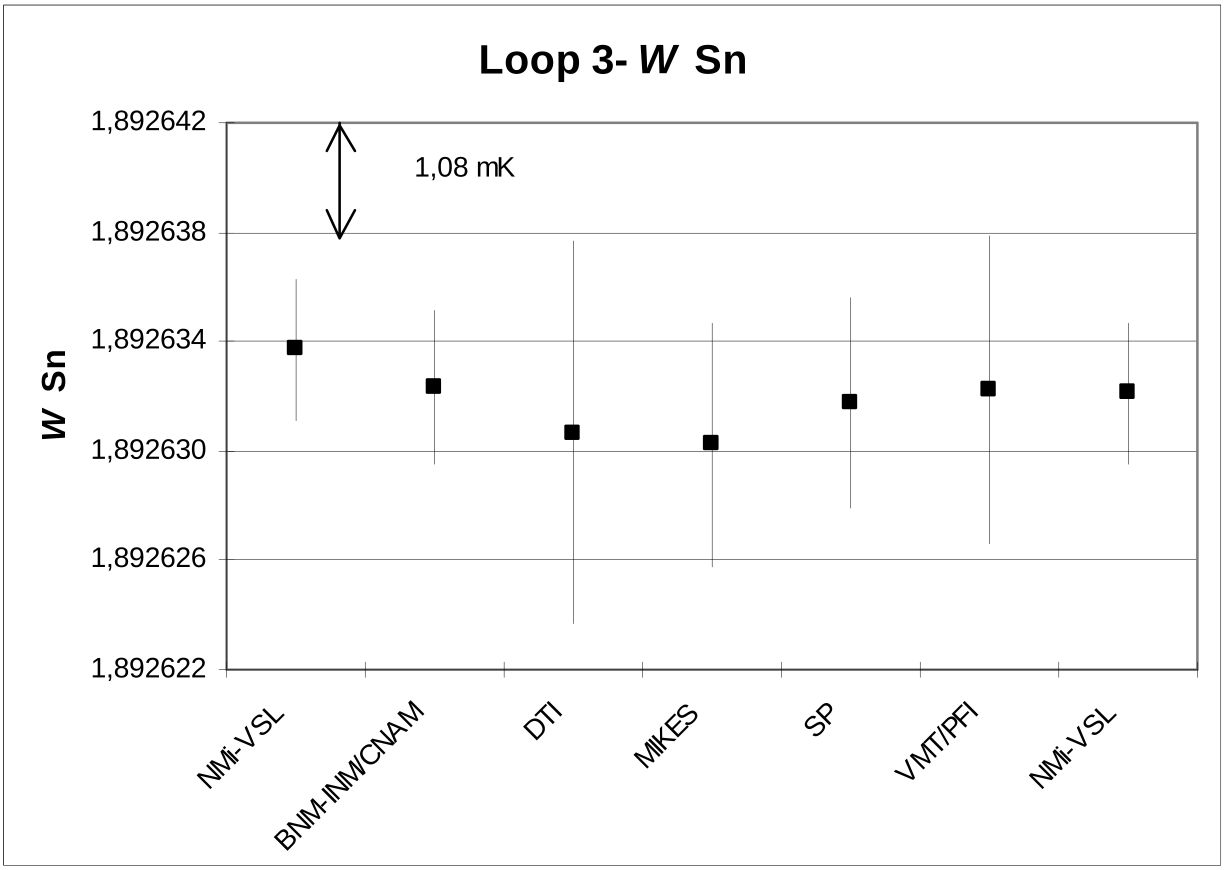
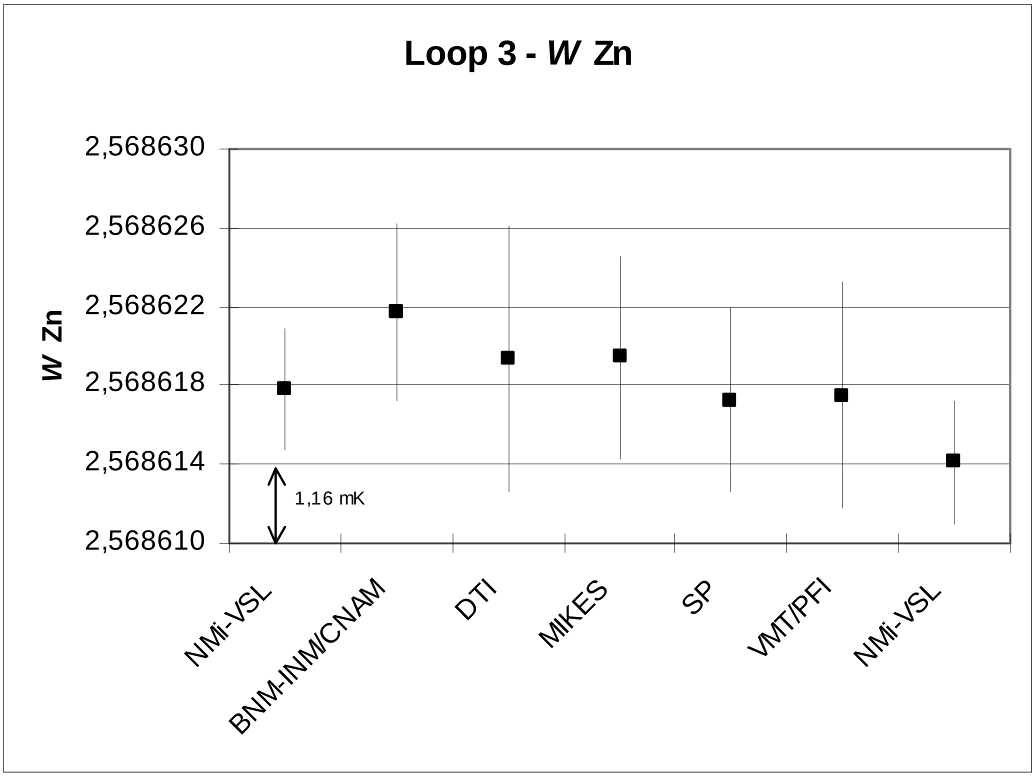


Figure 17 : Results of SPRT Tinsley 5187 n° 274686 calibration – Zn



Loop 4 – Co-pilot PTB

Table 8: Loop 4. Calibration of the SPRT YSI 8167 n° H99S4807

Point	*W (PTB)*	*U (PTB)* mK	*W (BNM-INM /CNAM)*	*U (BNM-INM /CNAM)* mK	*W (CMI)*	*U (CMI)* mK
Ar	0,2161162	0,67	0,2161180	0,68		
Hg	0,8441923	0,28	0,8441915	0,58	0,8441925	0,64
Ga	1,1180981	0,27	1,1180972	0,32	1,1180983	0,54
In	1,6095850	0,86	1,6095834	0,92	1,6095888	1,14
Sn	1,8924820	0,84	1,8924805	0,95	1,8924803	0,89
Zn	2,5683483	1,34	2,5683534	1,30	2,5683507	1,28

Point	*W (UME)*	*U (UME)* mK	*W (GUM)*	*U (GUM)* mK	*W (INM Ro)*	*U (INM Ro)* mK	*W (PTB)*	*U (PTB)* mK
Ar	0,2161132	0,79	0,2161143	0,90	0,2161187	0,80	0,2161173	0,67
Hg	0,8441900	0,65	0,8441919	0,69	0,8441954	0,80	0,8441928	0,28
Ga	1,1180977	0,55	1,1180983	0,57	1,1180982	0,44	1,1180983	0,27
In	1,6095849	1,68	1,6095906	1,31	1,6095690	4,94	1,6095843	0,86
Sn	1,8924797	1,18	1,8924789	1,22	1,8924716	2,76	1,8924818	0,84
Zn	2,5683487	1,53	2,5683546	1,42	2,5683446	3,60	2,5683492	1,34

Figure 18 : Results of SPRT YSI 8167 n° H99S4807 – Ar

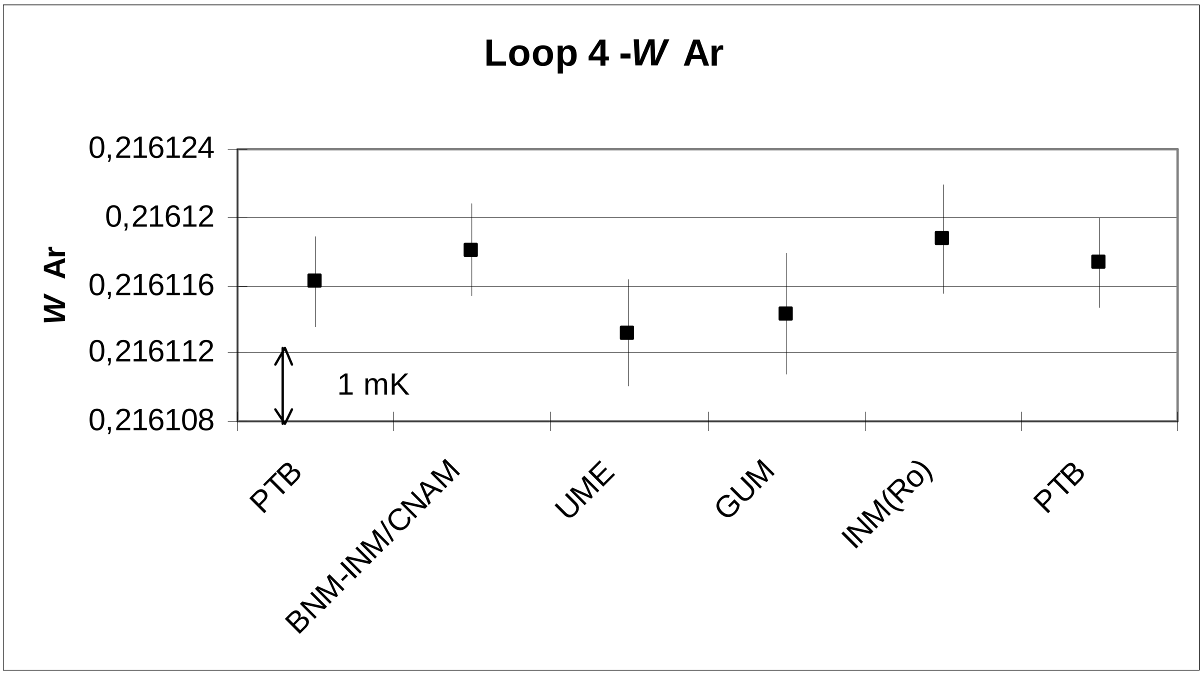


Figure 19 : Results of SPRT YSI 8167 n° H99S4807 – Hg

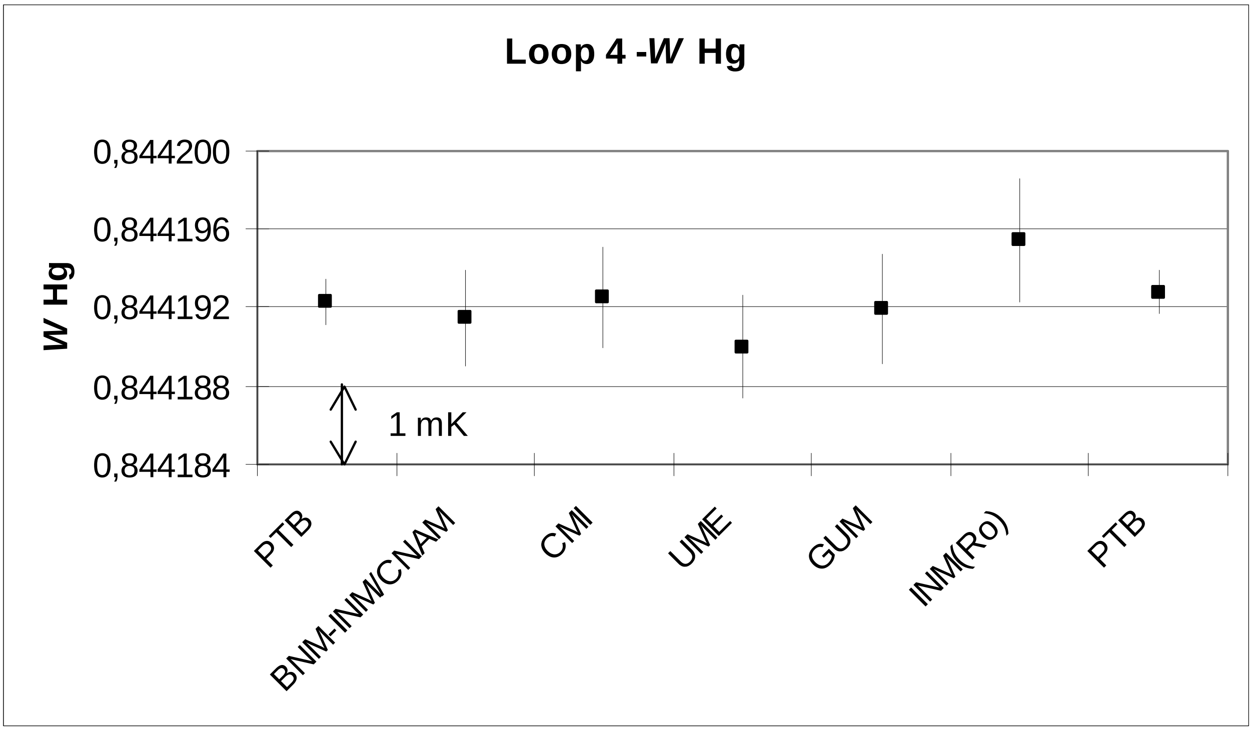


Figure 20 : Results of SPRT YSI 8167 n° H99S4807 – Ga

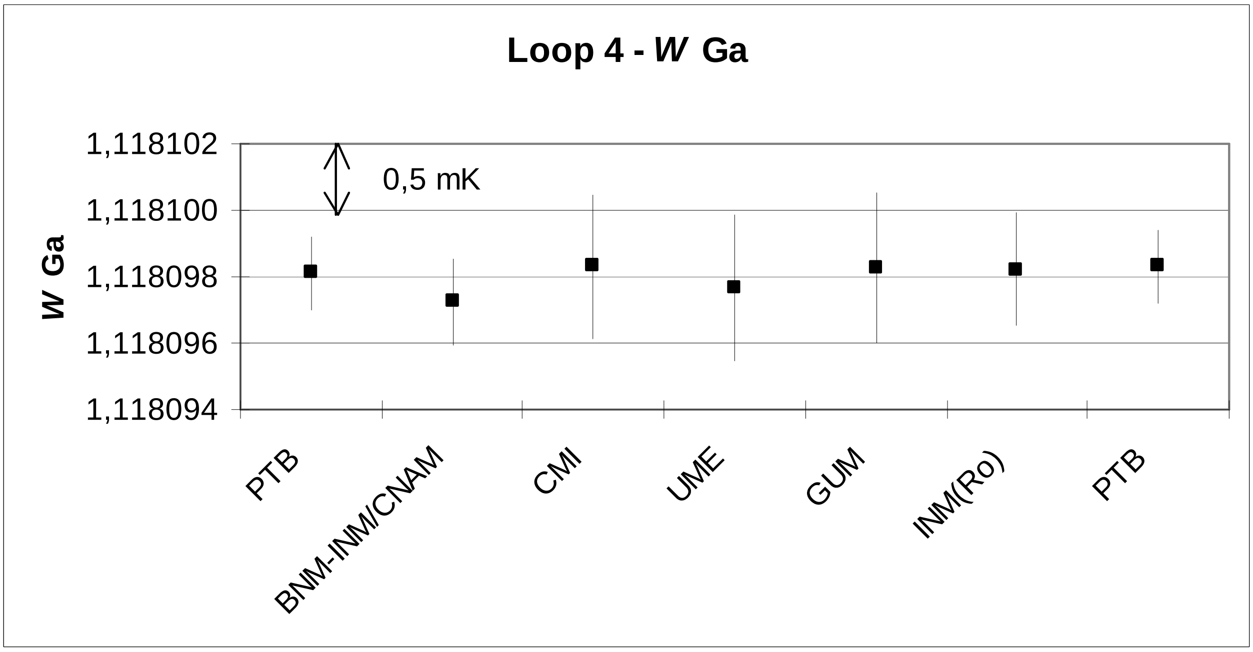


Figure 21 : Results of SPRT YSI 8167 n° H99S4807 – In

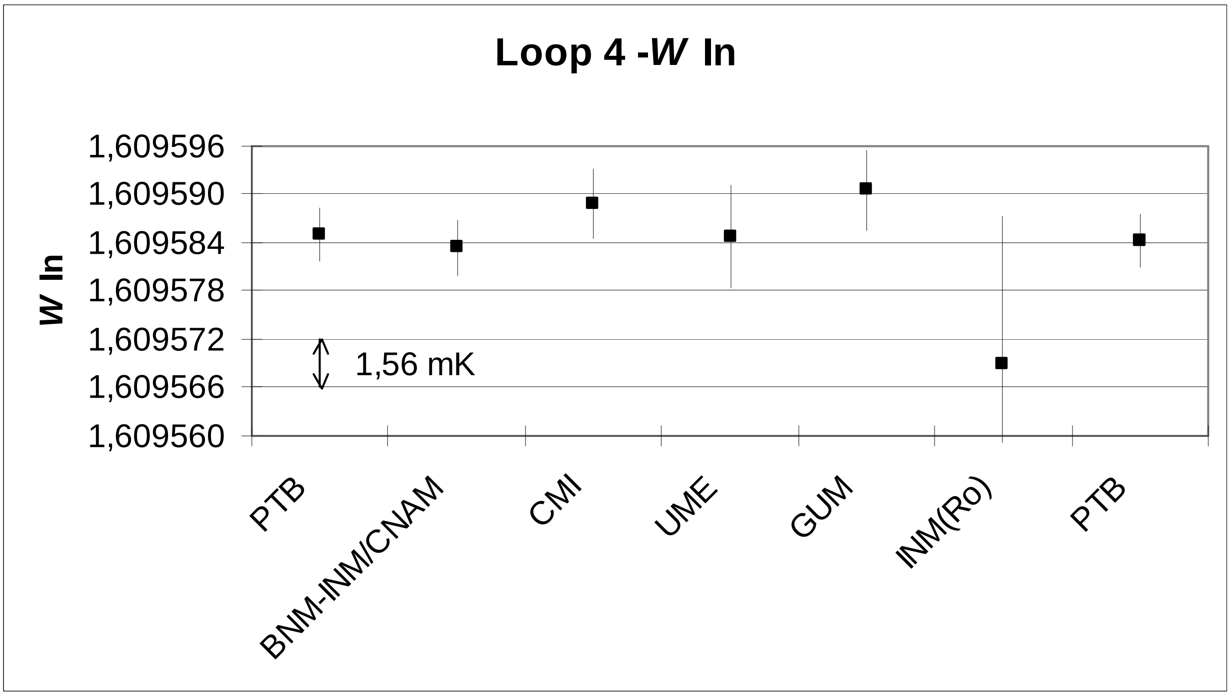


Figure 22 : Results of SPRT YSI 8167 n° H99S4807 – Sn

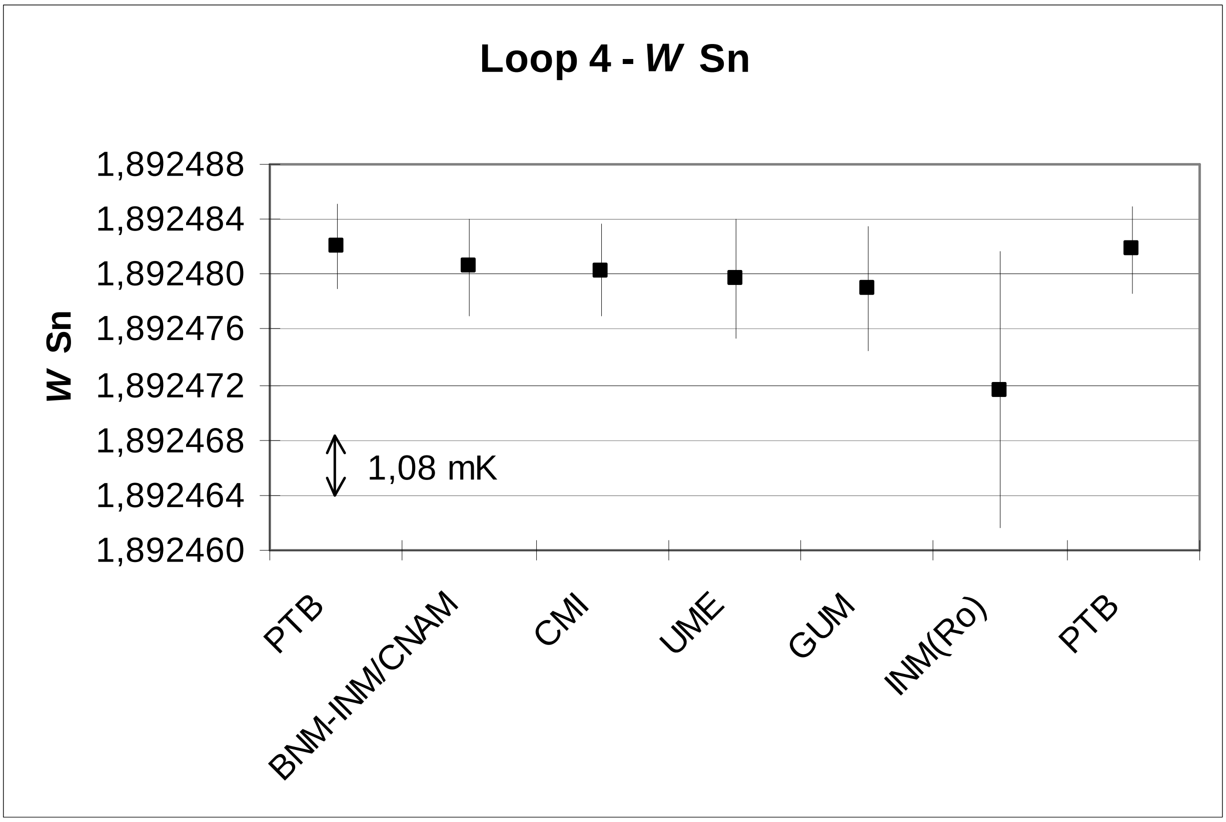
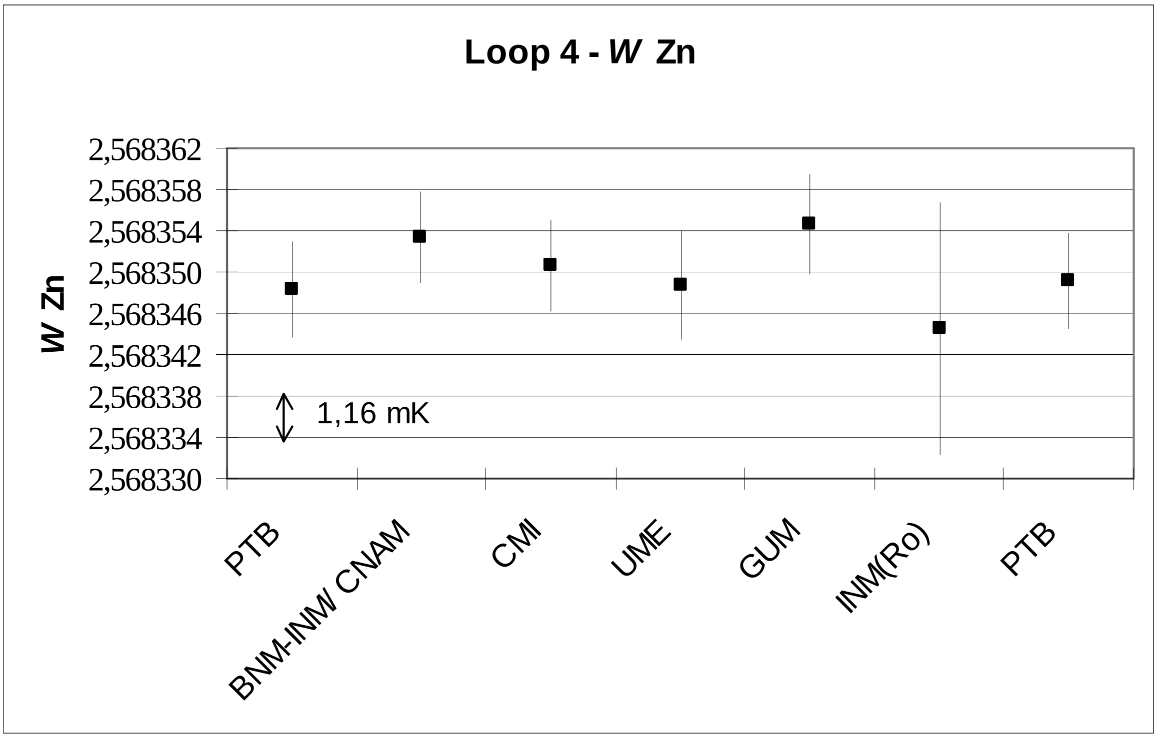


Figure 23 : Results of SPRT YSI 8167 n° H99S4807 – Zn



Loop 5 – Co-pilot NPL

Table 9: Loop 5. Calibration of the SPRT Tinsley 5187 n° 269586

Point	*W (NPL)*	*U (NPL)* mK	*W (BNM-INM /CNAM)*	*U (BNM-INM /CNAM)* mK	*W (NML)*	*U (NML)* mK
Ar	0,2159634	0,20	0,2159634	0,68		
Hg	0,8441620	0,36	0,8441603	0,62	0,8441630	0,68
Ga	1,1181198	0,36	1,1181203	0,28	1,1181210	0,71
In	1,6097024	0,78	1,6097049	0,71		
Sn	1,8926553	0,87	1,8926570	0,80	1,8926570	1,54
Zn	2,5686602	1,10	2,5686641	1,16	2,5686600	2,87

Point	*W (JV)*	*U (JV)* mK	*W (EIM)*	*U (EIM)* mK	*W (SMD)*	*U (SMD)* mK	*W (NPL)*	*U (NPL)* mK
Ar	0,2159636	0,85			0,2159667	0,76		
Hg	0,8441620	0,83	0,8441630	0,57	0,8441627	0,56	0,8441630	0,35
Ga	1,1181228	0,59	1,1181216	0,57	1,1181199	0,52	1,1181205	0,38
In	1,6097044	1,87	1,6097103	1,66	1,6097033	1,69	1,6097029	0,78
Sn	1,8926544	1,36	1,8926562	1,36	1,8926485	1,17	1,8926561	0,76
Zn	2,5686580	1,91	2,5686586	1,89	2,5686565	2,02	2,5686571	1,10

Figure 24 : Results of SPRT Tinsley 5187 n° 269586 – Ar

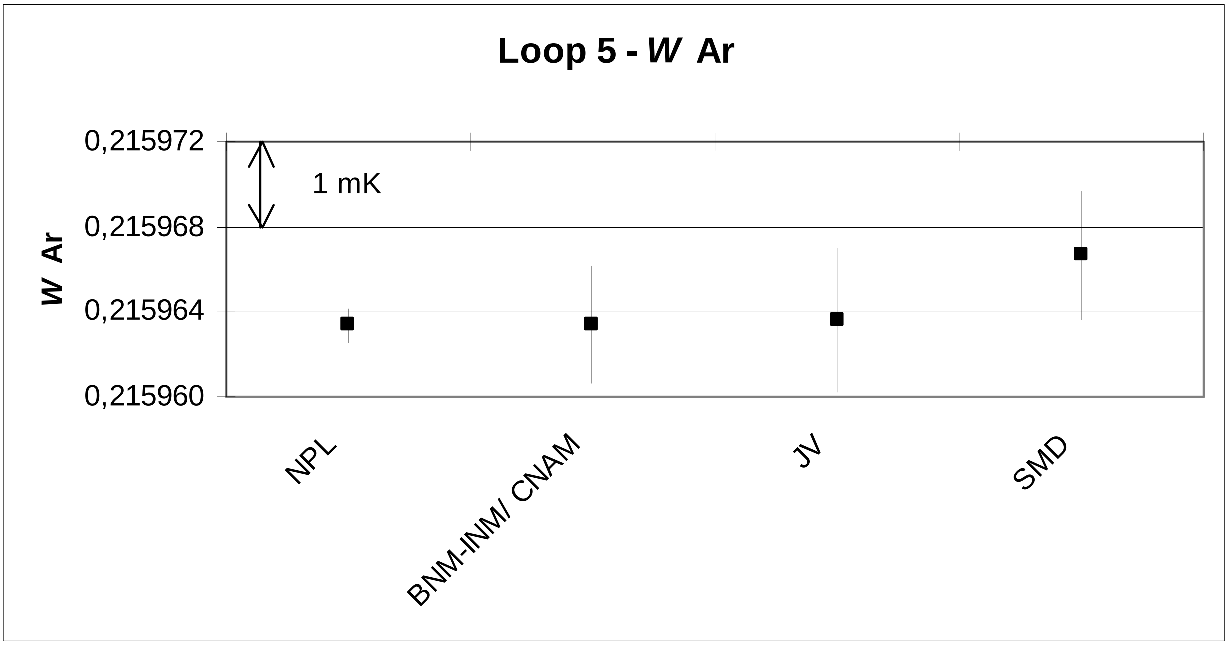


Figure 25 : Results of SPRT Tinsley 5187 n° 269586 – Hg

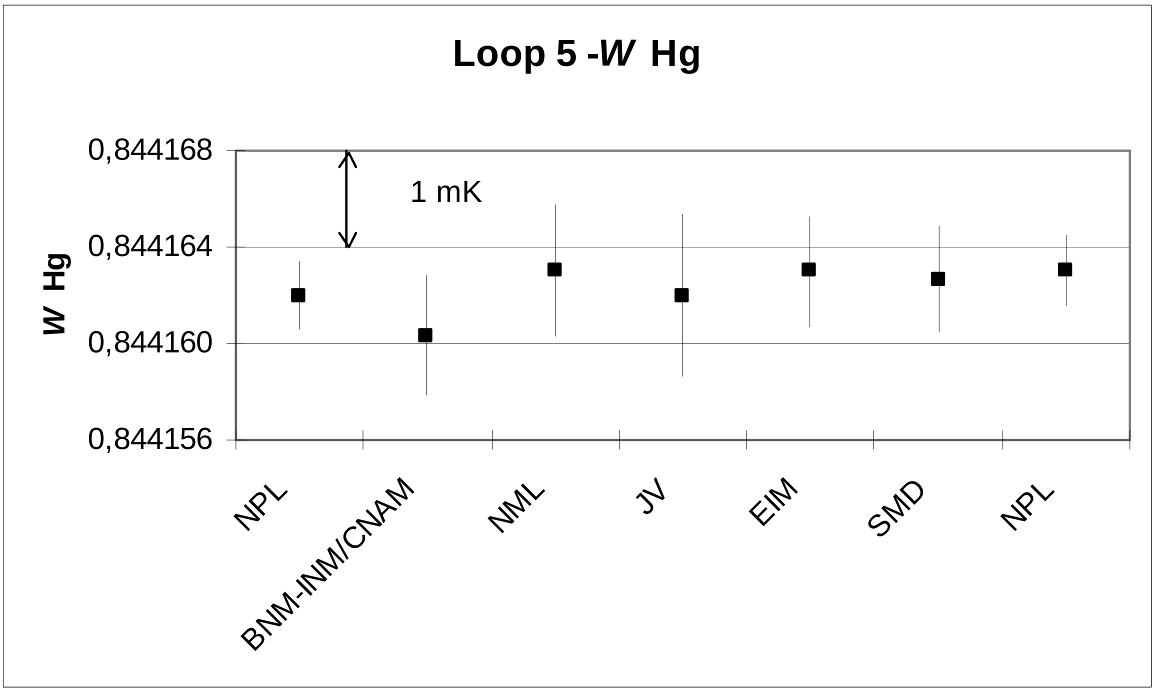


Figure 26 : Results of SPRT Tinsley 5187 n° 269586 – Ga

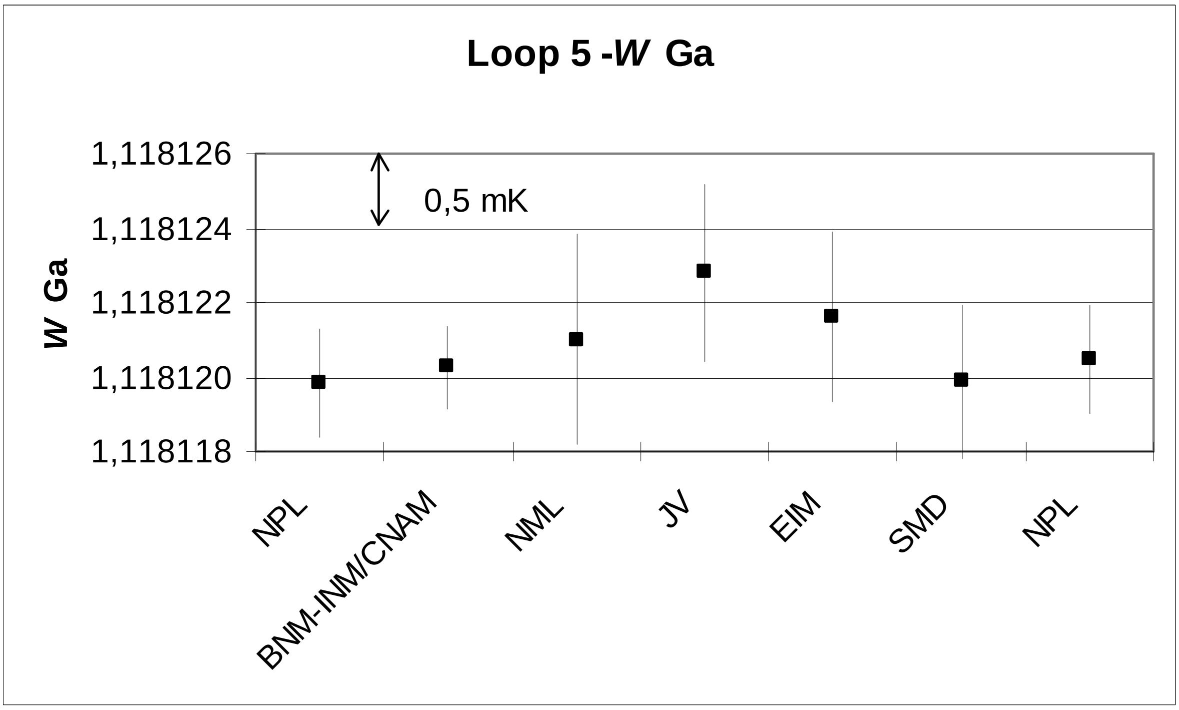


Figure 27 : Results of SPRT Tinsley 5187 n° 269586 – In

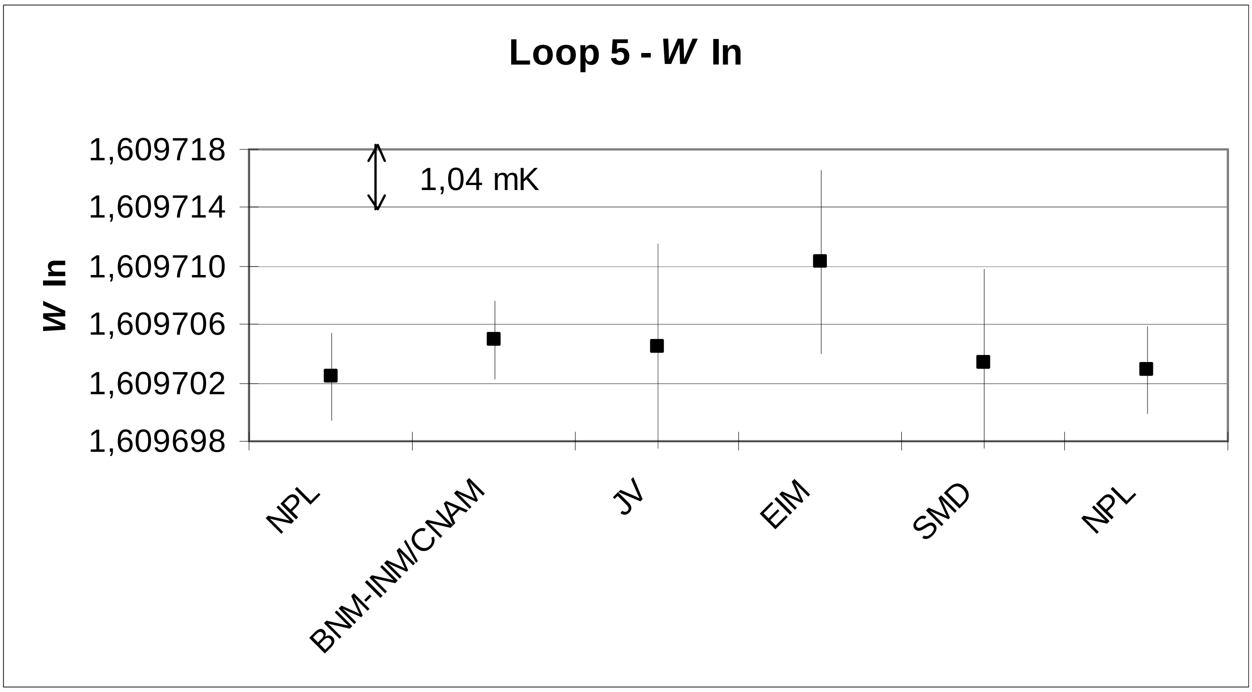


Figure 28 : Results of SPRT Tinsley 5187 n° 269586 – Sn

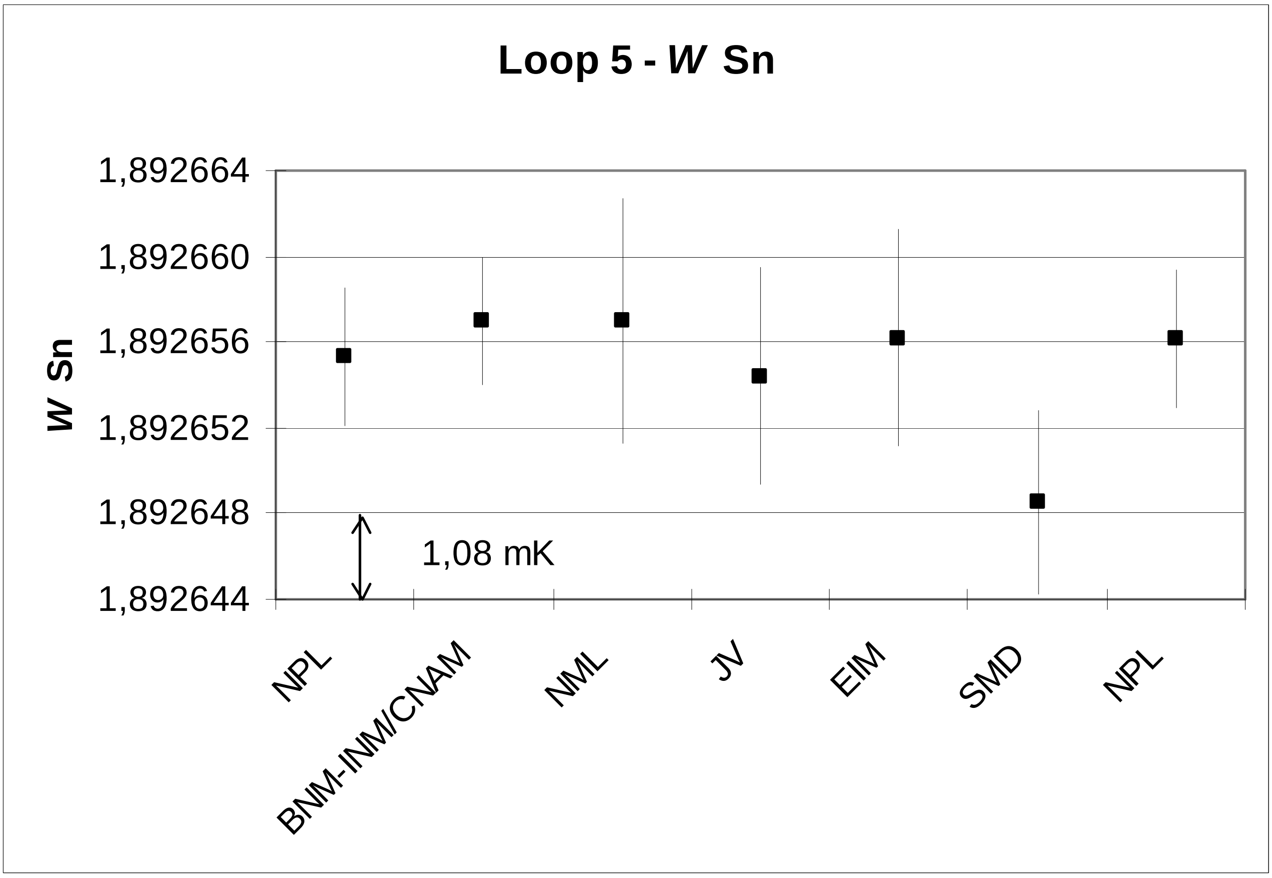
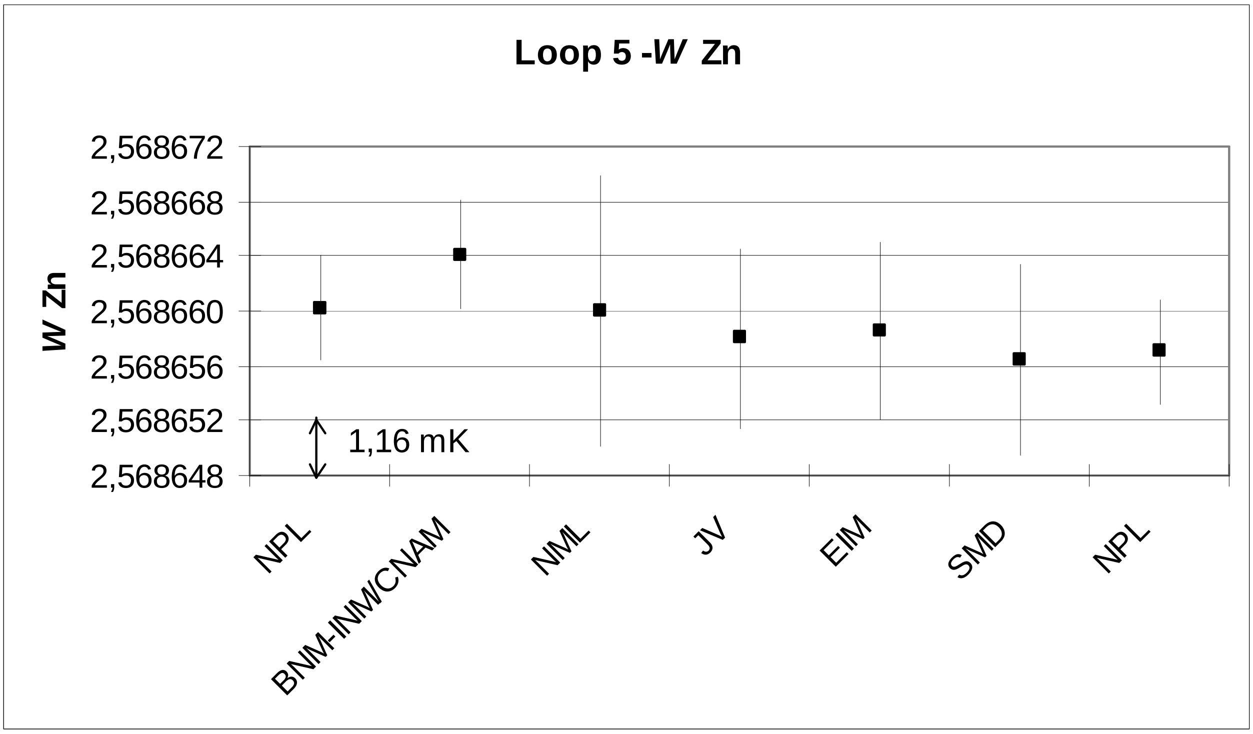


Figure 29 : Results of SPRT Tinsley 5187 n° 269586 – Zn



6. Uncertainties

Each participating laboratory provided resistance ratios, measured in their local fixed points. Each participant was requested to supply the uncertainty budget associated with the calibration at the different fixed points. It was asked to the laboratories to fill the "Uncertainty Excel file" included in the protocol and agreed by all the participants '(see Protocol). The uncertainty budgets can be found in Appendix C:
Table C1 for the calibration at the argon fixed point;
Table C2 for the calibration at the mercury fixed point;
Table C3 for the calibration at the gallium fixed point;
Table C4 for the calibration at the indium fixed point;
Table C5 for the calibration at the tin fixed point;
Table C6 for the calibration at the zinc fixed point.

For the components estimated using a type B method the degrees of freedom are assumed to be infinite. For the component estimated using a type A method, the degrees of freedom depends on the number of results. The combined uncertainties were computed by root-sum-of-squares of the type A and type B contributions.
Whatever the fixed point and the laboratory considered, the coverage factor $t_{95}(\nu)$ from the t-distribution is very close to 2. So, for all the laboratories a coverage factor k=2 was used in order to calculate the combined expanded uncertainties.

7. Additional Uncertainties

In addition to the uncertainties reported by each laboratory an uncertainty, for possible instabilities of the circulated SPRT over the course of the comparison, have to be taken into account. The BNM-INM/CNAM established the link between the five loops, nevertheless, the five circulated SPRTs were not calibrated during the same run at BNM-INM/CNAM. So, an additional uncertainty associated with the repeatibility of BNM-INM/CNAM calibration has to be added.

7.1 Uncertainty due to the instability of the circulated SPRTs

The co-pilot calibrations of the travelling instrument carried out during the time of the loop are used in order to establish the uncertainty component associated to the stability of the travelling SPRT.

For the SPRT and the fixed point considered, the uncertainty $u_{stabSPRT\,j}$ is calculated using a type B method and an hypothesis of a rectangular not symmetrical distribution (drift of the SPRT)

$$u_{StabSPRT_j} = \frac{\left| \left(W_{CP_j}\right)_{end} - \left(W_{CP_j}\right)_{beginning} \right|}{\sqrt{3}} \times \left(\frac{\delta T}{\delta W}\right)_T$$

With W_{CP_j} , value of the *W* measured by the co-pilot of the loop *j (j=1…5)*

Table 10. Stability of the circulating SPRT. Loop 1.

	Beginning of the loop		After BNM-INM calibration		End of the loop				
Fixed point	*W SMU*	*U SMU* mK	*W SMU*	*U SMU* mK	*W SMU*	*U SMU* mK	*Wend-Wbegi*	*Wend-Wbegi* expressed in mK	uncertainty $u_{stabSPRT1}$ mK
Hg	0,8441601	0,70			0,8441615	0,70	0,0000014	0,34	0,20
Ga	1,1181234	0,22	1,1181228	0,22	1,1181219	0,22	-0,0000015	-0,39	0,22
In	1,6097122	0,95			1,6097117	0,95	-0,0000005	-0,13	0,07
Sn	1,8926712	0,92			1,8926680	0,92	-0,0000032	-0,87	0,50
Zn	2,5686862	0,86	2,5686865	0.86	2,5686835	0,86	-0,0000027	-0,79	0,46

Table 11. Stability of the circulating SPRT. Loop 2

	Beginning of the loop		After BNM-INM calibration		End of the loop				
Fixed point	*W IMGC*	*U IMGC* mK	*W IMGC*	*U IMGC* mK	*W IMGC*	*U IMGC* mK	*Wend-Wbegi*	*Wend-Wbegi* expressed in mK	uncertainty $u_{stabSPRT2}$ mK
Ar	0,2159237	0,46			0,2159247	0,46	0,0000009	0,23	0,13
Hg	0,8441552	0,26			0,8441548	0,26	-0,0000004	-0,10	0,06
Ga	1,1181249	0,17	1,1181256	0,17	1,1181255	0,17	0,0000006	0,15	0,09
In	1,6097294	0,63			1,6097285	0,63	-0,0000009	-0,23	0,13
Sn	1,8926895	0,73			1,8926912	0,73	0,0000017	0,45	0,26
Zn	2,5687150	1,23	2,5687158	1,23	2,5687194	1,23	0,0000044	1,27	0,74

Table 12. Stability of the circulating SPRT. Loop 3

	Beginning of the loop		After BNM-INM calibration		End of the loop				
Fixed point	*W NMi-VSL*	*U NMi-VSL* mK	*W NMi-VSL*	*U NMi-VSL* mK	*W NMi-VSL*	*U NMi-VSL* mK	*Wend-Wbegi*	*Wend-Wbegi* expressed in mK	uncertainty $u_{stabSPRT3}$ mK
Ar	0,2159873	0,30			0,2159862	0,30	-0,0000011	-0,28	0,16
Hg	0,8441655	0,30			0,8441663	0,23	0,0000008	0,20	0,12
Ga	1,1181173	0,30	1,1181181	0,30	1,1181168	0,32	-0,0000005	-0,13	0,07
In	1,6096869	0,50			1,6096866	0,39	-0,0000003	-0,08	0,05
Sn	1,8926337	0,70	1,8926320	0,70	1,8926321	0,54	-0,0000016	-0,43	0,25
Zn	2,5686178	0,90	2,5686170	0,90	2,5686141	0,79	-0,0000037	-1,07	0,62

Table 13. Stability of the circulating SPRT. Loop 4.

	Beginning of the loop		After BNM-INM calibration		End of the loop				
Fixed point	*W PTB*	*U PTB* mK	*W PTB*	*U PTB* mK	*W PTB*	*U PTB* mK	*Wend-Wbegi*	*Wend-Wbegi* expressed in mK	uncertainty $u_{stabSPRT4}$ mK
Ar	0,2161162	0,67			0,2161173	0,79	0,0000011	0,28	0,16
Hg	0,8441923	0,28			0,8441928	0,28	0,0000005	0,12	0,07
Ga	1,1180981	0,27			1,1180983	0,27	0,0000002	0,05	0,03
In	1,6095850	0,86			1,6095843	0,86	-0,0000007	-0,18	0,11
Sn	1,8924820	0,84			1,8924818	0,84	-0,0000002	-0,05	0,03
Zn	2,5683483	1,34	2,5683494	1,34	2,5683492	1,34	0,0000009	0,26	0,15

Table 14. Stability of the circulating SPRT. Loop 5.

	Beginning of the loop		After BNM-INM calibration		End of the loop				
Fixed point	*W NPL*	*U NPL* mK	*W NPL*	*U NPL* mK	*W NPL*	*U NPL* mK	*Wend-Wbegi*	*Wend-Wbegi* expressed in mK	uncertainty $u_{stabSPRT5}$ mK
Ar	0,2159634	0,20							
Hg	0,8441620	0,36			0,8441630	0,35	0,0000010	0,26	0,15
Ga	1,1181198	0,36	1,1181212	0,36	1,1181205	0,38	0,0000006	0,16	0,09
In	1,6097024	0,78			1,6097029	0,78	0,0000005	0,13	0,08
Sn	1,8926553	0,87			1,8926561	0,76	0,0000008	0,21	0,12
Zn	2,5686602	1,10	2,5686573	1,10	2,5686571	1,10	-0,0000032	-0,92	0,53

As NPL didn't carry out a measurement at the Ar fixed point at the end of the loop, it is assumed in the rest of the document that the uncertainty due to the stability of the SPRT is the same at Ar and Hg fixed point.

7.2 Uncertainty due to the repeatability of the BNM-INM/CNAM calibration.

As some SPRTs were not stable, the 5 circulating SPRTs were not calibrated in the same run at BNM-INM/CNAM (It needs 3 runs). Even if it was not provided in the protocol of the comparison a BNM-INM/CNAM's SPRT was calibrated during each run at the gallium, indium, tin and zinc fixed points (see Tables 1, 2, 3). So, it is possible to estimate the repeatibility of the BNM-INM/CNAM calibration at these fixed points. The additional uncertainty due to the repeatability of BNM-INM/CNAM calibration is calculated from:

$$u_{reproducibilityT_p} = \frac{\left| (W_{1825320})_{\max} - (W_{1825320})_{\min} \right|}{2\sqrt{3}} \times \left(\frac{\delta T}{\delta W} \right)_T$$

With the hypothesis of a rectangular symmetrical distribution.
It appears that this repeatibility is very good and doesn't introduce a significant uncertainty component.

Table 15. Repeatibility of the calibration at BNM-INM/CNAM - SPRT L & N 1825320

Fixed point	*W BNM-INM* .01/10/2001	*W BNM-INM* .01/01/2003	*W BNM-INM* .01/06/2003	*Wmax-Wmin*	*Wmax-Wmin* expressed mK	$u_{reproducibilityTp}$ mK
Ga	1,1181132	1,1181130	1,1181136	0,0000006	0,14	0,04
In	1,6096631	1,6096631	1,6096632	0,0000002	0,04	0,01
Sn	1,8925950	1,8925945	1,8925959	0,0000013	0,36	0,11
Zn	2,5685566	2,5685566	2,5685570	0,0000004	0,11	0,03

At the mercury and argon fixed point, due to practical reasons, a BNM-INM/CNAM thermometer was not included in the calibration runs. The repeatibility of the BNM-INM/CNAM calibration was established using the laboratory knowledge and the uncertainty budgets.

$$u_{reproducibilityHg_p} = 0{,}10 \quad \text{mK}$$

$$u_{reproducibilityAr_p} = 0{,}10 \quad \text{mK}$$

8. EUROMET Reference Value

As a preliminary, it is expected that an EUROMET reference value will become established on the data of all the European participant laboratories in order to conform to the CCT-K3 data processing and so to follow the MRA rules.

Let $T_{Lab_{ij}}$ the value measured by the lab *i* in the loop *j*

where $i = 1 \ldots N_j$ lab index in loop *j*
$j = 1 \ldots 5$ loop index
N_j = number of labs in loop *j*

i=1 corresponds to the co-pilot of the loop. So, $T_{Lab_{1j}} = T_{CP_j}$ with T_{CP_j} value measured by the co-pilot (CP_j) on SPRT *j*

i=2 corresponds to the co-pilot of the loop. So, $T_{Lab_{2j}} = T_{P_j}$ with T_{P_j} value measured by pilot (BNM-INM/CNAM) on SPRT *j*

As a basis it is suggested to benefit from the advantage that BNM-INM/CNAM is involved in all the loops; and it is, therefore, possible to calculate $T_{Lab_{ij}} - T_{P_j}$.

$$T_{Lab_{ij}} - T_{P_j} = \left(W_{Lab_{ij}} - W_{P_j}\right) \cdot \left(\frac{\delta T}{\delta W}\right)_T$$

It is expected that, taking the uncertainty associated to the repeatibility of BNM-INM/CNAM calibration into account,

$$T_{P_j} = T_P \quad \text{(same cell, same furnace, same bridge,….)}$$

$$T_{Lab_{ij}} - T_{P_j} = T_{Lab_{ij}} - T_P$$

8.1 Designation of the EUROMET Reference Value

Three choices for the ERV were presented during the Workshop organized in Vienna (Austria) on 8 April 2005: the simple mean, T_{m552}, the weighted mean T_{wm552},, the median T_{med552},.

The difference $(T_{m552} - T_P)$ is calculated from:

$$T_{m552} - T_P = \frac{\sum_{i=1}^{N_j} \sum_{j=1}^{5} \left(T_{Lab_{ij}} - T_p \right)}{\sum_{j=1}^{5} N_j}$$

and the associated uncertainty according to the GUM (Chapter 4.2.3).

The difference $(T_{wm552} - T_P)$ is calculated from the uncertainties given by the participants:

$$T_{wm552} - T_P = \frac{\sum_{i=1}^{N_j} \sum_{j=1}^{5} \frac{\left(T_{Lab_{ij}} - T_p \right)}{u^2\left(T_{Lab_{ij}} - T_p \right)}}{\sum_{i=1}^{N_j} \sum_{j=1}^{5} \frac{1}{u^2\left(T_{Lab_{ij}} - T_p \right)}}$$

and the associated uncertainty:

$$u^2\left(T_{wm552} - T_P\right) = \frac{1}{\sum_{i=1}^{N_j} \sum_{j=1}^{5} \frac{1}{u^2\left(T_{Lab_{ij}} - T_P \right)}}$$

The median and the uncertainty of the median is calculated using the model of J.W. Müller [1]

As it is presented Figures 30 to 36 the differences between these values, obtained from a classical statistical analysis, are very small. The lowest uncertainty is associated with the median. Nevertheless, the participant laboratories (IT, TR, RO not represented) decided by vote during the workshop to be conservative and not to use the median. Eleven participants voted for the weighted mean, two for the median and one for the mean. By a second vote it was decided to not define

[1] Possible advantages of a robust evaluation of comparisons, J. W. Müller, *Journal of research of the NIST, Vol. 105, Number 4, July-August 2000*

outliers based on the reported results because the data distant of the values given by the other laboratories are always associated with a large uncertainty and consequently have no impact on the overall results.

Therefore, by a decision at the Vienna meeting, the weighted means, T_{wm552} , at each fixed point are adopted as the EUROMET Reference Value .

8.2 (T_{Labij} - T_{wm552}) computation

The value of T_{wm552} is not, a priori, known and has not any physical meaning, but the difference between a laboratory calibration value and the reference value can be computed. For example:

$$\left(T_{Lab_{ij}} - T_{wm552}\right) = \left(T_{Lab_{ij}} - T_P\right) - \left(T_{wm552} - T_P\right)$$

The value of T_p of the pilot (BNM-INM/CNAM) cancels out and does not affect the result of the comparison. The only condition is that the BNM-INM/CNAM value must be expected to be stable during the period of the comparison. However, T_p is the link between all the laboratories and its uncertainty is therefore included in the uncertainties in all the inter-laboratory differences.

The *W* values of the co-pilots are the mean of the *W* values measured at the beginning and at the end of the loop.

$$T_{CP_j} = \frac{\left(T_{CP_j}\right)_{beginning} + \left(T_{CP_j}\right)_{end}}{2}$$

The uncertainty of $\left(T_{Lab_{ij}} - T_{wm552}\right)$ is obtained by:

$$u_{\left(T_{lab_{ij}} - T_{wm552}\right)} = \sqrt{u^2_{\left(T_{lab_{ij}} - T_P\right)} + u^2_{\left(T_{wm552} - T_P\right)}}$$

The uncertainty associated to $T_{Lab_{ij}} - T_P$ is obtained from:

- The uncertainty on the measurement data given by the Lab_{ij} *(see Chapter 5)*
- The uncertainty associated with the stability of the circulating SPRT during the period of the loop measurements (depending of the loop. see Chapter 7.1)
- The repeatibility of the BNM-INM/CNAM calibration. As some SPRTs were not stable, the 5 circulating SPRTs were not calibrated in the same run at BNM-INM/CNAM (It needs 3 runs. See Chapter 7.2).

$$u_{(T_{Lab_{ij}} - T_P)} = \sqrt{u^2_{Lab_{ij}} + u^2_{stabSPRT_j} + u^2_{reproducibility\,Tp}}$$

The values of $u_{\left(T_{wm552} - T_P\right)}$ are given tables 16 to 21.

All the significant components are obtained from type B evaluation. It was assumed to have an infinite number of degrees of freedom for these components. So, finally the expanded uncertainties are computed by using a coverage factor of 2.

$U = 2 \times u$

Figure 30. Zinc fixed point. Simple mean, weighted mean, median

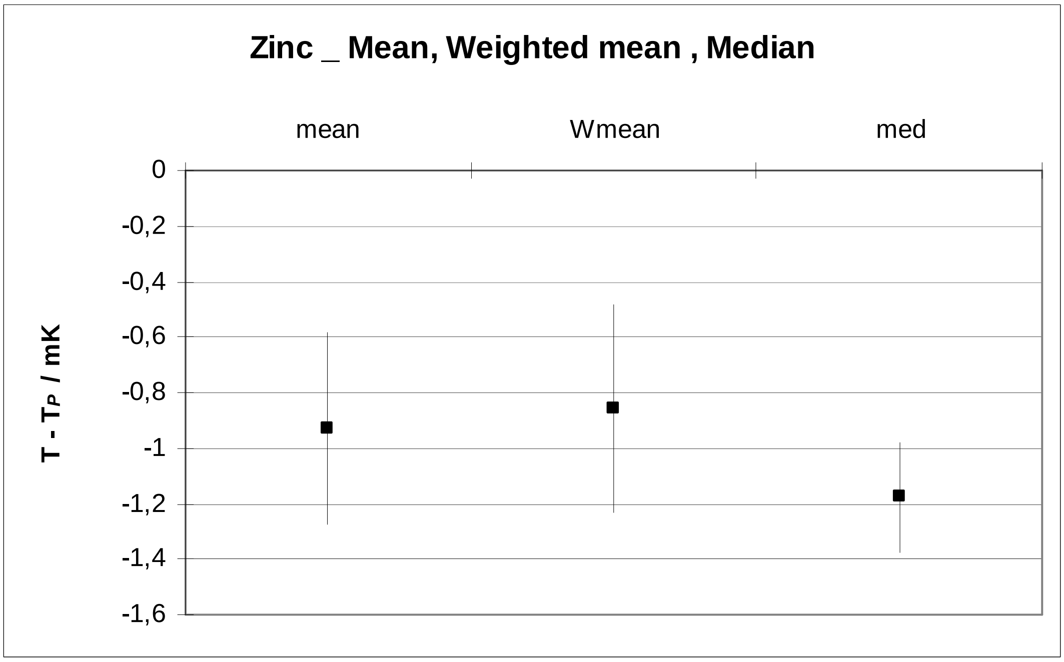


Figure 31. Tin fixed point. Simple mean, weighted mean, median

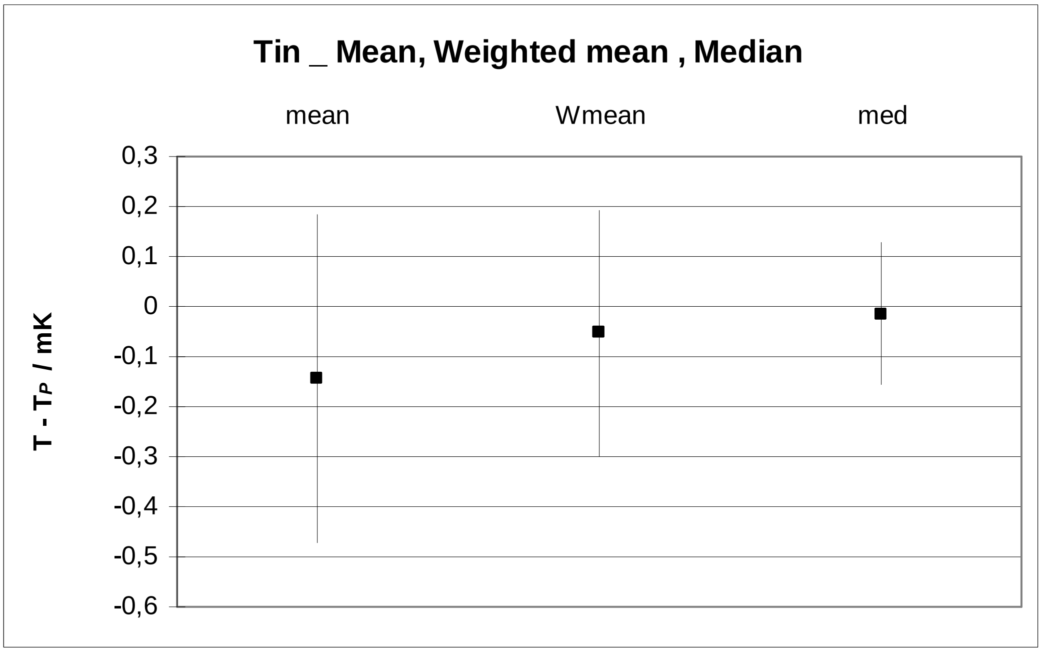


Figure 32. Indium fixed point. Simple mean, weighted mean, median

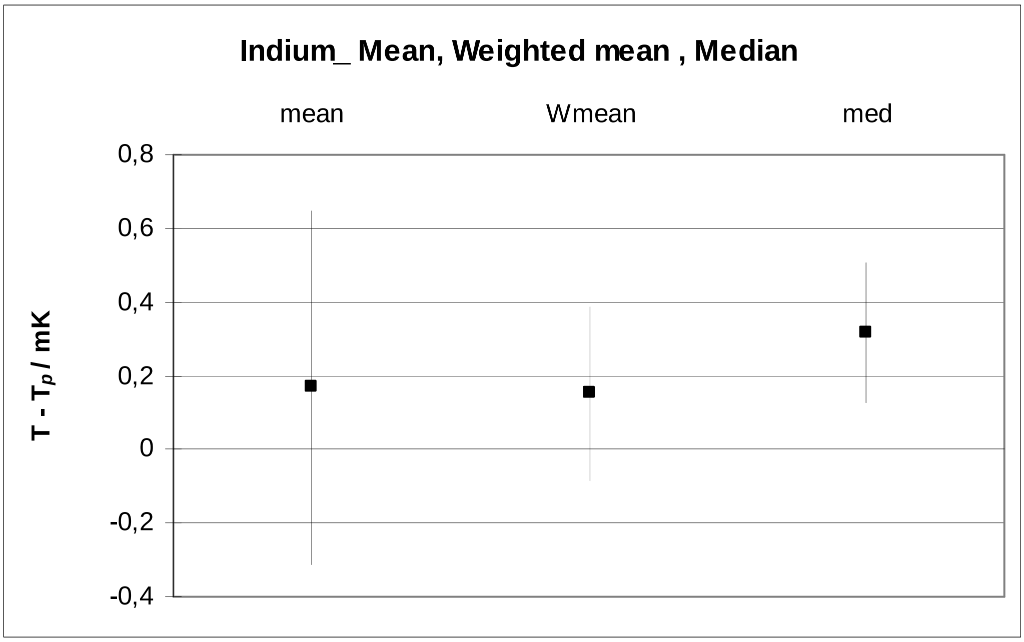


Figure 33. Gallium fixed point. Simple mean, weighted mean, median

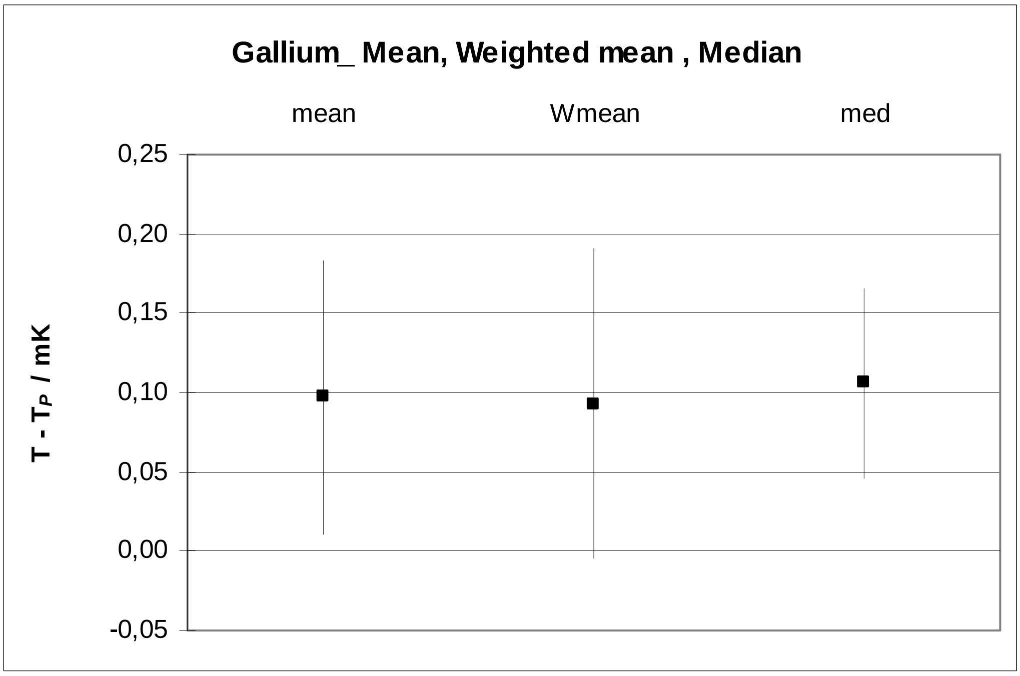


Figure 34. Mercury fixed point. Simple mean, weighted mean, median

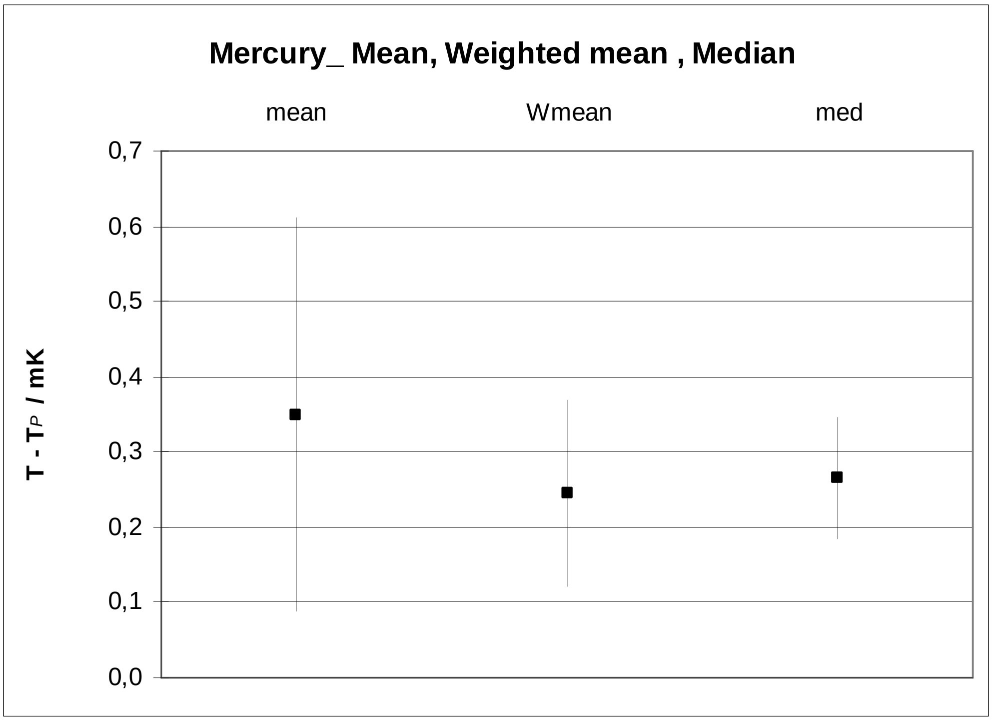
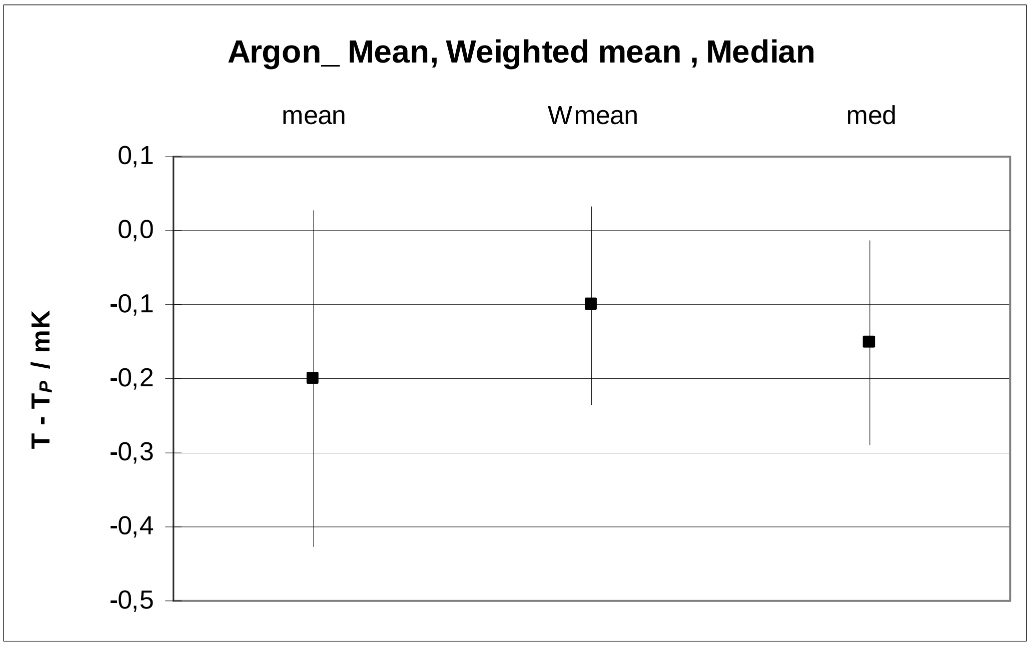


Figure 35. Argon fixed point. Simple mean, weighted mean, median



9. Values of $\left(T_{Lab_{ij}} - T_{wm552}\right)$ and the associated uncertainty $U_{\left(T_{Lab_{ij}} - T_{wm552}\right)}$

9.1 Zinc fixed point

For the zinc fixed point the differences $\left(T_{Lab_{ij}} - T_{wm552}\right)$ and their associated expanded uncertainties (k=2) can be found Table 16 and Figure 36.

Figure 36. Zinc fixed point - Differences $\left(T_{Lab_{ij}} - T_{wm552}\right)$ and their associated expanded uncertainties (k=2)

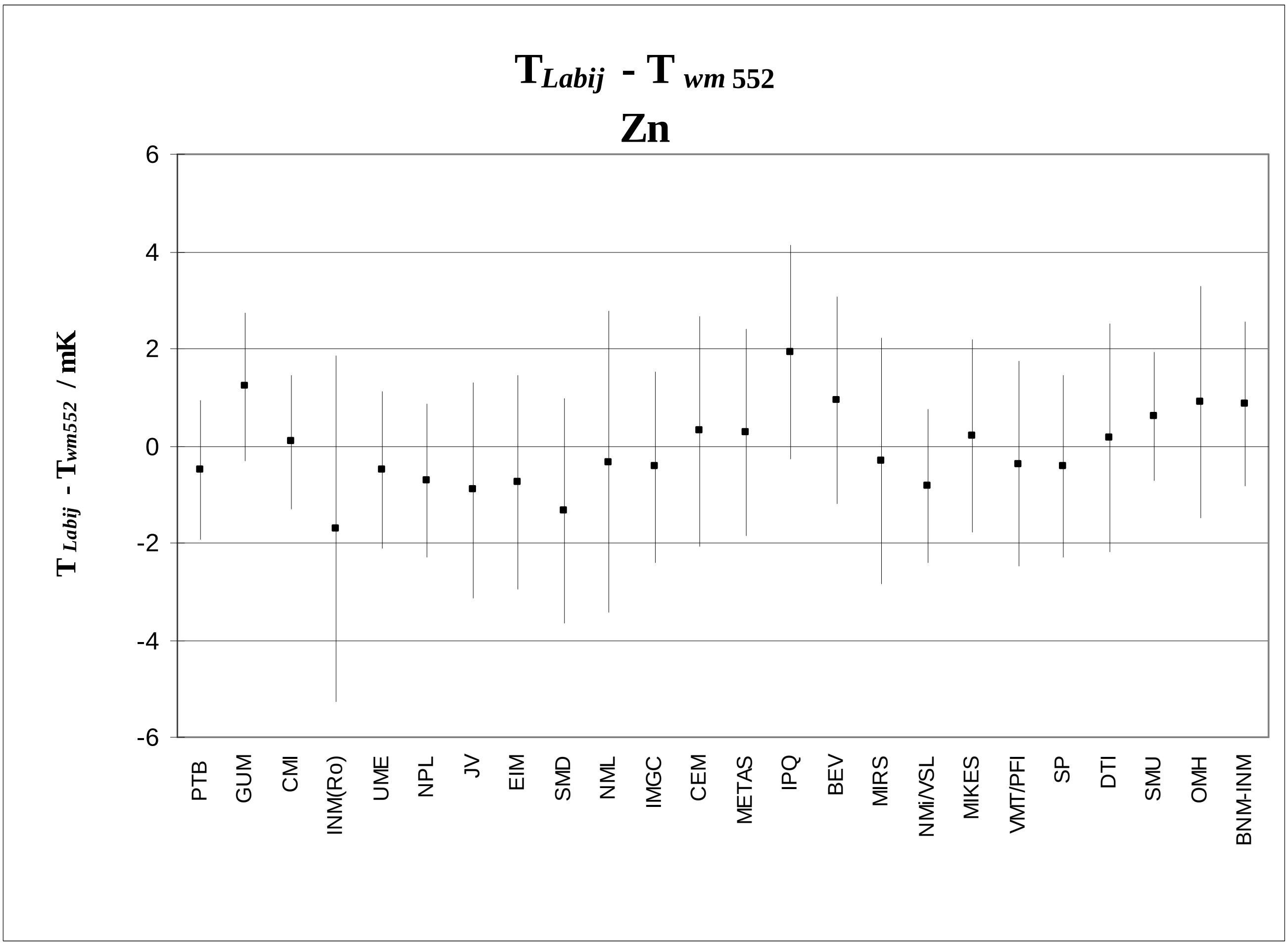


Table 16. Zinc fixed point - Differences $\left(T_{Lab_{ij}} - T_{wm552}\right)$ and their associated expanded uncertainties (k=2)

Lab	T_{Labij} - T_P mK	T_{Labij} - T_{wm552} mK	$U_{(TLabij-Twm552)}$ (k=2) mK
PTB	-1,35	-0,49	1,44
GUM	0,36	1,21	1,51
CMI	-0,78	0,07	1,38
INM(Ro)	-2,56	-1,70	3,57
UME	-1,36	-0,50	1,61
NPL	-1,58	-0,73	1,57
JV	-1,77	-0,92	2,21
EIM	-1,60	-0,75	2,20
SMD	-2,21	-1,35	2,31
NML	-1,19	-0,34	3,09
IMGC	-1,29	-0,43	1,96
CEM	-0,56	0,30	2,36
METAS	-0,59	0,27	2,13
IPQ	1,06	1,92	2,21
BEV	0,06	0,92	2,13
MIRS/FE-LMK	-1,16	-0,30	2,54
NMi/VSL	-1,68	-0,82	1,58
MIKES	-0,67	0,19	1,98
VMT/PFI	-1,23	-0,37	2,11
SP	-1,29	-0,44	1,87
DTI	-0,70	0,16	2,34
SMU	-0,25	0,60	1,32
OMH	0,05	0,91	2,39
BNM-INM	0,00	0,86	1,69

Standard uncertainty of $(T_{wm552} - T_P)$	0,19 mK
Expanded uncertainty of $(T_{wm552} - T_P)$ k=2	0,38 mK

9.2. Tin fixed point

For the tin fixed point the differences $\left(T_{Lab_{ij}} - T_{wm552}\right)$ and their associated expanded uncertainties (k=2) can be found Table 17 and Figure 37.

Figure 37. Tin fixed point - Differences $\left(T_{Lab_{ij}} - T_{wm552}\right)$ and their associated expanded uncertainties (k=2)

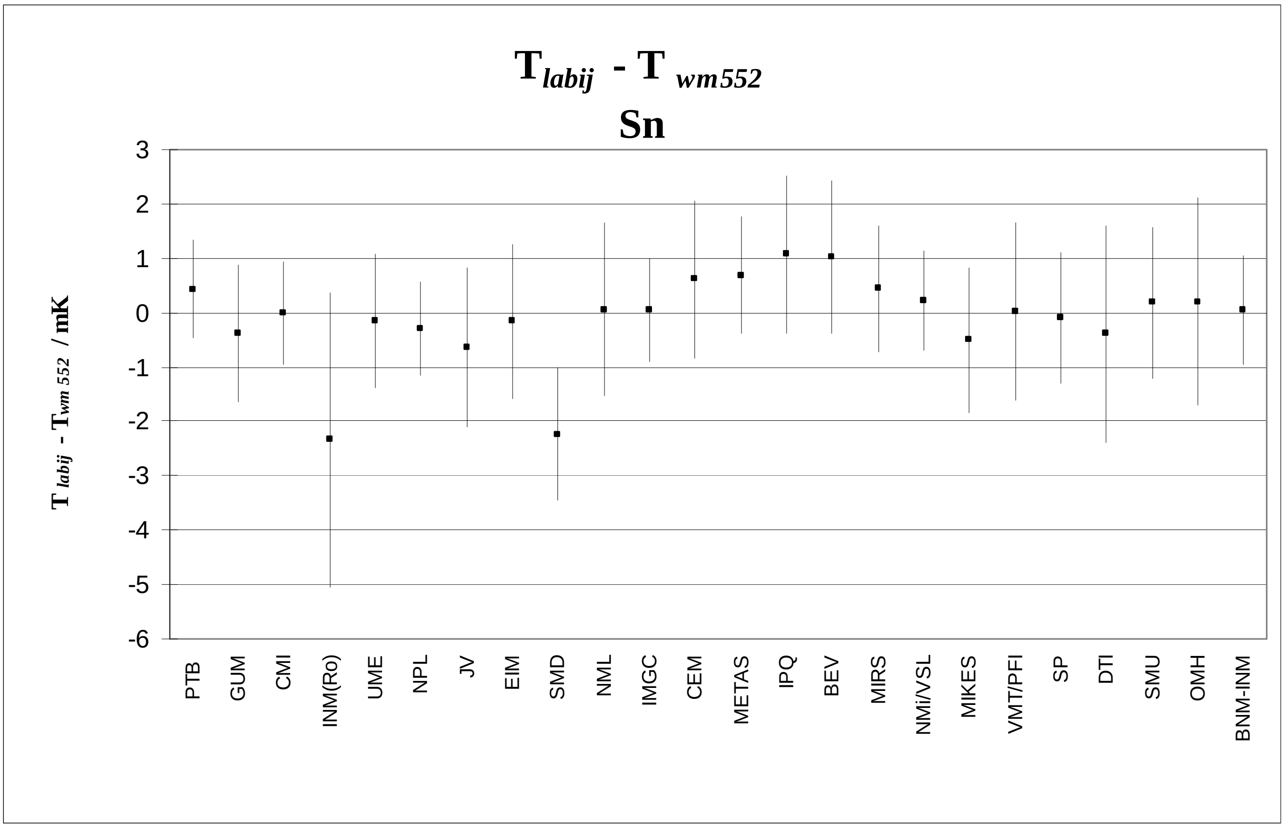


Table 17. Tin fixed point - Differences $\left(T_{Lab_{ij}} - T_{wm552}\right)$ and their associated expanded uncertainties (k=2)

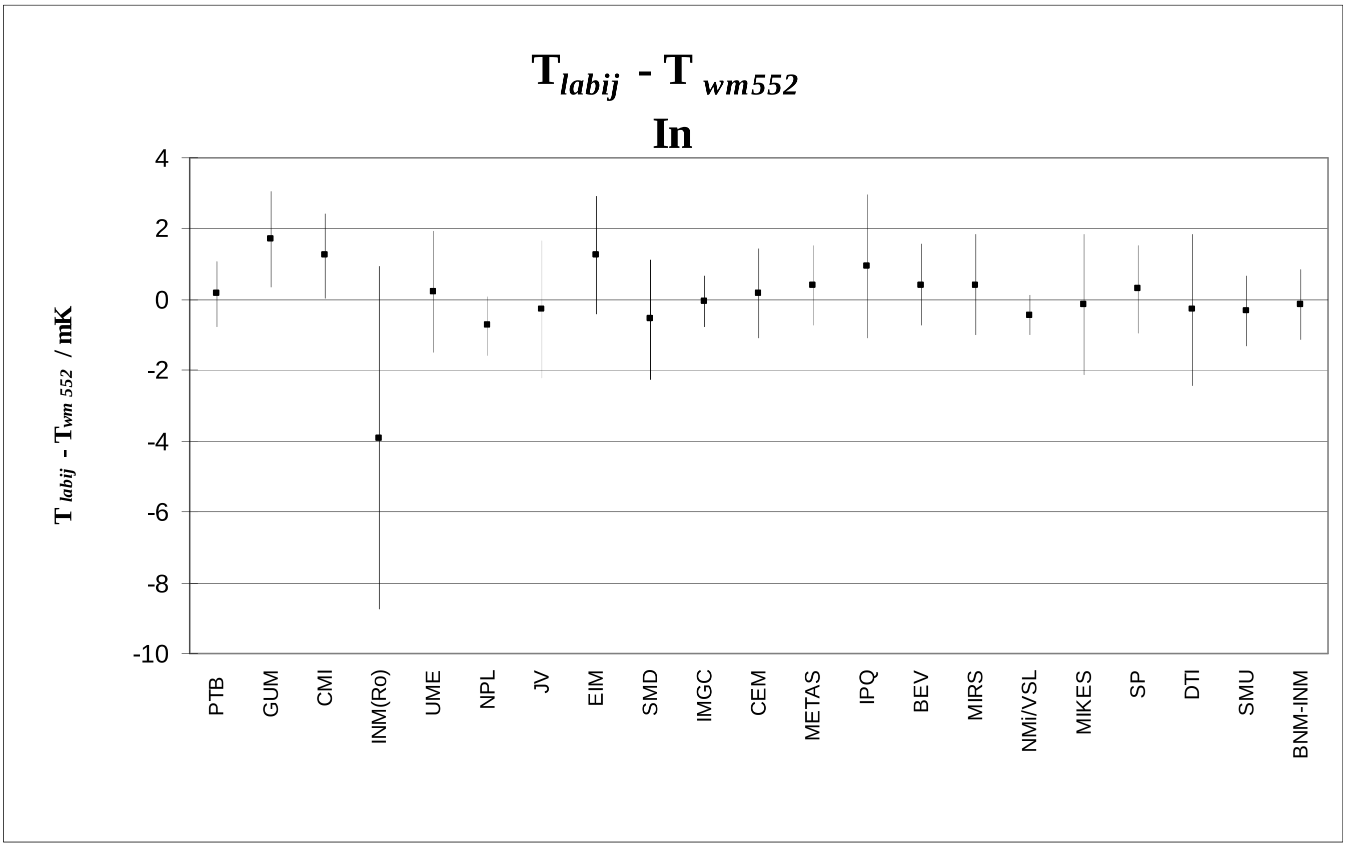
Lab	T_{Labij} - T_P mK	T_{Labij} - T_{wm552} mK	$U_{(TLabij-Twm552)}$ (k=2) mK
PTB	0,38	0,43	0,90
GUM	-0,43	-0,37	1,26
CMI	-0,06	0,00	0,95
INM(Ro)	-2,40	-2,34	2,72
UME	-0,21	-0,15	1,22
NPL	-0,34	-0,29	0,87
JV	-0,70	-0,65	1,45
EIM	-0,22	-0,16	1,42
SMD	-2,29	-2,24	1,22
NML	<0,01	0,06	1,59
IMGC	<0,01	0,06	0,95
CEM	0,55	0,61	1,43
METAS	0,63	0,69	1,07
IPQ	1,01	1,07	1,43
BEV	0,96	1,02	1,40
MIRS/FE-LMK	0,38	0,44	1,15
NMi/VSL	0,16	0,22	0,92
MIKES	-0,56	-0,50	1,34
VMT/PFI	-0,03	0,03	1,63
SP	-0,15	-0,09	1,20
DTI	-0,45	-0,39	1,98
SMU	0,12	0,18	1,39
OMH	0,15	0,20	1,90
BNM-INM	0,00	0,06	1,00

Standard uncertainty of $(T_{wm552} - T_P)$	0,12 mK
Expanded uncertainty of $(T_{wm552} - T_P)$ k=2	0,24 mK

93. Indium fixed point

For the indium fixed point the differences $\left(T_{Lab_{ij}} - T_{wm552}\right)$ and their associated expanded uncertainties (k=2, in K) can be found Table 18 and Figures 38 and 39.

Figure 38. Indium fixed point - Differences $\left(T_{Lab_{ij}} - T_{wm552}\right)$ and their associated expanded uncertainties (k=2)



<u>EIM Comment</u>
EIM (e-mail 07/02/05): "Our In49 cell was found in EUROMET project 712 to realize a temperature 0.65 mK higher than the BNM-INM/CNAM In114 cell"
<u>INM(Ro) Comment</u>
By an e-mail (18 March 2005), INM(Ro) requested that the INM(Ro) result at the indium point be excluded from the comparison. The difference from the mean is rather large; nevertheless it is less than the expanded uncertainty. So, there isn't any reason to consider it as an outlier. The participants decided (Workshop 8 April 2005) to keep it in the comparison and to present the results in two different graphs (with and without INM(Ro) results).

Figure 39. Indium fixed point - Differences $\left(T_{Lab_{ij}} - T_{wm552}\right)$ and their associated expanded uncertainties (k=2).

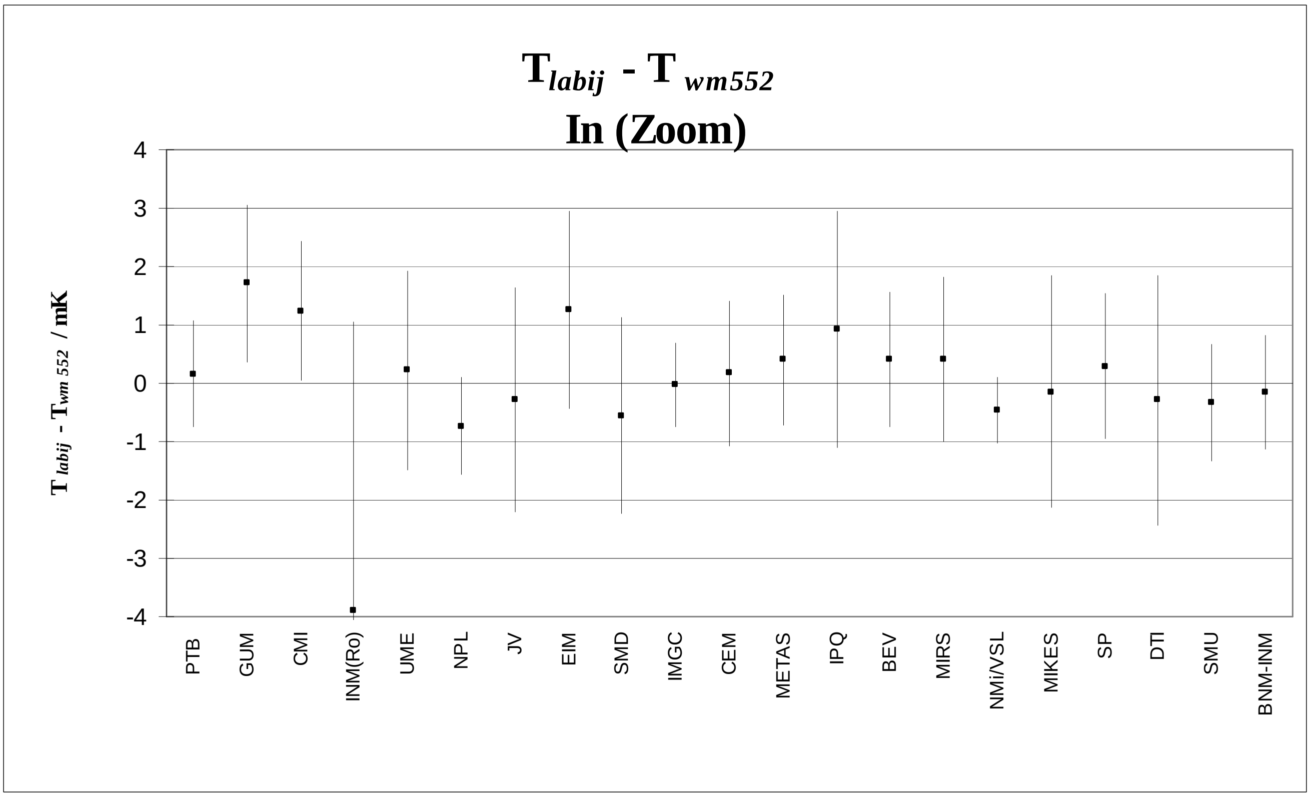


Table 18. Indium fixed point - Differences $\left(T_{Lab_{ij}} - T_{wm552}\right)$ and their associated expanded uncertainties (k=2)

Lab	T_{Labij} - T_P mK	T_{Labij} - T_{wm552} mK	$U_{(TLabij-Twm552)}$ (k=2) mK
PTB	0,32	0,16	0,92
GUM	1,86	1,71	1,35
CMI	1,40	1,24	1,18
INM(Ro)	-3,75	-3,90	4,95
UME	0,37	0,22	1,71
NPL	-0,58	-0,73	0,83
JV	-0,13	-0,28	1,92
EIM	1,41	1,25	1,68
SMD	-0,41	-0,56	1,68
IMGC	0,12	-0,03	0,72
CEM	0,32	0,17	1,25
METAS	0,56	0,40	1,12
IPQ	1,08	0,92	2,03
BEV	0,56	0,41	1,15
MIRS/FE-LMK	0,56	0,41	1,41
NMi/VSL	-0,30	-0,45	0,56
MIKES	0,01	-0,14	1,99
SP	0,44	0,29	1,24
DTI	-0,14	-0,29	2,14
SMU	-0,18	-0,33	0,99
BNM-INM	0,00	-0,15	0,99

Standard uncertainty of $(T_{wm552} - T_P)$	0,12 mK
Expanded uncertainty of $(T_{wm552} - T_P)$ k=2	0,24 mK

9.4. Gallium fixed point

For the gallium fixed point the differences $\left(T_{Lab_{ij}} - T_{wm552}\right)$ and their associated expanded uncertainties (k=2) can be found Table 19 and Figure 40.

Figure 40. Gallium fixed point - Differences $\left(T_{Lab_{ij}} - T_{wm552}\right)$ and their associated expanded uncertainties (k=2)

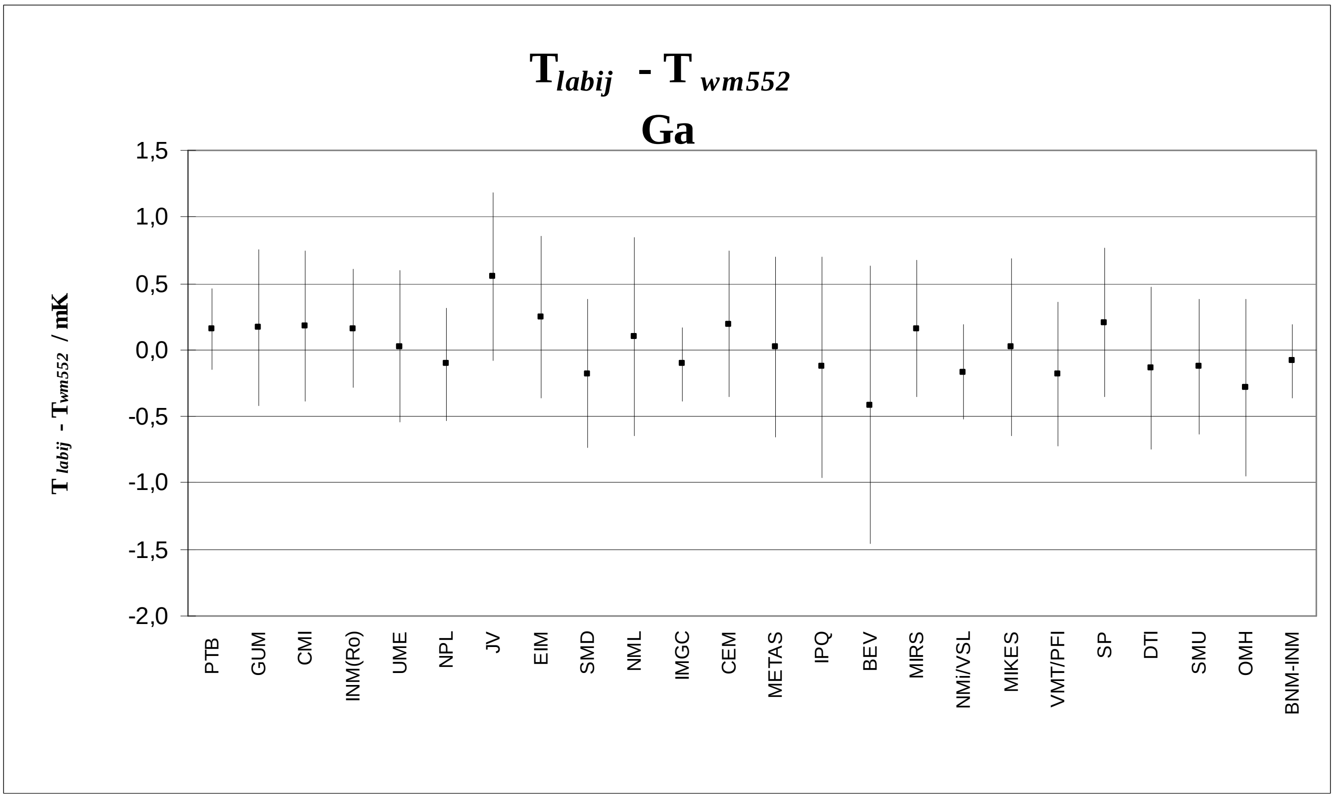


Table 19. Gallium fixed point - Differences $(T_{Lab_{ij}} - T_{wm552})$ and their associated expanded uncertainties (k=2)

Lab	T_{Labij} - T_P mK	T_{Labij} - T_{wm552} mK	$U_{(TLabij-Twm552)}$ (k=2) mK
PTB	0,24	0,15	0,30
GUM	0,25	0,17	0,59
CMI	0,26	0,18	0,56
INM(Ro)	0,25	0,16	0,44
UME	0,11	0,02	0,57
NPL	-0,02	-0,11	0,42
JV	0,64	0,55	0,63
EIM	0,34	0,25	0,61
SMD	-0,09	-0,18	0,56
NML	0,19	0,10	0,74
IMGC	-0,02	-0,11	0,28
CEM	0,28	0,20	0,55
METAS	0,11	0,02	0,68
IPQ	-0,04	-0,13	0,83
BEV	-0,33	-0,42	1,04
MIRS/FE-LMK	0,24	0,16	0,51
NMi/VSL	-0,08	-0,17	0,35
MIKES	0,11	0,02	0,67
VMT/PFI	-0,09	-0,18	0,54
SP	0,29	0,21	0,56
DTI	-0,05	-0,14	0,61
SMU	-0,04	-0,13	0,51
OMH	-0,20	-0,28	0,66
BNM-INM	0,00	-0,09	0,28

Standard uncertainty of $(T_{wm552} - T_P)$	0,05 mK
Expanded uncertainty of $(T_{wm552} - T_P)$ k=2	0,09 mK

9.5.Mercury fixed point

For the mercury fixed point the differences $\left(T_{Lab_{ij}} - T_{wm552}\right)$ and their associated expanded uncertainties (k=2) can be found Table 20 and Figure 41 and 42.

Figure 41. Mercury fixed point - Differences $\left(T_{Lab_{ij}} - T_{wm552}\right)$ and their associated expanded uncertainties (k=2)

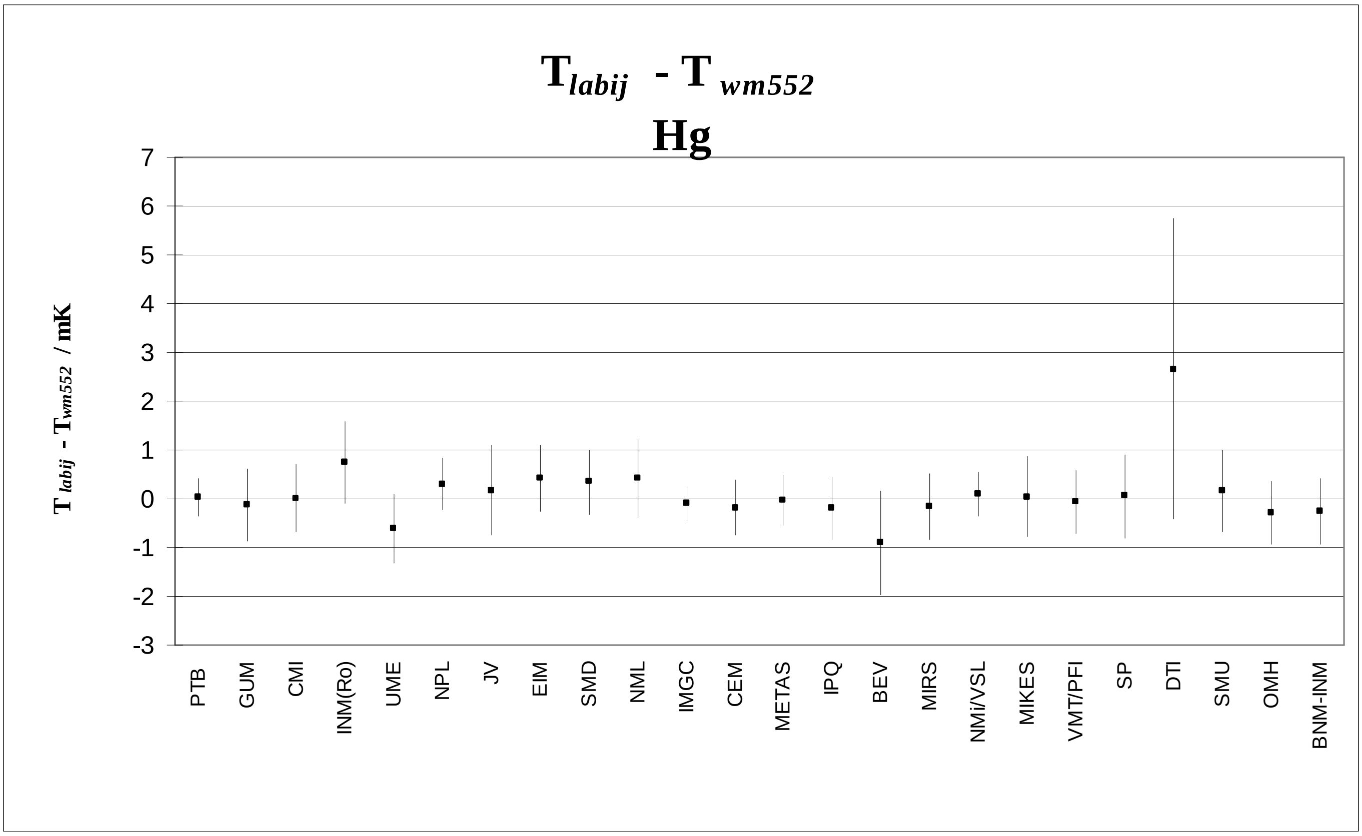


Figure 42. Mercury fixed point - Differences $\left(T_{Lab_{ij}} - T_{wm552}\right)$ and their associated expanded uncertainties (k=2).

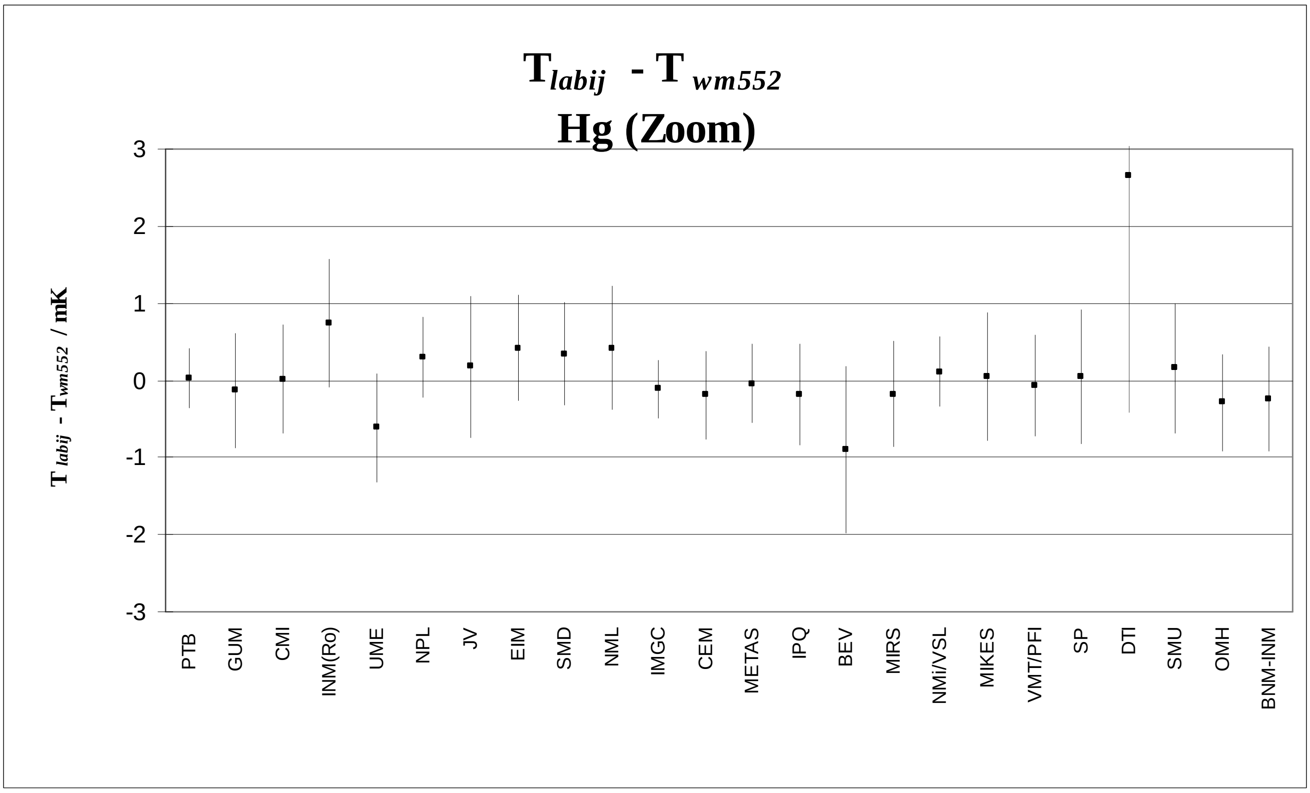


Table 20. Mercury fixed point - Differences $(T_{Lab_{ij}} - T_{wm552})$ and their associated expanded uncertainties (k=2)

Lab	T_{Lab} - T_P mK	T_{Lab} - T_{wm552} mK	$U_{(T-Twm552)}$ (k=2) mK
PTB	0,27	0,03	0,39
GUM	0,12	-0,13	0,74
CMI	0,26	0,01	0,70
INM(Ro)	0,99	0,74	0,84
UME	-0,37	-0,61	0,71
NPL	0,54	0,30	0,52
JV	0,42	0,17	0,91
EIM	0,66	0,42	0,69
SMD	0,59	0,34	0,67
NML	0,67	0,42	0,80
IMGC	0,13	-0,11	0,37
CEM	0,06	-0,19	0,57
METAS	0,21	-0,04	0,51
IPQ	0,06	-0,19	0,66
BEV	-0,65	-0,90	1,07
MIRS/FE-LMK	0,07	-0,17	0,68
NMi/VSL	0,36	0,11	0,45
MIKES	0,29	0,05	0,82
VMT/PFI	0,18	-0,07	0,65
SP	0,30	0,05	0,87
DTI	2,90	2,66	3,08
SMU	0,40	0,16	0,84
OMH	-0,04	-0,29	0,63
BNM-INM	0,00	-0,25	0,68

Standard uncertainty of $(T_{wm552} - T_P)$	0,06 mK
Expanded uncertainty of $(T_{wm552} - T_P)$ k=2	0,12 mK

9.6. Argon fixed point

For the argon fixed point the differences $\left(T_{Lab_{ij}} - T_{wm552}\right)$ and their associated expanded uncertainties (k=2) can be found Table 21 and Figure 43.

Figure 43. Argon fixed point - Differences $\left(T_{Lab_{ij}} - T_{wm552}\right)$ and their associated expanded uncertainties (k=2)

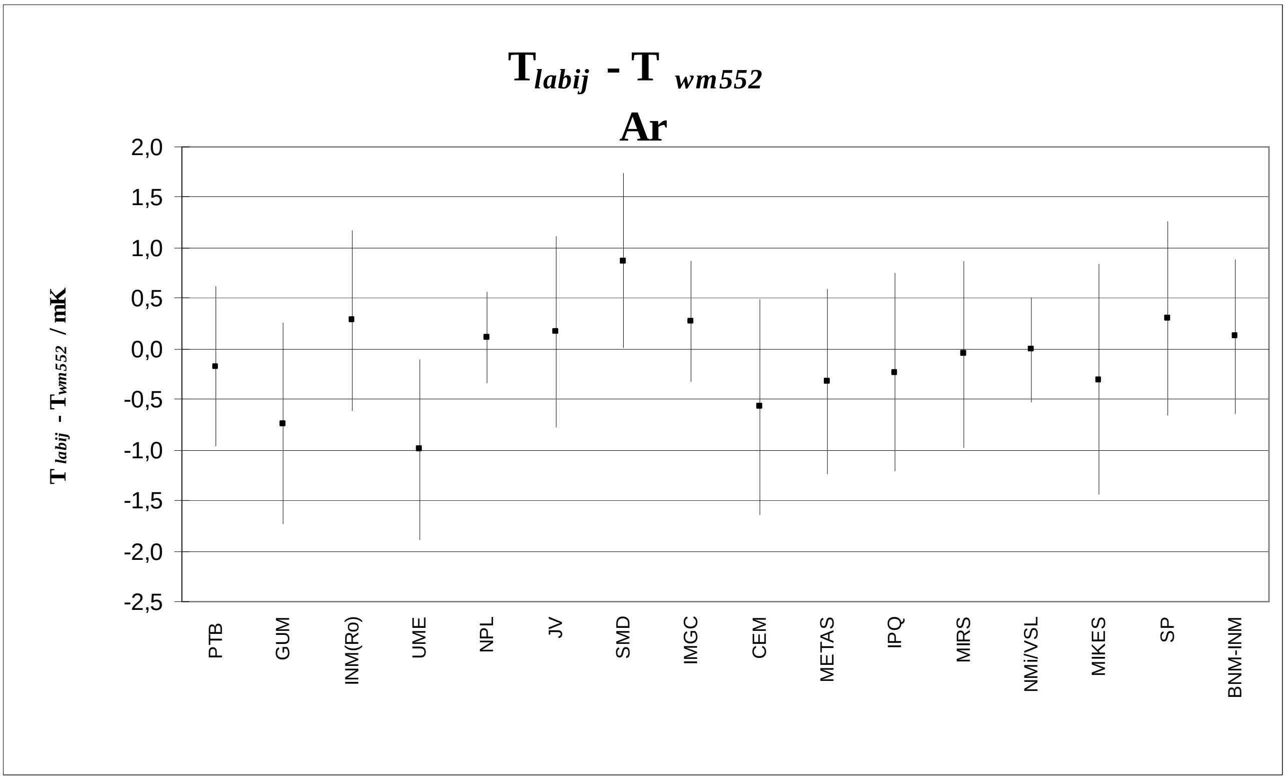


Table 21. Argon fixed point - Differences $\left(T_{Lab_{ij}} - T_{wm552}\right)$ and their associated expanded uncertainties (k=2)

Lab	T_{Labij} - T_P mK	T_{Labij} - T_{wm552} mK	$U_{(Tlabij-Twm552)}$ (k=2) mK
PTB	-0,30	-0,17	0,79
GUM	-0,86	-0,74	0,99
INM(Ro)	0,16	0,28	0,89
UME	-1,12	-1,00	0,89
NPL	-0,01	0,11	0,45
JV	0,05	0,17	0,94
SMD	0,75	0,87	0,86
IMGC	0,16	0,28	0,59
CEM	-0,70	-0,57	1,07
METAS	-0,44	-0,32	0,92
IPQ	-0,35	-0,23	0,98
MIRS/FE-LMK	-0,17	-0,05	0,92
NMi/VSL	-0,13	-0,01	0,52
MIKES	-0,43	-0,30	1,14
SP	0,17	0,30	0,96
BNM-INM	0,00	0,12	0,77

Standard uncertainty of $(T_{wm552} - T_P)$	0,09 mK
Expanded uncertainty of $(T_{wm552} - T_P)$ k=2	0,18 mK

10. Linkage between EUROMET 552 and CCT-K3

10.1 Hypothesis

We propose to use a group of "linking laboratories composed by the pilot and the co-pilots in order to link EUROMET 552" to CCT-K3. The hypothesis is that the mean temperature of the pilot and co-pilot laboratories is the same in EUROMET 552 as it was in CCT-K3:

$$\left(\frac{T_{BNM-INM}+T_{PTB}+T_{IMGC}+T_{NPL}+T_{NMi}+T_{SMU}}{6}\right)_{CCT-K3} = \left(\frac{T_{BNM-INM}+T_{PTB}+T_{IMGC}+T_{NPL}+T_{NMi}+T_{SMU}}{6}\right)_{EUROMET552}$$

$$\left(T_{(CP\&P)mean}\right)_{EUROMET552} = \left(T_{(CP\&P)mean}\right)_{CCT-K3}$$

In order to verify this hypothesis we can compare

$$T_{(P\ or\ CP_j)_{EUROMET\,552}} - \left(\frac{T_{BNM-INM}+T_{PTB}+T_{IMGC}+T_{NPL}+T_{NMi}+T_{SMU}}{6}\right)_{EUROMET\,552}$$

and

$$T_{(P\ or\ CP_j)_{\text{CCT-K3}}} - \left(\frac{T_{BNM-INM}+T_{PTB}+T_{IMGC}+T_{NPL}+T_{NMi}+T_{SMU}}{6}\right)_{CCT-K3}$$

In EUROMET 552

$$T_{(P\ or\ CP_j)_{EUROMET552}} - \left(\frac{T_{BNM-INM}+T_{PTB}+T_{IMGC}+T_{NPL}+T_{NMi}+T_{SMU}}{6}\right)_{EUROMET552}$$

$$= \left(T_{(P\ or\ CP_j)_{EUROMET552}} - T_{wm552}\right) - \frac{(T_{BNM-INM}-T_{wm552})+(T_{PTB}-T_{wm552})+(T_{IMGC}-T_{wm552})+(T_{NPL}-T_{wm552})+(T_{NMi-VSL}-T_{wm552})+(T_{SMU}-T_{wm552})}{6}$$

In the same way in CCT-K3

$$T_{(P\ or\ CP_j)_{CCT-K3}} - \left(\frac{T_{BNM-INM}+T_{PTB}+T_{IMGC}+T_{NPL}+T_{NMi}+T_{SMU}}{6}\right)_{CCT-K3}$$

$$= \left(T_{(P\ or\ CP_j)_{CCt-K3}} - ARVK3\right) - \left(\frac{(T_{BNM-INM}-ARVK3)+(T_{PTB}-ARVK3)+(T_{IMGC}-ARVK3)+(T_{NPL}-ARVK3)+(T_{NMi}-ARVK3)+(T_{SMU}-ARVK3)}{6}\right)$$

The values of ($T_{BNM-INM}$ – *ARVK3*), (T_{PTB} – *ARVK3*), (T_{IMGC} – *ARVK3*), (T_{NPL} – *ARVK3*), (T_{NMi} - *ARVK3*), (T_{SMU} – *ARVK3*), are extracted from the minutes of the meeting of the CCT WG8 (11-12 December 2003, Delft, The Netherlands). The differences $(T_{(PorCPj)} - T_{(CPj\&P)mean})$ in EUROMET 552 and CCT-K3 are tabulated in Tables 22 to 28 and plotted in Figures 36 to 41. The tables and figures also include the ranges of values according to the uncertainties affected to their results by the pilot and the co-pilot laboratories in CCT-K3 and EUROMET 552.

Table 22 . Zinc fixed point. Comparison of the results of the "linking laboratories" in EUROMET 552 and CCT-K3.

Lab	$[T(_{PorCPj}) - T(_{P\&CPj})_{mean}]-U$ mK	$[T(_{PorCPj}) - T(_{P\&CPj})_{mean}]+U$ mK	$[T(_{PorCPj}) - T(_{P\&CPj})_{mean}]$ mK
PTB/K3	-1,94	0,70	-0,62
PTB/552	-1,66	1,02	-0,32
NPL/ K3	-0,45	1,31	0,43
NPL/552	-1,66	0,54	-0,56
IMGC/K3	-1,57	0,11	-0,73
IMGC/552	-1,49	0,97	-0,26
NMi-VSL/K3	-0,70	1,22	0,26
NMi-VSL/552	-1,55	0,25	-0,65
SMU/K3	-0,90	1,10	0,10
SMU/552	-0,09	1,63	0,77
BNM-INM/K3	-0,72	1,84	0,56
BNM-INM/552	-0,28	2,32	1,02

$(ARVK3-T_{(P\&CPj)}\ mean)$	in mK	-0,06
$(T(_{wm552})-T(_{P\&CPj})_{mean})$	in mK	0,17

Figure 36 . Zinc fixed point. Comparison of the results of the "linking laboratories" in EUROMET 552 and CCT-K3.

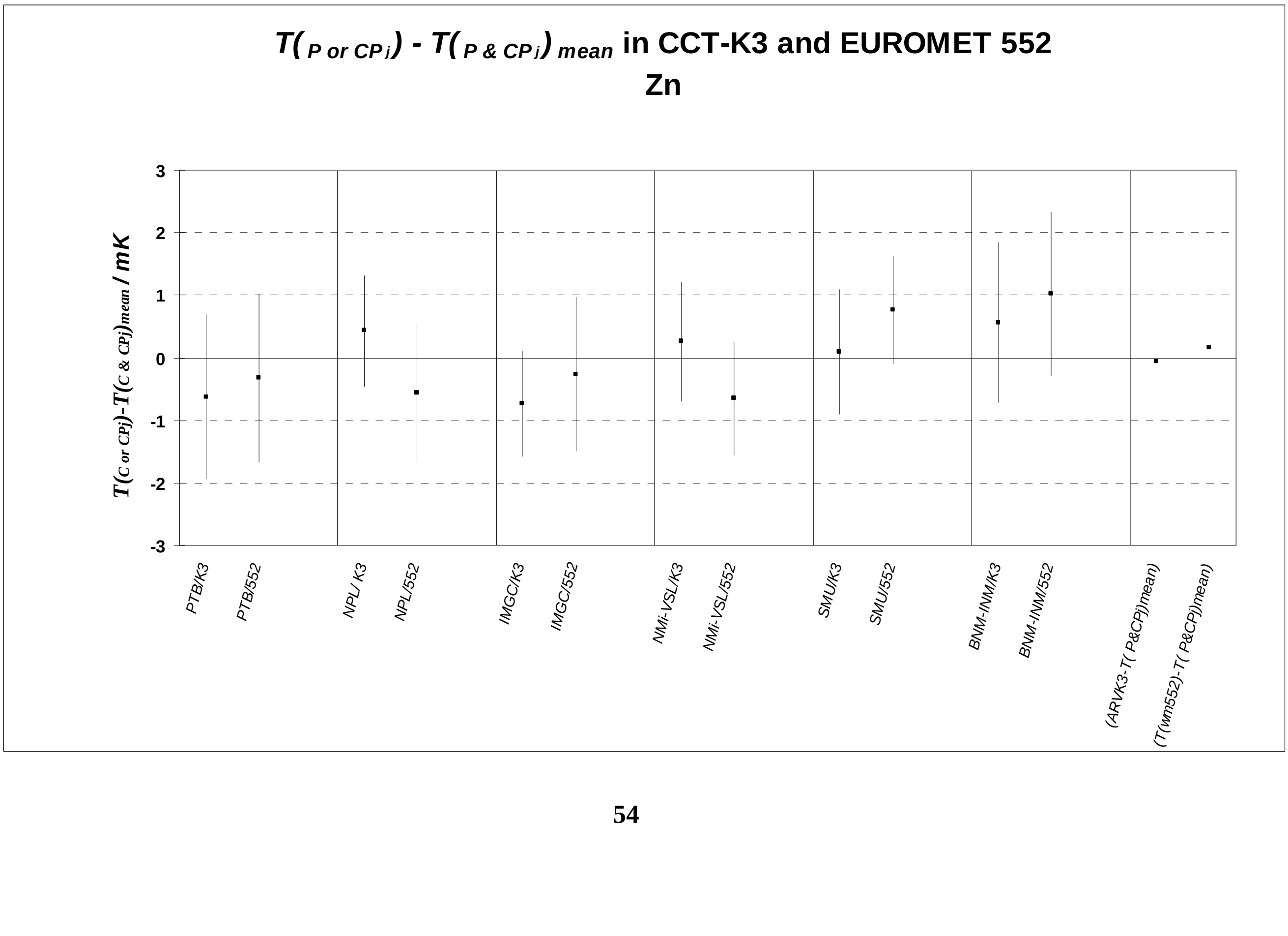


Table 23 . Tin fixed point. Comparison of the results of the "linking laboratories" in EUROMET 552 and CCT-K3.

Lab	$[T(_{PorCPj}) - T(_{P\&CPj})_{mean}]-U$ mK	$[T(_{PorCPj}) - T(_{P\&CPj})_{mean}]+U$ mK	$[T(_{PorCPj}) - T(_{P\&CPj})_{mean}]$ mK
PTB/K3	-0,51	1,33	0,41
PTB/552	-0,52	1,17	0,33
NPL/ K3	-0,80	0,68	-0,06
NPL/552	-1,27	0,48	-0,40
IMGC/K3	-0,34	0,50	0,08
IMGC/552	-0,79	0,68	-0,06
NMi-VSL/K3	-0,96	0,52	-0,22
NMi-VSL/552	-0,60	0,81	0,11
SMU/K3	-0,98	1,14	0,08
SMU/552	-0,85	1,00	0,08
BNM-INM/K3	-1,35	0,77	-0,29
BNM-INM/552	-1,01	0,90	-0,06

$(ARVK3-T_{(P\&CPj)}\ mean)$	in mK	-0,25
$(T(_{wm552})-T(_{P\&CPj})_{mean})$	in mK	-0,11

Figure 37 . Tin fixed point. Comparison of the results of the "linking laboratories" in EUROMET 552 and CCT-K3.

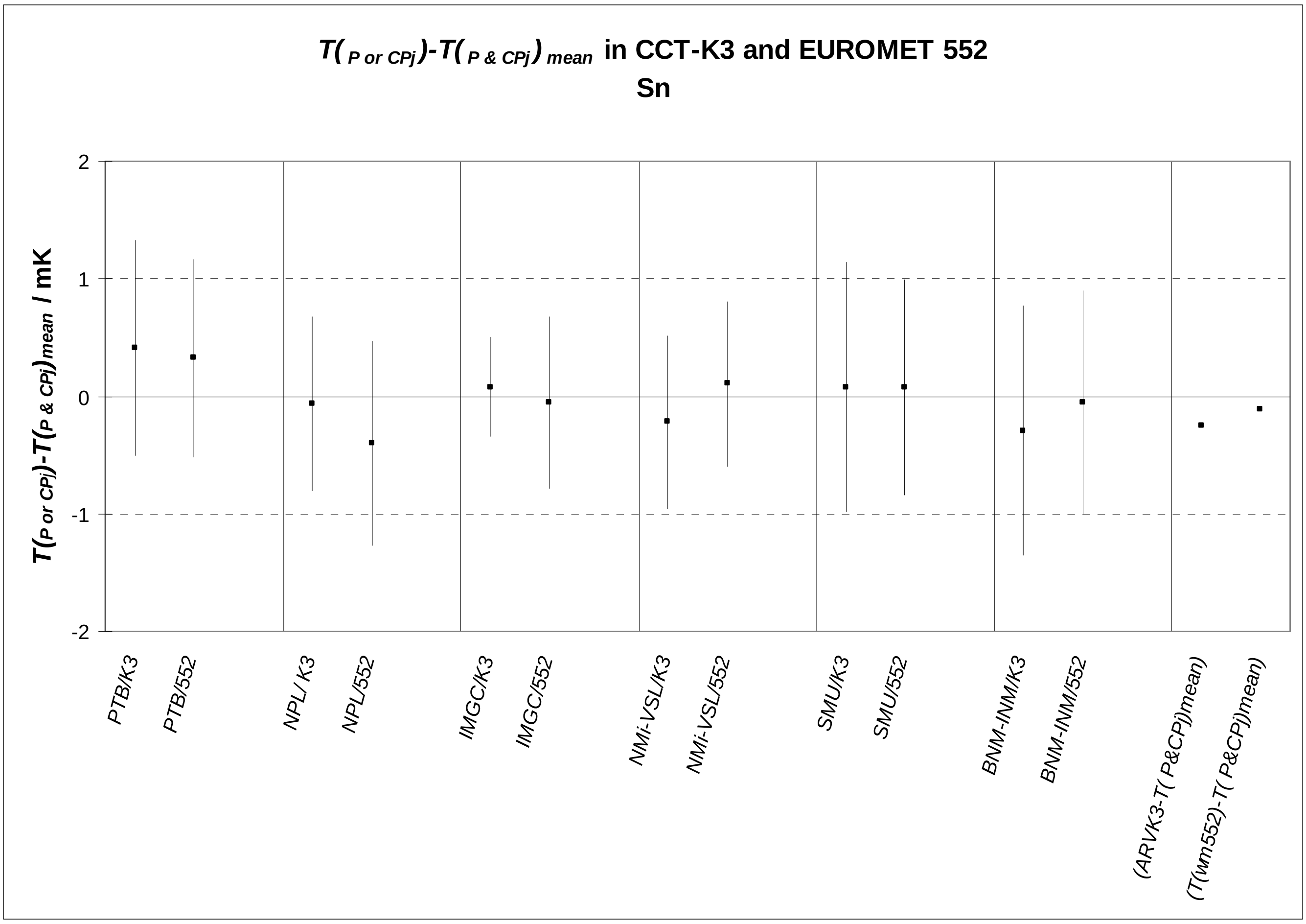


Table 24 . Indium fixed point. Comparison of the results of the “linking laboratories” in EUROMET 552 and CCT-K3.

Lab	$[T(_{PorCPj}) - T(_{P\&CPj})_{mean}]-U$ mK	$[T(_{PorCPj}) - T(_{P\&CPj})_{mean}]+U$ mK	$[T(_{PorCPj}) - T(_{P\&CPj})_{mean}]$ mK
PTB/K3	-0,87	1,49	0,31
PTB/552	-0,46	1,26	0,40
NPL/ K3	-0,76	0,64	-0,06
NPL/552	-1,27	0,29	-0,49
IMGC/K3	-0,26	0,98	0,36
IMGC/552	-0,42	0,84	0,21
NMi-VSL/K3	-1,26	0,06	-0,60
NMi-VSL/552	-0,71	0,29	-0,21
BNM-INM/K3	-0,67	0,65	-0,01
BNM-INM/552	-0,85	1,03	0,09

$(ARVK3-T_{(P\&CPj)}\ mean)$	in mK	0,16
$(T(_{wm552})-T(_{P\&CPj})_{mean})$	in mK	0,24

Figure 38 . Indium fixed point. Comparison of the results of the “linking laboratories” in EUROMET 552 and CCT-K3.

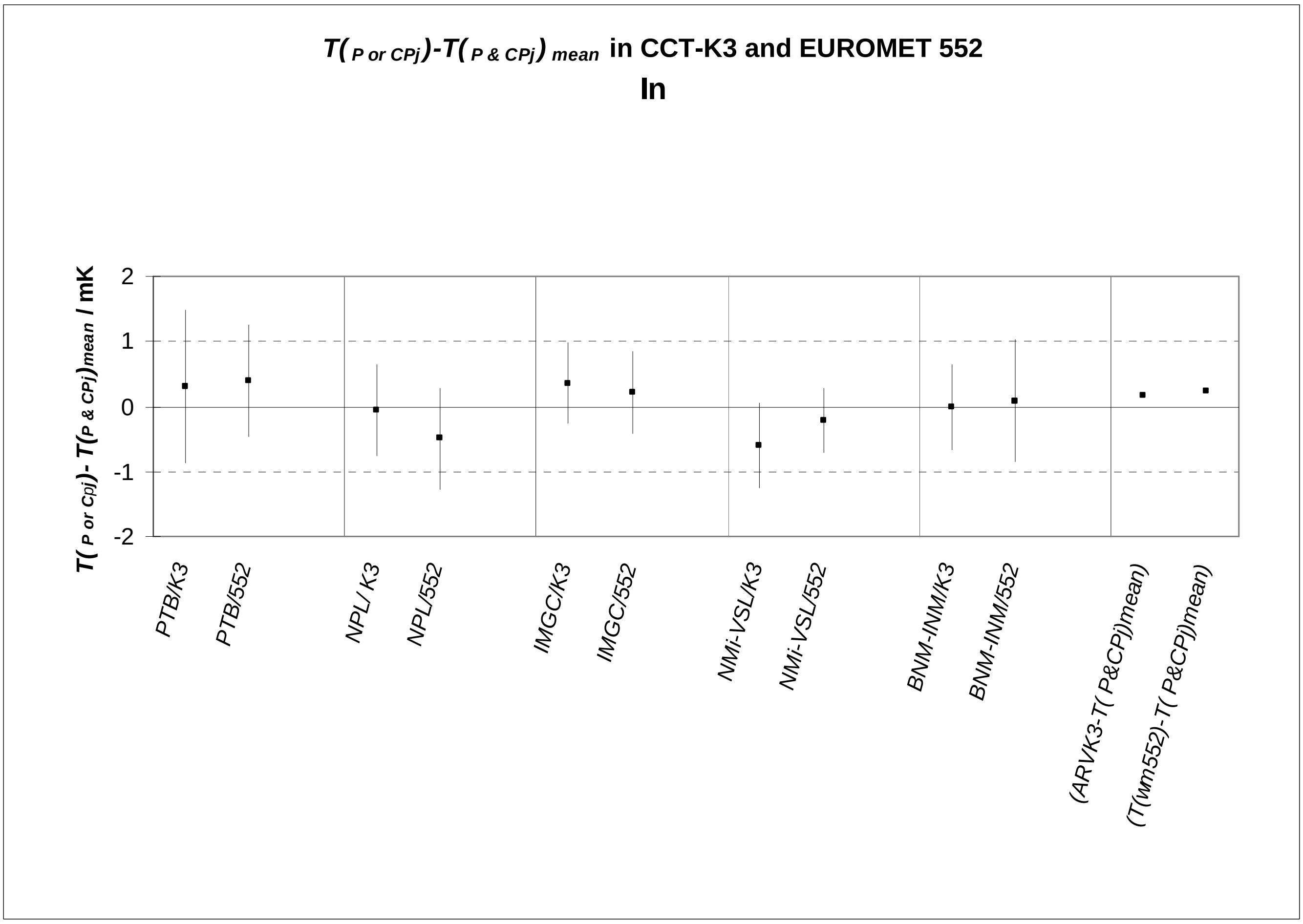


Table 25 . Gallium fixed point. Comparison of the results of the "linking laboratories" in EUROMET 552 and CCT-K3.

Lab	$[T(_{PorCPj}) - T(_{P\&CPj})_{mean}]-U$ mK	$[T(_{PorCPj}) - T(_{P\&CPj})_{mean}]+U$ mK	$[T(_{PorCPj}) - T(_{P\&CPj})_{mean}]$ mK
PTB/K3	-0,04	0,48	0,22
PTB/552	-0,04	0,50	0,23
NPL/ K3	-0,59	0,29	-0,15
NPL/552	-0,40	0,32	-0,04
IMGC/K3	-0,01	0,23	0,11
IMGC/552	-0,21	0,13	-0,04
NMi-VSL/K3	-0,63	0,21	-0,21
NMi-VSL/552	-0,40	0,20	-0,10
SMU/K3	-0,16	0,28	0,06
SMU/552	-0,28	0,16	-0,06
BNM-INM/K3	-0,31	0,29	-0,01
BNM-INM/552	-0,33	0,31	-0,01

$(ARVK3\text{-}T_{(P\&CPj)}\,mean)$	in mK	-0,02
$(T(_{wm552})\text{-}T(_{P\&CPj})_{mean})$	in mK	0,08

Figure 39. Gallium fixed point. Comparison of the results of the "linking laboratories" in EUROMET 552 and CCT-K3.

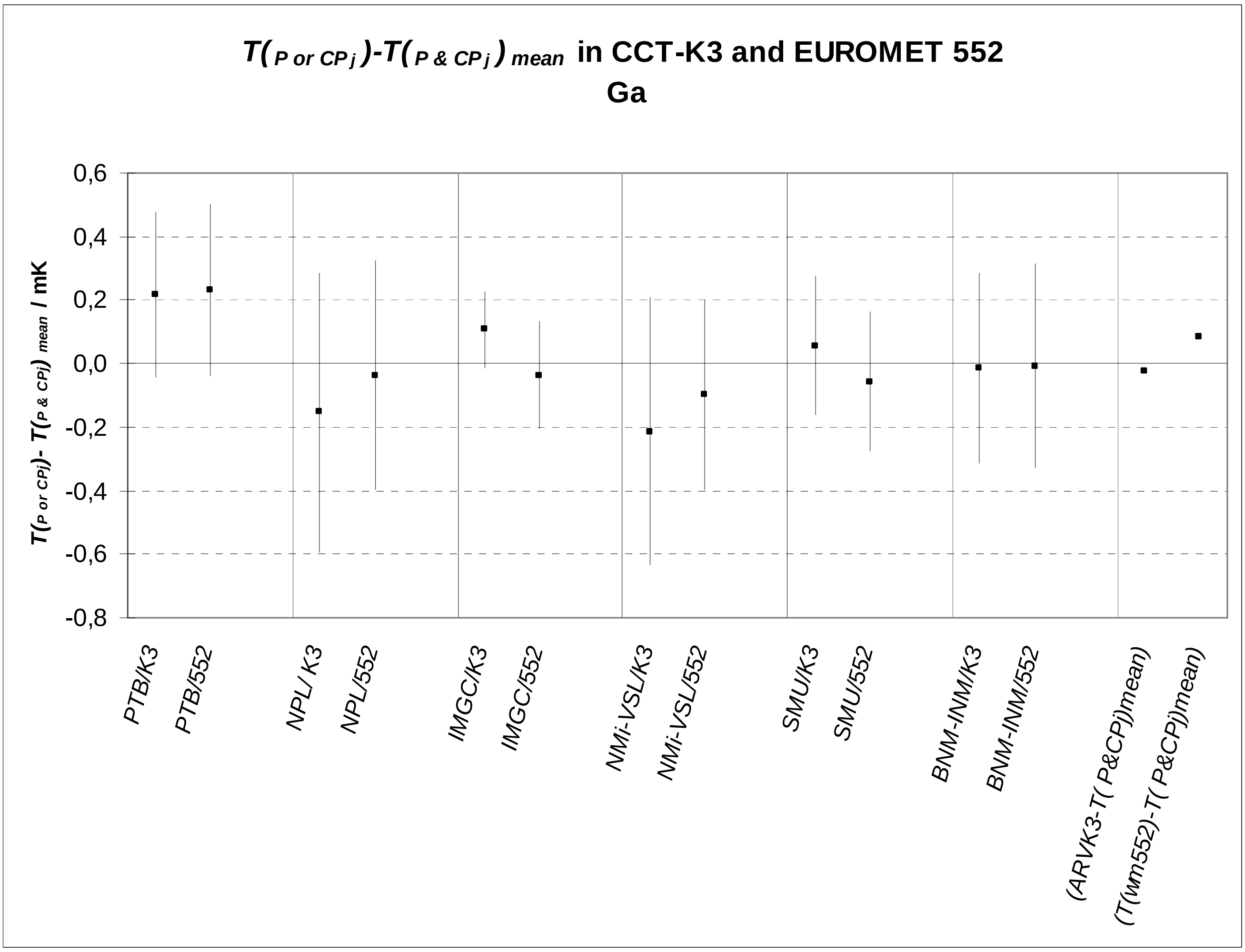


Table 26 . Mercury fixed point. Comparison of the results of the "linking laboratories" in EUROMET 552 and CCT-K3.

Lab	$[T(_{PorCPj}) - T(_{P\&CPj})_{mean}]-U$ mK	$[T(_{PorCPj}) - T(_{P\&CPj})_{mean}]+U$ mK	$[T(_{PorCPj}) - T(_{P\&CPj})_{mean}]$ mK
PTB/K3	-0,28	0,32	0,02
PTB/552	-0,27	0,29	0,01
NPL/ K3	-0,24	0,60	0,18
NPL/552	-0,08	0,64	0,28
IMGC/K3	-0,28	0,24	-0,02
IMGC/552	-0,39	0,13	-0,13
NMi-VSL/K3	-0,29	0,51	0,11
NMi-VSL/552	-0,21	0,35	0,09
BNM-INM/K3	-0,88	0,28	-0,30
BNM-INM/552	-0,89	0,35	-0,27

$(ARVK3-T_{(P\&CPj)}\ mean)$	in mK	0,12
$(T(_{wm552})-T(_{P\&CPj})_{mean})$	in mK	-0,02

Figure 40 . Mercury fixed point. Comparison of the results of the "linking laboratories" in EUROMET 552 and CCT-K3.

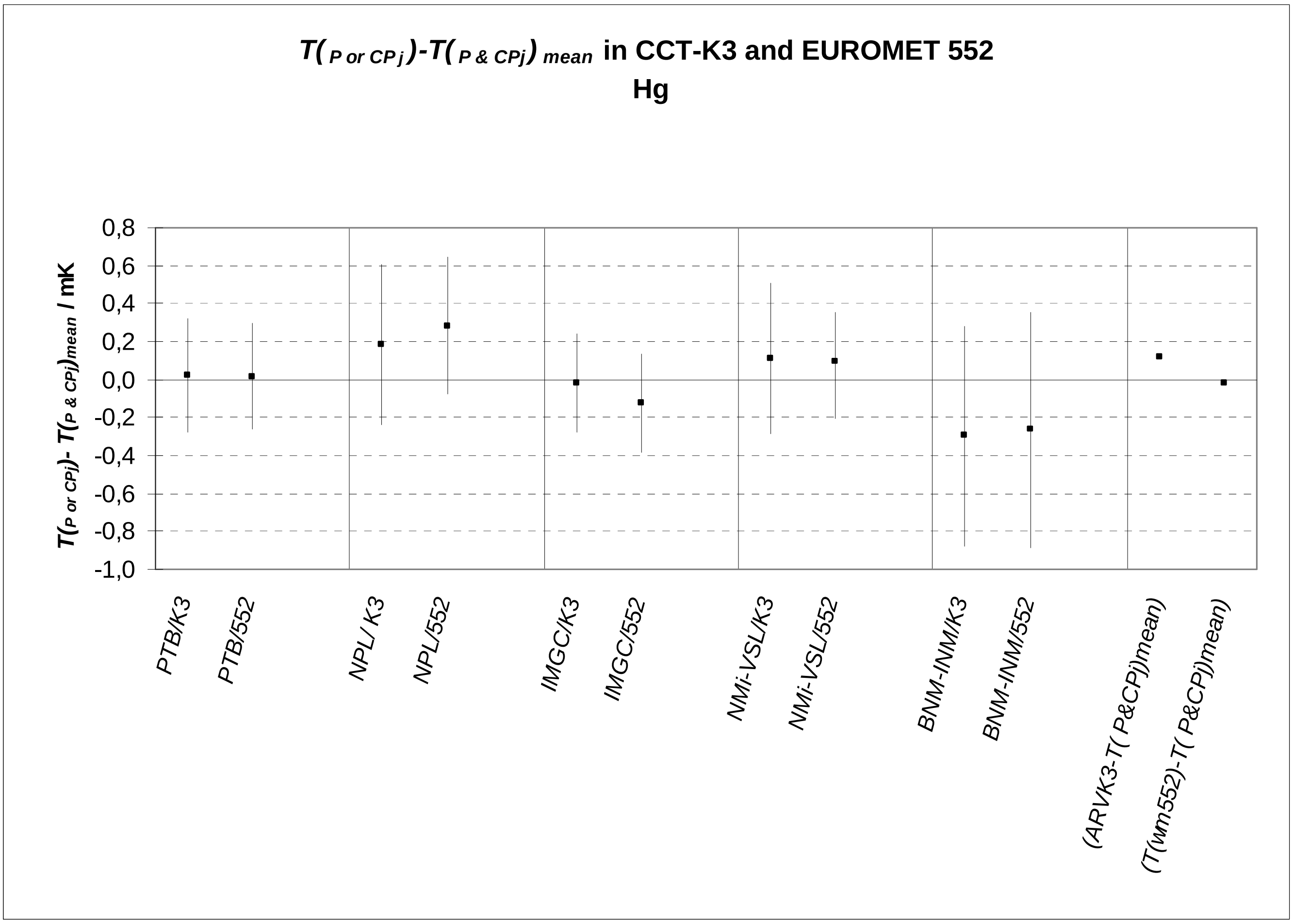
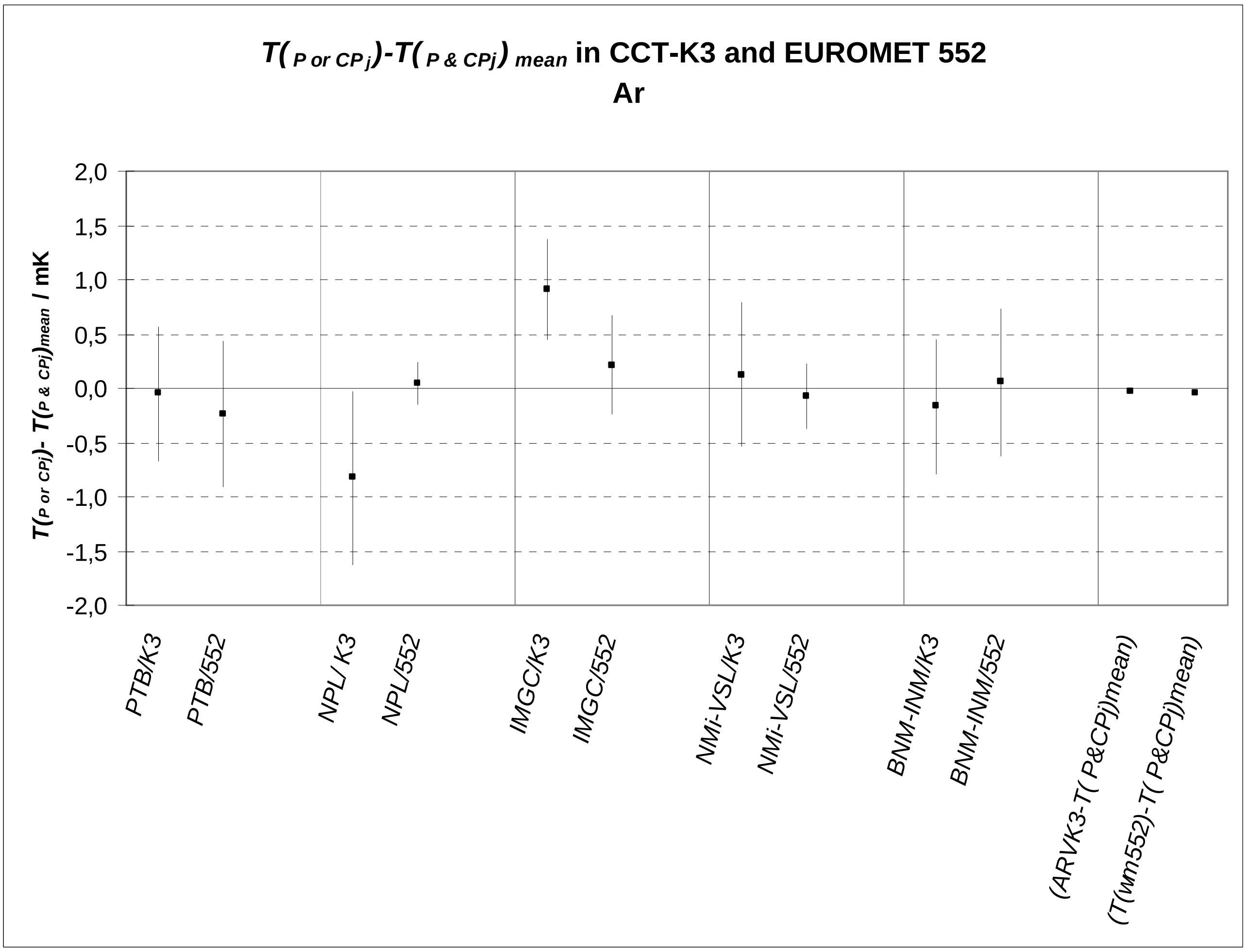


Table 27 . Argon fixed point. Comparison of the results of the "linking laboratories" in EUROMET 552 and CCT-K3.

Lab	$[T(_{PorCPj}) - T(_{P\&CPj})_{mean}]-U$ mK	$[T(_{PorCPj}) - T(_{P\&CPj})_{mean}]+U$ mK	$[T(_{PorCPj}) - T(_{P\&CPj})_{mean}]$ mK
PTB/K3	-0,67	0,57	-0,05
PTB/552	-0,91	0,43	-0,24
NPL/ K3	-1,63	-0,03	-0,83
NPL/552	-0,16	0,24	0,04
IMGC/K3	0,45	1,37	0,91
IMGC/552	-0,25	0,67	0,21
NMi-VSL/K3	-0,54	0,78	0,12
NMi-VSL/552	-0,38	0,22	-0,08
BNM-INM/K3	-0,79	0,45	-0,17
BNM-INM/552	-0,63	0,73	0,05

$(ARVK3-T_{(P\&CPj)}\ mean)$	in mK	-0,03
$(T(_{wm552})-T(_{P\&CPj})_{mean})$	in mK	-0,07

Figure 41 . Argon fixed point. Comparison of the results of the "linking laboratories" in EUROMET 552 and CCT-K3.



It can be seen that even when the results given by one or several members of the "linking laboratories" are not positioned in the same place in EUROMET 552 and CCT-K3 the mean calculated for the group is really reproducible.
The difference between *(ARVK3-$T_{(P\&CPj)mean}$)* and *($T_{(wm552)}$-$T_{(P\&CPj)mean}$)* is generally equal or smaller than 0.1 mK except at the Zinc (0.23 mK) and Tin (0.14 mK) fixed points.

10.2 Uncertainty linked with the reproducibility of $T_{(P\ or\ CP_j)_{mean}}$

We suggest to estimate the uncertainty linked to the reproducibility of $T_{(P\&CPj)mean}$ from the reproducibility of the members of this group:

$$D_{(P\ or\ CP_j)} = \left[T_{(P\ or\ CP_j)_{EUROMET552}} - \left(\frac{T_{BNM-INM} + T_{PTB} + T_{IMGC} + T_{NPL} + T_{NMi} + T_{SMU}}{6}\right)_{EUROMET552}\right] - \left[T_{(P\ or\ CP_j)_{CCT-K3}} - \left(\frac{T_{BNM-INM} + T_{PTB} + T_{IMGC} + T_{NPL} + T_{NMi} + T_{SMU}}{6}\right)_{CCT-K3}\right]$$

The uncertainty is obtained using the value of D associated with a rectangular distribution:

$$u_{reprod\ (PorCp_j)} = \frac{\left|D_{(P\ or\ Cp_j)}\right|}{2\sqrt{3}}$$

The uncertainty due to the reproducibility of $T_{(P\&CPj)mean}$ is obtained from:

$$u_{reprod\ (P\&CP_j)mean} = \frac{1}{6}\cdot\sqrt{u^2_{reprodBNM-INM} + u^2_{reprodPTB} + u^2_{reprodIMGC} + u^2_{reprodNPL} + u^2_{reprodNMi} + u^2_{reprodSMU}}$$

The table 28 gives for each fixed point the uncertainty associated with the reproducibility of each member of this group and the one related to $T_{(P\&CPj)mean}$

Table 28: Uncertainty derived from the reproducibility of each member of the "linking laboratories" group. Uncertainty on $T_{(P\&CPj)mean}$

Fixed point	BNM-INM	PTB	IMGC	SMU	NPL	NMi-VSL	$.u_{reprod\ (P\&Cpj)mean}$	$U_{reprod\ (P\&Cpj)mean}$ k=2
Zn	0.14	0.09	0.14	0.20	0.29	0.27	0.08	0.16
Sn	0.07	0.03	0.04	<0.01	0.10	0.10	0.03	0.05
In	0.03	0.03	0.04	/	0.13	0.11	0.04	0.07
Ga	<0.01	<0.01	0.04	0.03	0.03	0.03	0.01	0.02
Hg	<0.01	<0.01	0.03	/	0.03	<0.01	0.01	0.02
Ar	0.07	0.06	0.21	/	0.26	0.06	0.07	0.14

11. Bilateral Equivalence

11.1 Bilateral Equivalence for a direct comparison between two participants in the same loop of EUROMET 552

The degree of equivalence between the EUROMET participating laboratories in the same loop can be calculated from the results Table 16 to 22.

$$\left(T_{Lab_{ij}} - T_{Lab_{hj(h\neq i)}}\right) = \left(T_{Lab_{ij}} - T_{wm552}\right) - \left(T_{Lab_{hj(h\neq i)}} - T_{wm552}\right)$$

Which then leads to the uncertainty formula

$$u_{\left(T_{Lab_{ij}} - T_{Lab_{hj(h\neq i)}}\right)} = \sqrt{u^2_{T_{Lab_{ij}}} + u^2_{T_{Lab_{hj(h\neq i)}}} + u^2_{stabSPRT\ j}}$$

It is possible to calculate $u_{\left(T_{Lab_{ij}} - T_{Lab_{hj(h\neq i)}}\right)}$ from $u_{\left(T_{Lab_{ij}} - T_{wm552}\right)}$ and $u_{\left(T_{Lab_{hj(h\neq i)}} - T_{wm552}\right)}$

$$u_{\left(T_{Lab_{ij}} - T_{Lab_{hj(h\neq i)}}\right)} = \sqrt{u^2_{(T_{Lab_{ij}} - T_{wm552})} + u^2_{(T_{Lab_{hj(h\neq i)}} - T_{wm552})} - \left[\ 2\cdot\left(u^2_{(T_{wm552} - T_P\ )} + u^2_{reproducibilityT_p}\right) + u^2_{stabSPRT\ j}\right]}$$

The expanded uncertainty *U* (95%) is given by:

$$U_{\left(T_{Lab_{ij}} - T_{Lab_{hj(h\neq i)}}\right)} = 2\cdot\sqrt{u^2_{(T_{Lab_{ij}} - T_{wm552})} + u^2_{(T_{Lab_{hj(h\neq i)}} - T_{wm552})} - \left[\ 2\cdot\left(u^2_{(T_{wm552} - T_P)} + u^2_{reproducibilityT_p}\right) + u^2_{stabSPRT\ j}\right]}$$

$$U_{\left(T_{Lab_{ij}} - T_{Lab_{hj(h\neq i)}}\right)} = \sqrt{U^2_{(T_{Lab_{ij}} - T_{wm552})} + U^2_{(T_{Lab_{hj(h\neq i)}} - T_{wm552})} - \mathrm{A}}$$

with

$$A = \left[\ 2\cdot\left(U^2_{(T_{wm552} - T_P)} + U^2_{reproducibilityT_p}\right) + U^2_{stabSPRT\ j}\right]$$

The values of A according to the fixed point and the loop considered are given Table 29.

Table 29 . Values of A

Fixed point	Loop 1 A in mK^2	Loop 2 A in mK^2	Loop 3 A in mK^2	Loop 4 A in mK^2	Loop 5 A in mK^2
Ar	""""	0,187	0,222	0,222	0,209
Hg	0,269	0,123	0,166	0,128	0,199
Ga	0,226	0,065	0,177	0,036	0,065
In	0,136	0,184	0,126	0,164	0,142
Sn	1,212	0,482	0,504	0,216	0,270
Zn	1,142	2,486	1,834	0,426	1,420

Example: Determination of the bilateral equivalence at the Sn fixed point between METAS and IPQ (these two laboratories are involved in loop 2)

$$\left(T_{METAS}-T_{IPQ}\right)=\left(T_{METAS}-T_{wm552}\right)-\left(T_{IPQ}-T_{wm552}\right)=0.68\,\text{mK}-1.06\,\text{mK}=-0.38\,\text{mK}$$

$$U_{\left(T_{METAS}-T_{IPQ}\right)}=\sqrt{U^2_{\left(T_{METAS}-T_{wm552}\right)}+U^2_{\left(T_{IPQ}-T_{wm552}\right)}-\text{A}_{\text{Sn loop2}}}$$

$$U_{\left(T_{METAS}-T_{IPQ}\right)}=\sqrt{(1.07)^2+(1.44)^2-0.482}=1.65\,\text{mK}$$

11.2 Bilateral Equivalence for a direct comparison between two participants in different loops of EUROMET 552

The degree of equivalence between the EUROMET participating laboratories in different loops can be calculated from the results Table 16 to 22.

$$\left(T_{Lab_{ij}}-T_{Lab_{hg(g\neq j)}}\right)=\left(T_{Lab_{ij}}-T_{wm552}\right)-\left(T_{Lab_{hg(g\neq j)}}-T_{wm552}\right)$$

$T_{Lab_{hg(g\neq j)}}$: value measured by the lab *h* in the loop *g*

g = 1…..5
$h = 1….N_g$ lab index in loop *g*

$$u_{\left(T_{Lab_{ij}}-T_{Lab_{hg(g\neq j)}}\right)}=\sqrt{u^2_{T_{Lab_{ij}}}+u^2_{T_{Lab_{hg(g\neq j)}}}+u^2_{StabSPRT\ j}+u^2_{StabSPRT\ g}+u^2_{reproducibilityT\ P}}$$

The uncertainty can also be determined using $u_{\left(T_{Lab_{ij}}-T_{wm552}\right)}$ and $u_{\left(T_{Lab_{ig}}-T_{wm552}\right)}$

$$u_{\left(T_{Lab_{ij}}-T_{Lab_{ig(g\neq j)}}\right)}=\sqrt{u^2_{\left(T_{Lab_{ij}}-T_{wm552}\right)}+u^2_{\left(T_{Lab_{ig(g\neq j)}}-T_{wm552}\right)}-\left(2.u^2_{\left(T_{wm552}-T_P\right)}+u^2_{reproducibilityT\ P}\right)}$$

Finally, the expanded uncertainty U (95%) is given by:

$$U_{\left(T_{Lab_{ij}}-T_{Lab_{hj(h\neq i)}}\right)}=\sqrt{U^2_{(T_{Lab_{ij}}-T_{wm552})}+U^2_{(T_{Lab_{hj(h\neq i)}}-T_{wm552})}-\mathrm{B}}$$

with

$$B=\left\lfloor 2\cdot\left(U^2_{(T_{wm552}-T_P)}\right)+U^2_{reproducibilityT_p}\right\rfloor$$

The values of B according to the fixed point are given Table 30.

Table 30 . Values of B

Fixed point	B in mK^2
Ar	0.29
Hg	0.16
Ga	0.12
In	0.03
Sn	0.07
Zn	0.08

Example: Determination of the bilateral equivalence at the Sn fixed point between METAS (loop 2) and JV (loop 5)

$$(T_{METAS}-T_{JV})=(T_{METAS}-T_{wm552})-(T_{JV}-T_{wm552})=0.68\,\mathrm{mK}-(-0.65\,\mathrm{mK})=1.33\,\mathrm{mK}$$

$$U_{(T_{METAS}-T_{JV})}=\sqrt{U^2_{(T_{METAS}-T_{wm552})}+U^2_{(T_{JV}-T_{wm552})}-\mathrm{B_{Sn}}}$$

$$U_{(T_{METAS}-T_{JV})}=\sqrt{(1.07)^2+(1.46)^2-0.07}=1.76\,\mathrm{mK}$$

11.3 Bilateral Equivalence between the participants in EUROMET 552 and CCT-K3

Our proposal is to calculate the degree of equivalence between the EUROMET participating laboratories and the CCT-K3 participants by the following way:

$$\left(T_{Lab_{ij552}}-T_{Lab_{XXK3}}\right)=\left(T_{Lab_{ij552}}-T_{wm552}\right)-\left(T_{(P\,\&\,CP_j)mean}-T_{wm552}\right)$$
$$+\left(T_{(P\,\&\,CP_j)mean}-T_{Lab_{XXK3}}\right)$$

$\left(T_{Lab_{ij552}} - T_{wm552}\right)$ comes from the results presented Tables 16 to 21

$\left(T_{(P\,\&\,CPj)mean} - T_{wm552}\right)$ comes from the results presented Tables 22 to 27

$\left(T_{(P\,\&\,CP_j)mean} - T_{Lab_{XXK3}}\right)$ have to be calculated from the results of CCT-K3

$$u_{\left(T_{Lab_{ij552}} - T_{Lab_{XXK3}}\right)} = \sqrt{u^2_{\left(T_{Lab_{ij552}} - T_{wm552}\right)} + u^2_{\left(T_{(P\,\&\,CP_j)mean} - T_{Lab_{XXK3}}\right)} + u^2_{reprod\ (P\,\&\,CP_j)mean}}$$

$u_{\left(T_{Lab_{ij552}} - T_{wm552}\right)}$ comes from Tables 16 to 21

$u_{reprod\ (P\,\&\,CP_j)mean}$ comes from Table 28

$u_{\left(T_{(P\,\&\,CP_j)mean} - T_{Lab_{XXK3}}\right)}$ have to be calculated from the uncertainties given in CCT-K3

The expanded uncertainty *U* (95%) is :

$$U_{\left(T_{Lab_{ij552}} - T_{Lab_{XXK3}}\right)} = 2 \cdot u_{\left(T_{Lab_{ij552}} - T_{Lab_{XXK3}}\right)}$$

12. Conclusion

EUROMET Project 552 compares the various European local realisations of the ITS-90 from the triple point of Ar (83,805 8 K) to the freezing point of Zinc (692,677 K) using long-stem SPRTs. This project was agreed by the CCT-WG7 as a Regional Key comparison corresponding to CCT-K3 and was named EUROMET.T-K3.

The comparison involved 6 NMLs that have already taken part in CIPM key comparison CCT-K3 (BNM-INM/CNAM, SMU, IMGC, NMI-VSL, NPL, PTB) and 18 other European national laboratories. The comparison was divided in five different loops coordinated by a co-pilot that was chosen among the laboratories having participated to the CCT K3 comparison. BNM-INM/CNAM played the role of pilot and as a link between the loops.

In order to have sufficient information about a possible drift of the SPRTs, the co-pilots have performed a calibration over the full temperature range at the beginning and at the end of the loop.

Given that the protocol of the comparison contains a detailed description of how the uncertainties are to be calculated, the uncertainty budgets established by the participants seem consistent or, at least, homogeneous.

The results of the comparison were analysed by the pilot and the Draft A version 1 was sent to all the participants on January 2005. The ERV used for the version 1 was the simple mean of the results. The participant laboratories decided during a Workshop organized by the pilot in Vienna on

April 2005 to use as ERV the weighted mean. So, the Draft A version 2 is set up on this pronouncement.

For a matter of clarity, the results are firstly presented loop by loop, but a EUROMET Reference Value (ERV) taking into account the whole comparison had to be defined. In order to calculate this ERV it is proposed to take advantage of the presence of BNM-INM/CNAM in the five loops ; the differences between each laboratory's results and BNM-INM's were considered.

Finally, a method for establishing the bilateral equivalence between the participants in CCT-K3 and in EUROMET 552 is proposed by the pilot.

Appendix A. Technical protocol

Agreed EUROMET Project N° 552

Comparison of the realisations of the ITS-90 over the range 83,805 8 K to 692,677 K

"Technical protocol"

(version 3 – 10/04/2001)

Redactors:
Eliane Renaot
Yves Hermier
Georges Bonnier

1.Introduction

The project is expected to be complementary to the CIPM comparison K-3.

All participants of this comparison should follow the instructions, which are given below. Moreover, each laboratory should follow its normal practice when realising the ITS-90. The instructions are based on Appendix 1 of Report to the CCT on Key Comparison 3 (B. W. Mangum et al. of NIST, November 1999). The comparison strictly follows the protocols given in the Guidelines for CIPM key comparisons, Appendix F to the MRA, 1 March 1999. The Pilot Lab of this comparison is BNM-INM/CNAM (France).
It is intended to compare any EUROMET NML realization of the ITS-90 on the same basis than CIPM interlaboratory comparison. The range of temperature covered in this comparison is from the triple point of Ar (83,805 8 K) to the freezing point of Zn (692,677 K) using long-stem SPRTs.

The participating NMLs are required to perform calibration of SPRTs at ITS-90 fixed points as presented in their own CMCs, it means that restricted ranges are allowed.

The comparison will involve the 7 NMLs previously involved in CIPM K3 (BNM-INM/CNAM, SMU, IMGC, NMI-VSL, NPL, PTB, VNIIM) and 19 European national laboratories. The comparison will be divided in different 5 loops coordinated by a co-pilot chosen among the laboratories having participated to the CIPM K3 comparison. BNM-INM/CNAM will play the job of pilot in establishing the link between the five loops. .

The co-co-pilot will calibrate 2 SPRTs, of its own, and circulate one of them within its loop. The second one was kept for safety. The SPRTs used for this comparison will be selected by the co-pilots for their very good stability.

The thermometer is very fragile so it must be handled with extreme care. When not in use, it should be stored in a safe place in the groove of the protecting foam. The SPRT will be hand carried from laboratory to laboratory. Each lab is responsible for carriage of the thermometer to the following Lab in the list. The procedures required by the Department of Customs of various countries must be strictly obeyed when the thermometers are shipped outside EU. In these cases, the Carnet forms must be carefully and accurately completed. It is the responsibility of the laboratory carrying the transfer SPRT to the next laboratory to present the Carnet to Customs when leaving the country and upon arrival in the country of destination. Personnel at the receiving laboratory must check the

Carnet forms very carefully upon receipt. It is the duty of the co-pilot laboratory to find out a solution between the different participants (in this loop) for taking in charge the ATA carnet fees.

If thermometer has not been received in due time the co-pilot must be immediately informed in order the timetable be revised accordingly. The co-pilot informs the pilot and the further laboratories of the revision.

Any participant will, therefore, calibrate, at least, one thermometer. It will establish a calibration report.

This report will be sent (within 1 month) simultaneously to BNM-INM/CNAM and to the co-pilot responsible of its loop. From the delivered data, BNM-INM/CNAM will establish the difference between any pair of participating laboratories. BNM-INM/CNAM will establish, as well, the uncertainty associated with the calculated difference. At this juncture, common criteria for quoting uncertainties of calibration will be developed.

2. Scheme of the organization

See Page 3 of the draft A

3. Participating Laboratories

See Page 4 of the draft A

4. Provisional schedule

It is anticipated that the five parallel loops will be started by 1May 2001.

At the beginning of the circulation, BNM-INM/CNAM make the first calibration with co-pilot SPRT's. For the other participating lab the sub co-pilot of any loop will define the order in which the different laboratories will participate. For a given laboratory, the time allowed for a calibration (over the range 83,805 8 K to 692,677 K) is approximately estimated to be 8 weeks. The travelling time between two Labs could be rated at 2 weeks. In agreement with these estimations it is possible to establish a provisional schedule for a loop involving 6 participants (including BNM-INM/CNAM).

In order that calibration results performed by the co-co-pilot don't influence the BNM-INM/CNAM operator the Calibration Certificate established by the co-pilot is asked to be address at BNM-INM/CNAM just after the SPRT will be return to the co-co-pilot.

Table I

Period	Task	Lab.
By the end of April 2001	Selection and calibration of 2 SPRTs	Co-pilot X
1 May 2001	Starting the circulation of a SPRT	
1 May to15 November 2001 (depending BNM-INM/CNAM receipt's the circulating thermometers)	Calibration of the circulating SPRT	BNM-INM/CNAM
15 November to 30 December 2001	Check the stability of the circulating SPRT	Co-pilot X
30 December 2001 to 15 March 2002	Calibration of the circulating SPRT	Lab X1
15 March to 30 May 2002	Calibration of the circulating SPRT	Lab X2
1 June to 15 September 2002	Calibration of the circulating SPRT	Lab X3
15 September to 30 November 2002	Calibration of the circulating SPRT	Lab X4
30 November 2002 to 15 February 2003	Calibration of the circulating SPRT	Lab X5
15 February to 30 April 2003	Check the stability of the circulating SPRT	Co-pilot X

At the time of KC3 SMU was not able to perform measurements neither at the point of Mercury nor the point of Indium. During KC3 VNIIM was not able to perform measurements at the point of Mercury but have been participating to the comparison at the point of Indium. Today SMU wish to participate in 552 in including measurements at Mercury and Indium points. Therefore in order to have SMU included in a loop involving at least two laboratories having participated to KC3 it is necessary to include a complementary laboratory. This complementary laboratory will perform uniquely measurements at the Mercury point on thermometers delivered by SMU. This laboratory will be PTB, IMGC, NPL or NMI-VSLin accordance with their availability.

Provisional schedule for loop 1 (TABLE II)

Period	Task	Lab.
By the end of April 2001	Selection and calibration of 2 SPRTs	SMU
1 May 2001	Starting the circulation of a SPRT	
1 May to15 November 2001 (depending BNM-INM/CNAM receipt's the circulating thermometers)	Calibration of the circulating SPRT	BNM-INM/CNAM
15 November to 15 December 2001	Calibration of the circulating SPRT at the Hg fixed point	PTB or IMGC or NPL or NMI-VSL
15 December 2001to 30 January 2002	Check the stability of the circulating SPRT	SMU
30 January to 15 April 2002	Calibration of the circulating SPRT	Lab X1
15 April to 30 June 2002	Calibration of the circulating SPRT	Lab X2
30 June to 15 October 2002	Calibration of the circulating SPRT	Lab X3
15 October to 30 December 2002	Check the stability of the circulating SPRT	SMU

5. Procedures

All participants of this comparison should follow the instructions, which are given below. Moreover, each laboratory should follow its normal practice when realising the ITS-90. The instructions are based on Appendix 1 of Report to the CCT on Key Comparison 3 (B. W. Mangum et al. of NIST, November 1999). The comparison strictly follows the protocols given in the Guidelines for CIPM key comparisons, Appendix F to the MRA, 1 March 1999. The Pilot Lab of this comparison is BNM-INM/CNAM (France).

The participating NMLs are required to perform calibration of SPRTs at ITS-90 fixed points as presented in their own CMCs, it means that restricted ranges are allowed.

The co-pilot will calibrate 2 SPRTs, of its own, and circulate one of them within its loop. The second one was kept for safety. The SPRTs used for this comparison will be selected by the co-pilots for their very good stability.

The goal of the comparison is to compare the national highest accuracy realization of ITS-90 as the participating laboratories routinely establish them. Each laboratory, therefore, must calibrate (at least) one SPRT according its customary process. The uncertainties associated to this calibration will be delivered by filling the document "EUROMET552uncertaintyanalysis.xls".

The SPRTs supporting the comparisons will be carefully selected by the co-pilot laboratories paying a special attention to the stability of the instrument. The SPRTs are expected to be quartz sheathed 25 Ohms Long-Stem Platinum Resistance Thermometers.

Task of pilot lab:

The pilot laboratory will receive and calibrate the 5 thermometers supporting the comparisons in the 5 loops. The different calibrations will be performed in order to be as similar as possible in order to give the ability to link the different loops together.
The coordinator will collect the calibration reports and will establish an analysis of the results.

Task of Co-pilot labs:

- Select and calibrate two SPRTs
- To check the stability of the travelling instrument, co-pilot will perform a calibration of the full range at the beginning of the loop before sending it at BNM-INM/CNAM. After receipt the SPRT from BNM-INM/CNAM. The co-pilot will determine a new time the reduced resistance value of Ga and Zinc in order to check the SPRT stability. The co-pilot will perform again a calibration of the full range at the end of the loop
- Supply a SPRT of these ones to participants belonging to its loop
- Organize the SPRT circulation within the sub-loop.

Task of participating labs:

The travelling SPRT is to pass through the following sequence:

1) a measurement at the triple point of water (TPW)
2) a stabilisation procedure
3) a second measurement at the triple point of water

4) measurements at metal fixed points in order of decreasing temperatures alternating with a measurement at the triple point of water.

- Upon receipt of the SPRT, the host laboratory must inspect the devices for damage. Then the host laboratory must complete and forward (by e-mail or fax) the attached "Artefact Received Form" to co-pilot to report the condition of the artefact. If there is damage, the co-pilot laboratory will give instructions on how to proceed.
- If thermometer has not been receive in due time Co-pilot or pilot must be immediately informed to revise the timetable and inform the further laboratories of the revision.
- If no damage has been sustained and after reporting to the co-pilot laboratory, the host must measure the resistance of the travelling SPRT in a TPW cell at two measuring currents (in order to determine the zero-power value). The measurement current used must be such that the generated power does not exceed 250 μV. The 0 mA resistance values of the travelling SPRT at the TPW must be corrected for the hydrostatic head to obtain R_{TPW}. The value of R_{TPW} must be communicated to the co-pilot laboratory. After receiving approval from the co-pilot laboratory to proceed with the comparison, the host laboratory can begin the SPRT stabilization procedure:
    - Carefully insert the SPRT into a furnace at 480 °C.
    - Anneal the SPRT for two hours at 480 °C
    - Carefully remove the SPRT from the furnace directly to the room environment.
    - Re-determine The value of R_{TPW}
- If the resistance at TPW increases after annealing contact co-pilot laboratory for further instructions
- If the decrease in the calculated TPW resistance of the SPRT after annealing is equivalent to 0.5 mK or greater proceed to a second SPRT stabilization procedure. Re-determine the value of $R_{TPW.}$ If the decrease in the calculated TPW resistance of the SPRT after second annealing is greater to 0.2 mK communicate with co-pilot laboratory for further instructions
- If the decrease is less then 0.5 mK the completed calibration can be performed.
  Calibrate the SPRT at all of the fixed points in the range of comparison, i.e., measurements at TPW, Zn, TPW, Sn, TPW, In, TPW, Ga, TPW, Hg, TPW, Ar and TPW, in that order. If one or several fixed points are not available then the host laboratory may perform the comparison over a limited range. Existing techniques as practised by the participating Laboratory must be used. For each metal fixed point the $W=R_T/ R_{TPW}$ is calculated. R_{TPW} is the TPW resistance obtained immediately after the measurement of $R_{T.}$ R_T *et* R_{TPW} should have been corrected for self-heating, hydrostatic head and if any the pressure effect. At least 3 different phase transitions (3 freezings for Zn, Sn, In, 3 meltings for Ga, 3 triple points for Hg and Ar will be performed. The different values will be delivered together with the calculated mean.
- After completing all of the above measurements, the host laboratory must transmit the calibration report to the co-pilot laboratory and send a copy to the co-pilot laboratory.
- The host laboratory must hand delivered the SPRT to the next participating lab (or to the co-pilot at the end of the loop) and send to the co-pilot the attached "Artefact shipped Form".

Table III, Example:

Run for Zn fixed point	
Measurement in TPW	
Measurement in Zn fixed point	*W Zn 1*
Measurement in TPW	
Measurement in Zn fixed point	*W Zn 2*
Measurement in TPW	
Measurement in Zn fixed point	*W Zn 3*
Measurement in TPW	

6. Reporting of data

The participating host must send to coordinator and co-pilot labs the following information. If all of them are not received, the host's data will not be included in the report.

- For each fixed point cell that was used in the comparison, determine (using the circulating SPRT) and plot the change of phase transition temperature, *dT*, versus immersion, *dh*. On the same graph, plot the theoretical *dT/dh* curve using the hydrostatic pressure coefficients (mK/m of liquid) given in the ITS-90 text.

- Examples of Freezing curves in In, Sn and Zn cells, melting curve in Ga cell and triple–point curve in Hg and Ar

- Using the attached spreadsheet named 'EUROMET552 Calibrationdata.xls' to report the resistance ratios

$W=R_T / R_{TPW}$ where R_T is the resistance of the SPRT at each of the fixed points, and R_{TPW} is the resistance in the TPW cell obtained after the measurement of R_T . The values of R_T and R_{TPW} must be corrected for self heating, the hydrostatic head and if applicable, the pressure effect. In order to not increase the uncertainty on the comparison of the results the R_T values given by the different participating Lab must approximately correspond to the same percentage of metal in liquid phase. This percentage is not easy to determine. So it is better to use the concept of percentage of time of the total duration of the plateau. It is asked that the R_T values correspond to the percentage of time given in the table below.

Fixed point	Type	% of time passed since the starting of the plateau
Ar	Triple	20 to 40 %
Hg	Triple	60 to 80 %
Ga	Melting	70 to 80 %
In	Freezing	20 to 30 %
Sn	Freezing	20 to 30 %
Zn	Freezing	20 to 30 %

- Uncertainty analysis using the attached spreadsheet named 'EUROMET552Uncertaintyanalysis. xls.'

- Details of instrumentation, fixed point cells and techniques used in the realisation of the fixed points for this comparison should be given in the attached sheet 'EUROMET552Instrumentationdetails.xls.'

- The immersion curves, the freezing/melting curves and the completed forms
  'EUROMET552Calibrationdata.xls'
  'EUROMET552Uncertaintyanalysis.xls'
  'EUROMET552Instrumentationdetails.xls'
  should be e-mailed to the co-pilot lab. A paper copy must be send by post to the co-pilot and pilot labs.

Uncertainties

Participants are requested to use the attached spreadsheet 'EUROMET552Uncertaintyanalysis. xls' to calculate and report their estimated uncertainties for the determination of resistance ratios obtained from the SPRT at the fixed points that were used in this comparison. Calculations of uncertainties should follow the guidelines set out in the ISO Guide (1993) to the Expression of Uncertainty in Measurement.

For each uncertainty component, a standard uncertainty u_i and its associated degrees of freedom must be provided. The value of u_i should be given in terms of temperature. For type A evaluation, the number of degrees of freedom, is *n-1* where *n* is the number of measurements. For type B evaluation, any input is assumed to have an infinite number of degrees of freedom. The combined uncertainty *U*, the effective degrees of freedom and, subsequently, the expanded uncertainty at 95% level of confidence are calculated as set out in the Guide.

To assist with the determination of measurement uncertainties, the following section explains the meanings of the uncertainty components given in 'EUROMET552Uncertaintyanalysis.xls'.

W_t is determined according the following mathematical model obtained from the relationship.

$$W_t = \frac{(R_s + C_{Rs/3} + C_{Rs/4}) * (X_t + C_{Xt/1} + C_{Xt/2} + C_{Xt/3} + C_{Xt/4} + C_{Xt/5} + C_{Xt/6} + C_{Xt/7})}{(R_s) * (X_{0.01°C} + C_{X0.01/1} + C_{X0.01/2} + C_{X0.01/3} + C_{X0.01/4} + C_{X0.01/5} + C_{X0.01/6} + C_{X0.01/7})}$$

$$W_t = (1 + D_{Rs/3} + D_{Rs/4}) \cdot \frac{(X_t + C_{Xt/1} + C_{Xt/2} + C_{Xt/3} + C_{Xt/4} + C_{Xt/5} + C_{Xt/6} + C_{Xt/7})}{(X_{0.01°C} + C_{X0.01/1} + C_{X0.01/2} + C_{X0.01/3} + C_{X0.01/4} + C_{X0.01/5} + C_{X0.01/6} + C_{X0.01/7})}$$

Where

Rs	reference resistor value at the time of TPW measurement
$D_{Rs/3}$	relative drift of the resistance of the reference between TPW and FP measurements $= C_{Rs/3} / R_s$
$D_{Rs/4}$	relative temperature variation of resistance of the reference between TPW and FP Measurements $= C_{Rs/4} / R_s$

Effects linked with triple point of water calibration:

$X_{0.01°C}$	reading on the bridge at the triple point of water
$C_{x0.01/1}$	water triple point reference including isotope variation
$C_{x0.01/2}$	Hydrostatic pressure correction
$C_{x0.01/3}$	Perturbing heat exchanges
$C_{x0.01/4}$	Self-heating correction

$C_{x0.01/5}$	Bridge linearity
$C_{x0.01/6}$	Ac/dc measurement correction
$C_{x0.01/7}$	SPRT internal insulation leakage correction

Effects linked with the considered fixed point calibration:

X_t	Reading on the bridge
$C_{Xt/1}$	Chemical impurities
$C_{Xt/2}$	Hydrostatic pressure correction
$C_{Xt/3}$	Perturbing heat exchanges
$C_{Xt/4}$	Self-heating correction
$C_{Xt/5}$	Bridge measurement correction, lack of linearity
$C_{Xt/6}$	Ac/dc measurement correction
$C_{Xt/7}$	Gas pressure correction
S_{Wt}	W_t scatter

Any participant can complete this table with additional component for taking in account specific experimental conditions. In particular, it could be necessary to include a component linked with SPRT internal insulation leakage correction at the Ga fixed point. On the other hand, if component is considered as negligible they have to be quoted as “negligible” and it value must be justified

Combined standard uncertainty on Wt

$$\sigma^2{}_{Wt} = \left(\frac{\delta Wt}{\delta D_{RS/3}}\right)^2 * \sigma^2{}_{D_{RS/3}} + \left(\frac{\delta Wt}{\delta D_{RS/4}}\right)^2 * \sigma^2{}_{D_{RS/4}}$$

$$+ \left(\frac{\delta Wt}{\delta X_{0.01°C}}\right)^2 * \sigma^2{}_{X_{0.01}} + \left(\frac{\delta Wt}{\delta C_{X\,0.01/1}}\right)^2 * \sigma^2{}_{C_{X\,0.01/1}} + ... + \left(\frac{\delta Wt}{\delta C_{X\,0.01/7}}\right)^2 * \sigma^2{}_{C_{X\,0.01/7}}$$

$$+ \left(\frac{\delta Wt}{\delta X_t}\right)^2 * \sigma^2{}_{X_t} + \left(\frac{\delta Wt}{\delta C_{Xt/1}}\right)^2 * \sigma^2{}_{C_{Xt/1}} + ... + \left(\frac{\delta Wt}{\delta C_{Xt/7}}\right)^2 * \sigma^2{}_{C_{Xt/7}}$$

$$+ 2 \cdot \rho_1 \cdot \left(\frac{\delta Wt}{\delta C_{X\,0.01/1}}\right) \cdot \left(\frac{\delta Wt}{\delta C_{Xt/1}}\right) \cdot \sigma_{C_{X\,0.01/1}} \cdot \sigma_{C_{Xt/1}}$$

$$+ .....$$

$$+ 2 \cdot \rho_6 \cdot \left(\frac{\delta Wt}{\delta C_{X\,0.01/6}}\right) \cdot \left(\frac{\delta Wt}{\delta C_{Xt/6}}\right) \cdot \sigma_{C_{X\,0.01/6}} \cdot \sigma_{C_{Xt/6}} + \mathrm{S}_{\mathrm{W_t}}$$

The values of ρ_1, ρ_2, ρ_3, ρ_4, ρ_5, ρ_6 will be taken as equal to Zero if the laboratory have not better information on these values. Taking these values as zero is justified because :

1) $\delta W_t / \delta C_{X0.001/i}$ is negative

2) The values of ρ_1, ρ_2, ρ_3, ρ_4, ρ_5, ρ_6 are positive.

Consequently to give a null value to these correlation coefficients leads to maximise the value of σ_{Wt}^{2} .

$$\sigma^2{}_t = \left(\frac{\delta t}{\delta W_t} \right)^2 * \sigma^2{}_{W_t}$$

In sheet "EUROMET552Uncertainty analysis.xls" the sensibility coefficient correspond to

$$\left(\frac{\delta t}{\delta W_t} \right) * \left(\frac{\delta W_t}{\delta i} \right)$$

for example the sensibility coefficient linked with the quantity $C_{Xt/1}$ is

$$\left(\frac{\delta t}{\delta W_t} \right) * \left(\frac{\delta W_t}{\delta C_{Xt/1}} \right)$$

Components explanation and proposal of evaluation

Quantity	Standard Uncertainty	Method	Evaluation
X_t	Repeatability of readings. No change during a short time	- Same SPRT - Same cell - Same freezing - Same day	Type A
$C_{Xt/1}$	Purity	- During the recent EUROMET Workshop Dr B.Fellmuth from PTB explained clearly that it was physically impossible to quote the uncertainty linked to the impurities in simply using the Raoult's Law. Therefore it is proposed to quote this uncertainty from the dispersion of a batch of cells. This batch can be the property of the laboratory or it is the set of cells which have been participated to previous comparison (see proposal of PTB in attach document)	
$C_{Xt/2}$	hydrostatic pressure correction	Estimated from the uncertainty of the sensible element position and the uncertainty of the free liquid level	Established by the Laboratory
$C_{Xt/3}$	Perturbing heat exchanges (between the sensor and the surrounding parts different in temperature from the liquid-solid phase change)	-Deviation from expected hydrostatic pressure correction obtained by changing immersion depth over 5 cm (length of the sensor) -Modification of the thermal exchange between thermometer and its environment -Use of different container design	Established by the Laboratory Type B (Max value-Min value)/ 2√3
$C_{Xt/4}$	self-heating correction	Resolution of the bridge readings, uncertainty on the ratio between the two measuring currents Variation in self heating correction observed in an apparent similar environment	Established by the Laboratory or obtained in scientific literature Type B (Max value-Min value)/ 2√3
$C_{Xt/5}$	bridge linearity	Use of calibrated resistor for checking the bridge. Comparison between readings on different bridges. Checking the symmetry of the bridge (R1/R2 = 1/(R2/R1) ?)	Established by the aboratory or obtained in cientific literature

Quantity	Standard Uncertainty	Method	Evaluation
$C_{Xt/6}$	Difference between AC and DC measurements	Estimated by using DC and AC bridge	Established by the Laboratory or obtained in scientific literature Type B (Max value-Min value)/ 2√3
$C_{Xt/7}$	Gas pressure in the cell	Uncertainty on neutral gas pressure value during fixed point. 1 – open cells: uncertainty on line pressure measurement 2 - sealed cells: uncertainty on pressure measurement during sealing combined with temperature profile	Established by the Laboratory or obtained in scientific literature Type B (Max value-Min value)/ 2√3
$X_{0.01°C}$	a) Repeatability of readings. No change during a short time	- Same SPRT - Same cell and same mantle realization - Same day	Type A
	b) Repeatability of temperature realised by cell	- Same SPRT (assumed stable) - Same cell - Different realisations of the mantle (1) - Different dates of measurement for take into account mantle ageing (2)	Reasonably large set of data: type A Small number of data: type B (1)PD rectangular and symmetrical: (Max value-Min value)/ 2√3 (2)PD rectangular and not symmetrical: (Max value-Min value)/ √3
	c) Short Repeatability of SPRT to be calibrated	- Same cell - Variation between TPW measurement before and after the considered fixed point	
$C_{X0.01/1}$	Purity and isotopic composition	Comparison between several cells from different sources in the same conditions. Use of the interlaboratory comparison data.	Established by the Laboratory or obtained in scientific literature Type B (Max value-Min value)/ 2√3
$C_{X0.01/2}$	Hydrostatic pressure correction	Estimated from the uncertainty on the distance between the platinum sensor and the free liquid level	Established by the Laboratory Type B (Max value-Min value)/ 2√3
$C_{X0.01/3}$	Perturbing heat exchanges (between the sensor and the surrounding parts different in temperature from the liquid-solid phase change)	-Deviation from expected hydrostatic pressure correction obtained by changing immersion depth over 5 cm (length of the sensor) -Modification of the thermal exchange between thermometer and its environment -Use of different container design	Established by the Laboratory Type B (Max value-Min value)/ 2√3

Quantity	Standard Uncertainty	Method	Evaluation
***C**X0.01/4*	self-heating correction	Resolution of the bridge readings, uncertainty on the ratio between the two measuring currents Variation in self heating correction observed in an apparent similar environment	Established by the Laboratory or obtained in scientific literature Type B (Max value-Min value)/ 2√3
***C**X0.01/5*	bridge linearity	Use of calibrated resistor for checking the bridge. Comparison between readings on different bridges. Checking the symmetry of the bridge (R1/R2 = 1/(R2/R1) ?)	Established by the Laboratory or obtained in scientific literature Type B (Max value-Min value)/ 2√3
***C**X0.01/6*	Difference between AC and DC measurements	Estimated by using DC and AC bridge	Established by the Laboratory or obtained in scientific literature Type B (Max value-Min value)/ 2√3
***C**X0.01/7*	SPRT internal Insulation leakage (if any)	Decrease in resistance over some hours in the triple point	Established by the Laboratory or obtained in scientific literature Type B (Max value-Min value)/ 2√3
***D**RS/3*	Lack of stability of the reference resistance value	Negligible if measurement performed in a short time (within two successive days)	Established by the aboratory Type B (Max value-Min value)/ √3 (PD: rectangular no ymmetrical) (Max value-Min value)/ 2√3 (PD: rectangular symmetrical)
***D**RS/4*	Change in value of the standard resistor with thermostat temperature	- uncertainty on calibrating temperature - uncertainty on temperature at time of use - uncertainty on temperature coefficient	Established by the Laboratory Type B (Max value-Min value)/ 2√3
***S**Wt*	W_t scatter	- Same SPRT - Same cell - Different W values	Reasonably large set of data: type A Small number of data: type B PD rectangular and symmetrical: (Max value-Min value)/ 2√3 Different days

State-of-the-art estimates for the uncertainty component caused by impurities and isotopes

Basis of the estimates:

Standard deviations of the results near (CCT-K2) or at the fixed points (CCT-K3, CCT-K4) of the CIPM Key Comparisons

Fixed point	Estimate	Fixed point	Estimate
H_2	0.4 mK	Ga	0.2 mK
Ne	0.2 mK	In	0.8 mK
O_2	0.2 mK	Sn	0.5 mK
Ar (CSPRT)	0.3 mK	Zn	0.7 mK
Hg	0.25 mK	Al	1.5 mK
H_2O	0.1 mK	Ag	4 mK

Proposal:

These guideline estimates should be used for uncertainty budgets if

State-of-the-art high-purity materials are used
and
No individual information on the impurity content is available.

EUROMET Project 552 attach document:
proposal of PTB
(EUROMET Workshop Berlin 2001)

Amendment to

Agreed EUROMET Project N° 552

Comparison of the realisations of the ITS-90 over the range 83,805 8 K to 692,677 K

"Technical protocol"
(version 3 – 10/04/2001)

• Page 12

250µV

Is replaced by (typing mistake)

250µW

• Top of the page 13

- Carefully……….480°C
- Anneal ………480°C

Is replaced by:

- Carefully insert the SPRT into an annealing furnace. The co-pilot of the loop sets the annealing/stabilisation temperature of the circulating SPRT. Two rules must be observed:

  1-The annealing/stabilisation temperature must be between 440°C and 480°C.

  2- all the participants in a same loop must use the same annealing/stabilisation temperature. Consequently, the co-pilot must transmit the chosen annealing/stabilisation temperature to the participating labs in its loop.

- Anneal the SPRT for two hours at the annealing/stabilisation temperature set by the co-pilot

• Second line of page 14

"If all of them……..report"

Is replaced by:

"The data of a participating laboratory will not be included in the report if any of the required data are missing"

• Page 14

Under the table the following paragraph is added:

“Preferably, the measurements must correspond to the percentage given in the table. But it is possible to use the measurements obtained in other conditions. In this case, two complementary information must be given in the report:

1- the approximate percentage of time at the moment of the measurement
2- an estimate of the potential difference between the values corresponding to the recommended percentage of time and to the percentage of time used by the participating laboratory“

• Participating laboratories

Some address must be modified
See Page 4 of the draft A

VNIIM has a lot of work provided for the next months and finally Russia withdraws from this project

Appendix B. Instrumentation details

The Tables presented in the next pages correspond to the Instrumentation details Excel files sent by the participants in their reports

Instrumentation Details

EUROMET Regional Key Comparison (EUROMET Project 552)

Laboratory name	**BEV**	**SMD**	**CMI**	**Danish Technological Institute**
Bridge				
Manufacturer	Measurement International	ASL	ASL	ASL
Type	TT13	F18	F18	F18
AC or DC	DC	AC	AC	AC
If AC, give Frequency		75 Hz	75 Hz	75
If DC, give Period of reversal	4s			
Normal measurement current	1 mA	1 mA	1 mA	1 mA
Self-heating current	1.414 mA	1.414 mA	1,414 mA	1.414 mA
Evaluation of linearity of resistance				
bridge (yes or not)	yes	No	yes	no
Reference resistor				
Manufacturer	Fluke	Tinsley	Tinsley	H.M. Sullivan Ltd
Type	742A-100	5685A	5685 A (100 W), 5684 S (25 W)	1613
Reference resistor temperature control (yes or not)	yes	Yes	yes	yes
TPW Cell				
Home made or not	No -Hart Scientific	No - NPL	cells NPL type 32 N^{o} 1025 and 1038	no
Immersion depth of middle of the SPRT sensible element/cm	24 cm	18.3 cm	251 mm; 242 mm	~26 cm
How are mantles maintained (ice, bath,….)	Hart Scientific bath	Isotech bath	Water Triple Point Maintenance Bath Isotech	Isothermal enclosure with ice/water,
Zn Cell				
Home made or not	No - Isotech	No - Pyro-Contrôle	Isotech model ITL-M-17761 ZN76	no
Closed cell or open	Closed	Closed	closed cell	open
Nominal purity	99,9999%	99,999 9%	99,999 9%	99,999 9%
Immersion depth of middle of the SPRT sensible element/cm	24 cm	11.5 cm	128 mm	13 cm
Zn Furnace				
Home or not	no	No - Pyro-Contrôle	Isotech model ITL 17703	no
Type (1 zone, 3 zones, heat pipe, …….)	Heat pipe	1 - air flow	3 zone Medium Temperature Furnace	3 zones
Typical duration of the melting plateau	3 h	4h30	3 h	5 h
Typical duration of the freezing plateau	more than 10 h	5h30	10 h	10 h

Instrumentation Details

EUROMET Regional Key Comparison (EUROMET Project 552)

Laboratory name	**BEV**	**SMD**	**CMI**	**Danish Technological Institute**
Sn Cell				
Home made or not	no -Isotech	No - Pyro-Contrôle	Isotech model ITL-M-17669 SN46	no
Closed cell or open	Closed	Closed	closed cell	open
Nominal purity	99,9999%	99,999 9%	99,999 9%	99,999 9%
Immersion depth of middle of the SPRT sensible element/cm	24 cm	11.5 cm	127 mm	13 cm
Sn Furnace				
Home or not	no	Not - Pyro-Contrôle	Isotech model 17701	no
Type (1 zone, 3 zones, heat pipe, …….)	Heat pipe	1 - air flow	1 zone	3 zones
Typical duration of the melting plateau	3 h	3h	3 h	5 h
Typical duration of the freezing plateau	more than 10 h	4h	10 h	10 h
In Cell				
Home made or not	no	No - Pyro-Contrôle	Isotech model ITL-M-17668 IN33	no
Closed cell or open	Closed	Closed	closed cell	open
Nominal purity	99,9999%	99,999 9%	99,999 9%	99,999 9%
Immersion depth of middle of the SPRT sensible element/cm	24 cm	11.5 cm	113 mm	13 cm
In Furnace			Isotech model 17701	
Home or not	no	Not - Pyro-Contrôle	not	no
Type (1 zone, 3 zones, heat pipe, …….)	AYRIES (Al powder bath)	1 - air flow	1 zone	3 zones
Typical duration of the melting plateau	3 h	1h30	4 hours	
Typical duration of the freezing plateau	more than 10 h	5h30	13 hours	5 h
Ga Cell				
Home made or not	no	Not - Pyro-Contrôle	Isotech model 17401 GA137	no
Closed cell or open	Closed	Closed	closed cell	sealed
Nominal purity	99,999 9%	99,999 9%	99,999 99%	99,999 9%
Immersion depth of middle of the SPRT sensible element/cm	16,8 cm	12.5 cm	206 mm	20 cm
Ga Furnace				
Home or not	no	Not - Pyro-Contrôle	Isotech model 17402A	no
Type (1 zone, 3 zones, heat pipe, …….)	Hart Scientific 9230	1 - air flow	-	1 zone
Typical duration of the melting plateau	3 h	17h	14 h	12 h

Instrumentation Details

EUROMET Regional Key Comparison (EUROMET Project 552)

Laboratory name	**BEV**	**SMD**	**CMI**	**Danish Technological Institute**
Hg Cell				
Home made or not	no	Not - Isotech	TP cell ITL-M-17724 ISOTECH MO65	no
Closed cell or open	Closed	Closed	closed cell	sealed
Nominal purity	99,999 9%	99,999 95%	99,999 9%	99,999 9%
Immersion depth of middle of the SPRT sensible element/cm	24 cm	12.5 cm	148 mm	17cm
Hg cryostat				
Home or not	no	Not - Heto	Isotech model 17725	no
Type (cryostat, bath, …….)	Cryostat Isotech	Bath	cryostat	bath
Typical duration of the melting plateau	3 h	10h30	12 hours	6 h
Ar Cell				
Home made or not		Not - BNM-INM		
Closed cell or open		Closed		
Nominal purity		99,9999%		
Immersion depth of middle of the SPRT sensible element/cm		12 cm		
Ar cryostat				
Home or not		Not - BNM-INM		
Type (crycooler, bath,..)		Liquid N2 bath		
Typical duration of the plateau		4h00		

Instrumentation Details

EUROMET Regional Key Comparison (EUROMET Project 552)

Laboratory name	MIKES	BNM-INM	PTB	EIM
Bridge				
Manufacturer	easurements International Limite	guildline	ASL	Measurements International Ltd, Canada
Type	6015T	6675 (Ar and Ag)/ 9975	F18	6010B
Unity reading	cannot be made on this bridge	resistance ratio	1,0000001	0.000000001 in ratio
AC or DC	DC	DC	AC	DC
If AC, give Frequency			25 Hz	
Normal measurement current	1 mA	1 mA	1 mA	1mA
Self-heating current	1.4142 mA	1,414 mA	1,141 mA	1.414mA
Evaluation of linearity of resistance				
bridge (yes or not)	yes	not (Ar and Ag) / yes	Yes	yes
Reference resistor				
Manufacturer	Tinsley	guildline	H.Tinsley & Co Ltd., New Addington, England	SN:274988 Tinsley&Co Ltd
Type	5685A	9330	5685 A	5685A, 25ohms
Reference resistor temperature control (yes or not)	yes	yes	Yes	Yes
TPW Cell				
Home made or not	NPL type 32 sn 1041	not	commercial, manufacturer : NMI	997, NPL type 32, Laboratory of Gov. Chemist
			home made (Ar and Hg)	
Immersion depth of middle of the SPRT sensible element/cr	18.85 cm	19 cm	19 cm / 21,90cm (Ar and Hg)	18.75cm
How are mantles maintained (ice, bath,….)	tech 1 TS-M-18233 bath sn 1614	a bath Isotech	Water triple point bath from ISOTECH	Crashed Ice in Dewar Vessel
			temperature controlled enclosure (Ar and Hg)	
Zn Cell				
Home made or not	sotech ITL-M-17671 S sn Zn 156	Home made	home made	Zn161, type:ITL-M-17671, Isotech
Closed cell or open	closed	Closed cell	open	Closed
Nominal purity	99.999 995 %	99.999 9%	99,999 9%	99,999 9%
Immersion depth of middle of the SPRT sensible element/cr	15.35 cm	14,5 cm	15,5 cm	14.75cm
Zn Furnace				
Home or not	Isotech ITL-M-17706 sn 19219-1	Home made	commercial, manufacturer : ISOTECH	96034, type: 9114, Hart Scientific
Type (1 zone, 3 zones, heat pipe, …….)	potassium heat pipe	air furnace	3 zones furnace	3 zones
Typical duration of the melting plateau	7 h	4 h		8.6 h
Typical duration of the freezing plateau	12 h	11 h	6...10 h	10 h

Instrumentation Details

EUROMET Regional Key Comparison (EUROMET Project 552)

Laboratory name	MIKES	BNM-INM	PTB	EIM
Sn Cell				
Home made or not	sotech ITL-M-17669 S sn Sn 13	Home made	commercial, manufacturer : ISOTECH	Sn108, type:ITL-M-17669, Isotech
Closed cell or open	closed	Closed cell	open	Closed
Nominal purity	99.999 95 %	99.999 95 %	99,999 9%	99,999 9%
Immersion depth of middle of the SPRT sensible element/cr	15.35 cm	14,5 cm	15 cm	17.25cm
Sn Furnace				
Home or not	Isotech ITL-M-17707 sn 214 681	Home made	commercial, manufacturer : ISOTECH	96034, type: 9114, Hart Scientific
Type (1 zone, 3 zones, heat pipe, …….)	water heat pipe	air furnace	3 zones furnace	3 zones
Typical duration of the melting plateau	8 h	9 h		9 h
Typical duration of the freezing plateau	18 h	5 h	about 10 h	14 h
In Cell				
Home made or not	Isotech ITL-M-17668 O sn In-92	ntrôle under BNM-INM	commercial, manufacturer : ISOTECH	In49, type:ITL-M-17668, Isotech
Closed cell or open	open	Closed cell	open	Closed
Nominal purity	99.999 95 %	99,999 9%	99,999 9%	99,999 9%
Immersion depth of middle of the SPRT sensible element/cr	15.35 cm	15 cm	15 cm	14.75cm
In Furnace				
Home or not	Isotech ITL-M-17707 sn 214 681	Home made	commercial, manufacturer : ISOTECH	96034, type: 9114, Hart Scientific
Type (1 zone, 3 zones, heat pipe, …….)	water heat pipe	air furnace	3 zones furnace	3 zones
Typical duration of the melting plateau	3 h	4 h		7.5 h
Typical duration of the freezing plateau	5 h	10 h	about 8 h	10.8 h
Ga Cell				
Home made or not	llow Springs Ga M-17401 S.N. 1	Home made	commercial, manufacturer : YSI	Ga83, type:ITL-M-17401, Isotech
Closed cell or open	closed	Closed cell		Closed in teflon cashing, permeable to air
Nominal purity	99.999 9+ %	99,999 9%	better 99,999 99 %	99,999 9%
Immersion depth of middle of the SPRT sensible element/cr	20,35 cm	15 cm	26 cm	21.75cm
Ga Furnace				
Home or not	Hart 7037 sn 8C048	Home made	commercial, manufacturer : YSI	151125-1, type: 17402A, Isotech
Type (1 zone, 3 zones, heat pipe, …….)	water bath	air furnace		1 zone, Peltier heating and cooling
Typical duration of the melting plateau	6 h	16 h	about 14 h	14.3 h

Instrumentation Details

EUROMET Regional Key Comparison (EUROMET Project 552)

Laboratory name	MIKES	BNM-INM	PTB	EIM
Hg Cell				
Home made or not	home made (TTK)	Home made	commercial, manufacturer: ISOTECH Ltd.	Mo86, type:ITL-M-17924, Isotech
Closed cell or open	closed	open cell	closed cell, model: ITL-M-17724	Closed
Nominal purity	99,999 95 %	99,999 99 %	99,999 998 %	99,999 9%
Immersion depth of middle of the SPRT sensible element/cr	14,35 cm	20 cm	14,8 cm	14.75cm
Hg cryostat				
Home or not	Hetocal KB23-2 sn 8504198	home made	commercial, manufacturer: ISOTECH Ltd.	181303-4, type: ITL-M-17725, isotech
Type (cryostat, bath, …….)	alcohol bath	bath	elf-contained mechanically-refrigerated system	cryostat
			, model: ITL-M-17725	
Typical duration of the melting plateau	12 h	14 h	15 h	11.9 h
Ar Cell				
Home made or not	S.O.R.I.M.E sn Ar-INM-39-CMA	home made	commercial, manufacturer: BIPM-INM/CNAM	There is not an Ar cell
Closed cell or open	closed	closed cell	closed cell, Ar-INM-26-PTB	
Nominal purity	99.999 9 %	99.999 9 %	99.999 8 %	
Immersion depth of middle of the SPRT sensible element/cr	8.35 cm	7,5 cm	8 cm	
Ar cryostat				
Home or not	S.O.R.I.M.E	home made	commercial, manufacturer: BIPM-INM/CNAM	
Type (crycooler, bath,..)	liquid nitrogen cryostat	cryostat	Nitrogen cryostat	
Typical duration of the plateau	6 h	4 h	5 h	

Instrumentation Details

EUROMET Regional Key Comparison (EUROMET Project 552)

Laboratory name	**OMH**	**NML**	**IMGC**	**SMS/SPI**
Bridge				
Manufacturer	Guildline	ASL	Automatic Systems Laboratories	Measurements International Ltd., Canada
Type	9975	F18	F18	Automatic DC bridge, model 6010T
Unity reading	8 digit		1,0000000	
AC or DC	DC	AC	AC	DC
If AC, give Frequency		75Hz	25	
Normal measurement current	1 mA	1mA	2mA (1,4142 mA for Triple Point of Water)	1 mA
Self-heating current	1,414 mA	Square Root 2mA	2,8284 mA (2 mA for TPW)	1.414 mA
Evaluation of linearity of resistance				
bridge (yes or not)	Yes	Yes	yes	yes
Reference resistor				H. Tinsley & Co Ltd., UK
Manufacturer	Cambridge	Tinsley	Tinsley	Wilkins type, model 5685A - 25 Ohms
Type	10 ohm	5685A	5685A - 100 ?	yes, at 23 ^{o}C, +/- 0.01 ^{o}C
Reference resistor temperature control (yes or not)	Yes	Yes	yes	Resistor kept in the oil bath made by Isotech, model 455
TPW Cell				
Home made or not	Not home made	Not	Home made	Made by Hart Scientific, model 5901
Immersion depth of middle of the SPRT sensible element/cr	23 cm	0.1831m	22,5 cm	22,2 cm
How are mantles maintained (ice, bath,….)	bath	Ice	ice	Cell kept in the bath made by Hart Scientific, model 7012
Zn Cell				
Home made or not	Not home made	Not	NIST made	Made by Hart Scientific, model 5906
Closed cell or open	Closed cell	Closed	open	closed
Nominal purity	6 N	100,00%	99,9999%	99.9999%+
Immersion depth of middle of the SPRT sensible element/cr	18 cm	0.1351m	18 cm	16,2 cm
Zn Furnace				
Home or not	Not home made	Not	Home made	Made by Hart Scientific, model 9114
Type (1 zone, 3 zones, heat pipe, …….)	3 zones	1 Zone	Heat pipe	3 zones
Typical duration of the melting plateau	4 h	18 h		8 h
Typical duration of the freezing plateau	10 h	12 h	70 h	10 h

Instrumentation Details

EUROMET Regional Key Comparison (EUROMET Project 552)

Laboratory name	OMH	NML	IMGC	SMS/SPI
Sn Cell				
Home made or not	Not home made	Not	Home made	Made by Hart Scientific, model 5906
Closed cell or open	Closed cell	Closed	open	closed
Nominal purity	6 N	99,9999%	99,9999%	99.9999%+
Immersion depth of middle of the SPRT sensible element/cr	18 cm	0.1351m	18 cm	16,2 cm
Sn Furnace				
Home or not	Not home made	Not	Home made	Made by Hart Scientific, model 9114
Type (1 zone, 3 zones, heat pipe, …….)	1 zone	1 Zone	Heat pipe	3 zones
Typical duration of the melting plateau	6 hours	14.5 h		8 h
Typical duration of the freezing plateau	9 hours	13 h	50 h	10 h
In Cell				
Home made or not			Home made	
Closed cell or open			open	
Nominal purity			99,9999%	
Immersion depth of middle of the SPRT sensible element/cm			16 cm	
In Furnace				
Home or not			Home made	
Type (1 zone, 3 zones, heat pipe, …….)			Heat pipe	
Typical duration of the melting plateau				
Typical duration of the freezing plateau				
			40 h	
Ga Cell				
Home made or not	Not home made	Not	Home made	Made by Isotech, model ITL-M-17401
Closed cell or open	Closed cell	Closed	open	closed
Nominal purity	8 N	99,9999%	99,99999%	99.99999%+
Immersion depth of middle of the SPRT sensible element/cr	17 cm	0.2001m	12 cm	19,7 cm
Ga Furnace				
Home or not	Not home made	Not	Home made	Made by Hart Scientific, model 7037
Type (1 zone, 3 zones, heat pipe, …….)	Complet apparatus	ITL Model 17402(A)	1 zone	bath
Typical duration of the melting plateau	11 hours	13 h	150	10 h
Typical duration of the freezing plateau				10 h

Instrumentation Details

EUROMET Regional Key Comparison (EUROMET Project 552)

Laboratory name	**OMH**	**NML**	**IMGC**	**SMS/SPI**
Hg Cell				
Home made or not	Not home made	Not	Commercial	Made by Hart Scientific, model 5900
Closed cell or open	Closed cell	Closed	sealed	closed
Nominal purity	8 N	99,99999%	99,9999%	99.9999%+
Immersion depth of middle of the SPRT sensible element/cr	19 cm	0.1441m	15 cm	16,7 cm
Hg cryostat				
Home or not	Not home made	Not	Home made	Made by Hart Scientific, model 7037
Type (cryostat, bath, …….)	Cryostat	Cryostat	Heat exchanger	bath
Typical duration of the melting plateau	7 h	12 h	30 h	12 h
Ar Cell				
Home made or not			BNM model	
Closed cell or open				
Nominal purity				
Immersion depth of middle of the SPRT sensible element/cm				
Ar cryostat				
Home or not			BNM model	
Type (crycooler, bath,..)				
Typical duration of the plateau			6 h	

Instrumentation Details

EUROMET Regional Key Comparison (EUROMET Project 552)

Laboratory name	**NMi-VSL**	**Justervesenet**	**GUM**	**IPQ**
Bridge				
Manufacturer	ASL	ASL	ASL	ASL
Type	F18	F18	F18	F18
AC or DC	AC	AC	AC	AC
If AC, give Frequency	25 Hz	75Hz	75 Hz	75 Hz
If DC, give Period of reversal				
Normal measurement current	1 mA	1 mA	1 mA	1 mA
Self-heating current	1.41 mA	1,41 mA (1√2mA)	√2 mA	√2 mA
Evaluation of linearity of resistance				
bridge (yes or not)	yes	Not	not	No
Reference resistor				
Manufacturer	Tinsley	Tinsley	Tinsley	Tinsley
Type	5684	5685A	5685 A	Model 5685A
Reference resistor temperature control (yes or not)	Yes	Yes	yes	Yes
TPW Cell				
Home made or not	Home made	NPL-type	cells NPL type 32	Hart Scientific
Immersion depth of middle of the SPRT sensible element/cm	21.6 cm/20.6 cm dependent on cell	20 cm	19 cm	23 cm
How are mantles maintained (ice, bath,….)	stirred bath	Isotech maintenance bath	PVC box in ice	Bath; Yellow Springs,
Zn Cell				
Home made or not	Home made	Pyrocontrole, France	Isotech typ ITL-M-17671	Yellow Springs -
Closed cell or open	open	Closed	closed	Closed
Nominal purity	99,999 9%		99,999 9%	99,999 9%
Immersion depth of middle of the SPRT sensible element/cm	14,1 cm	15 cm	16 cm	15 cm
Zn Furnace				
Home or not	Home made	Isotech model ITL 17702	Isotech type ITL-M-17706	Yellow Springs -
Type (1 zone, 3 zones, heat pipe, …….)	3 zone	Heatpipe	heat pipe	1 zone
Typical duration of the melting plateau			2 hours	3 hours
Typical duration of the freezing plateau	> 10 hours	4 hours	6 hours	5 hours

Instrumentation Details

EUROMET Regional Key Comparison (EUROMET Project 552)

Laboratory name	NMi-VSL	Justervesenet	GUM	IPQ
Sn Cell				
Home made or not	Home made	Pyrocontrole, France	Isotech typ ITL-M-17669	Yellow Springs
Closed cell or open	open	Closed	closed	Closed
Nominal purity	99,999 9%		99,999 9%	99,999 9%
Immersion depth of middle of the SPRT sensible element/cm	16,1 cm	15 cm	16 cm	16,5 cm
Sn Furnace				
Home or not	Home made	Isotech Model ITL 17704	Isotech type ITL-M-17701	Yellow Springs -
Type (1 zone, 3 zones, heat pipe, …….)	3 zones	Heatpipe	1 zone	1 zone
Typical duration of the melting plateau			2 hours	3 hours
Typical duration of the freezing plateau	> 10 hours	4 hours	5 hours	5 hours
In Cell				
Home made or not	Home made	Pyrocontrole, France	Isotech typ ITL-M-17669	Isotech - Model ITL M-17668
Closed cell or open	open	Closed	closed	Closed
Nominal purity	99,999 99%			99,999 9%
Immersion depth of middle of the SPRT sensible element/cm	14,6 cm	15 cm	16 cm	18,4 cm
In Furnace				
Home or not	Home made	Isotech Model ITL 17704	Isotech type ITL-M-17701	Yellow Springs -
Type (1 zone, 3 zones, heat pipe, …….)	3 zones	Heatpipe	1 zone	1 zone
Typical duration of the melting plateau			2 hours	6 hours
Typical duration of the freezing plateau	> 10 hours	5 hours	5 hours	9 hours
Ga Cell				
Home made or not	Commercial	Engelhard Pyro Contorle	Isotech typ ITL-M-17401	Yellow Springs -
Closed cell or open	closed	Closed		Closed
Nominal purity	99,999 9%		99,999 9%	99,999 9%
Immersion depth of middle of the SPRT sensible element/cm	24,1 cm	16 cm	16 cm	17,5 cm
Ga Furnace				
Home or not	Commercial	Engelhard Pyro Contorle	Isotech typ ITL-M-17402A	Yellow Springs -
Type (1 zone, 3 zones, heat pipe, …….)	1 zone	Controled heater		1 zone
Typical duration of the melting plateau	6 hours	12 hours	12 hours	11 hours

Instrumentation Details

EUROMET Regional Key Comparison (EUROMET Project 552)

Laboratory name	NMi-VSL	Justervesenet	GUM	IPQ
Hg Cell				
Home made or not	Home made	YSI	ITL-M-17724 ISOTECH	Yellow Springs -
Closed cell or open	closed	Sealed	closed	Closed
Nominal purity	99,999 99%		99,999 9%	99,999 9%
Immersion depth of middle of the SPRT sensible element/cm	13,8 cm	18 cm	16 cm	17,8 cm
Hg cryostat				
Home or not	Commercial	YSI	ITL-M-17725 ISOTECH	Yellow Springs
Type (cryostat, bath, …….)	stirred alcohol bath	Cryostat		Cryostat
Typical duration of the melting plateau	> 10 hours	15 hours	12 hours	9 hours
Ar Cell				
Home made or not	BNM-INM	Pond	BNM-INM	BNM-INM
Closed cell or open		Closed	closed	Closed cell s
Nominal purity		99,999 9%		N60
Immersion depth of middle of the SPRT sensible element/cm	6,1 cm	13 cm	6 cm	7,5 cm
Ar cryostat				
Home or not	BNM-INM	Pond	BNM-INM	BNM-INM
Type (crycooler, bath,..)	Pressure controlled LN2 bath	Model K38		Crycooler
Typical duration of the plateau		2-3 hours	4 hours	4 hours

Instrumentation Details

EUROMET Regional Key Comparison (EUROMET Project 552)

Laboratory name	INM (Ro)	CEM	SMU	MIRS/FE-LMK
Bridge				
Manufacturer	Guildline	A.S.L.	ASL	Measurement International
Type	9975	F900	F18	6010 B
AC or DC	DC	AC	AC	DC
If AC, give Frequency		75 Hz	75 Hz	
If DC, give Period of reversal	4 s			10 s
Normal measurement current	1 mA	1 mA	1 mA	1 mA, unless otherwise mentioned
Self-heating current	√2 mA	√2 mA	1,414 mA	1,41 mA, unless otherwise mentioned
Evaluation of linearity of resistance				
bridge (yes or not)	Not	yes	Not at present time	yes
Reference resistor				
Manufacturer	ZIP-Krasnodarsk, USSR	Tinsley	Tinsley	Tinsley
Type	P-321 (10 ohms)	AC/DC model 5685 A	5685 A	Wilkins type 5685 A
Reference resistor temperature control (yes or not)	Yes	yes	Yes	yes
TPW Cell				
Home made or not	Laboratory of the Government Chemist (UK)	not	not	Not (made by VSL-Nmi, Delft, NL)
Immersion depth of middle of the SPRT sensible element/cm	19 cm	26 cm	20,5 cm	27 cm
How are mantles maintained (ice, bath,….)	Ice	stirred water bath	TPW bath (ISOTECH)	water triple point maintenance bath Isotech
Zn Cell				
Home made or not	Home made	not	not	Not
Closed cell or open	Closed	open	closed	Closed
Nominal purity	99.999 4 %	99,999 9 %	99,999 9 %	99,999 9 %
Immersion depth of middle of the SPRT sensible element/cm	21 cm	12 cm	17,5 cm	18 cm
Zn Furnace				
Home or not	Home made	not	not	Not
Type (1 zone, 3 zones, heat pipe, …….)	1zone, aluminium core	3 zones	3 zones	heat pipe, 3 zone and fluidised sand bath
Typical duration of the melting plateau	1.5 h	9 hours		3-6 hours
Typical duration of the freezing plateau	3 h	8,5 hours	12 h	8-10 hours

Instrumentation Details

EUROMET Regional Key Comparison (EUROMET Project 552)

Laboratory name	INM (Ro)	CEM	SMU	MIRS/FE-LMK
Sn Cell				
Home made or not	Home made	not	not	Not
Closed cell or open	Closed	open	closed	open
Nominal purity	NA	unknown	99,999 9 %	99,999 9 %
Immersion depth of middle of the SPRT sensible element/cm	22 cm	15 cm	17,5 cm	18 cm
Sn Furnace				
Home or not	Home made	not	not	Not
Type (1 zone, 3 zones, heat pipe, …….)	1zone, aluminium core	3 zones	3 zones	3 zone and fluidised sand bath
Typical duration of the melting plateau	2 h	10 hours		3-6 hours
Typical duration of the freezing plateau	4 h	9,5 hours	min. 12 h	8-10 hours
In Cell				
Home made or not	Home made	not	not	Not
Closed cell or open	Closed	open	closed	closed
Nominal purity	99.99 %	99,999 9 %	99,999 9 %	99,999 9 %
Immersion depth of middle of the SPRT sensible element/cm	16 cm	13 cm	17 cm	18 cm
In Furnace				
Home or not	Home made	not	not	Not
Type (1 zone, 3 zones, heat pipe, …….)	1zone, aluminium core	3 zones	3 zones	3 zone and fluidised sand bath
Typical duration of the melting plateau	0.5 h	8,5 hours		3-6 hours
Typical duration of the freezing plateau	1 h	8,5 hours	14 h	8-10 hours
Ga Cell				
Home made or not	Home made	not	home made	not
Closed cell or open	Closed	closed	closed	closed
Nominal purity	99.9999 %	99,999 9+ %	99.99999 %	>99,99999 %
Immersion depth of middle of the SPRT sensible element/cm	14 cm	25 cm	17,5 cm	25 cm
Ga Furnace				
Home or not	Not	not	not	Not
Type (1 zone, 3 zones, heat pipe, …….)	Water bath	1 zone	liquid bath	Isotech Gallium point apparatus
Typical duration of the melting plateau	21 h	9 hours	min. 15 h	14-16 hours

Instrumentation Details

EUROMET Regional Key Comparison (EUROMET Project 552)

Laboratory name	**INM(Ro)**	**CEM**	**SMU**	**MIRS/FE-LMK**
Hg Cell				
Home made or not	Home made	not	home made	Not
Closed cell or open	Closed cell	close	closed	closed
Nominal purity	NA	99,999 95%	99,999 9%	99,999 9%
Immersion depth of middle of the SPRT sensible element/cm	11 cm	17 cm	8,3 cm	17 cm
Hg cryostat				
Home or not	Home made	not	not	Not
Type (cryostat, bath, …….)	Bath	alcohol stirred bath	liquid bath	Bath
Typical duration of the melting plateau	1.5 h	9 hours	6 h	8-14 hours
	1 h	8,5 hours		4-6 hours
Ar Cell				
Home made or not	Home made	not		Not
Closed cell or open	Closed cell	closed		closed
Nominal purity	99.999 83 %	99,999 9 %		99,999 9 %
Immersion depth of middle of the SPRT sensible element/cm	10 cm	7 cm		9 cm
Ar cryostat				
Home or not	Home made	not		Not
Type (crycooler, bath,..)	Liquid N_2 bath	liquid nitrogen bath		Dewar made by the SORIME, France
Typical duration of the plateau	2.5 h	9 hours		6-8 hours

Instrumentation Details

EUROMET Regional Key Comparison (EUROMET Project 552)

Laboratory name	**SP**	**METAS**	**UME**	**NPL**
Bridge				
Manufacturer	ASL	MI	MI / ASL	ASL
Type	F18	6010T	6015T/ F18	F18
AC or DC	AC	DC	DC/ AC	AC
If AC, give Frequency	75 Hz		LOW	25 Hz (75 Hz for Hg, Ar)
If DC, give Period of reversal		6 s	20	
Normal measurement current	1 mA	1 mA	1 mA	1 mA
Self-heating current	1,41mA	1,41mA	1,41mA	?2 mA
Evaluation of linearity of resistance	not	yes	Yes	Yes
bridge (yes or not)				
Reference resistor				
Manufacturer	Tinsley	Guidline	Tinsley	H Tinsley & Co Ltd
Type	5685A 100ohm s/n 237850	9330	AC/DC Wilkinson	5684C (5685A for Hg, Ar) 100 ohm
Reference resistor temperature control (yes or not)	not	yes	Yes	yes
TPW Cell				
Home made or not	NPL 32	Hart Scientific	Home made	manufactured at LGC
Immersion depth of middle of the SPRT sensible element/cm	19,3 cm	24 cm	23,5 cm	18.5 cm (17.9 cm for Hg, Ar)
How are mantles maintained (ice, bath,….)	TPW bath ISOTECH	ice	In TPW cell maintanance bath □	stored in ice
Zn Cell				
Home made or not	Hart 5906	Hart Scientific	NPL	made at NPL
Closed cell or open	closed	closed	Closed	open
Nominal purity	99,999 9 %	99,999 9 %	99,999 9 %	99,999 9%
Immersion depth of middle of the SPRT sensible element/cm	16,0 cm	16 cm	17,8 cm	13.6 cm
Zn Furnace				
Home or not	Carbolite CTF 12/75	Isotech type M 17706	Not (Carbolite)	Carbolite Furnaces Ltd
Type (1 zone, 3 zones, heat pipe, …….)	1 zone With Al block	heat pipe	3-Zones	3-zone
Typical duration of the melting plateau	2 h	6 h	6 hours	8 hours
Typical duration of the freezing plateau	6 h	14 h	10 hours	8-10 hours

Instrumentation Details

EUROMET Regional Key Comparison (EUROMET Project 552)

Laboratory name	SP	METAS	UME	NPL
Sn Cell				
Home made or not	NPL	Hart Scientific	Not (NPL made)	made at NPL
Closed cell or open	open	closed	Closed	open
Nominal purity	99,999 9 %	99,999 9 %	99,999 9 %	99,999 9%
Immersion depth of middle of the SPRT sensible element/cm	14,5 cm	14,8 cm	17,7 cm	13.6 cm
Sn Furnace				
Home or not	Carbolite CTF 12/75	Isotech ITL-M-17707	Not (Carbolite)	Carbolite Furnaces Ltd
Type (1 zone, 3 zones, heat pipe, …….)	1 zone With Al block	heat pipe	3-Zones	3-zone
Typical duration of the melting plateau	2 h	6 h	6 hours	9 hours
Typical duration of the freezing plateau	6 h	14 h	more than 12 hours	8-10 hours
In Cell				
Home made or not	ISOTECh ITL-M-17668	Hart Scientific	Not (NPL made)	made at NPL
Closed cell or open	open	closed	Closed	open
Nominal purity	99,999 9 %	99,999 9 %	99,999 9 %	99,999 9%
Immersion depth of middle of the SPRT sensible element/cm	16,5 cm	14,5 cm	17,5 cm	13.6 cm
In Furnace				
Home or not	ISOTECH ITL-M-17702	ISOTECH ITL-M-17707	Not (Carbolite)	Carbolite Furnaces Ltd
Type (1 zone, 3 zones, heat pipe, …….)	water heat pipe	heat pipe	3-Zones	3-zone
Typical duration of the melting plateau	2 h	5 h	8 hours	12 hours
Typical duration of the freezing plateau	6 h	12 h	9 hours	8-10 hours
Ga Cell				
Home made or not	ISOTECH ITL-M-17401	YSI type 17401	Not (Isotech made)	made at NPL
Closed cell or open	closed	closed	closed	open
Nominal purity	99,999 99%	99,999 99 %	99,999 9 %	99,999 9%
Immersion depth of middle of the SPRT sensible element/cm	16,5 cm	22 cm	28 cm	13.7 cm
Ga Furnace				
Home or not	ISOTECH ITL-M-17402	YSI type 17402	Not (Isotech)	Grant Instruments (Cambridge) Ltd
Type (1 zone, 3 zones, heat pipe, …….)	1 zone	1 zone		stirred oil bath
Typical duration of the melting plateau	15 h	12 h	12 hours	>16 hours

Instrumentation Details

EUROMET Regional Key Comparison (EUROMET Project 552)

Laboratory name	**SP**	**METAS**	**UME**	**NPL**
Hg Cell				
Home made or not	ISOTECH ITL-M-17724	Hart Scientific	Not (NPL made)	made at NPL
Closed cell or open	closed	closed	Closed	closed
Nominal purity	99,999 9%	99,999 99%	99,999 9 %	99,999 99%
Immersion depth of middle of the SPRT sensible element/cm	16,5 cm	15,3 cm	26 cm	13.5 cm
Hg cryostat				
Home or not	Heto SA-121	YSI type 17725	Not (Pond Engineering)	assembled at NPL
Type (cryostat, bath, …….)	Ethanol bath	cryostat	Bath	refrigerated probe in stirred bath
Typical duration of the melting plateau	2 h	25 h	10 hours	20 hours
Ar Cell				
Home made or not	BNM-INM	BNM-INM	Not (Termis)	made at NPL
Closed cell or open	closed	closed	Closed	closed
Nominal purity	99,999 9 %	99,999 9 %	99,999 9 %	99,999 9%
Immersion depth of middle of the SPRT sensible element/cm	5,5 cm	9,3 cm	8 cm	7 cm approx.
Ar cryostat				
Home or not	Ets AG SALVE	BNM-INM	Not (Termis)	made at NPL
Type (crycooler, bath,..)	LN2 bath	LN2 bath	LN2 bath	pressurised bath of liquid nitrogen
Typical duration of the plateau	5 hours	3 h	5 hours	5 hours

Appendix C. Uncertainties budgets

C1. Freezing point of Zinc

Quantity Q_i	Components	Uncertainty contribution ui in mK		
		Loop 1	SPRT ISOTECH 036	
		BNM-INM	SMU	OMH
X_t	Repeatability of readings	included in Wt scatter		0,225
$C_{Xt/1}$	Uncertainty linked with purity	0,441	0,270	0,563
$C_{Xt/2}$	Uncertainty linked Hydrostatic pressure correction	0,008	0,013	0,024
$C_{Xt/3}$	Uncertainty linked with perturbing heat exchanges	0,118	0,050	0,045
$C_{Xt/4}$	Uncertainty linked with self-heating correction	0,029	0,030	0,168
$C_{Xt/5}$	Uncertainty linked with bridge linearity	0,059	0,060	0,015
$C_{Xt/6}$	Uncertainty linked with AC/DC current	negligible		0,000
$C_{Xt/7}$	Uncertainty linked with gas pressure	included in Cxt/1	0,047	0,675
$X_{0.01\,°C}$	Repeatability of readings	included in Wt scatter		0,145
	Repeatability of temperature realized by cell	0,064		0,058
	Short repeatability of calibrated SPRT	0,197		0,058
$C_{0.01°C/1}$	Uncertainty linked with purity and isotopic composition	0,151	0,130	0,029
$C_{0.01°C/2}$	Uncertainty linked Hydrostatic pressure correction	0,006	0,005	0,025
$C_{0.01°C/3}$	Uncertainty linked with perturbing heat exchanges	0,076	0,050	0,029
$C_{0.01°C/4}$	Uncertainty linked with self-heating correction	0,076	0,030	0,047
$C_{0.01°C/5}$	Uncertainty linked with bridge linearity	included in Cxt/5	0,130	0,015
$C_{0.01°C/6}$	Uncertainty linked with AC/DC current	negligible		
$C_{0.01°C/7}$	Uncertainty linked with internal insulation leakage	0,026		
$D_{RS/1}$	Uncertainty linked with stability of RS	negligible		0,367
$D_{RS/2}$	Uncertainty linked with temperature of RS	0,022	0,020	0,367
S_{Wt}	Wt scatter	0,200	0,250	0,022
Combined uncertainty		0,570	0,430	1,085
Expanded uncertainty		1,150	0,860	2,170

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Zinc

Quantity Q_i	Components	Uncertainty contribution ui in mK						
		Loop 2 SPRT 1283						
		BNM-INM	IMGC	CEM	IPQ	METAS	MIRS/FE-LMK	BEV
X_t	Repeatability of readings	included in Wt scatter	0,006	0,050	0,010	0,013	0,030	0,052
	Repeatability of temperature realized by cells							0,019
$C_{Xt/1}$	Uncertainty linked with purity	0,441	0,312	0,540	0,700	0,541	0,400	0,100
$C_{Xt/2}$	Uncertainty linked Hydrostatic pressure correction	0,008	0,005	0,030	-0,016	0,016	0,012	0,010
$C_{Xt/3}$	Uncertainty linked with perturbing heat exchanges	0,118	0,035	0,030	0,162	0,048	0,100	0,026
$C_{Xt/4}$	Uncertainty linked with self-heating correction	0,029	0,007	0,060	0,002	0,344	0,030	0,262
$C_{Xt/5}$	Uncertainty linked with bridge linearity	0,059	0,001	0,130	0,015	0,042	0,050	0,400
$C_{Xt/6}$	Uncertainty linked with AC/DC current	negligible	0,001	0,120		0,100	0,000	0,001
$C_{Xt/7}$	Uncertainty linked with gas pressure	included in Cxt/1	0,029	0,020		0,063	0,050	0,010
$X_{0.01\,°C}$	Repeatability of readings	included in Wt scatter	0,058	0,040	0,047	0,010	0,020	0,020
	Repeatability of temperature realized by cell	0,064		0,010	0,105	0,017	0,050	0,480
	Short repeatability of calibrated SPRT	0,302		0,560	0,098	0,063		0,050
$C_{0.01°C/1}$	Uncertainty linked with purity and isotopic composition	0,151		0,100	0,100	0,006	0,050	0,100
$C_{0.01°C/2}$	Uncertainty linked Hydrostatic pressure correction	0,006		0,010	0,001	0,004	0,005	0,010
$C_{0.01°C/3}$	Uncertainty linked with perturbing heat exchanges	0,076		0,020	0,016	0,038	0,010	0,000
$C_{0.01°C/4}$	Uncertainty linked with self-heating correction	0,076		0,120	0,003	0,134	0,030	0,050
$C_{0.01°C/5}$	Uncertainty linked with bridge linearity	included in Cxt/5		0,340	0,006	0,014	0,050	0,000
$C_{0.01°C/6}$	Uncertainty linked with AC/DC current	negligible		0,090		0,050	0,000	0,000
$C_{0.01°C/7}$	Uncertainty linked with internal insulation leakage	0,026	0,003	negligible		0,006	0,000	0,000
$D_{RS/1}$	Uncertainty linked with stability of RS	negligible		negligible	0,058	0,006	0,000	0,001
$D_{RS/2}$	Uncertainty linked with temperature of RS	0,022	0,001	negligible	0,003	0,029	0,005	0,000
S_{Wt}	Wt scatter	0,31	0,522	0,020	0,266	0,352	0,906	0,250
Combined uncertainty		0,67	0,613	0,890	0,790	0,760	1,015	0,742
Expanded uncertainty		1,34	1,225	1,780	1,580	1,520	2,029	1,484

Zinc

Quantity Qi	Components	Uncertainty contribution ui in mK					
		Loop 3	Tinsley274686				
		BNM-INM	NMI-VSL	MIKES	DTI	SP	SMS/SPI
X_t	Repeatability of readings	included in Wt scatter	0,115	0,014	0,200	0,030	0,037
$C_{Xt/1}$	Uncertainty linked with purity	0,441	0,312	0,700	0,700	0,400	0,700
$C_{Xt/2}$	Uncertainty linked Hydrostatic pressure correction	0,008	0,016	0,016	0,020	0,020	0,008
$C_{Xt/3}$	Uncertainty linked with perturbing heat exchanges	0,118	0,017	0,067	0,100	0,460	0,029
$C_{Xt/4}$	Uncertainty linked with self-heating correction	0,029	0,004	0,017	0,200	0,060	0,033
$C_{Xt/5}$	Uncertainty linked with bridge linearity	0,059	0,115	0,007	0,030	0,010	0,045
$C_{Xt/6}$	Uncertainty linked with AC/DC current	negligible	0,200	0,046		0,120	negligible
$C_{Xt/7}$	Uncertainty linked with gas pressure	included in Cxt/1	0,001	0,017	0,600	0,010	0,022
$X_{0.01\,°C}$	Repeatability of readings	included in Wt scatter	0,077	0,005	0,010	0,030	0,134
	Repeatability of temperature realized by cell	0,064		0,189	0,020	0,010	0,141
	Short repeatability of calibrated SPRT	0,302		0,048	0,020	0,170	0,283
	uncertainty of correction to EUROMET 549 value			0,096			
$C_{0.01°C/1}$	Uncertainty linked with purity and isotopic composition	0,151	0,090	0,100	0,010	0,060	0,257
$C_{0.01°C/2}$	Uncertainty linked Hydrostatic pressure correction	0,006	0,005	0,001	0,040	0,010	0,003
$C_{0.01°C/3}$	Uncertainty linked with perturbing heat exchanges	0,076	0,026	0,023	0,010	0,030	0,032
$C_{0.01°C/4}$	Uncertainty linked with self-heating correction	0,076	0,005	0,001	0,050	0,060	0,042
$C_{0.01°C/5}$	Uncertainty linked with bridge linearity	included in Cxt/5	0,074	0,003	0,030	0,010	0,014
$C_{0.01°C/6}$	Uncertainty linked with AC/DC current	negligible		0,021		0,060	negligible
$C_{0.01°C/7}$	Uncertainty linked with internal insulation leakage	0,026		0,003	0,010		0,040
$D_{RS/1}$	Uncertainty linked with stability of RS	negligible	0,064	0,036	0,030	negligible	negligible
$D_{RS/2}$	Uncertainty linked with temperature of RS	0,022		0,006	0,050	0,120	0,021
S_{Wt}	Wt scatter	0,290	0,080	0,047	0,020	0,070	0,027
Combined uncertainty		0,650	0,442	0,748	0,975	0,675	0,828
Expanded uncertainty		1,300	0,884	1,496	1,951	1,350	1,656

Zinc

Quantity Q_i	Components	Uncertainty contribution ui in mK					
		Loop 4	**YSI 4807**				
		BNM-INM	PTB	GUM	CMI	INM (Ro)	UME
X_t	Repeatability of readings	included in Wt scatter	see Wt scatter	0,111		0,004	0,051
$C_{Xt/1}$	Uncertainty linked with purity	0,441	0,540	0,600	0,540	1,750	0,700
$C_{Xt/2}$	Uncertainty linked Hydrostatic pressure correction	0,008	0,019	0,016	0,005	0,010	0,014
$C_{Xt/3}$	Uncertainty linked with perturbing heat exchanges	0,118	0,100	0,078	0,200	0,230	0,078
$C_{Xt/4}$	Uncertainty linked with self-heating correction	0,029	0,228	0,109	0,200	0,061	0,200
$C_{Xt/5}$	Uncertainty linked with bridge linearity	0,059	0,171	0,218	0,110	0,094	0,013
$C_{Xt/6}$	Uncertainty linked with AC/DC current	negligible				0,011	0,005
$C_{Xt/7}$	Uncertainty linked with gas pressure	included in Cxt/1	0,120	0,120	0,017	0,022	0,000
$X_{0.01\,°C}$	Repeatability of readings	included in Wt scatter	see Wt scatter	0,074		0.150	0,030
	Repeatability of temperature realized by cell	0,064	see Wt scatter	0,056			0,067
	Short repeatability of calibrated SPRT	0,378	see Wt scatter	0,093			0,125
$C_{0.01°C/1}$	Uncertainty linked with purity and isotopic composition	0,151	0,079	0,154	0,050	0,100	0,070
$C_{0.01°C/2}$	Uncertainty linked Hydrostatic pressure correction	0,006	0,004	-0,011	0,002	0,006	0,004
$C_{0.01°C/3}$	Uncertainty linked with perturbing heat exchanges	0,076	0,026	0,020	0,020	0,029	0,022
$C_{0.01°C/4}$	Uncertainty linked with self-heating correction	0,076	0,077	0,056	0,040	0,029	0,040
$C_{0.01°C/5}$	Uncertainty linked with bridge linearity	included in Cxt/5	0,064	0,021	0,040	0,242	0,005
$C_{0.01°C/6}$	Uncertainty linked with AC/DC current	negligible				0,029	0,041
$C_{0.01°C/7}$	Uncertainty linked with internal insulation leakage	0,026	0,026			0,006	0,000
$D_{RS/1}$	Uncertainty linked with stability of RS	negligible	0,001	0,005	0,005	0	0,010
$D_{RS/2}$	Uncertainty linked with temperature of RS	0,022	0,100	0,007	0,100	0,044	0,100
S_{Wt}	Wt scatter	0,140	0,144	0,076	0,095	0,129	0,055
Combined uncertainty		0,645	0,668	0,709	0,640	1,800	0,763
Expanded uncertainty		1,290	1,336	1,419	1,279	3,600	1,526

Zinc

Quantity Q_i	Components	Uncertainty contribution ui in mK					
		Loop 5 SPRT 269586					
		BNM-	NPL	JV	EIM	SMD	NML
X_t	Repeatability of readings	included in Wt scatter	0,079	0,0001	0,002	0,003	0,067
$C_{Xt/1}$	Uncertainty linked with purity	0,441	0,289	0,700	0,700	0,700	0,710
$C_{Xt/2}$	Uncertainty linked Hydrostatic pressure correction	0,008	0,008	0,039	0,008	0,012	0,016
$C_{Xt/3}$	Uncertainty linked with perturbing heat exchanges	0,029	0,115	0,328	0,003	0,149	0,043
$C_{Xt/4}$	Uncertainty linked with self-heating correction	0,029	0,008	0,096	0,009	0,154	0,040
$C_{Xt/5}$	Uncertainty linked with bridge linearity	0,059	0,033	0,004	0,036	0,160	0,042
$C_{Xt/6}$	Uncertainty linked with AC/DC current	negligible	not estimated	0,042		neg.	not estimated
$C_{Xt/7}$	Uncertainty linked with gas pressure	included in Cxt/1	0,032	0,252	0,120	0,140	0,981
$X_{0.01\,°C}$	Repeatability of readings	included in Wt scatter	0,114		0,006	0,006	0,211
	Repeatability of temperature realized by cell	0,064	0,170	0,312	0,147	0,129	0,642
	Short repeatability of calibrated SPRT	0,265	0,176	0,084	0,482	0,100	0,233
$C_{0.01°C/1}$	Uncertainty linked with purity and isotopic composition	0,151	0,337	0,100	0,293	0,100	0,169
$C_{0.01°C/2}$	Uncertainty linked Hydrostatic pressure correction	0,006	0,006	0,011	0,006	0,008	0,003
$C_{0.01°C/3}$	Uncertainty linked with perturbing heat exchanges	0,076	0,035	0,060	0,005	0,010	0,042
$C_{0.01°C/4}$	Uncertainty linked with self-heating correction	0,076	0,015	0,017	0,010	0,007	0,062
$C_{0.01°C/5}$	Uncertainty linked with bridge linearity	included in Cxt/5	0,085	0,004	0,002	0,015	0,042
$C_{0.01°C/6}$	Uncertainty linked with AC/DC current	negligible	not estimated	0,042		neg.	not estimated
$C_{0.01°C/7}$	Uncertainty linked with internal insulation leakage	0,026	not estimated		0,021	neg.	not estimated
$C_{0.01°C/8}$	Uncertainty linked with gas pressure					0,020	
$D_{RS/1}$	Uncertainty linked with stability of RS	negligible			0,007	neg.	0,033
$D_{RS/2}$	Uncertainty linked with temperature of RS	0,022	0,018	0,004	0,074	neg.	0,007
S_{Wt}	Wt scatter	0,143	0,052	0,339	0,207	0,629	0,198
Combined uncertainty		0,570	0,550	0,953	0,946	1,010	1,438
Expanded uncertainty		1,140	1,100	1,906	1,892	2,020	2,876

C2. Freezing point of Tin

Quantity Q_i	Components	Uncertainty contribution ui in mK		
		Loop 1	SPRT ISOTECH 036	
		BNM-INM	SMU	OMH
X_t	Repeatability of readings	included in Wt scatter		0,07
$C_{Xt/1}$	Uncertainty linked with purity	0,294	0,350	0,21
$C_{Xt/2}$	Uncertainty linked Hydrostatic pressure correction	0,006	0,011	0,02
$C_{Xt/3}$	Uncertainty linked with perturbing heat exchanges	0,088	0,050	0,08
$C_{Xt/4}$	Uncertainty linked with self-heating correction	0,029	0,030	0,08
$C_{Xt/5}$	Uncertainty linked with bridge linearity	0,029	0,050	0,01
$C_{Xt/6}$	Uncertainty linked with AC/DC current	negligible		0,00
$C_{Xt/7}$	Uncertainty linked with gas pressure	included in Cxt/1	0,036	0,64
$X_{0.01\,°C}$	Repeatability of readings	included in Wt scatter		0,10
	Repeatability of temperature realized by cell	0,047		0,04
	Short repeatability of calibrated SPRT	0,025		0,04
$C_{0.01°C/1}$	Uncertainty linked with purity and isotopic composition	0,111	0,090	0,02
$C_{0.01°C/2}$	Uncertainty linked Hydrostatic pressure correction	0,004	0,004	0,02
$C_{0.01°C/3}$	Uncertainty linked with perturbing heat exchanges	0,056	0,040	0,02
$C_{0.01°C/4}$	Uncertainty linked with self-heating correction	0,056	0,020	0,03
$C_{0.01°C/5}$	Uncertainty linked with bridge linearity	included in Cxt/5	0,090	0,01
$C_{0.01°C/6}$	Uncertainty linked with AC/DC current	negligible		
$C_{0.01°C/7}$	Uncertainty linked with internal insulation leakage	0,019		
$D_{RS/1}$	Uncertainty linked with stability of RS	negligible		0,25
$D_{RS/2}$	Uncertainty linked with temperature of RS	0,015	0,010	0,25
S_{Wt}	Wt scatter	0,108	0,250	0,01
Combined uncertainty		0,360	0,460	0,79
Expanded uncertainty		0,720	0,920	1,58

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Quantity Q_i	Components	Uncertainty contribution (ui in mK)						
		Loop 2	SPRT 1283					
		BNM-INM	IMGC	CEM	IPQ	METAS	MIRS/FE-LMK	BEV
X_t	Repeatability of readings	included in Wt scatter	0,006	0,030	0,017	0,013	0,030	0,058
	repeatability of temperature realized by cells							0,009
$C_{Xt/1}$	Uncertainty linked with purity	0,294	0,175	0,310	0,500	0,304	0,250	0,100
$C_{Xt/2}$	Uncertainty linked Hydrostatic pressure correction	0,006	0,004	0,020	0,013	0,013	0,012	0,022
$C_{Xt/3}$	Uncertainty linked with perturbing heat exchanges	0,029	0,017	0,060	0,037	0,013	0,100	0,019
$C_{Xt/4}$	Uncertainty linked with self-heating correction	0,029	0,008	0,060	0,006	0,258	0,030	0,384
$C_{Xt/5}$	Uncertainty linked with bridge linearity	0,029	0,001	0,120	0,011	0,029	0,050	0,400
$C_{Xt/6}$	Uncertainty linked with AC/DC current	negligible	0,001	0,060		0,100		0,001
$C_{Xt/7}$	Uncertainty linked with gas pressure	included in Cxt/1	0,023	0,020		0,050	0,050	0,010
$X_{0.01^\circ C}$	Repeatability of readings	included in Wt scatter	0,043	0,020	0,031	0,009	0,020	0,020
	Repeatability of temperature realized by cell	0,047		0,010	0,105	0,017	0,050	0,228
	Short repeatability of calibrated SPRT	0,111		0,470	0,109	0,010	0,300	0,050
$C_{0.01^\circ C/1}$	Uncertainty linked with purity and isotopic composition	0,111		0,070	0,100	0,006	0,050	0,100
$C_{0.01^\circ C/2}$	Uncertainty linked Hydrostatic pressure correction	0,004		0,010	0,001	0,004	0,005	0,001
$C_{0.01^\circ C/3}$	Uncertainty linked with perturbing heat exchanges	0,056		0,010	0,016	0,038	0,010	
$C_{0.01^\circ C/4}$	Uncertainty linked with self-heating correction	0,056		0,080	0,002	0,136	0,030	0,050
$C_{0.01^\circ C/5}$	Uncertainty linked with bridge linearity	included in Cxt/5		0,240	0,006	0,014	0,050	
$C_{0.01^\circ C/6}$	Uncertainty linked with AC/DC current	negligible		0,070		0,050		
$C_{0.01^\circ C/7}$	Uncertainty linked with internal insulation leakage	0,019		negligible		0,005		
$D_{RS/1}$	Uncertainty linked with stability of RS	negligible		negligible	0,058	0,003		0,001
$D_{RS/2}$	Uncertainty linked with temperature of RS	0,015	0,001	negligible	0,003	0,029	0,005	0,000
S_{Wt}	Wt scatter	0,172	0,318	0,100	0,378	0,067	0,249	0,080
Combined uncertainty		0,399	0,367	0,650	0,658	0,450	0,490	0,629
Expanded uncertainty		0,799	0,734	1,300	1,315	0,900	0,981	1,258

Tin

Quantity Q_i	Components	Uncertainty contribution ui in mK					
		Loop 3 Tinsley274686					
		BNM-INM	NMI-VSL	MIKES	DTI	SP	SMS/SPI
X_t	Repeatability of readings	included in Wt scatter	0,115	0,002	0,300	0,030	0,066
$C_{Xt/1}$	Uncertainty linked with purity	0,294	0,175	0,500	0,700	0,290	0,500
$C_{Xt/2}$	Uncertainty linked Hydrostatic pressure correction	0,006	0,013	0,013	0,020	0,010	0,006
$C_{Xt/3}$	Uncertainty linked with perturbing heat exchanges	0,029	0,017	0,023	0,100	0,120	0,014
$C_{Xt/4}$	Uncertainty linked with self-heating correction	0,029	0,004	0,041	0,200	0,060	0,016
$C_{Xt/5}$	Uncertainty linked with bridge linearity	0,029	0,115	0,005	0,030	0,010	0,043
$C_{Xt/6}$	Uncertainty linked with AC/DC current	negligible	0,022	0,043		0,120	negligible
$C_{Xt/7}$	Uncertainty linked with gas pressure	included in Cxt/1	0,001	0,013	0,500	0,010	0,017
$X_{0.01\,^{\circ}C}$	Repeatability of readings	included in Wt scatter		0,005	0,010	0,030	0,098
	Repeatability of temperature realized by cell	0,047		0,189	0,020	0,010	0,104
	Short repeatability of calibrated SPRT	0,095	0,057	0,224	0,020	0,350	0,510
	uncertainty of correction to EUROMET 549 value			0,096			
$C_{0.01^{\circ}C/1}$	Uncertainty linked with purity and isotopic composition	0,111	0,066	0,100	0,010	0,060	0,189
$C_{0.01^{\circ}C/2}$	Uncertainty linked Hydrostatic pressure correction	0,004	0,004	0,001	0,040	0,010	0,002
$C_{0.01^{\circ}C/3}$	Uncertainty linked with perturbing heat exchanges	0,056	0,019	0,023	0,010	0,030	0,023
$C_{0.01^{\circ}C/4}$	Uncertainty linked with self-heating correction	0,056	0,004	0,000	0,050	0,060	0,026
$C_{0.01^{\circ}C/5}$	Uncertainty linked with bridge linearity	included in Cxt/5	0,055	0,003	0,030	0,010	0,010
$C_{0.01^{\circ}C/6}$	Uncertainty linked with AC/DC current	negligible		0,021		0,060	negligible
$C_{0.01^{\circ}C/7}$	Uncertainty linked with internal insulation leakage	0,019		0,003	0,010		0,030
$C_{0.01^{\circ}C/8}$	Uncertainty linked with gas pressure					0,020	
$D_{RS/1}$	Uncertainty linked with stability of RS	negligible		0,021	0,030	negligible	negligible
$D_{RS/2}$	Uncertainty linked with temperature of RS	0,015	0,047	0,004	0,050	0,120	0,015
S_{Wt}	Wt scatter	0,110	0,190	0,044	0,020	0,120	0,070
Combined uncertainty		0,370	0,328	0,602	0,944	0,525	0,762
Expanded uncertainty		0,740	0,655	1,204	1,888	1,050	1,524

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Quantity Q$_i$	Components	Uncertainty contribution ui in mK					
		Loop 4 **YSI 4807**					
		BNM-INM	PTB	GUM	CMI	INM (Ro)	UME
X_t	Repeatability of readings	included in Wt scatter	see Wt scatter	0,086		0,013	0,086
$C_{Xt/1}$	Uncertainty linked with purity	0,294	0,304	0,550	0,310	1,299	0,500
$C_{Xt/2}$	Uncertainty linked Hydrostatic pressure correction	0,006	0,015	0,013	0,005	0,009	0,011
$C_{Xt/3}$	Uncertainty linked with perturbing heat exchanges	0,088	0,100	0,020	0,200	0,110	0,044
$C_{Xt/4}$	Uncertainty linked with self-heating correction	0,029	0,162	0,111	0,160	0,060	0,200
$C_{Xt/5}$	Uncertainty linked with bridge linearity	0,029	0,108	0,111	0,110	0,089	0,010
$C_{Xt/6}$	Uncertainty linked with AC/DC current	negligible				0,011	0,010
$C_{Xt/7}$	Uncertainty linked with gas pressure	included in Cxt/1	0,083	0,080	0,013	0,016	
$X_{0.01\,°C}$	Repeatability of readings	included in Wt scatter	see Wt scatter	0,055		0,242	0,006
	Repeatability of temperature realized by cell	0,047	see Wt scatter	0,025			0,004
	Short repeatability of calibrated SPRT	0,278	see Wt scatter	0,068			0,010
$C_{0.01°C/1}$	Uncertainty linked with purity and isotopic composition	0,111	0,058	0,114	0,050	0,100	0,070
$C_{0.01°C/2}$	Uncertainty linked Hydrostatic pressure correction	0,004	0,003	0,008	0,002	0,006	0,004
$C_{0.01°C/3}$	Uncertainty linked with perturbing heat exchanges	0,056	0,019	0,015	0,020	0,020	0,022
$C_{0.01°C/4}$	Uncertainty linked with self-heating correction	0,056	0,057	0,041	0,040	0,020	0,040
$C_{0.01°C/5}$	Uncertainty linked with bridge linearity	included in Cxt/5	0,047	0,016	0,040	0,168	0,005
$C_{0.01°C/6}$	Uncertainty linked with AC/DC current	negligible				0,020	0,050
$C_{0.01°C/7}$	Uncertainty linked with internal insulation leakage	0,019	0,010			0,004	0,000
$D_{RS/1}$	Uncertainty linked with stability of RS	negligible	0,001	0,004	0,005		0,010
$D_{RS/2}$	Uncertainty linked with temperature of RS	0,015	0,100	0,005	0,100	0,031	0,100
S_{Wt}	Wt scatter	0,160	0,104	0,090	0,095	0,288	0,163
Combined uncertainty		0,470	0,421	0,611	0,446	1,380	0,588
Expanded uncertainty		0,940	0,843	1,221	0,893	2,760	1,177

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Quantity Q_i	Components	Uncertainty contribution ui in mK					
		Loop 5	**SPRT 269586**				
		BNM-INM	NPL	JV	EIM	SMD	NML
X_t	Repeatability of readings	included in Wt scatter	0,019	0,0001	0,002	0,006	0,069
$C_{Xt/1}$	Uncertainty linked with purity	0,294	0,231	0,500	0,500	0,500	0,520
$C_{Xt/2}$	Uncertainty linked Hydrostatic pressure correction	0,006	0,006	0,032	0,006	0,009	0,013
$C_{Xt/3}$	Uncertainty linked with perturbing heat exchanges	0,088	0,058	0,309	0,003	0,176	0,029
$C_{Xt/4}$	Uncertainty linked with self-heating correction	0,029	0,008	0,088	0,049	0,092	0,080
$C_{Xt/5}$	Uncertainty linked with bridge linearity	0,029	0,031	0,003	0,020	0,120	0,029
$C_{Xt/6}$	Uncertainty linked with AC/DC current	negligible	not estimated	0,029		*neg.*	
$C_{Xt/7}$	Uncertainty linked with gas pressure	included in Cxt/1	0,025	0,193	0,080	0,130	0,404
$X_{0.01\,^\circ C}$	Repeatability of readings	included in Wt scatter	0,024		0,004	0,004	0,120
	Repeatability of temperature realized by cell	0,047	0,114	0,216	0,102	0,091	0,446
	Short repeatability of calibrated SPRT	0,206	0,097	0,058	0,305	0,071	0,279
$C_{0.01\,^\circ C/1}$	Uncertainty linked with purity and isotopic composition	0,111	0,233	0,100	0,203	0,100	0,117
$C_{0.01\,^\circ C/2}$	Uncertainty linked Hydrostatic pressure correction	0,004	0,004	0,011	0,004	0,006	0,002
$C_{0.01\,^\circ C/3}$	Uncertainty linked with perturbing heat exchanges	0,056	0,024	0,041	0,004	0,007	0,012
$C_{0.01\,^\circ C/4}$	Uncertainty linked with self-heating correction	0,056	0,012	0,012	0,059	0,005	0,044
$C_{0.01\,^\circ C/5}$	Uncertainty linked with bridge linearity	included in Cxt/5	0,059	0,003	0,002	0,015	0,029
$C_{0.01\,^\circ C/6}$	Uncertainty linked with AC/DC current	negligible	not estimated	0,029		*neg.*	not estimated
$C_{0.01\,^\circ C/7}$	Uncertainty linked with internal insulation leakage	0,019	not estimated		0,015	*neg.*	not estimated
$D_{RS/1}$	Uncertainty linked with stability of RS	negligible			0,005	*neg.*	0,031
$D_{RS/2}$	Uncertainty linked with temperature of RS	0,015	0,012	0,003	0,052	*neg.*	0,006
S_{Wt}	Wt scatter	0,010	0,071	0,086	0,227	0,036	0,105
Combined uncertainty		0,390	0,382	0,680	0,680	0,587	0,768
Expanded uncertainty		0,780	0,763	1,360	1,359	1,174	1,536

C3. Freezing point of Indium

Quantity Q_i	Components	Uncertainty contribution ui in mK		
		Loop 1	**SPRT ISOTECH 036**	
		BNM-INM	SMU	OMH
X_t	Repeatability of readings	included in Wt scatter		
$C_{Xt/1}$	Uncertainty linked with purity	0,294	0,400	
$C_{Xt/2}$	Uncertainty linked Hydrostatic pressure correction	0,010	0,016	
$C_{Xt/3}$	Uncertainty linked with perturbing heat exchanges	0,118	0,070	
$C_{Xt/4}$	Uncertainty linked with self-heating correction	0,029	0,030	
$C_{Xt/5}$	Uncertainty linked with bridge linearity	0,059	0,050	
$C_{Xt/6}$	Uncertainty linked with AC/DC current	negligible		
$C_{Xt/7}$	Uncertainty linked with gas pressure	included in Cxt/1	0,060	
$X_{0.01℃}$	Repeatability of readings	included in Wt scatter		
	Repeatability of temperature realized by cell	0,040		
	Short repeatability of calibrated SPRT	0,137		
$C_{0.01℃/1}$	Uncertainty linked with purity and isotopic composition	0,095	0,080	
$C_{0.01℃/2}$	Uncertainty linked Hydrostatic pressure correction	0,003	0,005	
$C_{0.01℃/3}$	Uncertainty linked with perturbing heat exchanges	0,047	0,030	
$C_{0.01℃/4}$	Uncertainty linked with self-heating correction	0,047	0,020	
$C_{0.01℃/5}$	Uncertainty linked with bridge linearity	included in Cxt/5	0,080	
$C_{0.01℃/6}$	Uncertainty linked with AC/DC current	negligible		
$C_{0.01℃/7}$	Uncertainty linked with internal insulation leakage	0,016		
$D_{RS/1}$	Uncertainty linked with stability of RS	negligible		
$D_{RS/2}$	Uncertainty linked with temperature of RS	0,012	0,010	
S_{Wt}	Wt scatter	0,079	0,200	
Combined uncertainty		0,380	0,480	
Expanded uncertainty		0,760	0,950	

Indium

Quantity Q_i	Components	Uncertainty contribution ui in mK						
		Loop 2	SPRT 1283					
		BNM-INM	IMGC	CEM	IPQ	METAS	MIRS/FE-LMK	BEV
X_t	Repeatability of readings	included in Wt scatter	0,006	0,020	0,016	0,014	0,030	0,049
	repeatability of temperature realized by cells							0,001
$C_{Xt/1}$	Uncertainty linked with purity	0,294	0,270	0,470	0,800	0,469	0,500	0,100
$C_{Xt/2}$	Uncertainty linked Hydrostatic pressure correction	0,010	0,006	0,030	0,019	0,019	0,015	0,033
$C_{Xt/3}$	Uncertainty linked with perturbing heat exchanges	0,118	0,012	0,170	0,023	0,063	0,025	0,016
$C_{Xt/4}$	Uncertainty linked with self-heating correction	0,029	0,008	0,060	0,002	0,151	0,030	0,328
$C_{Xt/5}$	Uncertainty linked with bridge linearity	0,059	0,001	0,120	0,009	0,022	0,050	0,400
$C_{Xt/6}$	Uncertainty linked with AC/DC current	negligible	0,001	0,040		0,1	0,000	0,001
$C_{Xt/7}$	Uncertainty linked with gas pressure	included in Cxt/1	0,035	0,030		0,074	0,050	0,010
$X_{0.01\,°C}$	Repeatability of readings	included in Wt scatter	0,036	0,020	0,019	0,011	0,020	0,030
	Repeatability of temperature realized by cell	0,040		0,010	0,105	0,017	0,050	0,000
	Short repeatability of calibrated SPRT	0,047		0,190	0,118	0,037	0,300	0,050
$C_{0.01°C/1}$	Uncertainty linked with purity and isotopic composition	0,095		0,060	0,100	0,006	0,050	0,100
$C_{0.01°C/2}$	Uncertainty linked Hydrostatic pressure correction	0,003		0,010	0,001	0,004	0,005	0,001
$C_{0.01°C/3}$	Uncertainty linked with perturbing heat exchanges	0,047		0,010	0,016	0,038	0,010	0,000
$C_{0.01°C/4}$	Uncertainty linked with self-heating correction	0,047		0,070	0,002	0,076	0,030	0,050
$C_{0.01°C/5}$	Uncertainty linked with bridge linearity	included in Cxt/5		0,200	0,006	0,014	0,050	0,000
$C_{0.01°C/6}$	Uncertainty linked with AC/DC current	negligible		0,050		0,05	0,000	0,000
$C_{0.01°C/7}$	Uncertainty linked with internal insulation leakage	0,016		negligible		0,006	0,000	0,000
$D_{RS/1}$	Uncertainty linked with stability of RS	negligible		negligible	0,058	0,006	0,000	0,001
$D_{RS/2}$	Uncertainty linked with temperature of RS	0,012	0,001	negligible	0,003	0,029	0,005	0,000
S_{Wt}	Wt scatter	0,029	0,154	0,040	0,543	0,133	0,340	0,056
Combined uncertainty		0,351	0,315	0,600	0,988	0,54	0,687	0,548
Expanded uncertainty		0,702	0,631	1,200	1,975	1,08	1,374	1,096

Indium

Quantity Q_i	Components	Uncertainty contribution u_i in mK					
		Loop 3	Tinsley274686				
		BNM-INM	NMI-VSL	MIKES	DTI	SP	SMS/SPI
X_t	Repeatability of readings	included in Wt scatter	0,115	0,004	0,400	0,030	
$C_{Xt/1}$	Uncertainty linked with purity	0,294	0,027	0,800	0,800	0,460	
$C_{Xt/2}$	Uncertainty linked Hydrostatic pressure correction	0,010	0,019	0,020	0,020	0,020	
$C_{Xt/3}$	Uncertainty linked with perturbing heat exchanges	0,118	0,017	0,196	0,200	0,290	
$C_{Xt/4}$	Uncertainty linked with self-heating correction	0,029	0,002	0,014	0,150	0,060	
$C_{Xt/5}$	Uncertainty linked with bridge linearity	0,059	0,115	0,004	0,030	0,010	
$C_{Xt/6}$	Uncertainty linked with AC/DC current	negligible	0,022	0,036		0,120	
$C_{Xt/7}$	Uncertainty linked with gas pressure	included in Cxt/1	0,002	0,000	0,500	0,010	
$X_{0.01\,°C}$	Repeatability of readings	included in Wt scatter		0,005	0,010	0,030	
	Repeatability of temperature realized by cell	0,040		0,189	0,020	0,010	
	Short repeatability of calibrated SPRT	0,071	0,048	0,477	0,020	0,120	
	uncertainty of correction to EUROMET 549 value			0,096			
$C_{0.01°C/1}$	Uncertainty linked with purity and isotopic composition	0,095	0,056	0,100	0,010	0,060	
$C_{0.01°C/2}$	Uncertainty linked Hydrostatic pressure correction	0,003	0,003	0,001	0,040	0,010	
$C_{0.01°C/3}$	Uncertainty linked with perturbing heat exchanges	0,047	0,016	0,023	0,010	0,030	
$C_{0.01°C/4}$	Uncertainty linked with self-heating correction	0,047	0,003	0,006	0,050	0,060	
$C_{0.01°C/5}$	Uncertainty linked with bridge linearity	included in Cxt/5	0,047	0,003	0,030	0,010	
$C_{0.01°C/6}$	Uncertainty linked with AC/DC current	negligible		0,021		0,060	
$C_{0.01°C/7}$	Uncertainty linked with internal insulation leakage	0,016		0,003	0,010		
$D_{RS/1}$	Uncertainty linked with stability of RS	negligible		0,025	0,030	negligible	
$D_{RS/2}$	Uncertainty linked with temperature of RS	0,012	0,040	0,004	0,050	0,120	
S_{Wt}	Wt scatter	0,240	0,130	0,044	0,020	0,100	
Combined uncertainty		0,430	0,230	0,983	1,060	0,605	
Expanded uncertainty		0,860	0,460	1,966	2,120	1,210	

Indium

Quantity Q_i	Components	Uncertainty contribution ui in mK					
		Loop 4 YSI 4807					
		BNM-INM	PTB	GUM	CMI	INM (Ro)	UME
X_t	Repeatability of readings	included in Wt scatter	see Wt scatter	0,129		0,010	0,026
$C_{Xt/1}$	Uncertainty linked with purity	0,294	0,258	0,550	0,470	2,454	0,800
$C_{Xt/2}$	Uncertainty linked Hydrostatic pressure correction	0,010	0,023	0,029	0,010	0,010	0,017
$C_{Xt/3}$	Uncertainty linked with perturbing heat exchanges	0,118	0,200	0,219	0,200	0,087	0,023
$C_{Xt/4}$	Uncertainty linked with self-heating correction	0,029	0,158	0,118	0,160	0,060	0,150
$C_{Xt/5}$	Uncertainty linked with bridge linearity	0,059	0,105	0,079	0,110	0,087	0,008
$C_{Xt/6}$	Uncertainty linked with AC/DC current	negligible				0,010	0,031
$C_{Xt/7}$	Uncertainty linked with gas pressure	included in Cxt/1	0,098	0,100	0,020	0,024	
$X_{0.01\,^{\circ}C}$	Repeatability of readings	included in Wt scatter	see Wt scatter	0,046		0,109	0,021
	Repeatability of temperature realized by cell	0,040	see Wt scatter	0,055			0,025
	Short repeatability of calibrated SPRT	0,237	see Wt scatter	0,058			0,047
$C_{0.01\,^{\circ}C/1}$	Uncertainty linked with purity and isotopic composition	0,095	0,050	0,097	0,050	0,100	0,070
$C_{0.01\,^{\circ}C/2}$	Uncertainty linked Hydrostatic pressure correction	0,003	0,002	0,007	0,002	0,006	0,004
$C_{0.01\,^{\circ}C/3}$	Uncertainty linked with perturbing heat exchanges	0,047	0,016	0,013	0,020	0,017	0,022
$C_{0.01\,^{\circ}C/4}$	Uncertainty linked with self-heating correction	0,047	0,048	0,035	0,040	0,017	0,040
$C_{0.01\,^{\circ}C/5}$	Uncertainty linked with bridge linearity	included in Cxt/5	0,040	0,070	0,040	0,139	0,005
$C_{0.01\,^{\circ}C/6}$	Uncertainty linked with AC/DC current	negligible				0,017	0,076
$C_{0.01\,^{\circ}C/7}$	Uncertainty linked with internal insulation leakage	0,016	0,010			0,003	
$D_{RS/1}$	Uncertainty linked with stability of RS	negligible	0,001	0,003	0,005		0,010
$D_{RS/2}$	Uncertainty linked with temperature of RS	0,012	0,100	0,005	0,100	0,025	0,100
S_{Wt}	Wt scatter	0,180	0,133	0,074	0,095	0,187	0,122
Combined uncertainty		0,460	0,432	0,654	0,569	2,470	0,840
Expanded uncertainty		0,920	0,865	1,308	1,139	4,940	1,681

Indium

Quantity Q_i	Components	Uncertainty contribution ui in mK					
		Loop 5 SPRT 269586					
		BNM-INM	NPL	JV	EIM	SMD	NML
X_t	Repeatability of readings	included in Wt scatter	0,072	0,0001	0,002	0,005	
$C_{Xt/1}$	Uncertainty linked with purity	0,294	0,289	0,800	0,800	0,800	
$C_{Xt/2}$	Uncertainty linked Hydrostatic pressure correction	0,010	0,010	0,048	0,010	0,013	
$C_{Xt/3}$	Uncertainty linked with perturbing heat exchanges	0,059	0,058	0,301	0,009	0,066	
$C_{Xt/4}$	Uncertainty linked with self-heating correction	0,029	0,009	0,083	0,029	0,009	
$C_{Xt/5}$	Uncertainty linked with bridge linearity	0,059	0,030	0,002	0,013	0,110	
$C_{Xt/6}$	Uncertainty linked with AC/DC current	negligible	not estimated	0,024		neg.	
$C_{Xt/7}$	Uncertainty linked with gas pressure	included in Cxt/1	0,037	0,287	0,100	0,120	
$X_{0.01 °C}$	Repeatability of readings	included in Wt scatter	0,064		0,003	0,003	
	Repeatability of temperature realized by cell	0,040	0,095	0,180	0,084	0,076	
	Short repeatability of calibrated SPRT	0,076	0,032	0,049	0,028	0,059	
$C_{0.01°C/1}$	Uncertainty linked with purity and isotopic composition	0,095	0,194	0,100	0,169	0,100	
$C_{0.01°C/2}$	Uncertainty linked Hydrostatic pressure correction	0,003	0,003	0,011	0,004	0,005	
$C_{0.01°C/3}$	Uncertainty linked with perturbing heat exchanges	0,047	0,020	0,034	0,003	0,006	
$C_{0.01°C/4}$	Uncertainty linked with self-heating correction	0,047	0,010	0,010	0,049	0,004	
$C_{0.01°C/5}$	Uncertainty linked with bridge linearity	included in Cxt/5	0,049	0,002	0,001	0,015	
$C_{0.01°C/6}$	Uncertainty linked with AC/DC current	negligible	not estimated	0,024		neg.	
$C_{0.01°C/7}$	Uncertainty linked with internal insulation leakage	0,016	not estimated		0,012	neg.	
$C_{0.01°C/8}$	Uncertainty linked with gas pressure					0,020	
$D_{RS/1}$	Uncertainty linked with stability of RS	negligible			0,004	neg.	
$D_{RS/2}$	Uncertainty linked with temperature of RS	0,012	0,010	0,002	0,043	neg.	
S_{Wt}	Wt scatter	0,011	0,034	0,061	0,019	0,154	
Combined uncertainty		0,340	0,390	0,934	0,832	0,845	
Expanded uncertainty		0,680	0,780	1,869	1,664	1,690	

C4. Melting point of Gallium

Quantity Q_i	Components	Uncertainty contribution ui in mK		
		Loop 1	SPRT ISOTECH 036	
		BNM-INM	SMU	OMH
X_t	Repeatability of readings	included in Wt scatter		0,030
$C_{Xt/1}$	Uncertainty linked with purity	0,059	0,010	0,040
$C_{Xt/2}$	Uncertainty linked Hydrostatic pressure correction	0,004	0,006	0,010
$C_{Xt/3}$	Uncertainty linked with perturbing heat exchanges	0,029	0,025	0,020
$C_{Xt/4}$	Uncertainty linked with self-heating correction	0,029	0,020	0,018
$C_{Xt/5}$	Uncertainty linked with bridge linearity	0,029	0,050	0,006
$C_{Xt/6}$	Uncertainty linked with AC/DC current	negligible		0,000
$C_{Xt/7}$	Uncertainty linked with gas pressure	included in Cxt/1	0,002	0,100
$X_{0.01\,°C}$	Repeatability of readings	included in Wt scatter		0,022
	Repeatability of temperature realized by cell	0,028		0,022
	Short repeatability of calibrated SPRT	0,008		0,022
$C_{0.01°C/1}$	Uncertainty linked with purity and isotopic composition	0,066	0,060	0,011
$C_{0.01°C/2}$	Uncertainty linked Hydrostatic pressure correction	0,002	0,002	0,009
$C_{0.01°C/3}$	Uncertainty linked with perturbing heat exchanges	0,033	0,020	0,011
$C_{0.01°C/4}$	Uncertainty linked with self-heating correction	0,033	0,011	0,019
$C_{0.01°C/5}$	Uncertainty linked with bridge linearity	included in Cxt/5	0,060	0,006
$C_{0.01°C/6}$	Uncertainty linked with AC/DC current	negligible		
$C_{0.01°C/7}$	Uncertainty linked with internal insulation leakage	0,011		
$D_{RS/1}$	Uncertainty linked with stability of RS	negligible		0,141
$D_{RS/2}$	Uncertainty linked with temperature of RS	0,008	0,003	0,141
S_{Wt}	Wt scatter	0,025	0,030	0,001
Combined uncertainty		0,119	0,110	0,240
Expanded uncertainty		0,238	0,220	0,480

Gallium

Quantity Q_i	Components	Uncertainty contribution ui in mK						
		Loop 2 SPRT 1283						
		BNM-INM	IMGC	CEM	IPQ	METAS	MIRS/FE-LMK	BEV
X_t	Repeatability of readings	included in Wt scatter	0,006	0,020	0,030	0,019	0,020	0,034
	repeatability of temperature realized by cells							0,094
$C_{Xt/1}$	Uncertainty linked with purity	0,059	0,008	0,120	0,200	0,014	0,100	0,100
$C_{Xt/2}$	Uncertainty linked Hydrostatic pressure correction	0,004	0,002	0,010	0,007	0,007	0,010	0,106
$C_{Xt/3}$	Uncertainty linked with perturbing heat exchanges	0,029	0,003	0,010	0,023	0,073	0,010	0,011
$C_{Xt/4}$	Uncertainty linked with self-heating correction	0,029	0,007	0,050	0,005	0,151	0,030	0,224
$C_{Xt/5}$	Uncertainty linked with bridge linearity	0,029	0,001	0,120	0,006	0,016	0,050	0,400
$C_{Xt/6}$	Uncertainty linked with AC/DC current	negligible	0,001	0,040		0,050	0,000	0,001
$C_{Xt/7}$	Uncertainty linked with gas pressure	included in Cxt/1	0,001	0,050		0,029	0,050	0,010
$X_{0.01\,°C}$	Repeatability of readings	included in Wt scatter	0,025	0,020	0,022	0,009	0,020	0,030
	Repeatability of temperature realized by cell	0,028		negligible	0,105	0,017	0,050	0,008
	Short repeatability of calibrated SPRT	0,033		0,040	0,032	0,012	0,100	0,050
$C_{0.01°C/1}$	Uncertainty linked with purity and isotopic composition	0,066		0,040	0,100	0,006	0,050	0,100
$C_{0.01°C/2}$	Uncertainty linked Hydrostatic pressure correction	0,002		negligible	0,001	0,004	0,005	0,001
$C_{0.01°C/3}$	Uncertainty linked with perturbing heat exchanges	0,033		0,010	0,016	0,038	0,010	0,000
$C_{0.01°C/4}$	Uncertainty linked with self-heating correction	0,033		0,050	0,003	0,039	0,030	0,050
$C_{0.01°C/5}$	Uncertainty linked with bridge linearity	included in Cxt/5		0,130	0,006	0,014	0,050	0,000
$C_{0.01°C/6}$	Uncertainty linked with AC/DC current	negligible		0,040		0,050	0,000	0,000
$C_{0.01°C/7}$	Uncertainty linked with internal insulation leakage	0,011	0,001	negligible		0,006	0,000	0,000
$D_{RS/1}$	Uncertainty linked with stability of RS	negligible		negligible	0,014	0,006	0,000	0,001
$D_{RS/2}$	Uncertainty linked with temperature of RS	0,008	0,001	negligible	0,001	0,029	0,005	0,000
S_{Wt}	Wt scatter	0,12	0,078	0,040	0,317	0,260	0,136	0,056
Combined uncertainty		0,17	0,083	0,240	0,406	0,330	0,232	0,511
Expanded uncertainty		0,35	0,166	0,480	0,813	0,660	0,464	1,022

Gallium

Quantity Q_i	Components	Uncertainty contribution ui in mK					
		Loop 3	Tinsley274686				
		BNM-INM	NMI-VSL	MIKES	DTI	SP	SMS/SPI
X_t	Repeatability of readings	included in Wt scatter	0,058	0,003	0,080	0,030	0,058
$C_{Xt/1}$	Uncertainty linked with purity	0,059	0,079	0,200	0,200	0,120	0,200
$C_{Xt/2}$	Uncertainty linked Hydrostatic pressure correction	0,004	0,003	0,007	0,010	0,010	0,003
$C_{Xt/3}$	Uncertainty linked with perturbing heat exchanges	0,029	0,017	0,026	0,020	0,030	0,008
$C_{Xt/4}$	Uncertainty linked with self-heating correction	0,029	0,002	0,002	0,050	0,060	0,003
$C_{Xt/5}$	Uncertainty linked with bridge linearity	0,029	0,029	0,003	0,030	0,010	0,005
$C_{Xt/6}$	Uncertainty linked with AC/DC current	negligible	0,022	0,003		0,120	negligible
$C_{Xt/7}$	Uncertainty linked with gas pressure	included in Cxt/1	0,087	0,018	0,150		0,012
$X_{0.01\,°C}$	Repeatability of readings	included in Wt scatter		0,005	0,010	0,030	0,058
	Repeatability of temperature realized by cell	0,028		0,189	0,020	0,010	0,061
	Short repeatability of calibrated SPRT	0,033	0,034	0,017	0,020	0,120	0,018
	uncertainty of correction to EUROMET 549 value			0,096			
$C_{0.01°C/1}$	Uncertainty linked with purity and isotopic composition	0,066	0,039	0,100	0,010	0,060	0,112
$C_{0.01°C/2}$	Uncertainty linked Hydrostatic pressure correction	0,002	0,002	0,001	0,040	0,010	0,001
$C_{0.01°C/3}$	Uncertainty linked with perturbing heat exchanges	0,033	0,011	0,023	0,010	0,030	0,014
$C_{0.01°C/4}$	Uncertainty linked with self-heating correction	0,033	0,002	0,020	0,050	0,060	0,006
$C_{0.01°C/5}$	Uncertainty linked with bridge linearity	included in Cxt/5	0,032	0,003	0,030	0,010	0,006
$C_{0.01°C/6}$	Uncertainty linked with AC/DC current	negligible		0,021		0,060	negligible
$C_{0.01°C/7}$	Uncertainty linked with internal insulation leakage	0,011		0,003	0,010		0,018
$D_{RS/1}$	Uncertainty linked with stability of RS	negligible		0,025	0,030	negligible	negligible
$D_{RS/2}$	Uncertainty linked with temperature of RS	0,008	0,028	0,002	0,050	0,120	0,008
S_{Wt}	Wt scatter	0,080	0,050	0,068	0,020	0,010	0,019
Combined uncertainty		0,140	0,161	0,320	0,288	0,265	0,254
Expanded uncertainty		0,280	0,322	0,641	0,575	0,530	0,508

Gallium

Quantity Q_i	Components	Uncertainty contribution ui in mK					
		Loop 4	**YSI 4807**				
		BNM-INM	PTB	GUM	CMI	INM (Ro)	UME
X_t	Repeatability of readings	included in Wt scatter	see Wt scatter	0,041		0,001	0,060
$C_{Xt/1}$	Uncertainty linked with purity	0,059	0,055	0,250	0,200	0,058	0,200
$C_{Xt/2}$	Uncertainty linked Hydrostatic pressure correction	0,004	0,008	0,007	0,002	0,005	0,006
$C_{Xt/3}$	Uncertainty linked with perturbing heat exchanges	0,029	0,010	0,025	0,050	0,017	0,012
$C_{Xt/4}$	Uncertainty linked with self-heating correction	0,029	0,030	0,055	0,050	0,030	0,050
$C_{Xt/5}$	Uncertainty linked with bridge linearity	0,029	0,010	0,037	0,025	0,083	0,006
$C_{Xt/6}$	Uncertainty linked with AC/DC current	negligible				0,010	0,011
$C_{Xt/7}$	Uncertainty linked with gas pressure	included in Cxt/1	0,010	0,010	0,008	0,010	
$X_{0.01\,°C}$	Repeatability of readings	included in Wt scatter	see Wt scatter	0,032		0,058	0,100
	Repeatability of temperature realized by cell	0,028	see Wt scatter	0,023			0,005
	Short repeatability of calibrated SPRT	0,033	see Wt scatter	0,040			0,009
$C_{0.01°C/1}$	Uncertainty linked with purity and isotopic composition	0,066	0,035	0,067	0,050	0,100	0,070
$C_{0.01°C/2}$	Uncertainty linked Hydrostatic pressure correction	0,002	0,002	0,005	0,002	0,006	0,004
$C_{0.01°C/3}$	Uncertainty linked with perturbing heat exchanges	0,033	0,011	0,009	0,020	0,011	0,022
$C_{0.01°C/4}$	Uncertainty linked with self-heating correction	0,033	0,034	0,048	0,040	0,011	0,040
$C_{0.01°C/5}$	Uncertainty linked with bridge linearity	included in Cxt/5	0,028	0,032	0,040	0,093	0,005
$C_{0.01°C/6}$	Uncertainty linked with AC/DC current	negligible				0,110	0,034
$C_{0.01°C/7}$	Uncertainty linked with internal insulation leakage	0,011	0,010			0,002	
$D_{RS/1}$	Uncertainty linked with stability of RS	negligible	0,001	0,002	0,051		0,010
$D_{RS/2}$	Uncertainty linked with temperature of RS	0,008	0,100	0,003	0,100	0,017	0,100
S_{Wt}	Wt scatter	0,090	0,008	0,014	0,095	0,015	0,021
Combined uncertainty		0,150	0,133	0,284	0,271	0,220	0,275
Expanded uncertainty		0,300	0,266	0,568	0,542	0,440	0,549

Gallium

Quantity Q_i	Components	Uncertainty contribution ui in mK					
		Loop 5 SPRT 269586					
		BNM-	NPL	JV	EIM	SMD	NML
X_t	Repeatability of readings	included in Wt scatter	0,018	0,0001	0,002	0,004	0,080
$C_{Xt/1}$	Uncertainty linked with purity	0,059	0,058	0,200	0,200	0,200	0,200
$C_{Xt/2}$	Uncertainty linked Hydrostatic pressure correction	0,004	0,003	0,017	0,003	0,005	0,007
$C_{Xt/3}$	Uncertainty linked with perturbing heat exchanges	0,003	0,023	0,029	0,014	0,036	0,009
$C_{Xt/4}$	Uncertainty linked with self-heating correction	0,029	0,007	0,061	0,002	0,030	0,023
$C_{Xt/5}$	Uncertainty linked with bridge linearity	0,029	0,029	0,002	0,003	0,020	0,016
$C_{Xt/6}$	Uncertainty linked with AC/DC current	negligible	not estimated	0,016		neg.	not estimated
$C_{Xt/7}$	Uncertainty linked with gas pressure	included in Cxt/1	0,029	0,117	0,010	0,010	0,006
$C_{Xt/8}$	Uncertainty linked with internal insulation leakage of SPRT at Ga (in mK)				0,030		
$X_{0.01^\circ C}$	Repeatability of readings	included in Wt scatter	0,008		0,002	0,002	0,046
	Repeatability of temperature realized by cell	0,028	0,063	0,120	0,056	0,052	0,247
	Short repeatability of calibrated SPRT	0,010	0,041	0,033	0,143	0,041	0,065
$C_{0.01^\circ C/1}$	Uncertainty linked with purity and isotopic composition	0,066	0,130	0,100	0,113	0,100	0,065
$C_{0.01^\circ C/2}$	Uncertainty linked Hydrostatic pressure correction	0,002	0,002	0,011	0,002	0,003	0,001
$C_{0.01^\circ C/3}$	Uncertainty linked with perturbing heat exchanges	0,033	0,014	0,023	0,002	0,004	0,003
$C_{0.01^\circ C/4}$	Uncertainty linked with self-heating correction	0,033	0,007	0,006	0,005	0,003	0,020
$C_{0.01^\circ C/5}$	Uncertainty linked with bridge linearity	included in Cxt/5	0,033	0,002	0,001	0,015	0,016
$C_{0.01^\circ C/6}$	Uncertainty linked with AC/DC current	negligible	not estimated	0,016		neg.	not estimated
$C_{0.01^\circ C/7}$	Uncertainty linked with internal insulation	0,011	not estimated		0,008	neg.	not estimated
$C_{0.01^\circ C/8}$	Uncertainty linked with gas pressure					0,020	
$D_{RS/1}$	Uncertainty linked with stability of RS	negligible			0,003	neg.	0,029
$D_{RS/2}$	Uncertainty linked with temperature of RS	0,008	0,007	0,002	0,029	neg.	0,001
S_{Wt}	Wt scatter	0,010	0,074	0,019	0,041	0,098	0,074
Combined uncertainty		0,110	0,188	0,293	0,283	0,260	0,355
Expanded uncertainty		0,220	0,376	0,586	0,567	0,520	0,710

C5. Triple point of Mercury

Quantity Qi	Components	Uncertainty contribution ui in mK		
		Loop 1	**SPRT ISOTECH 036**	
		BNM-INM	SMU	OMH
X_t	Repeatability of readings	0,010		0,05
$C_{Xt/1}$	Uncertainty linked with purity	0,240	0,250	0,04
$C_{Xt/2}$	Uncertainty linked Hydrostatic pressure correction	0,036	0,040	0,07
$C_{Xt/3}$	Uncertainty linked with perturbing heat exchanges	0,020	0,100	0,02
$C_{Xt/4}$	Uncertainty linked with self-heating correction	0,050	0,030	0,01
$C_{Xt/5}$	Uncertainty linked with bridge linearity	negligible	0,050	0,00
$C_{Xt/6}$	Uncertainty linked with AC/DC current	negligible		0,00
$C_{Xt/7}$	Uncertainty linked with gas pressure	no effect	0,040	0,10
$X_{0.01\,°C}$	Repeatability of readings	0,030		0,04
	Repeatability of temperature realized by cell	0,050		0,02
	Short repeatability of calibrated SPRT	0,050		0,02
$C_{0.01°C/1}$	Uncertainty linked with purity and isotopic composition	0,066	0,040	0,01
$C_{0.01°C/2}$	Uncertainty linked Hydrostatic pressure correction	0,002	0,002	0,01
$C_{0.01°C/3}$	Uncertainty linked with perturbing heat exchanges	0,033	0,020	0,01
$C_{0.01°C/4}$	Uncertainty linked with self-heating correction	0,050	0,010	0,01
$C_{0.01°C/5}$	Uncertainty linked with bridge linearity	negligible	0,040	0,00
$C_{0.01°C/6}$	Uncertainty linked with AC/DC current	negligible		
$C_{0.01°C/7}$	Uncertainty linked with internal insulation leakage	negligible		
$D_{RS/1}$	Uncertainty linked with stability of RS	negligible		0,10
$D_{RS/2}$	Uncertainty linked with temperature of RS	0,004	0,010	0,10
S_{Wt}	Wt scatter	0,100	0,200	0,00
Combined uncertainty		0,290	0,350	0,22
Expanded uncertainty		0,580	0,700	0,43

Mercury

Quantity Q_i	Components	Uncertainty contribution ui in mK						
		Loop 2 SPRT 1283						
		BNM-INM	IMGC	CEM	IPQ	METAS	MIRS/FE-LMK	BEV
X_t	Repeatability of readings	0,010	0,006	0,010	0,009	0,01	0,020	0,006
	repeatability of temperature realized by cells							0,134
$C_{Xt/1}$	Uncertainty linked with purity	0,240	0,115	0,120	0,250	0,02	0,150	0,100
$C_{Xt/2}$	Uncertainty linked Hydrostatic pressure correction	0,036	0,020	0,070	0,040	0,041	0,035	0,070
$C_{Xt/3}$	Uncertainty linked with perturbing heat exchanges	0,020	0,006	0,060	0,025	0,03	0,020	0,008
$C_{Xt/4}$	Uncertainty linked with self-heating correction	0,050	0,006	0,040	0,002	0,151	0,030	0,168
$C_{Xt/5}$	Uncertainty linked with bridge linearity	negligible	0,001	0,110	0,005	0,012	0,050	0,400
$C_{Xt/6}$	Uncertainty linked with AC/DC current	negligible	0,001	0,020		0,050	0,000	0,001
$C_{Xt/7}$	Uncertainty linked with gas pressure	no effect	0,001	negligible		0,010	0,050	0,010
$X_{0.01\,°C}$	Repeatability of readings	0,030	0,019	0,010	0,006	0,009	0,020	0,030
	Repeatability of temperature realized by cell	0,050		negligible	0,105	0,017	0,050	0,090
	Short repeatability of calibrated SPRT	0,050		0,040	0,083	0,018	0,080	0,050
$C_{0.01°C/1}$	Uncertainty linked with purity and isotopic composition	0,066		0,030	0,100	0,006	0,050	0,100
$C_{0.01°C/2}$	Uncertainty linked Hydrostatic pressure correction	0,002		negligible	0,001	0,004	0,005	0,001
$C_{0.01°C/3}$	Uncertainty linked with perturbing heat exchanges	0,033		0,010	0,016	0,038	0,010	0,000
$C_{0.01°C/4}$	Uncertainty linked with self-heating correction	0,050		0,030	0,002	0,118	0,030	0,050
$C_{0.01°C/5}$	Uncertainty linked with bridge linearity	negligible		0,100	0,006	0,014	0,050	0,000
$C_{0.01°C/6}$	Uncertainty linked with AC/DC current	negligible		0,030		0,05	0,000	0,100
$C_{0.01°C/7}$	Uncertainty linked with internal insulation leakage	negligible	0,001	negligible		0,006	0,000	0,100
$D_{RS/1}$	Uncertainty linked with stability of RS	negligible		negligible	0,014	0,006	0,000	0,001
$D_{RS/2}$	Uncertainty linked with temperature of RS	0,004	0,001	negligible	0,001	0,029	0,005	0,000
S_{Wt}	Wt scatter	0,100	0,047	0,030	0,076	0,034	0,227	0,063
Combined uncertainty		0,290	0,128	0,230	0,315	0,22	0,312	0,519
Expanded uncertainty		0,580	0,255	0,460	0,629	0,44	0,623	1,038

Mercury

Quantity Q_i	Components	Uncertainty contribution ui in mK					
		Loop 3 Tinsley274686					
		BNM-INM	NMI-VSL	MIKES	DTI	SP	SMS/SPI
X_t	Repeatability of readings	0,010	0,058	0,002	0,120	0,030	0,041
$C_{Xt/1}$	Uncertainty linked with purity	0,240	0,012	0,250	0,250	0,140	0,250
	Uncertainty linked with determination of triple point temperature				1,480		
$C_{Xt/2}$	Uncertainty linked Hydrostatic pressure correction	0,036	0,020	0,043	0,040	0,040	0,020
$C_{Xt/3}$	Uncertainty linked with perturbing heat exchanges	0,020	0,035	0,003	0,060	0,030	0,013
$C_{Xt/4}$	Uncertainty linked with self-heating correction	0,050	0,002	0,000	0,050	0,060	0,012
$C_{Xt/5}$	Uncertainty linked with bridge linearity	negligible	0,029	0,002	0,030	0,010	0,005
$C_{Xt/6}$	Uncertainty linked with AC/DC current	negligible	0,022	0,015		0,120	
$C_{Xt/7}$	Uncertainty linked with gas pressure	no effect	0,004		0,260	0,010	
$X_{0.01\,°C}$	Repeatability of readings	0,030		0,005	0,010	0,030	0,044
	Repeatability of temperature realized by cell	0,050		0,189	0,020	0,010	0,046
	Short repeatability of calibrated SPRT	0,050	0,025	0,104	0,020	0,230	0,014
	uncertainty of correction to EUROMET 549 value			0,096			
$C_{0.01°C/1}$	Uncertainty linked with purity and isotopic composition	0,066	0,030	0,100	0,010	0,060	0,084
$C_{0.01°C/2}$	Uncertainty linked Hydrostatic pressure correction	0,002	0,002	0,001	0,040	0,010	0,001
$C_{0.01°C/3}$	Uncertainty linked with perturbing heat exchanges	0,033	0,008	0,023	0,010	0,030	0,010
$C_{0.01°C/4}$	Uncertainty linked with self-heating correction	0,050	0,002	0,026	0,050	0,060	0,010
$C_{0.01°C/5}$	Uncertainty linked with bridge linearity	negligible	0,024	0,003	0,030	0,010	0,004
$C_{0.01°C/6}$	Uncertainty linked with AC/DC current	negligible		0,021		0,060	
$C_{0.01°C/7}$	Uncertainty linked with internal insulation leakage	negligible		0,003	0,010		0,013
$D_{RS/1}$	Uncertainty linked with stability of RS	negligible	0,021	0,095	0,030	negligible	
$D_{RS/2}$	Uncertainty linked with temperature of RS	0,004		0,002	0,050	0,230	0,006
S_{Wt}	Wt scatter	0,100	0,110	0,033	0,020	0,010	0,025
Combined uncertainty		0,290	0,146	0,377	1,540	0,400	0,278
Expanded uncertainty		0,580	0,292	0,753	3,080	0,800	0,556

Mercury

Quantity Q_i	Components	Uncertainty contribution ui in mK					
		Loop 4 YSI 4807					
		BNM-INM	PTB	GUM	CMI	INM (Ro)	UME
X_t	Repeatability of readings	0,010	see Wt scatter	0,008		0,002	0,020
$C_{Xt/1}$	Uncertainty linked with purity	0,240	0,060	0,325	0,250	0,346	0,250
$C_{Xt/2}$	Uncertainty linked Hydrostatic pressure correction	0,036	0,036	0,041	0,014	0,021	0,036
$C_{Xt/3}$	Uncertainty linked with perturbing heat exchanges	0,020	0,020	0,049	0,100	0,130	0,010
$C_{Xt/4}$	Uncertainty linked with self-heating correction	0,050	0,039	0,031	0,050	0,030	0,050
$C_{Xt/5}$	Uncertainty linked with bridge linearity	negligible	0,024	0,020	0,025	0,082	0,004
$C_{Xt/6}$	Uncertainty linked with AC/DC current	negligible				0,010	0,070
$C_{Xt/7}$	Uncertainty linked with gas pressure	no effect	0,032	0,010	0,020	0,000	
$X_{0.01\,°C}$	Repeatability of readings	0,030	see Wt scatter	0,024		0,052	0,030
	Repeatability of temperature realized by cell	0,050	see Wt scatter	0,029			0,040
	Short repeatability of calibrated SPRT	0,050	see Wt scatter	0,030			0,015
$C_{0.01°C/1}$	Uncertainty linked with purity and isotopic composition	0,066	0,034	0,051	0,050	0,100	0,070
$C_{0.01°C/2}$	Uncertainty linked Hydrostatic pressure correction	0,002	0,001	0,004	0,002	0,006	0,004
$C_{0.01°C/3}$	Uncertainty linked with perturbing heat exchanges	0,033	0,008	0,007	0,020	0,008	0,022
$C_{0.01°C/4}$	Uncertainty linked with self-heating correction	0,050	0,034	0,037	0,040	0,008	0,040
$C_{0.01°C/5}$	Uncertainty linked with bridge linearity	negligible	0,021	0,007	0,040	0,069	0,005
$C_{0.01°C/6}$	Uncertainty linked with AC/DC current	negligible				0,008	0,040
$C_{0.01°C/7}$	Uncertainty linked with internal insulation leakage	negligible	0,008			0,002	
$D_{RS/1}$	Uncertainty linked with stability of RS	negligible	0,012	0,002	0,051		0,010
$D_{RS/2}$	Uncertainty linked with temperature of RS	0,004	0,012	0,002	0,100	0,013	0,100
S_{Wt}	Wt scatter	0,100	0,086	0,036	0,095	0,030	0,115
Combined uncertainty		0,290	0,138	0,345	0,322	0,400	0,326
Expanded uncertainty		0,580	0,276	0,690	0,645	0,800	0,652

Mercury

Quantity Q_i	Components	Uncertainty contribution ui in mK					
		Loop 5 SPRT 269586					
		BNM-	NPL	JV	EIM	SMD	NML
X_t	Repeatability of readings	0,010	0,018	0,0001	0,006	0,002	0,097
$C_{Xt/1}$	Uncertainty linked with purity	0,240	0,115	0,250	0,250	0,250	0,250
$C_{Xt/2}$	Uncertainty linked Hydrostatic pressure correction	0,036	0,020	0,102	0,020	0,026	0,020
$C_{Xt/3}$	Uncertainty linked with perturbing heat exchanges	0,020	0,029	0,284	0,004	0,016	0,029
$C_{Xt/4}$	Uncertainty linked with self-heating correction	0,050	0,006	0,048	0,009	0,022	0,021
$C_{Xt/5}$	Uncertainty linked with bridge linearity	negligible	0,029	0,001	0,003	0,020	0,012
$C_{Xt/6}$	Uncertainty linked with AC/DC current	negligible	not estimated	0,012		neg.	not estimated
$C_{Xt/7}$	Uncertainty linked with gas pressure	no effect	not estimated		0,010	0,010	0,006
$X_{0.01\,°C}$	Repeatability of readings	0,030	0,013		0,002	0,002	0,046
	Repeatability of temperature realized by cell	0,050	0,046	0,089	0,049	0,037	0,183
	Short repeatability of calibrated SPRT	0,050	0,050	0,024	0,063	0,029	0,030
$C_{0.01°C/1}$	Uncertainty linked with purity and isotopic composition	0,066	0,095	0,000	0,099	0,100	0,048
$C_{0.01°C/2}$	Uncertainty linked Hydrostatic pressure correction	0,002	0,002	0,011	0,002	0,002	0,001
$C_{0.01°C/3}$	Uncertainty linked with perturbing heat exchanges	0,033	0,010	0,017	0,002	0,003	0,004
$C_{0.01°C/4}$	Uncertainty linked with self-heating correction	0,050	0,005	0,005	0,002	0,002	0,010
$C_{0.01°C/5}$	Uncertainty linked with bridge linearity	negligible	0,024	0,001	0,001	0,015	0,012
$C_{0.01°C/6}$	Uncertainty linked with AC/DC current	negligible	not estimated	0,012		neg.	not estimated
$C_{0.01°C/7}$	Uncertainty linked with internal insulation leakage	negligible	not estimated		0,007	neg.	not estimated
$C_{0.01°C/8}$	Uncertainty linked with gas pressure					0,020	
$D_{RS/1}$	Uncertainty linked with stability of RS	negligible			0,003	neg.	0,029
$D_{RS/2}$	Uncertainty linked with temperature of RS	0,004	0,005	0,001	0,025	neg.	0,001
S_{Wt}	Wt scatter	0,100	0,025	0,086	0,010	0,015	0,049
Combined uncertainty		0,290	0,176	0,415	0,283	0,278	0,341
Expanded uncertainty		0,580	0,352	0,830	0,566	0,556	0,682

C5. Triple point of Argon

Quantity Q_i	Components	Uncertainty contribution ui in mK					
		Loop 2 SPRT 1283					
		BNM-INM	IMGC	CEM	IPQ	METAS	MIRS/FE-LMK
X_t	Repeatability of readings	0,030	0,006	0,180	0,005	0,010	0,040
$C_{Xt/1}$	Uncertainty linked with purity	0,200	0,028	0,300	0,300	0,290	0,200
$C_{Xt/2}$	Uncertainty linked Hydrostatic pressure correction	0,017	0,006	0,030	0,019	0,019	0,017
$C_{Xt/3}$	Uncertainty linked with perturbing heat exchanges	0,160	0,115	0,140	0,081	0,200	0,150
$C_{Xt/4}$	Uncertainty linked with self-heating correction	0,050	0,004	0,030	0,001	0,087	0,030
$C_{Xt/5}$	Uncertainty linked with bridge linearity	negligible	0,001	0,110	0,001	0,030	0,050
$C_{Xt/6}$	Uncertainty linked with AC/DC current	negligible	0,001	0,090		0,100	0,000
$C_{Xt/7}$	Uncertainty linked with gas pressure	no effect	0,003	0,010			0,073
$X_{0.01\,°C}$	Repeatability of readings	0,030	0,005	negligible	0,007	0,009	0,020
	Repeatability of temperature realized by cell	0,050		negligible	0,105	0,017	0,050
	Short repeatability of calibrated SPRT	0,050		0,010	0,229	0,059	0,080
$C_{0.01°C/1}$	Uncertainty linked with purity and isotopic composition	0,066		0,010	0,100	0,006	0,050
$C_{0.01°C/2}$	Uncertainty linked Hydrostatic pressure correction	0,002		negligible	0,001	0,004	0,005
$C_{0.01°C/3}$	Uncertainty linked with perturbing heat exchanges	0,033		negligible	0,016	0,038	0,010
$C_{0.01°C/4}$	Uncertainty linked with self-heating correction	0,050		0,010	0,005	0,110	0,030
$C_{0.01°C/5}$	Uncertainty linked with bridge linearity	negligible		0,020	0,006	0,014	0,050
$C_{0.01°C/6}$	Uncertainty linked with AC/DC current	negligible		0,010		0,050	0,000
$C_{0.01°C/7}$	Uncertainty linked with internal insulation leakage	negligible	0,001	negligible		0,006	0,000
$D_{RS/1}$	Uncertainty linked with stability of RS	negligible		negligible	0,006	0,006	0,000
$D_{RS/2}$	Uncertainty linked with temperature of RS	0,001	0,001	negligible	0,000	0,029	0,005
S_{Wt}	Wt scatter	0,100	0,196	0,230	0,045	0,136	0,294
Combined uncertainty		0,340	0,229	0,470	0,416	0,427	0,419
Expanded uncertainty		0,680	0,458	0,940	0,884	0,854	0,837

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Quantity Q_i	Components	Uncertainty contribution ui in mK					
		Loop 3 Tinsley274686					
		BNM-INM	NMI-VSL	MIKES	DTI	SP	SMS/SPI
X_t	Repeatability of readings	0,030	0,144	0,002		0,030	
$C_{Xt/1}$	Uncertainty linked with purity	0,200	0,032	0,300		0,170	
$C_{Xt/2}$	Uncertainty linked Hydrostatic pressure correction	0,017	0,019	0,020		0,060	
$C_{Xt/3}$	Uncertainty linked with perturbing heat exchanges	0,160	0,017	0,093		0,290	
$C_{Xt/4}$	Uncertainty linked with self-heating correction	0,050	0,004	0,009		0,060	
$C_{Xt/5}$	Uncertainty linked with bridge linearity	negligible	0,012	0,001		0,010	
$C_{Xt/6}$	Uncertainty linked with AC/DC current	negligible	0,022	0,025		0,120	
$C_{Xt/7}$	Uncertainty linked with gas pressure	no effect					
$X_{0.01\,°C}$	Repeatability of readings	0,030	0,060	0,005		0,030	
	Repeatability of temperature realized by cell	0,050		0,189		0,010	
	Short repeatability of calibrated SPRT	0,050		0,007		0,120	
	uncertainty of correction to EUROMET 549 value			0,096			
$C_{0.01°C/1}$	Uncertainty linked with purity and isotopic composition	0,066	0,008	0,100		0,060	
$C_{0.01°C/2}$	Uncertainty linked Hydrostatic pressure correction	0,002	0,000	0,001		0,010	
$C_{0.01°C/3}$	Uncertainty linked with perturbing heat exchanges	0,033	0,002	0,325		0,030	
$C_{0.01°C/4}$	Uncertainty linked with self-heating correction	0,050	0,000	0,025		0,060	
$C_{0.01°C/5}$	Uncertainty linked with bridge linearity	negligible	0,006	0,003		0,010	
$C_{0.01°C/6}$	Uncertainty linked with AC/DC current	negligible		0,021		0,060	
$C_{0.01°C/7}$	Uncertainty linked with internal insulation leakage	negligible		0,003			
$D_{RS/1}$	Uncertainty linked with stability of RS	negligible		0,095		negligible	
$D_{RS/2}$	Uncertainty linked with temperature of RS	0,001	0,005	0,000		0,120	
S_{Wt}	Wt scatter	0,100	0,010	0,095		0,080	
Combined uncertainty		0,340	0,153	0,529		0,425	
Expanded uncertainty		0,680	0,306	1,057		0,850	

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Quantity Q_i	Components	Uncertainty contribution ui in mK					
		Loop 4 YSI 4807					
		BNM-INM	PTB	GUM	CMI	INM (Ro)	UME
X_t	Repeatability of readings	0,030	see Wt scatter	0,043		0,003	0,030
$C_{Xt/1}$	Uncertainty linked with purity	0,200	0,200	0,420		0,120	0,300
$C_{Xt/2}$	Uncertainty linked Hydrostatic pressure correction	0,017	0,033	0,019		0,050	0,040
$C_{Xt/3}$	Uncertainty linked with perturbing heat exchanges	0,160	0,100	0,129		0,320	0,098
$C_{Xt/4}$	Uncertainty linked with self-heating correction	0,050	0,018	0,040		0,040	0,050
$C_{Xt/5}$	Uncertainty linked with bridge linearity	negligible	0,009	0,027		0,076	0,001
$C_{Xt/6}$	Uncertainty linked with AC/DC current	negligible				0,009	0,090
$C_{Xt/7}$	Uncertainty linked with gas pressure	no effect				0,000	
$X_{0.01\,°C}$	Repeatability of readings	0,030	see Wt scatter	0,006		0,008	0,020
	Repeatability of temperature realized by cell	0,050	see Wt scatter	0,010			0,050
	Short repeatability of calibrated SPRT	0,050	see Wt scatter	0,008			0,017
$C_{0.01\,°C/1}$	Uncertainty linked with purity and isotopic composition	0,066	0,009	0,013		0,100	0,070
$C_{0.01\,°C/2}$	Uncertainty linked Hydrostatic pressure correction	0,002		0,001		0,006	0,004
$C_{0.01\,°C/3}$	Uncertainty linked with perturbing heat exchanges	0,033	0,002	0,002		0,002	0,022
$C_{0.01\,°C/4}$	Uncertainty linked with self-heating correction	0,050	0,009	0,009		0,002	0,040
$C_{0.01\,°C/5}$	Uncertainty linked with bridge linearity	negligible	0,005	0,003		0,016	0,005
$C_{0.01\,°C/6}$	Uncertainty linked with AC/DC current	negligible				0,002	0,029
$C_{0.01\,°C/7}$	Uncertainty linked with internal insulation leakage	negligible	0,002			0,001	
$D_{RS/1}$	Uncertainty linked with stability of RS	negligible	0,012				0,010
$D_{RS/2}$	Uncertainty linked with temperature of RS	0,001	0,012	0,001		0,003	0,100
S_{Wt}	Wt scatter	0,100	0,248	0,052		0,154	0,145
Combined uncertainty		0,340	0,337	0,448		0,400	0,394
Expanded uncertainty		0,680	0,674	0,896		0,800	0,787

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Quantity Q_i	Components	Uncertainty contribution ui in mK					
		Loop 5 SPRT 269586					
		BNM-INM	NPL	JV	EIM	SMD	NML
X_t	Repeatability of readings	0,030	0,026	0,0001		0,002	
$C_{Xt/1}$	Uncertainty linked with purity	0,200	0,058	0,300		0,300	
$C_{Xt/2}$	Uncertainty linked Hydrostatic pressure correction	0,017	0,028	0,048		0,012	
$C_{Xt/3}$	Uncertainty linked with perturbing heat exchanges	0,160	0,058	0,264		0,139	
$C_{Xt/4}$	Uncertainty linked with self-heating correction	0,050	0,004	0,061		0,044	
$C_{Xt/5}$	Uncertainty linked with bridge linearity	negligible	0,027			0,010	
$C_{Xt/6}$	Uncertainty linked with AC/DC current	negligible	not estimated	0,003		neg.	
$C_{Xt/7}$	Uncertainty linked with gas pressure	no effect	not applicable				
$X_{0.01\,°C}$	Repeatability of readings	0,030	0,004				
	Repeatability of temperature realized by cell	0,050	0,012	0,021		0,009	
	Short repeatability of calibrated SPRT	0,050	0,005	0,006		0,007	
$C_{0.01°C/1}$	Uncertainty linked with purity and isotopic composition	0,066	0,023			0,100	
$C_{0.01°C/2}$	Uncertainty linked Hydrostatic pressure correction	0,002		0,011		0,001	
$C_{0.01°C/3}$	Uncertainty linked with perturbing heat exchanges	0,033	0,002	0,004		0,001	
$C_{0.01°C/4}$	Uncertainty linked with self-heating correction	0,050	0,001	0,001			
$C_{0.01°C/5}$	Uncertainty linked with bridge linearity	negligible	0,006			0,015	
$C_{0.01°C/6}$	Uncertainty linked with AC/DC current	negligible	not estimated	0,003		neg.	
$C_{0.01°C/7}$	Uncertainty linked with internal insulation leakage	negligible	not estimated			neg.	
$C_{0.01°C/8}$	Uncertainty linked with gas pressure					0,020	
$D_{RS/1}$	Uncertainty linked with stability of RS	negligible				neg.	
$D_{RS/2}$	Uncertainty linked with temperature of RS	0,001	0,001			neg.	
S_{Wt}	Wt scatter	0,100	0,024	0,113		0,147	
Combined uncertainty		0,340	0,101	0,423		0,379	
Expanded uncertainty		0,680	0,202	0,846		0,758	