

A European comparison of the mercury fixed point.

Y. Hermier, G. Bonnier
 BNM-INM (Bureau National de Métrologie - Institut National de Métrologie) - France
 V. Chimenti F. Perezagua, D. del Campo
 CEM (Centro Español de Metrologia) - Spain
 T. Weckström
 CMA (Centre for Metrology and Accreditation) - Finland
 P. Marcarino, R. Dematteis
 IMGC (Istituto di Metrologia « G. Colonnetti ») - Italy
 E. Filipe, I. Lobo
 IPQ (Instituto Português da Qualidade) - Portugal
 C. Rauta -
 DM (now JusterVesenet) - Norway
 J.F. Dubbeldam, M. De Groot
 NMI (Nederlands Meetinstituut) - The Netherlands
 D.I. Head, R. Rusby
 NPL (National Physical Laboratory) - United Kingdom
 A. Wittwer, W. Münch
 OFMET (Office Federal de METrologie) - Switzerland
 F. Edler, B. Fellmuth
 PTB (Physikalisch-Technische Bundesanstalt) - Germany
 J. Ivarsson
 SP (Sveriges Provnings-och Forskningsinstitut) - Sweden

In the framework of the EUROMET project n°280, several laboratories decided to compare their mercury point cells. These cells are intended to be used to calibrate long stem type SPRT's at $T_{90} = 243,315\ 6\ K$.

BNM-INM proposed to circulate one of its cells among the participating laboratories with the aim of comparing it with a local mercury cell. Before circulating the cell, BNM-INM compared the cell to its batch of mercury cells. After the various comparisons were achieved in the participating laboratories, the circulating cell returned to BNM-INM to be compared again with the batch of mercury cells in order to detect any temperature drift.

Each participating laboratory sent to BNM-INM a report, giving the conditions of the comparisons, the temperature differences between the cells and the uncertainty on the differences.

This comparison was not a comparison of the realisation of the mercury fixed point. It was a comparison of mercury cells and it was of the responsibility of each participating laboratory to put into place their own instrumentation and procedures so to reach the lower uncertainty on the differences in cell temperatures.

After the EUROMET comparison was achieved, it was asked to each laboratory to establish the difference between the local cell participating to the comparison and the National reference at the mercury point and so the difference between the National reference and the circulating cell with the associated uncertainty.

Details on the comparison can be read in the EUROMET n°280 Synthesis report.

The results are summarised in table I (compared to the table given in the report, some values were slightly modified by some laboratory to homogenise the uncertainties).

Table I. Budget of uncertainty on the difference in temperature between the local cell (X_i) and the circulating cell (BNM-INM).

Uncertainty components	σ_i or u_i (mK)									
	CEM	CMA	DM	IMGC	IPQ	NMI	NPL	OFMET	PTB	SP
(*) Repeatability of the temperature differences	0,017	0,018	0,05	0,040	0,023	0,05	0,05	0,08	0,07	0,07
Electrical measurement	0,036	0,016	0,015	0,014	0,075	0,026	0,02	0,06	0,03	0,072
Self heating	0,018	0,001	0,014	0,035	0,014	0,044	0,015	0,09	0,03	0,058
Thermometer repeatability	Included in (*)	Included in (*)	Included in (*)	0,042	Included in (*)					
Spurious heat flux	0,027	0,075	0,003	0,035	0,072	0,06	0,025	0,03	0,01	0,058
Correction to hydrostatic pressure effect	0,041	0,012	0,032	0,028	0,029	0,036	0,015	0,01	0,06	0,040
Interpretation of the plateau	0,03	0,029	0,013	0,021	0,016	0,08	Included in (*)	0,02	0,085	0,058
Propagation of uncertainty at the water triple point (*)	0,013	0,042	0,044					0,06		0,04
Expanded uncertainty (k=2)	0,28	0,19	0,16	0,17	0,22	0,25	0,12	0,30	0,26	0,31

(*) when W values and not R values were used for the comparison.

In the table above are bold-faced the two main source of uncertainty for each participating laboratory. The table does not show one dominant uncertainty contribution that is common to all laboratories.

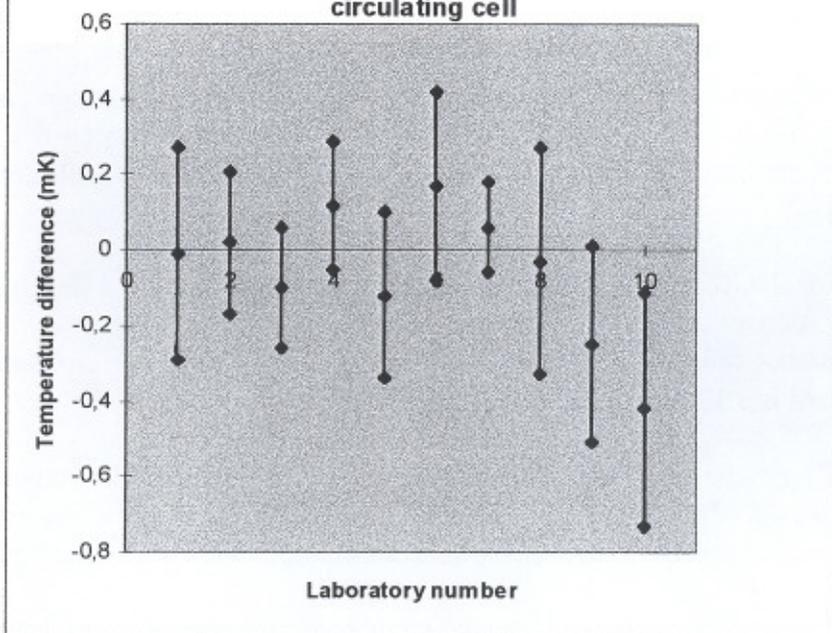
In the table II are given, for each laboratory, the temperature difference ($T_L - T_C$), between the local cell (L) and the circulating cell (C) and the expanded uncertainty (with $k=2$), $2s$.

Table II.

Laboratory	$(T_L - T_C)$ (mK)		$2s$ (mK)
1. CEM	+0,002	±	0,28
2. CMA	+0,02	±	0,19
3. DM	-0,1	±	0,16
4. IMGC	+0,116	±	0,17
5. IPQ	-0,12	±	0,22
6. NMI	+0,17	±	0,25
7. NPL	+0,06	±	0,12
8. OFMET	-0,03	±	0,30
9. PTB	-0,25	±	0,26
10. SP	-0,42	±	0,31

The same results are presented in the figure 1.

Fig 1. Expanded uncertainty on the difference in temperature between the local cell and the circulating cell



To compare the different national references, after the comparison was done, each laboratory sent information on the temperature difference between the local cell used for the comparison and what they consider as the national reference at the mercury point. The answers are resumed as follows.

BNM-INM : The reference is maintained on a batch of eight home-made sealed cells, made of stainless steel, associated with long stem thermometers and filled with mercury from various suppliers. In one of the cell in this batch, the inner diameter of the thermometer pit is 10 mm, allowing the comparison of the cells mentioned above with open cells placed in an adiabatic calorimeter associated with capsule type thermometers. This whole batch of cells is completed with a sealed cell in an adiabatic calorimeter for long stem thermometers. The cell #75, used as the circulating cell, is representative of the batch and the associated uncertainty takes into account the results of the periodic comparisons of the cells within the batch.

CEM : The mercury cell used as local cell was the reference cell that maintains the national realisation of the fixed point. The working cells, for normal calibration of SPRT, are compared with the reference cell and the correction applied is the measured difference.

CMA : The mercury cell used as local cell was the reference cell that maintains the national realisation of the fixed point.

DM (now named JV) : The mercury cell used as local cell was the reference cell that maintains the national realisation of the fixed point.

IMGC : A real cell is considered as the IMGC national reference. For each fixed point, at least two or more cells are normally manufactured, characterised and compared. Among these, the best cell (as purity and reproducibility) is selected as « standard reference cell » and the other ones as « standard working cell ». The IMGC standard reference cell is the Italian standard national reference and it was used for the comparison.

IPQ : The mercury cell used as local cell was the reference cell that maintains the national realisation of the fixed point.

NMi : NMi uses two identical cells to realise the national mercury point. The cells were filled with mercury from the same batch . The difference between the Dutch national realisation of the mercury point and the circulating cell is identical to the difference given in the EUROMET report.

NPL : For the EUROMET comparison, NPL compared a local stainless steel cell to the circulating cell. It drove to the uncertainty given above.

The reference cells are glass cells and the difference between the circulating cell and the reference standard is $0,12 \pm 0,23$ mK.

OFMET : At the comparison time, the cell participating to the intercomparison was considered as the OFMET National Standard. OFMET has extended the number of cells, therefore the National Standards are changing from a single to the batch concept.

PTB : The PTB cell compared to the circulating cell was compared with the mercury home-made cells. The measured difference is 0,16 mK lower. This difference has an estimated standard uncertainty of 0,13 mK.

SP : The mercury cell used as local cell was the reference cell that maintains the national realisation of the fixed point.

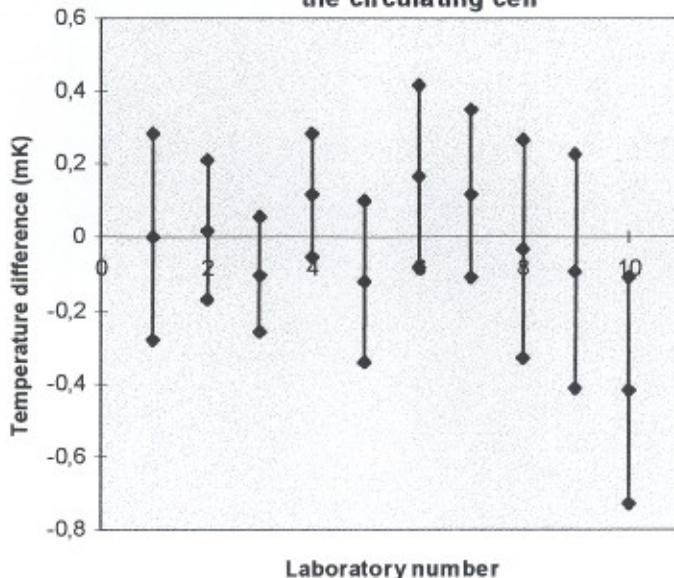
Most of the laboratories have made only minor modifications, if any, to the previous results. Table II will be changed into table III were T_R refers to the national reference at the mercury point.

Table III.

Laboratory	$(T_R - T_C)$ (mK)		2s (mK)
1. CEM	+0,002	±	0,28
2. CMA	+0,02	±	0,19
3. DM	-0,1	±	0,16
4. IMGc	+0,116	±	0,17
5. IPQ	-0,12	±	0,22
6. NMi	+0,17	±	0,25
7. NPL	+0,12	±	0,23
8. OFMET	-0,03	±	0,30
9. PTB	-0,09	±	0,32
10. SP	-0,42	±	0,31

These same results are presented on the figure 2.

Fig 2. Expanded uncertainty on the difference in temperature between the reference standard and the circulating cell



At BNM-INM, the main component of the uncertainty budget on the national realisation of the mercury fixed point is the uncertainty coming from the chemical impurities. The expanded uncertainty ($k=2$) is evaluated to be 0,25 mK.

Before and after the cell circulation, and before the cell was sent to NMi (the last laboratory who participated to the comparison), the cell #75 was compared at new to the BNM-INM mercury cell batch. The lack of reproducibility of the mercury cell was estimated to be 0,09 mK (expanded uncertainty with $k=2$).