Thermometry

EURAMET Project No. 1058

A bilateral comparison (VSL, the Netherlands, and Danish Technological Institute (DTI), Denmark) of the fixed point of mercury has been conducted. The transfer instrument was a standard platinum resistance thermometer (SPRT). The results were found to be in agreement and validate a calibration measurement capability of 0.5 mK of SPRT´s in the fixed point of mercury at DTI.

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Content

Abstract

A bilateral comparison (VSL, the Netherlands, and Danish Technological Institute (DTI), Denmark) of the fixed point of mercury has been conducted. The transfer instrument was a standard platinum resistance thermometer. The results were found to be in agreement and validate a calibration measurement capability of 0.5 mK for the DTI mercury cell.

Introduction and background

The fixed point of mercury is a reference point for the International Temperature Scale of 1990.

In 2005 the key comparison EURAMET T-K3 (project 552) was finalized. The results suggested that the DTI mercury point was faulty.

Another cell was bought – a discrepancy was found between the two cells.

This comparison confirms the results of the key comparison and validates the stated CMC's of the new DTI mercury cell.

Equipment

Name of laboratory	VSL	DTI
Bridge		
Manufacturer	Measurements International Inc	
Type	6015T	
Manufacturer	Automatic Systems Laboratories	ASL
Type	F18	F18
AC or DC	DC and AC	AC
If AC, give frequency	25 Hz	25
If DC, give period of reversal	4 seconds	
Normal measurement current	2 mA	1 mA
Self-heating current	2.82 mA	1.41 mA
Evaluation of linearity of resistance bridge (yes or no)	Yes	Yes
If yes, how?	RBC calibrator	Configurations of reference resistors
Reference resistor		
Manufacturer	Tinsley	H.W. Sullivan
Type	5684	Class S Resistance Standard, Type Special
Reference resistor temperature control (yes or no)	Yes	Yes
If yes, how?	Temperature controlled oil bath	Temperature controlled oil bath
TPW Cell		
Homemade or not	Homemade	Isotech Jarret cell A11
Immersion depth of middle of the SPRT sensible element/cm	21.6 cm/20.6 cm dependent on cell	25.5 cm
How are mantles maintained (ice, bath, …)	Stirred bath	Ice
Hg Cell		
Homemade or not	Homemade	Pond Engineering
Closed cell or open	Closed	Closed
Nominal purity	7N	7N
Immersion depth of middle of the SPRT sensible element/cm	13.8	14 cm
Hg Cryostat		
Homemade or not	Isotech	Heto
Type (cryostat, bath, …)	818	Bath
Typical duration of melting plateau	7.5 hours	>8 hours
Typical duration of freezing plateau	Not used	Not used

Table 1: Equipment

Transfer standard

As the transfer standard a quartz sheated Tinsley 5187SA SN: 232762 was selected.

EURAMET 1058 – Results

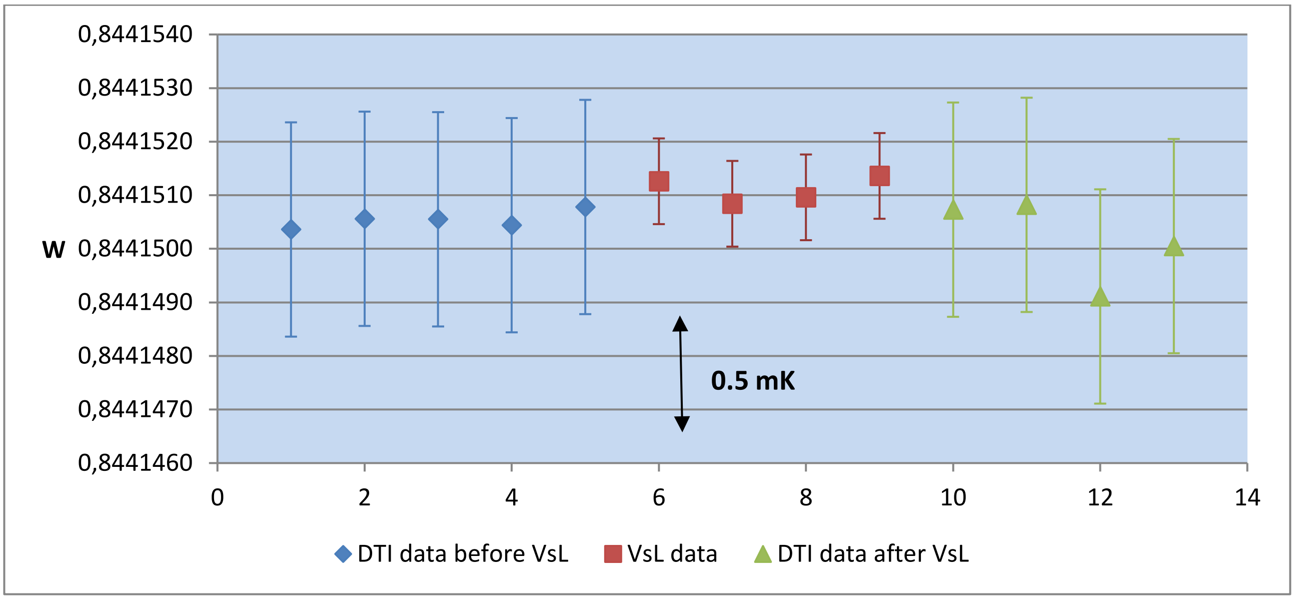
In order to maintain a link as close as possible to EURAMET T-K3, the protocols and reporting templates are identical.

Comparison measurements

Before transporting the transfer thermometer to VSL, it was compared in 2008 with the DTI mercury cell. After return, it was once more compared with the DTI cell. These results are given in Table 2. All data obtained at DTI are pooled to obtain a single value for comparison. The values in the coulumn “Rcorrected” are corrected for hydrostatic head and thermometer self-heating.

Point	Rmeasured ohm 1 mA	Self-heating ohm	Hydrostatic ohm	Pressure Pa	Rcorrected ohm	W	
Hg	21.587237	0.000309	-0.000114	NaN	21.586814	0.84415036	DTI data before VSL
TPW	25.572520	0.000302	0.000020	NaN	25.572238		
Hg	21.587237	0.000304	-0.000114	NaN	21.586819	0.84415056	
TPW	25.572520	0.000302	0.000020	NaN	25.572238		
Hg	21.587230	0.000291	-0.000114	NaN	21.586825	0.84415055	
TPW	25.572539	0.000313	0.000020	NaN	25.572245		
Hg	21.587220	0.000284	-0.000114	NaN	21.586822	0.84415044	
TPW	25.572539	0.000313	0.000020	NaN	25.572245		
Hg	21.587224	0.000285	-0.000114	NaN	21.586826	0.84415078	
TPW	25.572531	0.000311	0.000020	NaN	25.572240		
Hg	21.587992	0.001150	0.000108	NaN	21.586734	0.84415126	VSL data
TPW	25.573287	0.001190	-0.000019	NaN	25.572116		
Hg	21.587979	0.001140	0.000108	NaN	21.586731	0.84415084	
TPW	25.573406	0.001300	-0.000019	NaN	25.572125		
Hg	21.587994	0.001160	0.000108	NaN	21.586726	0.84415096	
TPW	25.573397	0.001300	-0.000019	NaN	25.572116		
Hg	21.587974	0.001130	0.000108	NaN	21.586736	0.84415136	
TPW	25.573306	0.001210	-0.000019	NaN	25.572115		
Hg	21.587255	0.000282	-0.000114	NaN	21.586860	0.84415073	DTI data after VSL
TPW	25.572568	0.000306	0.000020	NaN	25.572282		
Hg	21.587283	0.000292	-0.000114	NaN	21.586877	0.84415082	
TPW	25.572585	0.000306	0.000020	NaN	25.572298		
Hg	21.587252	0.000288	-0.000114	NaN	21.586850	0.84414911	
TPW	25.572605	0.000306	0.000020	NaN	25.572319		
Hg	21.587253	0.000289	-0.000114	NaN	21.586850	0.84415005	
TPW	25.572577	0.000306	0.000020	NaN	25.572291		
DTI average of W for Hg (9 measurements)						0.84415038	
VSL average of W for Hg (4 measurements)						0.84415110	

Table 2: Comparison results



Graphical presentation of the results in Table 2

Bilateral equivalence

On the basis of the comparison of the transfer thermometer between the Danish National Standard and the Dutch National Standard – the degree of equivalence, $D_{ij} = T_i - T_j$, is computed as

$$D_{VSL-DTI} = 180\ \mu K$$

with a standard uncertainty of

$$\boldsymbol{u_{VSL-DTI} = 314\ \mu K}$$

obtained by summation of the quadrature of the individual standard deviations of the mean W-value as measured at VSL and DTI and the declared uncertainty from the respective uncertainty budgets. The expanded uncertainty on a 95 % confidence level is thus:

$$\boldsymbol{U_{VSL-DTI} = 628\ \mu K}$$

Uncertainty

The uncertainty budgets for the comparison at VSL and DTI are reported in Table 3 and Table 4.

Quantity	Components	Standard uncertainty	Degrees of freedom Components evaluated by a type A method	Sensitivity coefficient	Uncer-tainty contri-bution
Q_i		u(Qi) in mK	v_i		u_i in mK
X_t	Repeatability of readings (in this case the value for the plateau progress has been used)		inf		0.058
$C_{Xt/1}$	Uncertainty linked with purity		inf		0.012
$C_{Xt/2}$	Uncertainty linked hydrostatic pressure correction		inf		0.020
$C_{Xt/3}$	Uncertainty linked with perturbing heat exchanges		inf		0.035
$C_{Xt/4}$	Uncertainty linked with self-heating correction		inf		0.002
$C_{Xt/5}$	Uncertainty linked with bridge linearity		inf		0.029
$C_{Xt/6}$	Uncertainty linked with AC/DC current (this value has been estimated from the observed change in W and therefore it includes C 0.01 °C/6)		inf		0.045
$C_{Xt/7}$	Uncertainty linked with gas pressure		inf		0.004
$X_{0.01\,°C}$	Repeatability of readings	0.030	25	0.844151104	0.025
	Repeatability of temperature realized by cell				
	Short repeatability of calibrated SPRT				
$C_{0.01°C/1}$	Uncertainty linked with purity and isotopic composition	0.035	inf	0.844151104	0.030
$C_{0.01°C/2}$	Uncertainty linked hydrostatic pressure correction	0.002	inf	0.844151104	0.002
$C_{0.01°C/3}$	Uncertainty linked with perturbing heat exchanges	0.010	inf	0.844151104	0.008
$C_{0.01°C/4}$	Uncertainty linked with self-heating correction	0.002	inf	0.844151104	0.002
$C_{0.01°C/5}$	Uncertainty linked with bridge linearity	0.029	inf	0.844151104	0.024
$C_{0.01°C/6}$	Uncertainty linked with AC/DC current (included in C Xt/6)				
$C_{0.01°C/7}$	Uncertainty linked with internal insulation leakage				
$D_{RS/1}$	Uncertainty linked with stability of RS		inf		0.021
$D_{RS/2}$	Uncertainty linked with temperature of RS				
S_{Wt}	Wt scatter (this is the standard deviation from different plateaus)		inf		0.067
Combined uncertainty					0.123
Effective degrees of freedom					inf
Expanded uncertainty					0.2

Table 3: Uncertainty budget - VSL

Quantity	Components	Standard uncertainty	Degrees of freedom Components evaluated by a type A method	Sensitivity coefficient	Uncer-tainty contri-bution
Q_i		**u(Qi) in mK**	**v_i**		**u_i in mK**
Xt	Repeatability of readings	0.072	9	1	0.07
C Xt/1	Uncertainty linked with purity	0.12		1	0.12
C Xt/2	Uncertainty linked hydrostatic pressure correction	0.058		1	0.058
C Xt/3	Uncertainty linked with perturbing heat exchanges	0.067		1	0.067
C Xt/4	Uncertainty linked with self-heating correction	0.090	9	1	0.090
C Xt/5	Uncertainty linked with bridge linearity	0.084		1	0.084
C Xt/6	Uncertainty linked with AC/DC current				
C Xt/7	Uncertainty linked with gas pressure			1	0.000
X0.01 °C	Repeatability of readings	0.0070	9	1	0.0035
	Repeatability of temperature realized by cell	0.014		1	0.014
	Short repeatability of calibrated SPRT	0.020		1	0.020
C 0.01°C/1.1	Uncertainty linked with purity	0.010		1	0.010
C 0.01°C/1.2	Uncertainty linked with isotopic composition	0.035		1	0.035
C 0.01°C/2	Uncertainty linked hydrostatic pressure correction	0.010		1	0.010
C 0.01°C/3	Uncertainty linked with perturbing heat exchanges	0.011		1	0.011
C 0.01°C/4	Uncertainty linked with self-heating correction	0.046	9	1	0.046
C 0.01°C/5	Uncertainty linked with bridge linearity	0.084		1	0.084
C 0.01°C/6	Uncertainty linked with AC/DC current				
C 0.01°C/7	Uncertainty linked with internal insulation leakage	0.010		1	0.010
DRS/1	Uncertainty linked with stability of RS	0.030		1	0.030
DRS/2	Uncertainty linked with temperature of RS	0.029		1	0.029
SWt	Wt scatter	0.09		1	0.090
Combined uncertainty					0.25
Effective degrees of freedom					2.00
Expanded uncertainty					0.50

Table 4: Uncertainty budget - DTI

Conclusions

The bilateral comparison was conducted without any irregularities except that the time schedule was not completely followed.

The difference between the two laboratories was within their respectively stated uncertainties and thus validates the DTI CMC of 0.5 mK (k=2).