WORKING GROUP 4 REPORT TO CCT
25 April 2012

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assisted by Richard Rusby

Topic of WG: thermodynamic temperature determinations and extension of the ITS-90 to lower temperatures

Terms of reference: to review and make recommendations concerning thermodynamic temperature determination and the definition of the kelvin

Working Group 4 is **tasked** with continuing to review measurements of T-T_{90} and with monitoring progress on the redefinition of the kelvin in terms of the Boltzmann constant.

Since the preparation of the last report of WG4 to CCT, CCT/10-15/rev2, dated 05 May 2010, the members met at the 9th International Temperature Symposium (ITS-9) in Los Angeles, CA, held from 19 to 23 March 2012.

In 2011 the summary paper by J. Fischer, M. DePodesta, K. D. Hill, M. Moldover, L. Pitre, R. Rusby, P. Steur, O. Tamura, R. White, L. Wolber: "Present estimates of the differences between thermodynamic temperatures and the ITS-90" has been published in Int. J. Thermophys. **32**, 12–25 (2011). The paper is the first complete account of the differences T-T_{90} since the adoption of the ITS-90 more than 20 years ago. In addition, two smooth interpolation functions were recommended for convenience of the user. WG4 has provided the data to WG1 for inclusion in the Mise en pratique for the definition of the kelvin (see document CCT/12-03). The amended MeP-K 2011 (see document CCT/12-02) including the present estimates of the differences T-T_{90} has been approved unanimously by email vote of the full CCT in December 2011.

Clearly, considering the various weaknesses discussed in CCT/08-13/rev, it would be premature to base a new temperature scale on these estimates. However, the recommended smooth interpolation functions will allow values of T_{90} to be corrected to T, where it is desired to do so. In view of the preliminary state of the present differences T-T_{90} it was deemed not useful to provide uncertainty estimates of the smooth interpolation functions. In future, the input of WG4 to the Mise en pratique will be updated when the discrepancies of the differences T-T_{90} below 77 K will have been resolved.

New measurements on T-T_{90}

To prepare the update new measurements on T-T_{90} were discussed. In the following table all recent determinations of thermodynamic temperatures not taken into account in the IJOT 2010 consensus estimate of WG4 are listed. From the last column it can be seen that only a few measurements produced valid results for consideration in WG4.

In detail, low temperature CVGT results obtained at NMIJ, a determination of the copper point by radiation thermometry at INRiM, NIST acoustic gas thermometer results between 391 K and 633 K, and NIST noise thermometer results between 693 K and 800 K are to be included in the next consensus estimate of WG4.

Further measurements have been announced between 250 K and 400 K by NIM using refractive index gas thermometry and NMIJ is developing Johnson noise thermometry. In Europe, between 2012 and 2015, further measurements are effectively supported by the EMRP-Project "Implementing the new kelvin".

Authors	***Paper Title***	***Journal***	***Method***	***T Range / K***	***Ref. Temp.***	***Comments***	***Include Results***
F. Sparasci, L. Pitre, D. Truong, L. Risegari, Y. Hermier	*Realization of a ^{3}He–^{4}He Vapor-Pressure Thermometer for Temperatures Between 0.65 K and 5 K at LNE-CNAM*	*Int J Thermophys (2011) **32**, 139–152*	*Vapor pressure, Melting pressure, AGT*	*0.65 to 5*		*Calibrate pressure sensors He shortage*	*no*
O. Tamura, S. Takasu, T. Nakano, H. Sakurai	*Constant-Volume Gas Thermometry with Different Helium-3 Gas Densities at NMIJ/AIST*	*Int J Thermophys (2011) **32**, 1366–1377*	*CVGT*	*3 to 24.5*	*Ne TP*		***yes, use instead of older data***
T. Keawprasert, K. Anhalt, D. R. Taubert, J. Hartmann	*Monochromator-Based Absolute Calibration of Radiation Thermometers*	*Int J Thermophys (2011) **32**, 1697–1706*	*Monochro-mator based radiation thermometry*	*Au, Cu*		T-T_{90} = 52 mK (Au) T-T_{90} = -50 mK (Cu); u = **158** mK	*no*
W. L. Tew, S. P. Benz, P. D. Dresselhaus, K. J. Coakley, H. Rogalla, D. R. White, J. R. Labenski	*Progress in Noise Thermometry at 505 K and 693 K Using Quantized Voltage Noise Ratio Spectra*	*Int J Thermophys (2010) **31**, 1719–1738*	*Noise*	*Sn, Zn*	*(Sn)*	T-T_{90} = (4 ± 18) mK (Zn) spectral aberations	*no*
C. Gaiser, B. Fellmuth, N. Haft	*Dielectric-Constant Gas-Thermometry Scale from 2.5 K to 36 K Applying 3He, 4He, and Neon in Different Temperature Ranges*	*Int J Thermophys (2010) **31**, 1428–1437*	*DCGT*	*2.5 to 36*		*new measurements from 23 K to 36 K*	*no, wait for extension to higher temperatures*
M. Battuello, M. Florio, F. Girard	*Indirect determination of the thermo-dynamic temperature of the copper point by a multi-fixed-point technique*	*Metrologia (2010) **41**, 231–238*	*Radiation Thermo-metry*	*Cu*	*Ag*	T-T_{90} = (70 ± 47) mK (Cu)	***yes***
G. Strouse, W. Murdock, D. Ripple, J. Schooley	*NIST acoustic thermometer results above 550 K*	*ITS-9*	*AGT*	*391, 430, 597 (2008) 440, 603, 633 (2011)*		*Continue to 800 K smaller uncertainties in new paper, u = 1.8…2.4 mK*	***yes, use the final version of paper***
M. Moldover, J. Schmidt	*Thermodynamic Temperatures using the refractive indices of Helium and Argon*	*ITS-9*	*RIGT*	*Hg, Ga*		*2 mK uncertainties to come*	*no results*
Z. Yuan, X. Lu, X. Hao, W. Dong, T. Wang, Y. Lin, J. Wang, Y. Duan	*Thermodynamic temperature measurements of silver freezing point and HTFPs*	*ITS-9*	*Radiation Thermometr y*	*Ag*		*discrepancies between 633 nm: T-T_{90}* = (0.28± 0.24) mK and 900nm: T-T_{90} = (-0.09±0.34) mK	*no*

J. Qu, S. Benz, J. Zhang, H. Rogalla, Y. Fu, A. Pollarolo, J. Zhang	*Development of a quantum voltage calibrated noise thermometer at NIM*	*ITS-9*	*Noise*			*Boulder type, wider bandwidth Random noise similar to NIST*	*no results T-T_{90} Determination of k with u_r = 23ppm*
A. Pollarolo, T.H. Jeong, S. Benz, P. Dresselhaus, H. Rogalla, W. Tew	*Johnson noise thermometry based on a quantized-voltage noise source at NIST*	*ITS-9*	*Noise*			*Spectral aberrations reduced, 200 Ohm rest. 5 ppm expected*	*no results T-T_{90} Review paper on determination of k*
K. Yamazawa, W. Tew, S. Benz, H. Rogalla, P. Dresselhaus, A. Pollarolo	*Improvements to the Johnson noise thermometry system for measurements at 505-800 K*	*ITS-9*	*Noise*	*693 730 764 800*	*505 K*	*u = 25 mK*	***yes, use the final version of paper***
L. Risegari, F. Sparasci, L. Pitre, D. Truong	*Preliminary measurements on a 3He-4He vapour pressure thermometer for temperatures between 0. 65 K and 5 K*	*ITS-9*	*Vapor pressure*	*0.65 to 5*		*with 4 He : 10 points 3 He very expensive don´t know when to measure*	*preliminary, no results, no printed paper*