WORKING GROUP FOR CONTACT THERMOMETRY REPORT TO CCT
June 2017

Members Joachim Fischer (PTB) chairman, Michael de Podesta (NPL), Vladimir Kytin (VNIIFTRI), Tohru Nakano (NMIJ/AIST), Laurent Pitre (LNE-CNAM), Anatolii Pokhodun (VNIIM), Patrick Rourke (NRC), Roberto Gavioso (INRiM), Weston Tew (NIST), Rod White (MSL), Inseok Yang (KRISS), Jintao Zhang (NIM)

The **terms of reference** of WG-CTh are to review and document progress in contact thermometry, with a focus on thermodynamic temperature determination and defined scales. The list of tasks has been updated according to the discussions at the WG-SP meeting at 31 May 2017 and is given below:

Tasks

- reviewing and reporting on measurements of $T - T_{90}$ and $T - T_{2000}$;
- selecting key comparisons in contact thermometry;
- reviewing the research and application of primary contact thermometers to realize the kelvin;
- considering the development of a new scale with defining fixed points and interpolation functions to realize the kelvin, replacing the scales ITS-90 and PLTS-2000;
- updating the *Mise en Pratique* of the definition of the kelvin;
- updating the Guide to the Realization of the ITS-90;
- reviewing novel contact thermometry techniques.

Since CCT-27 in 2014, the members met twice: In Zakopane, Poland at **01 July 2016** at the conference venue of TEMPMEKO 2016, and at BIPM, right before CCT-28, at **30 May 2017**.

Participants of the 2017 meeting:

Joachim Fischer (PTB) chairman, Michael de Podesta (NPL), Vladimir Kytin (VNIIFTRI), Tohru Nakano (NMIJ/AIST), Laurent Pitre (LNE-Cnam), Anatolii Pokhodun (VNIIM), Patrick Rourke (NRC), Peter Steur (INRiM), Roberto Gavioso (INRiM), Zeeshan Ahmed (NIST), Inseok Yang (KRISS), Jintao Zhang (NIM)
Invited experts: Pieter Bloombergen (NIM), Nonhlanhla Cele (NMISA), Bo Gao (TIPC), Christof Gaiser (PTB), Sergey Kondratev (VNIIM), Jonathan Pearce (NPL), Kirill Pilipenko (VNIIFTRI), Jianping Sun (NIM)

Agenda

- welcome, approval of agenda (Joachim Fischer)
- introduction of invited experts (invited experts)
- membership issues: NMI representatives in the future WG CTh (all)
- proposals for new chair for WG CTh (all)
- nature of supplementary material to be archived for contributions of T-T_{90} to WG-CTh (subgroup led by Michael de Podesta)
- review of new measurements of T-T_{90} (all)
- new tasks for WG CTh (all): ITS-XX

NMI representatives in the future WG CTh

After CCT-28 the task groups TG-SI and TG-K will be dissolved because they have successfully fulfilled their duties when the new SI is established. Then, WG-CTh will take full responsibility of all the revised

tasks as given above. The present members discussed with their colleagues at their home institutes possible appropriate membership in WG-CTh. The above membership list represents the resulting actual state.

Proposals for new chair for WG CTh

Joachim Fischer will step down as chair after this meeting as he retires end of 2017. Christof Gaiser of PTB was suggested as the new chair and was unanimously recommended by WG-CTh as candidate.

Supplementary material to be archived

Michael de Podesta explained that we should specify the nature of the supplementary material that we would like to see archived that would assist future working groups if they needed to re-assess current contributions. It is important to be clear about this relatively soon because it will be easy to comply with if known in advance, but very difficult if enquired about retrospectively.

The subgroup chaired by Michael presented a draft definition document which was discussed and welcomed by the full WG-CTh. The subgroup continues with adding the archive specifications for additional primary thermometers to the document.

Review of new results on T-T_{90}

In table 1 all determinations of thermodynamic temperatures and thus on T-T_{90} since the 2011 consensus estimate of WG4 published in Int. J. Thermophys. are listed. All determinations not mentioned already in the document CCT/14-19 (state as of 2014) have a green background.

The results of NPL AGT between 120 K and 220 K and PTB DCGT between 120 K and 140 K are clearly above the consensus estimate. In contrast to the consensus estimate, the new AGT results reveal no change of the slope of T-T_{90} at the triple point of water. For spectral radiation thermometry in the region above 500 K many new measurements are to come, only the Copper point was recently determined. There is still a paucity of data between 40 K and 77 K and more measurements of thermodynamic temperatures should be published before CCT WG-CTh can make a new consensus estimate.

New tasks for WG CTh: ITS-XX

Document CCT/17-17 was presented by Patrick Rourke. After some discussion it was concluded that the replacement of ITS-90 is only required if there are clear advantages of a new ITS-XX for the user, e.g. in industry. Presently, this is not the case and this task will be considered again in a few years.

Key comparisons

After finishing key comparison CCT-K9, the highest priority has now a follow-up of CCT-K7, comparison of water triple point cells. NMIs are asked to consider piloting this comparison to start in 2018-2019. Regarding a follow-up of CCT-K4, temperature range from the aluminium to the silver freezing point, bilateral comparisons are preferred for the moment. Regarding a follow-up of CCT-K2, Realizations of the ITS-90 from 13.8 K to 273.16 K, the more recent star intercomparison of sealed triple-point cells filled with cryogenic gases may serve for traceability at the moment.

Table 1: „Published“ determinations of thermodynamic temperatures since WG4 IJOT 2011 consensus estimate **30 May 2017**

Authors	Title	Journal	Method	T Range / K measured to date	Ref. Temp.	Comments	Include Results
O. Tamura, S. Takasu, T. Nakano, H. Sakurai T. Nakano, T. Shimazaki, O. Tamura	Constant-Volume Gas Thermometry with Different Helium-3 Gas Densities at NMIJ/AIST Reproducibility of the helium-3 constant-volume gas thermometry and new data down to 1.9 K at NMIJ/AIST	Int J Thermophys (2011) **32**, 1366–1377 Int J Thermo phys (2017), **38**, 105	CVGT	3 to 24.5 1.9 to 24.5	Ne TP	use instead of older data which are consistent with the new ones results see publication	**yes**
C. Gaiser, B. Fellmuth, N. Haft	Primary thermometry from 2.5 K to 140 K applying dielectric-constant gas thermometry (replaces Gaiser et al., IJOT 2010) DIELECTRIC-CONSTANT GAS THERMOMETRY WITH NEON AND HELIUM FROM 30 K TO 140 K	Metrologia (2017) **54**, 141-147	DCGT	2.5 to 140		results see publication	**yes**
B. Gao, L. Pitre, E.C. Luo, M.D. Plimmer, P. Lin, J.T. Zhang, X.J. Feng, Y.Y. Chen, F. Sparasci	Feasibility of primary thermometry using refractive index measurements at a single pressure	Measureme nt (2017) **103**, 258-262	Relative RIGT	5 to 25	Ne TP	no results published in this paper	**n.a.**
L. Pitre, F. Sparasci, L. Risegari, C. Guianvarc'h, M. Plimmer	ACOUSTIC THERMOMETRY WITH A 3 LITRE COPPER QUASI-SPHERE FROM 220 K TO 303 K AT LNE-CNAM	to be submitted to Int J Thermophys	AGT	220.9; 230; 234.31; 240; 245; 253; 256; 260; 265; 278; 288.09; 289.09; 298; 302.914		only preliminary results available at TEMPMEKO 2016	**n.a.**
R. Underwood, M. de Podesta, G. Sutton, L. Stanger, R. Rusby, P. Harris, P. Morantz, G. Machin	Estimates of the difference between thermodynamic temperature and the ITS-90 in the range 118 K to 303 K FURTHER ESTIMATES OF T-T_{90} CLOSE TO THE TRIPLE POINT OF WATER	Phil. Trans. R. Soc. A (2016) **374** 20150046 Int J Thermophys (2017) **38**, 44	AGT	118 - 303		results see publications	**yes**

R. M. Gavioso, D. Madonna Ripa, P. P. M. Steur, R. Dematteis, F. Bertiglia, L. Pitre	Acoustic determinations of the thermodynamic temperature in helium between 234 K and 430 K	to be submitted to Metrologia	AGT	235.14 236.62 247.00 260.12 302.91	TPW	T-T_{90} = (-2.19 ± 0.57) mK (-2.17 ± 0.58) mK (-2.34 ± 0.57) mK (-1.43 ± 0.61) mK (3.77 ± 0.89) mK	**n.a.**
J. Zhang, K. Zhang, X. Feng, H. Lin	CYLINDRICAL ACOUSTIC GAS THERMOMETER IN THE TEMPERATURES FROM 230 K TO 310 K	to be submitted to Metrologia	c-AGT	234.21 243.11 258.08 292.69 298.23 303.26	TPW	T-T_{90} = (-1.83 ± 0.9) mK (-3.29 ± 0.7) mK (-0.56 ± 0.6) mK (2.09 ± 0.8) mK (2.39 ± 0.7) mK (3.66 ± 0.6) mK	**n.a.**
P. M. C. Rourke	NRC MICROWAVE REFRACTIVE INDEX GAS THERMOMETRY IMPLEMENTATION BETWEEN 24.5 K AND 84 K	Int J Thermophys (2017) **38**, 107	RIGT	24.5561 54.3584 83.8058		T-T_{90} = (-0.6 ± 0.56) mK (-2.0 ± 1.3) mK (-4.0 ± 2.9) mK	**yes**
V. Kytin, G. Kytin, E. Aslanyan, S. Osadchiy, B. Potapov, A. Schipunov	VNIIFTRI acoustic gas thermometry for temperatures from 5.2 K to 273.16 K	to be submitted to Metrologia in June 2017	AGT	162.0003 234.3152		T-T_{90} = (-7.0 ± 1.3) mK (-2.6 ± 1.4) mK	**n.a.**
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 (replaces Tew et al., IJOT 2010)	TIMCSI, Vol. 8, AIP Conf. Proc. (2013) **1552**, 50-55	Noise Thermometry	692.6 730.0 764.4 799.9	505 K	T-T_{90} = (4.0 ± 23.0) mK (16.6 ± 23.3) mK (-2.8 ± 24.1) mK (4.2 ± 25.7) mK	**yes**
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	TIMCSI, Vol. 8, AIP Conf. Proc. (2013) **1552**, 56-59	Radiation Thermometry	Ag		*633 nm:* T-T_{90} = (0.28 ± 0.12) K 900 nm: T-T_{90} = (-0.09 ± 0.17) K	no, discrepancies between 633 nm and 900 nm filters
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, uncertainties too high
M. Ballico	Thermodynamic Temperature Measurements Traceable to Photometric Standards	Int J Thermophys (2011) **32**, 2206–2216	Radiometry	Au		T-T_{90} = (50 ± 75) mK	**yes**
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 Thermometry	Cu	Ag	T-T_{90} = (70 ± 47) mK	**yes**
H. C. McEvoy, M. Sadli , F. Bourson, S. Briaudeau, B.	A comparison of the NPL and LNE-Cnam silver and copper fixed-point	Metrologia (2013) **50**,	Radiation Thermometry	Cu	Ag	*NPL:* T-T_{90} = (96 ± 15) mK *LNE:* T-T_{90} = (76 ± 15) mK	**yes**

Rougié	blackbody sources, and measurement of the silver/cop. temperature interval	559–571					
Y. Yamaguchi, Y. Yamada	Thermodynamic Temperature Measurement to the Indium Point Based on Radiance Comparison	Int J Thermophys (2017) **38**, 49	Relative Radiation Thermometry	In Sn Zn Al Ag	Cu	T-T_{90} = (-42 ± 140) mK (-68 ± 82) mK (-76 ± 38) mK (-99 ± 44) mK (-4 ± 52) mK	**yes**

upper case titles refer to TEMPMEKO 2016 presentations, green background: update 2017