# CCT WG NCTh Activity Report May 2014 to May 2017

Report prepared by: Graham Machin, NPL
Date of report: 31 May 2017

This report details the activities undertaken by CCT WG NCTh over the period between CCT Convocations CCT/27 and CCT/28.

**Terms of reference of CCT WG NCTh** are; to study and advise the CCT on issues related to thermal radiation and other non-contact methods for temperature measurement.

Working Group Non-Contact Thermometry is tasked with:

- Evaluate thermodynamic measurement results obtained using non-contact thermometry methods;
- Coordinate activities related to high-temperature fixed points;
- Provide appropriate input into the *mise en pratique* for the definition of the kelvin;
- Provide, where required, updates for a) the supplementary information and b) approximating techniques for the ITS-90;
- Provide definitive guidance, when required, on the use of secondary non-contact thermometry methods (e.g. phosphor, gold-cup thermometry);
- Support world-wide efforts in standardization of radiation thermometer and thermal imager testing and calibrations;
- Develop appropriate uncertainty budgets for radiation thermometry;
- Recommend key comparisons relevant to WG-NCTh to the CCT;
- Develop, when required, guidance for measurement best practices in novel non-contact thermometry techniques (e.g. plasma and flame thermometry).

**Members:** As agreed at CCT, May 2014

A*STAR (Wang Li), CEM (Maria Jose Martin Hernandez), CENAM (Daniel Cardenas-Garcia), INMETRO (Renato Teixeira), INRIM (Ferruccio Girard), KRISS (Seon Do Lim), LNE-Cnam (Mohamed Sadli), MSL (Peter Saunders), NIM (Zundong Yuan), NIST (Howard Yoon), NMIA (Eric van der Ham), NMIJ (Yoshiro Yamada), NPL (Graham Machin, chair), NRC (Andrew Todd), PTB (Joerg Hollandt), UME (Ahmet Diril)[1], VNIIM (Mikhail Matveyev), CCPR official representative (Nigel Fox)

**Co-opted members**
NIM (Tiejun Wang), NIM, formerly NMIJ and VSL, (Pieter Bloembergen), NPL (Emma Woolliams), PTB (Klaus Anhalt), VNIIOFI (Boris Khlevnoy). Observer status was accorded to NMSIA (Dr E. Ejigu).

**Membership changes between May 2014 and May 2017**
There have been four delegate changes:
Eric van der Ham became the official NMIA delegate replacing Mark Ballico. Yoshiro Yamada became the official NMIJ delegate replacing Juntaro Ishii.

[1] Was observer subsequently became a full member of CCT WG NCTh

Peter Nemecek resigned from the WG as SMU delegate, no replacement has been proposed.
Edgar Moreno Vuelban resigned from the WG as VSL delegate, no replacement has been proposed.

*Other changes to WG NCTh contributors*
Nigel Fox (NPL) ceased to be the CCPR official representative and the role closed as its objectives were deemed to have been achieved.
Emma Woolliams (NPL) resigned as a co-opted member.

**List of meetings held in period May 2014 to May 2017**

19th May 2014, BIPM, Paris
CCT-WG-NCTh (then WG5) held its formal meeting in conjunction with CCT/27 on 19th May 14:00 to 18:00 at BIPM, Petit Pavillon. The minutes of that meeting can be found on the BIPM website at: http://www.bipm.org/wg/CCT/CCT-WG-NCTh/Allowed/WG5_Meeting_2014/Minutes_CCT-WG5_May_2014_v3_0.pdf. The action points and decisions are given in Annex 1 of this report and they are all completed.

Other CCT-WG-NCTh meetings
A formal meeting of CCT-WG-NCTh took place on 1st July 2016 at Zakopane, Poland, immediately after Tempmeko '16. At that meeting it was decided to write and issue a declaration on primary radiometry "Declaration of CCT WG-NCTh concerning the realisation of thermodynamic temperature by primary radiometry". In addition two new task groups were established: *CCT NCTh Task Group for Non-Contact Thermometry CMCs* and *CCT NCTh Task Group for Non-Contact Thermometry HTFP Uncertainties.* The text of the declaration along with the terms of reference of the task groups can be found at http://www.bipm.org/en/committees/cc/wg/cct-wg-ncth.html. Annex 2 contains the minutes, action record and decisions of that meeting.

**Documents produced or under development**

*Text for "Supplementary information" and "Approximating techniques" for the ITS-90*
A TG of WG NCTh (then WG5) (members: MJMH, MM, AT, Helen McEvoy [NPL]) chaired by HY (NIST) lead the development of new text for the *Sinf* (now known as the "Guide to the realisation of ITS-90") relating to radiation thermometry.
This text is now complete and available from the CCT website in Ch 6 of the "Guide".

It was thought that text was required for the approximating techniques for the ITS-90. However, in consultation with the chair of TG for Guides on Thermometry this was not seen as a high priority and no further work was performed on this document.

**Task Groups of CCT WG NCTh**
There are three task groups of the WG, each have a specific time limited task.

*NCTh Task Group for primary radiometric temperature uncertainties*

A task group (TG) established for developing a definitive guidance document on uncertainties in radiometric temperature measurement. The original document was produced by EW and reported at the WG meeting in May 2014. Subsequent work towards finalisation has been led by PS (chair). Other members of the group are MS, HY, KA, AT, PS [with technical experts Stéphan Briaudeau (CNAM) and Dieter Taubert (PTB)]. Progress towards completing this document will be reviewed at the WG NCTh meeting in May 2017 and steps agreed for completing the document.

*CCT NCTh Task Group for Non-Contact Thermometry CMCs*
This TG has been asked to prepare a revision of the Radiation Thermometry CMC Review Protocol for approval by the CCT WG-CMC.
Membership of the group is: YY (Chair), MS (Co-chair), XL, KA, AT, BK, MM, co-opted Jovan Bojkovski (Univ. Ljubljana, WG-CMC Chair).
The TG will report on progress to WG-NCTh at CCT/28.

*CCT NCTh Task Group for Non-Contact Thermometry HTFP Uncertainties*
Membership of the TG is: AT (Chair), KA, PB, BK, DL, MS, NS. It undertakes the following tasks on behalf of the WG NCTh:

- Construct comprehensive list of uncertainty components for determining *T* of HTFPs and their use as thermodynamic temperature references (or artefacts);
- Categorize the items in the list as either *well specified* or as *requiring further investigation*;
- Report back to CCT WG NCTh in May 2017 with a list and recommendations for next steps.

**Key comparison**

*K10 key comparison above the Ag point*
CCT-K10 for Radiation Thermometry (Primary realization above Ag fixed point) is in progress, with NPL as the pilot. The APMP and SIM loops are complete. The artefacts are now in COOMET (VNIIM) region. Anticipated measurement completion April 2018. A report will be given by the coordinator on KC10 at WG NCTh May 2017.

Annex1: Action points and decisions from: CCT-WG-NCTh (then WG5) 19th May 2014, BIPM, Paris, held in conjunction with CCT/27

Action Points

AP.2014-01: Emma Woolliams to send draft minutes to Graham Machin and Graham Machin to edit and then circulate to all participants. DONE

AP.2014-02: Howard Yoon to prepare and circulate a new outline for the Techniques for Approximating ITS-90 document with assigned names to write each section. Howard Yoon to send this to Graham Machin for circulation to CCT-WG5. Have asked Peter Saunders 3 Nov 14, he agreed 4 Nov 2014

Action: AP.2014-03: All instrument providers for comparison to provide Helen McEvoy with serial numbers. Klaus Anhalt to provide Helen McEvoy with information on LP3 maximum temperature and on LP3 packaging. Helen McEvoy to update the protocol with this information and to clarify the situation with insurance. DONE

Action AP.2014-04: Graham Machin to find out how the cut-off is being treated in CCT-K9. Helen McEvoy to update the protocol to include a definition of the cut-off that matches that of the CCPR. DONE

Action AP.2014-05: Helen McEvoy to summarise approach for analysing the comparison with two KCRVs and discuss this with Andrea Peruzzi chair of WG on KCs. DONE

Action AP.2014-06: Helen McEvoy to update the protocol to say that the signal should be reported at the temperature (rather than measured). DONE

Action AP.2014-07: Helen McEvoy to produce a final version of the protocol and submit it to participants and to CCT-WG7. All participants and CCT-WG7 to formally confirm approval of the protocol by June 2014. NPL will start measurements in July 2014. DONE

Decisions

Decision DP.2014.i: Two secondary methods will be presented in the 'blue book' text – one based on SPRTs and a heat pipe and the other based on fixed-point interpolation.

Decision DP.2014.ii: The 'blue book' text will not (for now) include 10 μm radiometers. It will focus on 0.9 μm and 1.6 μm radiation thermometers and temperatures from the indium point to the silver point

Decision DP.2014.iii: A new task group will prepare the blue book text, led by Howard Yoon and with Andrew Todd, Eric van der Ham and Jörg Hollandt writing the text and Maria-José and Ferruccio Girard reading the final document to offer comments. The section assignments are given in the table.

Decision: DP.2014-iv: The text of the radiometry uncertainties document will be completed as soon as possible. Values will be filled into the tables and the whole document reviewed at the end of InK-WP1.

Decision DP.2014-v: The LP3 for the comparison will operate at 650 nm.

Annex 2: Minutes and action record of CCT-WG-NCTh meeting 1st July 2016,

**Minutes CCT-NCTherm, 1 July 2016, 13:30-17:30**

**Location: Zakopane, Poland**

Attendees
*Members*
Graham Machin (chair, NPL), Efrem Ejigu (NMISA), Ferruccio Girard (INRIM), Eric van der Ham (NMIA), Joerg Hollandt (PTB), Maria Jose Martin (CEM), Mikhail Matveyev (VNIIM), Mohamed Sadli (LNE-Cnam), Peter Saunders (MSL), Renato N Teixeira (INMETRO), Andrew Todd (NRC), Yoshiro Yamada (NMIJ), Howard Yoon (NIST), Wang Li (NMC-A-STAR), Zundong Yuan (NIM)

*Coopted members*
Klaus Anhalt (PTB), Pieter Bloembergen (NIM), Boris Khlevnoy Boris Khlevnoy (VNIIOFI), Helen McEvoy (NPL), Tiejun Wang (NIM)

*Invited guests*
Sam Boles (NMSI), Charles Gibson (NIST), Leonard Hanssen (NIST), Lenka Kňazovická (CMI), Edgar Mendez Lango (CENAM), Dave Lowe (NPL), Jose Manuel Mantilla (CEM), Humbet Nasibli (UME), Özlem Pehlivan (UME), Xiaofeng Lu (NIM)

*Apologies*
Daniel Cardenas Garcia (CENAM), Seon Do Lim (KRISS)

*President of CCT*
Duan Yuning (part attendance)

The meeting began with an introduction of participants and agreement of the agenda. These notes follow the agenda topics.

1) Review of actions and decisions of CCT NCTherm May 2014

Matters arising. The outstanding action is a TG under HY was established to write text for the blue book about radiation thermometry. However it was unclear how to proceed or even if this was still needed.

*ACTION 01*: WG chair to contact Rod White to clarify if this is still needed and if so what exactly. DONE and Rod given guidance – to be reviewed in the future but not at WG meeting in May 2017 as that is too soon.

2) Progress with CCT KC10 (HCM)

HCM gave a review of the progress of the above KC. It is likely to have slipped a year from its initial schedule by the time the measurements are complete (projected early summer 2017).

HCM presentation on restricted part of CCT NCTherm website.

*ACTION 02*: HCM to circulate the most up to date schedule for CCT K10 to participants DONE

3) Cmc review protocol [to discuss revising and including T and HTFPs], possible formation of a CMC review protocol task group (YY/MS)

YY gave a detailed presentation explaining the requirement for modifying the review protocol and service categories to allow for the realisation and dissemination of thermodynamic temperature. His presentation is on restricted part of CCT NCTherm website.

*DECISION 01*: Establish task group to advance review of CMC review protocol: DONE

TG CMC review for thermodynamic temperature members: YY chair, members: MS, YY, XL, KA, AT, BK

*ACTION 03a*: TG to agree ToR with CCT WG NCTherm chair (July 16) DONE
*ACTION 03b*: TG identify and develop proposed changes to CMC review protocol and service categories: by (Apr 17) DONE
*ACTION 03c*: TG reports to WG CCT NCTherm proposals for discussion and agreement immediately before next CCT (May 17) IN PROGRESS

*ACTION 03d*: WG chair to brief CCT president on activities in developing CMCs for high temperature radiometry. DONE

4) Recommendations to CCT arising from InK-1 results (GM/MS/KA)

Document circulated and discussed. Although content was agreed the document is not currently in the correct form for a recommendation.

*ACTION 04a*: WG members to propose amendments to the WG chair (July 16) DONE
*ACTION 04b*: WG chair to produce next version of recommendations for circulation to WG (Sep 16) DONE
*ACTION 04c*: WG to propose final changes and WG chair to finalise version for discussion at CCT (May 17) – DONE – this was actually issued as a CCT NCTh declaration and is available on the CCT website.

5) Remaining research into HTFPs
   a. T of fixed points measured during InK-1 (DL)

DL gave a shortened presentation of his Tempmeko ’16 paper. It became clear that there were still a number of issues regarding uncertainties of HTFP T assignment to be resolved. This lead to work item b. below to be changed.

   b. Proposal for a TG of CCT WG NCTherm for determining T of remaining HTFPs, including WC-C (All, GM)

It was felt that the community was not yet ready to take this definitive step as there were a number of ill-defined uncertainty components that needed further quantitative investigation.

*DECISION 02*: Postpone the establishment of TG of CCT WG NCTherm for determining T of remaining HTFPs, including WC-C. Establish a TG for identifying all the key uncertainty components surrounding the T determination of HTFPs and highlight the ones that need further investigation.

TG on uncertainties in T determination of HTFPs was established, members were: AT (Chair), MS, KA, DL, PB, BK, YY

Objectives of the TG are to: a) establish a definitive list of uncertainty components associated with determining T for HTFPs, categorise them into well specified or requiring further investigation; b) Ensure format is consistent with the document produced in 6) below for direct incorporation into that document, c) Report back to CCT WG NCTherm

*ACTION 05a*: Establish a definitive list of uncertainty components associated with determining T for HTFPs, categorise them into well specified or requiring further investigation DONE
*ACTION 05b*: Report to CCT WG NCTherm on findings and for agreement of next steps (May 2017) IN PROGRESS

DL presentation on restricted part of CCT NCTherm website.

It was noted that the biggest source of radiometric uncertainty within high temperature radiometry is the uncertainty associated with aperture area determination.

*ACTION 05c*: WG chair to make CCT president aware of this requirement so that action could potentially be initiated in CCL to improve this situation DONE

6) Radiometric uncertainty document (PS)

PS gave an overview of the status of the radiometric uncertainty document that Emma Woolliams began to produce before she had to leave the WG. The document is about 80% complete. He outlined where input was required and various WG members agreed to help with different sections.

Section
4.1.3.6 “geometric factors” /aperture diameters – BK
4.1.5 Out-of-band transmission – HY and MS
4.1.6 Stray light - Stephan Briaudeau, MS to remind
5.1.2 Sensitivity to angular dependence – Dieter Taubert (JH to remind)
Table 9 – EvdH
6.1.5 not required
6.2.2 fixed point effects (to take output of TG uncertainties in T determination of HTFPs)
Example budgets – to be assembled by KA

*ACTION 06a*: All identified above WG members to complete sections and send to PS by end of 2016 NOT DONE
*ACTION 06b*: Report progress to final document at WG CCT NCTherm May 17 IN PROGRESS

7) Thermal imaging standardisation and uncertainties (JH)

JH presented the activities in thermal imaging standardisation to the WG.

JH presentation on restricted part of CCT NCTherm website.

No actions:

8) AOB

Discussion was held on the value of determining definitive $T$-$T_{90}$ values above the Cu point. However this was felt to be specified by the thermodynamic uncertainty of the ITS-90 defining fixed points and hence was not necessary. The chair noted that InK 2 will develop data, by primary radiometry, for $T$-$T_{90}$ below the silver point and the working group should be prepared to develop consensus values for that data when available in late 2018.

WG chair thanked the participants for their contributions and closed the meeting at 16:00.

*ACTION 07*: WG chair to upload meeting documents to the restricted part of the WG NCTherm website - DONE

Annex 3: Agenda of CCT-WG-NCTh 31st May 2017, BIPM, Sevres, Paris

Agenda for CCT NCTherm

Date: 31 May 2017

Time: 09:00 to 13:00

Location: BIPM, Sevres, Paris

1. 09:00 – 09:05: Opening of meeting (GM)

2. 09:05 – 09:15: Introduction of participants (all)

3. 09:15 – 09:20: Review of actions from previous meeting (GM)

4. 09:20 – 09:45: Report on radiometric temperature measurement uncertainties (PS)

5. 09:45 – 10:05: Key comparison above the silver point – progress report (HCM)

6. 10:05 – 10:30: Progress with CCT TG-NCTh-CMC (YY)

7. 10:30 – 10:55: Coffee break

8. 10:55 – 11:25: Progress with CCT TG-NCTh-HTFPU (AT)

9. 11:25 – 11:40: Assigning T to HTFPs (DL)

10. 11:40 – 11:55: InK – 2 classical radiometric temperature measurements (HCM/MS/KA)

11. 11:55 – 12:15: InK -2 non-classical radiometric temperature measurements (KA/BK)

12. 12:15 – 12:35: The use of InGaAs detectors in radiometry/radiation thermometry (MS/HY/KA)

13. 12:35 – 12:45: Input into the MeP-K-19 (GM)

14. 12:45 -13:00: AOB [1. PB document (PB), 2. Thermal imaging standardisation, other thermal imaging matters (TCT workshop on thermal imaging, Thermology meeting) {JH,GM}, 3. Future temperature scale ITS-xx – views? (all), 4. Proposed venue of next meeting IMEKO World Congress Sep 2108]

15. 13:00: Close of meeting