CCT-WG5 Activity Report to CCT 22-23 May 2008

Chair: Graham Machin, NPL
Date of report: 24 April 2008

Terms of reference of WG5 are:

- Producing a document on uncertainty in radiation thermometry at temperatures below the Ag point.
- With coordination of thermodynamic measurement results at higher temperatures.
- With continuing the examination and coordination of activities related to high temperature fixed-points.
- Providing appropriate input into the mise-en-pratique for the realisation for the kelvin.

Membership
A*STAR (Wang Li), INRIM (Mauro Battuello), KRISS (Chul Woung Park), LNE-INM (Mohamed Sadli), MSL (Peter Saunders), NIM (Zundong Yuan), NIST (Howard Yoon), NMIA (Mark Ballico), NMIJ (Juntaro Ishii), NMI-VSL (Eric van der Ham), NPL (Graham Machin), PTB Joerg Hollandt, SMU (Peter Nemecek), UME (Ahmet Diril), VNIIM (Mikhail Matveyev), Nigel Fox (CCPR official representative)

Co-opted members
(Formerly NMi-VSL and NMIJ), Pieter Bloembergen, PTB (Juergen Hartmann), VNIIOFI (Boris Khlevnoy), NMIJ (Yoshiro Yamada)

Introduction
A summary of activity by the WG5 is given in this report. Various annexes are attached in support of the activity summary. Finally the draft agenda of the WG5 meeting to be held at BIPM 21st May 2008 is given in Annex 3.

Summary of activity
Membership: Since the last CCT meeting the group has gained one new member Ahmet Diril (UME) and two new co-opted member Boris Khlevnoy (VNIIOFI) and Juergen Hartmann (PTB).

Meetings: Two formal meetings were held I) 8 June 2006 at LNE-INM, Paris and II) 25 May 2007, Lake Louise, Canada. The minutes, agenda and action record of the first of these meetings can be found on the BIPM website CCT-WG5 (restricted). The record of the second of these meetings can be found on the BIPM website at http://www.bipm.org/wg/CCT/CCT-WG5/Allowed/Miscellaneous/CCT_wg5_tempmeko_07.pdf

Formal activities:

Terms of reference: The terms of reference were examined by the WG at the 8 June 06 meeting and felt in need of revision. New terms were discussed and agreed at the meeting, these were subsequently agreed by the whole WG and the full CCT by email voting. The new terms of reference are given at the top of this document.

Uncertainty document in low temperature radiation thermometry:
The WG, led by Peter Saunders of MSL, has produced a guide to the estimation of uncertainty for low temperature radiation thermometry. This has been the subject of much discussion as terms, and values, were clarified. This document is now almost complete and will become available from the BIPM website, CCT-WG5 open access documents. A summary will shortly be published in the International Journal of Thermophysics.

High temperature fixed point research:
A research plan was elaborated by a sub-group of WG5 (GM, YY, PB) to move HTFPs from the current state of research to main-stream temperature metrology tools by 2011. This is found in full on the BIPM website:
http://www.bipm.org/wg/CCT/CCT-WG5/Allowed/Miscellaneous/CCT-WG5-docs-01.pdf
This has been a topic of much discussion at both WG5 meetings and also by email. Protocols have been elaborated for two of the technical workpackages; WP1 "long term stability tests", and WP4 "evaluation of absolute radiation thermometry capability". The current state of progress is that the project has just started and stability tests have been performed on Pt-C by NIM, Co-C by NMIJ (underway April 08). NIST will perform stability tests on Re-C, after a furnace refit, hopefully in May 08. The cells will then be transported to PTB for the start of WP4 and will include eight participants.

A workshop on all aspects of HTFP research will be held at the end of the Newrad 2008 conference in Dajeon, South Korea on 16/17 Oct 2008.

Progress in KC5 strip lamp comparison to 1700 °C
The KC5 strip lamp comparison has been making progress to completion. The coordinator (EvdH) completed the next (and hopefully) final step in the analysis on 23rd April. The documentation has been circulated to WG5 and participant members for comment and it is hoped by the CCT meeting to have KC5 completed and ready for entry on the KCDB.

There is a significant issue with the KC in that it does not substantiate cmc entries neither in uncertainty nor range. This issue will need to be addressed, though the current WG5 view is that a new KC would be premature given that KC5 still has to be finalised and the rapid pace of developments in the technical area (minutes of WG5 25th May 2007).

Input into the mise-en-pratique above the silver point
WG5 recognize the requirement to produce input for the mise-en-pratique for the kelvin for temperatures at and above the silver point. The task was outlined in a discussion document given in Annex 1. However the WG5 meetings held subsequent to the last CCT both ran out of time to give proper consideration to this important activity. This will be addressed at the May 2008 WG5 meeting with a draft discussion of the text to be constructed by a target date of Oct 08.

It is likely that any such text will include absolute radiometric temperature measurements. To then properly implement the MeP cmc categories for thermodynamic temperature measurement (category 1.5) need to be put in place as agreed by WG8 at the TS2002.

Other activities

The issue of thermal imager standardisation was discussed at the May 2007 meeting. In particular an ISO standard was being written for the use of thermal imaging for control of transmission of infectious diseases. Grave concerns were expressed concerning the temperature metrology in that standard. GM read the standard and on behalf of WG5 wrote to the world standardisation bodies expressing the concerns of WG5 (the letter text is given in Annex 2). As a result the standard was revised significantly in Jan 08 with WG5 input and as a result it now contains much more realistic temperature metrology, though some concerns as to its technical feasibility remain.

Annex 1: Creation of a proposed addition to the mise-en-pratique for the kelvin above the silver point

CCT recommendation T 3 (2005) to the CIPM recommended the following:

- the creation of a mise en pratique of the definition of the kelvin containing in due course, recommendations concerning the direct determination of thermodynamic temperature, the text of the ITS-90, the text of the PLTS-2000, a Technical Annex of material essential for the unambiguous realisation of both the ITS-90 and the PLTS-2000, and a section discussing difference $T-T_{90}$, and $T-T_{2000}$ together with their uncertainties
- approval by the CIPM of the text entitled “Technical annex for the mise en pratique of the definition of the kelvin”, adopted by the CCT at its 23rd meeting, as initial entry to the Technical Annex

This recommendation was agreed by the CIPM in September 2005, and because of this, an addendum to this mise en pratique covering the temperature range above the silver point will need to be developed.

A mise en pratique above the silver point will give the following advantages

- it will allow the formal definition of the ITS-90 to stand
- it will formally recognise differing/improved methods of realising/disseminating the kelvin above the silver point
- it would state the uncertainties and possible differences of the each method

An outline discussion document ultimately to be added to the mise en pratique will be developed in close co-operation with CCT-WG5 members, and the chair of WG1. The document will formalise the n=0, n=1, n=2 and n=2+ schemes and focus on methods for realising and disseminating the kelvin above the silver point.

The aim should be to have a discussion document ready for the next CCT-WG5 meeting at CCT May 08.

Annex 2: <u>Open letter to world standards bodies re thermal imaging for control of transmission of infectious diseases</u>

Our Ref: CCT-WG5 comment on IEC draft 62D/616/CDV
and new work item proposal 62D/615/NP

National Standardisation Bodies: Open letter from CIPM committee CCT-WG5 (radiation thermometry) on the above standards

Dear Sir/Madam

I am writing on behalf of the CCT-WG5 to express our concern about the temperature measurement uncertainty and traceability requirements in the above standard.

The CCT-WG5 is a technical committee, concerned with non-contact thermometry measurement, of the CCT[1] which is in turn a committee of the CIPM[2], the world metrology body located at the BIPM[3], Paris. The CCT-WG5 is comprised of technical experts in non-contact thermometry from all of the world metrology regions and its role is to ensure good non-contact thermometry practice is followed, encourage and facilitate improvements in non-contact thermometry and the proper functioning and implementation of the SI by non-contact thermometry.

The clause numbers in this letter relate to 62D/616/CDV

We as a committee welcome this standard in principle. It attempts to introduce measurement rigour into a situation of critical importance, that of the monitoring and control of infectious disease, at ports of exit and entry. There is a wider requirement that should also be addressed that of an ISO standard for the specification and calibration of thermal imagers in general, but we recognise, given the urgent need, for a standard for the specific application treated in 62D/616/CDV.

Our concerns centre on five issues that we believe ought to have further consideration:

1) the effect of skin emissivity – in particular the effect of moisture/sweat on the skin – clause 201.3.220 – NOTE and 201.101.10
2) the minimum humidity requirements 201.7.9.3.101
3) the accuracy of the external reference source 201.101.3.1
4) the minimum radiometric temperature accuracy 201.101.2.2
5) Annex BB: Calibration source

These are discussed in more detail below.

<u>The effect of skin emissivity</u> – in particular the effect of moisture/sweat on the skin – clause 201.3.220 – NOTE and 201.101.10

---

[1] Consultative committee of thermometry
[2] International committee of weights and measures
[3] International bureau of weights and measures

Dry skin emissivity is stated to be between 0.96 and 0.98. No uncertainties are given for these values but given that even the best emissivity measurements have typical expanded uncertainties of 2-5 % it could be reasonably assumed that at best the uncertainty on these values is 2%. A 2% uncertainty error on skin emissivity translates to more than 0.5 °C uncertainty at 5 μm, and worse for longer wavelengths (scaling as λT^2, where λ is the wavelength of operation of the thermal imager and T is the thermodynamic temperature of measurement (273.15+37) kelvins.

When moisture or sweat appears on the skin then these values are modified in an unspecified (maybe unknown?) way, but certainly increasing the radiometric temperature uncertainty.

Considering the above we recommend the following:

- *That proper consideration be given to the uncertainty in skin emissivity, at least guidance to alert users to the possible uncertainties in radiometric temperatures*
- *That a statement be included that quantifies the effect of skin moisture on radiometric temperature, and if necessary a study be undertaken to quantify this effect*

<u>The minimum humidity requirements</u> 201.7.9.3.101
The stated requirement of a relative humidity of <50% is of course good measurement practice. However is it actually attainable in reality? Also acclimatisation is very important here, how long has the subject been at <50% humidity before the thermogram has been taken, this could, in particular weather conditions and climates have a significant effect on the temperature reading.

A limit on the relative humidity level is given. For proper implementation of the standard this implies that the humidity sensors should be calibrated and traceable to national standards – the comments in the section on Annex BB below apply.

Finally some thermal imagers are prone to sensitivity to air relative humidity, this should be noted in some way in the standard and mitigation strategies mentioned (e.g. a reference source in image at the same distance as the subject, or select a thermal imager operating in an appropriate wavelength region that is not affected by the variations in air relative humidity, or observe the manufacturers guidance on usable relative humidity range of operation [provided this means that moisture in air does not affect the thermal imager output]).

Considering the above we recommend the following:

- *That consideration be given to situations where it is not possible to attain <50% humidity*
- *That where such conditions exist the issue of acclimatisation is considered*
- *That humidity sensors used to set this limit are properly calibrated traceable to national standards*
- *That a statement be included concerning the possible sensitivity of thermal imagers to air relative humidity and simple mitigation strategies discussed.*

<u>The accuracy of the external reference source</u> 201.101.3.1

Manufacturers of thermal imaging equipment generally give uncertainties of ±1% of temperature hence it is both right and proper to seek to validate the performance of thermal imagers when used in critical situations such as those for which this standard is being developed.

However, in the opinion of this committee, it is not possible to attain the stated uncertainty ±0.1 °C within the range of 34 °C to 40 °C for a blackbody used in the field. To illustrate; the National Physical Laboratory (NPL) [which has world leading IR thermometry standards] calibrates blackbody reference sources by comparison, at the appropriate wavelengths, with its national reference standards. The lowest uncertainty, accredited to ISO 17025, for this calibration is ±0.2 °C (k=2) in the given temperature range. When the blackbody is taken from the laboratory environment and used other factors would have to be taken into account, such as environmental conditions and internal sensor drift, that would increase this uncertainty.

In certain cases special blackbody sources could be developed and calibrated, if the appropriate precautions were taken, to give lower uncertainties than ±0.2 °C (k=2) in the given temperature range. However whether such sources would retain their calibration in use would be a moot point, and it is certain that they would need regular recalibration and in-use cross checks to attain such low uncertainties with confidence.

To summarise we believe that no calibration laboratory exists that can perform an accredited traceable calibration, on a routine basis, with the low uncertainties stated in the standard, to a blackbody intended for in-field thermal imager validation.

The issue of calibration and traceability will be discussed below in the section relating to Annex BB.

It is not clear in the standard whether the “external reference source” i.e. the one used in-situ is the same as the “calibration source” – this should be clarified. The standard implies that they are different and the “calibration source” is the reference against which the “external reference source” is periodically checked. If this is the case it is even less likely that the “external reference source” could attain an uncertainty of ±0.1°C.

Also, and more generally, the terms accuracy and uncertainty appear to be used in the standard as interchangeable terms. These are not interchangeable metrological terms and the authors should clarify what they mean and strive to be more consistent in the application of the terms. We note that in section 201.3 that accuracy is defined (201.3.201) but not uncertainty.

Considering the above we recommend the following:

- *That the uncertainty of the temperature reference source be reconsidered and more realistic values included in the standard*
- *Clarification of the standard with regards the “calibration source” and the “external reference source” should be made*
- *The wording of the standard be clarified, particularly with regards the use of terms accuracy (a qualitative term) and uncertainty (a quantitative term)*

<u>The minimum radiometric temperature accuracy</u> 201.101.2.2

This section considers the minimum temperature uncertainty performance of the thermal imager used for the taking of thermograms. The required uncertainty is certainly lower than that quoted by thermal imager manufacturers and therefore, rightly, an external reference source is required to achieve this uncertainty.

However given the potential uncertainty of the temperature reference source is likely to be well in excess of ±0.2 °C (*k*=2), and given that the imager itself will be a source of several uncertainties the minimum radiometric temperature accuracy requirement is exceedingly challenging. Such a low uncertainty is possibly only attainable in an accredited laboratory with short and valid traceability routes to a world-class national standard or in a National Measurement Institute.

It should be noted that the treatment of uncertainties in the proposed standard does not follow international guidelines as laid out in the Guide to the Expression of Uncertainty in Measurement (the "GUM"). In addition not all possible uncertainty components are considered.

Considering the above we recommend the following:

- *That the minimum radiometric temperature accuracy be reconsidered and more realistic value included in the standard.*
- *That the uncertainties be reworked according to the recognised international standard and care is taken to identify and quantify all the uncertainty components*

<u>Annex BB: Calibration source</u>
The standard rightly recognises that the calibration source itself needs to be calibrated to ensure proper performance. However, given the critical nature of the application, in the view of CCT-WG5 the issue of calibration and traceability has not been properly addressed in this Annex.

Leaving aside the problematic temperature uncertainty requirement (discussed above) the wording "traceable to appropriate national or international standards" is clearly insufficient to guarantee rigorous traceability.

The current temperature scale in use throughout the world is the International Temperature Scale of 1990 (ITS-90). Any temperature measurement should be demonstrably traceable to this scale. To demonstrate this with confidence it is essential that any laboratory performing such tests can demonstrate traceability to national standards. This is done through the calibration laboratory meeting the requirements of the accreditation standard ISO 17025, and being third party accredited to that standard.

A technical issue arises with regards the blackbody cavity emissivity. If the blackbody is calibrated <u>radiometrically</u> in the wavelength range of operation of the thermal imager under test then the emissivity recommendation is sound. However if the contact thermometry sensor is used to determine the cavity temperature, and its emissivity is only 0.995, this could lead to significant differences between the contact sensor temperature and the radiance temperature, certainly in excess of 0.5 °C.

Given the above we recommend the following:

- **Careful consideration be given to the issue of calibration, traceability and accreditation**
- **The wording in the annex be changed to address these concerns in particular with regards traceability to ISO 17025**
- **The emissivity requirement be clarified, particularly if a contact thermometry sensor is being used to infer the radiometric temperature of the cavity**

In conclusion: We the CCT-WG5 urge that the above recommendations be accepted and in addition the following recommendations be implemented:

a) *more time be given to consider these issues before the standards progress to the next stage*
b) *one or more members from CCT-WG5 be co-opted onto the committee drafting these standards to ensure that the measurement aspects are considered fully*

We trust that these recommendations are a positive contribution to the development of these important standards. Our intention is to ensure that the best possible standard is produced for this critical measurement application. We would be pleased to engage in dialogue with the members of the standards committee drafting these standards. This should be done in the first instance through CCT-WG5 chair.

Yours sincerely

Prof Graham Machin
Head, Temperature Standards, Chair, CCT-WG5

On behalf of the members of CCT-WG5: Graham Machin (NPL, UK, Chair), Mark Ballico (NMIA, Australia) Mauro Battuello, (INRIM, IT), Nigel Fox (NPL, UK), Eric van der Ham (NMi-VSL, NL), Joerg Hollandt (JHt, PTB, DE), Juntaro Ishii (NMIJ, JP), Wang Li (SPRING, SP), Mikhail Matveyev (VNIIM, RU), Chul Woung Park (KRISS. KR), Mohamed Sadli (LNE-INM/Cnam, FR), Peter Saunders (MSL, NZ), Zundong Yuan (NIM, China), Howard Yoon (NIST, US), Pieter Bloembergen (Formerly NMi-VSL, NL & NMIJ, JP), Juergen Hartmann (JH, PTB, DE), Boris Khlevnoy (VNIIOFI, RU), Yoshiro Yamada (NMIJ, JP)

Annex 3: Draft agenda of CCT-WG5 meeting 21 May 2008

9:00-9:05 Introduction, welcome, new members
9:05-9:15 Review of minutes and action record of last meeting (25th May 2007)
9:15-9:30 Review of terms of reference and tasks – need for updating e.g. thermal imaging?
9:30- 10:15 Input into the mise-en-pratique for the kelvin above the silver point
10:15-11:00 KC5 completion
11:00-11:20 Coffee
11:20-12:10 HTFP

a. research plan progress
b. international workshop at KRISS

12:10-12:30 Thermal imaging standards[4] – fever screening, OIML….
12:30 –12:45 Preliminary discussions re future KC
12:45-12:55 Next meeting Newrad 08? Tempbeijing 08? VNIIM 09?
13:00 AOB and close of meeting

[4] Peter Saunders comments on thermal imager standards "there is no mention of size-of-source effect. In my experience, thermal imagers tend to suffer from SSE to a much greater extent than normal pyrometers. This should be investigated."