Minutes of CCT-WG5 Meeting

Chair: Graham Machin
Date: 22 May 2012
Time: 09:00 – 13:00
Location: BIPM, Sevres, Paris, France

Attendees

Attending Members

Maria Jose Martin (CEM), Mohamed Sadli (LNE-CNAM), Renato Teixeira (INMETRO), Ferruccio Girard (INRIM), Wang Li (A*STAR), Zundong Yuan (NIM), Howard Yoon (NIST), Juntaro Ishii (NMIJ), Andrew Todd (NRC), Joerg Hollandt (PTB), Edgar Moreno Vuelban (VSL)

Invited experts

Yoshiro Yamada (NMIJ), Helen McEvoy (NPL), Emma Woolliams (NPL), Klaus Anhalt (PTB),

Attending observer

Leonard Hanssen (NIST), Seda Aytekin (UME) [for Ahmet Diril], Victor Fuksov [for Mikhael Matveyev] (VNIIM)

Apologies

Daniel Cardenas Garcia (CENAM), Peter Saunders (MSL), Pieter Bloembergen (NIM), Tiejun Wang (NIM), Mark Ballico (NMIA), Nigel Fox (NPL) [CCPR link, substituted by ERW), Peter Nemecek (SMU), Ahmet Diril (UME), Boris Khlevnoy (VNIIOFI)

Introduction

CCT-WG5 met on 22nd May 2012, 09:00 – 13:00, at the BIPM. The original agenda for the meeting is given in Appendix I of these minutes. The agenda was modified slightly to keep discussions on the HTFPs together. These minutes reflect the new agenda order, they are also the action record of the meeting. Actions described in the body of the text are summarised in Appendix II.

1. Membership

The meeting opened with each attendee introducing themselves and their participation in this WG. There was one new member Andrew Todd of NRC. In addition the VSL representative had been replaced by Edgar Moreno Vuelban.

2. Review of last minutes and action list

The minutes of the 6th May 2010 meeting were accepted as a true record of the meeting and are thus signed off.

The action list from the previous meeting was discussed. Almost all actions were either completed as written or delivered in an appropriate alternative manner where the situation had changed. Action item 12 was not completed but is no longer necessary. Action items 5 and 6 were discussed in more detail.

> Action 05-2010: GM and TG for *MeP*-K HT to finalise background document CCT/10-12 by; resolving of remaining issues concerning the refractive index and agree revised values of HTFPs (led by MS)

Action 06-2010: WG5 – all WG5 members to send any new measured values of HTFPs to MS (LNE-INM/Cnam)

MS has an up to date list of published values for the HTFP melting temperatures. This list was not circulated because WP4 values still need to be included. Now this WP is complete the intention is to derive and circulate revised T and T_{90} values for the HTFPs.

There was some discussion about how to present the obtained values, given that some were measurements of T and some of T_{90}. MS will review this in informal discussions with others and then circulate an up-to-date list of HTFP temperature measurements.

AP.2012-01: MS to discuss with others how to deal with T and T_{90} values and then send out a revised list of HTFP temperatures incorporating WP4 values.

3. Review of regional thermal imaging services

At the last meeting it was agreed to organise a questionnaire to be circulated among the RMOs concerning the calibration of thermal imagers. Helen McEvoy (HCM) coordinated responses from Euramet and JI coordinated responses from APMP. Both gave presentations of the results of these surveys.

HCM reported that 17 Euramet laboratories responded to the survey, 15 of these make calibrations of thermal imagers. Most do these calibrations as for a radiation thermometer against a blackbody reference source, although some additionally use a large grey-body (plate) source. The SSE is often measured, the distance effect not generally investigated unless specifically requested by the customer. Field uniformity tests are carried out by moving the blackbody source in the field of view. Two NMIs follow the OIML standard.

JI reported that 7 APMP laboratories responded to the survey, 6 of whom make calibrations of thermal imagers. The results are similar to Euramet: they all use blackbody sources with relatively small apertures as references. NIM follow a Chinese standard others their own procedures. SSE is tested by a few NMIs and nobody measures distance effect. Field uniformity is measured “where customers are willing to pay”.

The work on IEC committee concerning Thermal imager standardisation was discussed. GM said that he had resigned as committee chair and Masahiko Gotoh is currently the interim chair until a new chair can be appointed. Once the committee work continues they will first identify the parameters required for specifying the performance of the imagers (almost complete). Once agreed the committee will then detail how these parameters are to be measured. Finally the committee will write a standard on recommended best practice how to calibrate thermal imagers. It is likely that CCT-WG5 will need more collaboration with that committee at that later stage.

There was a long discussion about how these instruments are calibrated as a radiation thermometer, and often as a black-box. Only some manufacturers (eg FLIR) provide ‘raw’ data in any open format, most provide data that has included correction algorithms. A full characterisation of these instruments (especially to make realistic statements of uncertainty) requires both an understanding of their underlying processes, gained through discussion with the customer, and considerable time – far more time than most customers are willing to pay for. WL described the importance of testing the different emissivity settings as these are often wrongly implemented.

HY emphasised that there is an active community of users of these instruments, in the USA through the American Society of Non-Destructive Testing. Similar organisations and manufacturers offer

detailed training courses to ensure these instruments are used appropriately. We should only get actively involved if we can add value to these already active communities.

Discussion considered whether it was appropriate or possible to hold a comparison of thermal imager calibration methods. The general consensus was that it was too early for this, or to be clear what the key parameters to be determined in a comparison would be.

HCM and JI were thanked for their contributions. GM agreed to place both presentations onto the CCT-WG5 webpage. This action is included in AP2012.11.

4. Best practice guidance on thermal imager calibration – new TG?

A discussion was held whether WG5 needed to set up a task group on thermal imager calibration. It was recognised there was a need but that it was premature for such a task group to be formed within WG5 because it would be in danger of duplicating the activity of the IEC committee. It was felt better to wait until that committee was reactivated with a new chair and to represent our views on this subject there (a number of CCT-WG5 are members of that committee). GM agreed to discuss this with the IEC committee chair to see when progress may happen there.

AP.2012-02: GM to talk with the IEC interim committee chair to understand timescales for that committee and to report back to the CCT-WG5.

As part of this discussion, HY asked about progress of the ISO working group on thermal imagers for fever scanners. The WG has published a standard, but it is widely thought that this standard is impractical: both far too stringent for the device under test ("impossible to pass") and requiring too much work by a test laboratory (e.g. 17 days of continuous stability testing).

5. SInf TG progress report

HY presented progress of the Task Group developing the Supplementary Information for the ITS-90 text. Several WG members had contributed, MM, HCM, MJM and in particular PS.

As SInf to the ITS-90 this text needs to follow the ITS-90. This caused some concern with measurements at temperatures below the silver point. There was some discussion about whether 'strict ITS-90' required the fixed-point temperatures to be verified with SPRT measurements before being used as references for radiation thermometer calibration. This is because in practice the Sakuma Hattori interpolation approach is generally performed using fixed point blackbodies that have not been validated by contact thermometry. The conclusion was that below the silver point radiation thermometry is not strictly ITS-90 because ITS-90 includes the fixed points, the interpolation instrument (SPRT) and equations – not just the fixed points. However it is recognised that this approach is used widely and is very reliable so should be included in the revision of "Approximating techniques for ITS-90" currently being revised by WG2. GM undertook to discuss this with the chair of WG2 and HY agreed to extend his activity to include developing appropriate text for the "Approximating techniques" book.

AP.2012-03:GM to discuss with WG2 chair including radiation thermometry below the silver point using ITS-90 fixed points in the "Approximating techniques for the ITS-90" revision.

AP. 2012-04: HY to lead activity within WG5 in developing appropriate text for the "Approximating techniques of the ITS-90" using the fixed-point interpolating method of realising ITS-90 for radiation thermometry below the silver point

In reviewing the existing Supplementary Information text there were some clear changes to make. Mention of tungsten strip lamps was removed. The discussion of effective wavelength has been removed and replaced with discussion on extrapolation using the Sakuma-Hattori equation and use of the full integral form of the Planck-function. The recommendation to use only narrow band filter radiometers has been removed. One minor problem was that ITS-90 states a value for c_2, this is now superseded by the more recent CODATA. Although the effect is insignificant it is recommended that any future temperature scale just recommends using the most current CODATA value for c_2.

The aim is for the text to be completed within the next two months and then circulated to CCT-WG5 for comment (one month) and then ballot with the aim of submitting this to CCT for e-approval by October 2012.

YY asked about the statement requiring the use of an integrating sphere after the monochromator, which is introduced to ensure spectral mixing, and whether this was really needed with a double monochromator. EW commented that this may not be required with a subtractive-mode double monochromator, which has a uniform spectral distribution on the exit slit. EW agreed to find an appropriate reference for this and HY agreed to add a statement on this in the text.

AP.2012-05: EW to find appropriate reference on subtractive mode double monochromators and HY to introduce this to text before final draft circulated.

6. Completing the HT *MeP*-K text for inclusion in the *MeP*-K

GM explained the next stage activities of CCT-WG1 relating to the development of the *MeP*-K. He expects to need to reduce the text to a single page, with appropriate reference to the background documents. A meeting of WG1 (22 May 2012, pm) will agree the nomenclature for the *MeP*-K and mechanism for incorporating primary thermometry. YY explained a potential problem in the approach considered by the CCT-WG1. Their previously suggested document lists “primary thermometry”, “ITS-90” and “approximations to thermodynamic temperature” as independent and separate headings. He suggested that this may cause problems introducing HTFPs for thermodynamic temperature – these would fit in both the first and third categories. He suggested asking the CCT-WG1 to reconsider this hierarchy so that there are only two categories: ITS-90 and thermodynamic temperature. GM agreed to take these concerns to the afternoon meeting.

AP.2012-06: GM to take YY concerns to CCT-WG1 and to provide feedback on how *MeP*-K will be structured. GM to write shortened text for *MeP*-K, as required.

7. Linkage of HTFP work to the EMRP InK project

GM presented an overview of the Euramet EMRP project Implementing the new kelvin (InK). This project will develop primary thermometry at very high (>1000 °C) and ultra low (< 1 K) temperatures and new values for $T - T_{90}$ for temperatures from 1 K to 933 K.

The InK project will start with a kick-off meeting on the 10-11 October 2012. Immediately following this kick-off meeting (on the 12th October), a workshop will be held, organised by MS, on the uncertainties in radiometric temperature measurement. MS presented ideas for the workshop. The aim is to share best practice and lessons-learnt in a discussion-workshop, reviewing the different experimental techniques used to minimise and understand uncertainty components. It should ensure that WP5 of the HTFP research programme has reliable uncertainty information prior to analysis. There are a lot of potential topics, and MS invited views and suggestions for discussion topics for the workshop. EW asked for the programme to include a discussion on describing the correlations in the (eg WP5) measurements. Those who would be unable to attend a one-day meeting, could still be involved through video conferencing or webex (or similar link). FG agreed to discuss this point with Roberto

Gavioso who is organising the practical aspects of the InK kick-off meeting to look into whether this was possible.

AP.2012-07: MS to prepare a 1-page advertisement for the uncertainties workshop and send out to the CCT and CCPR. All to send MS ideas on discussion topics for the workshop

AP.2012-08: FG to ask INRIM/Roberto Gavioso if video links/webex would be possible during the workshop

8. Key comparison with HTFPs – planned start date Autumn 2013

GM presented a proposal for a CCT-WG5 Key Comparison on radiation thermometry using HTFPs as transfer standards. The purpose of this comparison would be to probe the ITS-90 uncertainty claims of the NMIs. Other NMIs, particularly those who were unable to use HTFPs, would participate in secondary RMO comparisons, with a larger associated uncertainty, which use alternative transfer artefacts.

The discussion that followed this proposal covered three main concerns: a) the 'blindness' of HTFPs as reference standards, b) the problem with linking the RMO comparison to the key comparison and c) the required uncertainties of a comparison.

There was a concern in using HTFPs as transfer standards for a comparison, even using 'other' fixed-points (i.e. not Co-C, Pt-C, Re-C), because temperatures for these fixed-points are given in the literature. However, there was acceptance that it should be possible to dope the HTFPs to change the temperature. Ongoing work at Inmetro and NIM on doping cells will support this. WL gave the example of an APMP comparison using a modified argon cell as an artefact that had been doped to change its value. A related concern, expressed by YY, was that HTFPs are not necessarily sufficiently robust to be used as comparison artefacts and there was a risk of breakage, though this is true of any comparison artefact.

A more general problem in a two-step comparison was in how to link between a CCT KC with one artefact (a source) and an RMO comparison with a different artefact (detector based). This needs consideration in detail during the protocol preparation if HTFPs are to be used for a KC. Any participants of the higher level comparison would be obliged to provide this link, and this may require additional measurements at the time of the CCT comparison to ensure that a proper link, with different artefacts, could be completed later. EW explained that it was standard practice at the CCPR for the CCPR comparison to have a very limited number of participants and for this to be followed by strong RMO comparisons, and that there were examples where different artefacts were used for the CCPR and RMO comparisons.

Generally Euramet members were positive about the idea of this dual comparison: a CCT comparison with HTFPs, and RMO comparisons with other artefacts. PTB gave strong support. APMP members are more concerned. The recommendation from APMP was to use radiation thermometers as transfer artefacts, as they are planning with their upcoming comparison. However this was only possible because of the star arrangement of the comparison allowing for continual checking of the comparison artefact stability. Also concern was expressed that this approach may not probe ITS-90 realisations and only act as a proficiency test for calibrations. This highlighted a difference, perhaps a difference of viewpoints between APMP and Euramet, about the purpose of the comparisons – was it to probe the CMCs (for which a radiation thermometer is a sufficiently useful artefact), or to probe the best capability of the NMIs (for some of whom a better artefact would be needed). GM agreed to raise this point, again, at CCT. GM also noted that within Euramet as part of InK a circulation of HTFPs will occur in the next three years probing ITS-90 realisations in the participating NMIs.

Summary of discussion conclusions. GM will ask CCT for clarity regarding the purpose of KC and aim to get a definitive answer. The APMP comparison will proceed (see point 8b below), which will test a comparison with radiation thermometers as reference standards. InK WP2 will undertake a high level ITS-90 comparison in the Euramet region using HTFPs as comparison artefacts. Other work on, e.g. doping HTFPs will give more options. In two years' time WG5 will have a lot more information to make a decision of the comparison. No consensus could be reached on how to run a comparison at this point in time though all agreed a comparison was needed.

AP.2012-09: GM to raise discussion at CCT about the role of a KC

8b. Key comparison in APMP

YY presented details of the upcoming comparison organised by APMP. This will be a comparison of radiation thermometry in the temperature range from 160 °C to 2800 °C (the range covered in three parts using different instruments with different operational wavelengths).

The comparison will be arranged as a star comparison and will involve circulating both radiation thermometers and Cu, Ag, Al, Zn, Sn and In fixed-point cells with a portable furnace. The measurements will take place from November 2012 and the reporting is expected to be complete in September 2014.

HY asked how the blindness was controlled with these fixed-points being circulated. The answer was that these are the typical types of customer fixed-points and determining the difference from these to ITS-90 references was a standard service for which CMCs need testing. It's likely that they will differ from the reference temperature by ~100 mK.

9. Report from CCPR

EW gave the official liaison report from CCPR to CCT-WG5 on behalf of NF. The members of the CCPR are very actively involved in the development of filter radiometry, both for temperature measurement (high temperature blackbodies, but also lower temperatures, e.g. the calibration of sea surface temperature satellite instruments by radiometric measurements of a blackbody source at 10 µm) and for direct realisation of spectral irradiance scales (using different filter radiometers across the spectral region from 200 nm to 2000 nm to measure lamp irradiance directly).

EW also described the work done by the CCPR in the area of comparison guidelines. The CCPR now has a set of guidelines for how to run comparisons – the organisation of CCPR, RMO and bilateral comparisons, and the analysis of these. This includes a detailed pre-phase A and phase A analysis process, that is designed to reduce the likelihood of outliers due to poor artefacts or underestimated uncertainties. For round 2 comparisons the CCPR supports both step-by-step (multiple averaging) analysis and least squares analysis and is developing software to automate least squares analysis for a general case. EW agreed to provide the CCPR published and draft guidelines to GM for further circulation as appropriate in the CCT.

AP.2012-10: EW to provide GM with the CCPR guidelines for comparisons. GM to forward to CCT-WG responsible for KC

10. Overview of results of Euramet 658 extension

Helen McEvoy presented the results of the Euramet 658 project. This was a comparison involving two InGaAs radiation thermometers and a Zn fixed-point circulated to correct for the radiation thermometer drift. The thermometers were characterised for SSE, gain ratios, sensitivity to ambient temperature and humidity and were calibrated against fixed-points and variable temperature blackbodies.

In general the results agreed well, though there was some spread for the SSE results, especially for the direct-method evaluations. The indirect method gave more reproducible results, though there was one 'outlier'. The use of a travelling fixed-point allowed corrections for the real drift in one of the instruments and minor drift in the other. Jörg Hollandt expressed his thanks for the running of this comparison – the first comparison in this temperature range for Euramet for a very long time – and suggested that the results would be used to support CMCs in Euramet, since a key comparison is not required for radiation thermometry in this temperature range.

11. Progress with the HTFP research plan

The coordinators of the different HTFP research plan workpackages presented the progress.

WP1 was presented by MS. This WP aims to assess the long-term stability of Co-C, Pt-C and Re-C. It was started in 2008 and involved cells of each type being aged for 50 hours and compared against cells used less. This work showed the value of the then-new 'hybrid' cell design, which was used for the tested Co-C cells, but not for the Pt-C and Re-C cells.

The cells used for WP1 were circulated for the WP4 assessment of radiometric capability and had considerable use during that assessment. The next and final step for WP1 will be to retest these cells to understand the effect of further ageing. The original test laboratories will repeat these tests, thus VNIIOFI will test the Re-C cells, NIM the Pt-C cells and NMIJ the Co-C cells. These measurements will take place shortly. MS is also reviewing the documentation for WP4 to determine the history of each of the cells.

WP2 was presented by YY. This is the workpackage that has built and selected cells for the WP5 measurements. The first construction/selection cycle was completed in March 2012 and some cells were selected because they met the required criteria listed in the protocol. After that selection process, 5 Pt-C, 4 Co-C and 4 Cu cells were chosen. There were problems, particularly with Co-C and Re-C. Following that work, the Re-C cells are being re-evaluated and new cells are being made, although there is some delay in obtaining the pure materials. It is hoped that this will lead to at least 5 good cells of each type. There may be problems caused by the fact that most accepted cells use metals supplied by the same supplier. In discussion it was agreed that it would be useful for VNIIOFI and NPL to make a new Co-C cell, with suitable metal from Alfa-Aesar. GM agreed to ask NPL to make such a cell, and YY agreed to ask VNIIOFI to provide a cell.

AP.2012-11:	GM to ask NPL to make a Co-C cell. YY to ask VNIIOFI to do so.

MS asked whether there was a plan to publish the work involved in cell manufacture and selection. There is a publication in ITS-9 on the selection protocol, but it was generally agreed that this work should be published preferably before Tempmeko 2013. YY agreed to, if possible, publish this information after the final cell selection takes place.

AP.2012-12:	YY to prepare paper for publication on the work of WP2

WP3 was not presented, with Pieter Bloembergen absent.

WP4 was presented by KA. This was an assessment of radiometric capability carried out in advance of WP5 to ascertain the status of world radiometry and to provide a 'practise run' for lessons to be learnt. Re-C, Pt-C and Co-C cells were circulated: two cells of each type in two independent loops. PTB measured cells at the start and end of the assessment. KA showed that there was a very broad range of techniques used in the WP4 assessment, with different traceability chains and different methods for measuring the fixed-points. Measurements were also made at different wavelengths. Despite this everyone's uncertainties were broadly in agreement. There were some problems, particularly in an observed drift in one of the Re-C cells, of around 0.5 K, but the overall results were very promising and showed broad agreement. It was generally agreed that the broad range of

methods, wavelengths and calibration approaches was a benefit, especially where uncertainties were similar. This means that determining an average value will be meaningful.

WP5 was presented by EW. WP5 will be the culmination of the project and will involve the highest accuracy radiometric determination of the thermodynamic temperature of the pure fixed points (Co-C, Pt-C and Re-C, as well as Cu) under equilibrium conditions. There is a need to balance the ideal requirements to determine the fundamental quantity with the practical requirements to do the work within the timescales and according to existing capabilities. This was discussed at length in a meeting after the WG5 meeting.

12. Any other business?

GM said he was willing to continue as chair of WG5 but enquired whether anyone else would be interested in taking the chair. There were no objections to GM continuing as chair.

There was a general interest in seeing the provided presentations after the meeting. GM agreed to put these on the closed part of the CCT website and circulate the password.

AP.2012-13: GM to arrange for the executive secretary of the CCT to put the presentations given at this meeting on the CCT website and circulate the password.

The meeting was closed at 13:00.

(Following these minutes – Appendix I provides the agenda, Appendix II lists the action points)

Appendix I: Agenda for meeting

Date: Tuesday 22 May 2012

Time: 9:00-13:00

Venue: BIPM, Sevres

Draft agenda

1. Introduction of participants and new members [all]
2. Review of last minutes and action record [GM]
3. Review of regional thermal imaging services; Euramet Helen McEvoy, APMP [JI]
4. Best practice guidance on thermal imager calibration – new TG? [GM]
5. SInf TG progress report [HY]
6. Completing the HT MeP-K text for inclusion in the MeP-K [GM]
7. Linkage of HTFP work to the EMRP InK project [GM]
8. Key comparison with HTFPs – planned start date Autumn 2013 – [GM & MS]
9. Progress of WG5 HTFP research plan [GM]
10. Progress with WP1 (HTFP stability and next measurements) [MS]
11. Progress with cell selection for T assignment [WP2] [YY]
12. Progress with primary radiometry [WP4] [KA]
13. T assignment protocol [WP5], satellite meeting this afternoon [EW]
14. Report from CCPR [EW]
15. Overview of results of Euramet 658 extension [HCM]
16. AOB
17. Close of meeting

Appendix II: List of action points

AP.2012-01: MS to discuss with others how to deal with T and T90 values and then send out a revised list of HTFP temperatures incorporating WP4 values.

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AP.2012-11: GM to ask NPL to make a Co-C cell. YY to ask VNIIOFI to do so.

AP.2012-12: YY to prepare paper for publication on the work of WP2

AP.2012-13: GM to arrange for the executive secretary of the CCT to put the presentations given at this meeting on the CCT website and circulate the password.