Minutes of CCT-WG5 Meeting
Chair: Graham Machin
Date of meeting: 19th May 2014
Time: 14:00 – 17:45
Location: BIPM, Sévres, France

Date of issue of minutes: 17th June 2014 version 3.0

Attendees

Attending Members

Wang Li (A*STAR) [for second half of meeting], Maria José Martin Hernandez (CEM), Daniel Cárdenas-Gárcia (CENAM), Renato Teixeira (INMETRO), Ferruccio Girard (INRIM), Seon Do Lim (KRISS), Mohamed Sadli (LNE-CNAM), Zundong Yuan (NIM), Howard Yoon (NIST), Eric van der Ham (NMIA), Graham Machin (NPL), Andrew Todd (NRC), Jörg Hollandt (PTB), Mikhail Matveyev (VNIIM) [for second half of meeting], Edgar Moreno-Vuelban (VSL)

Attending invited experts

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

President of CCT:

Yuning Duan

Attending observers

Murat Kalemci (UME), Viktor Fuksov (VNIIM), Peter Pavlasek (SMU)

Apologies

Peter Saunders (MSL), Peter Nemecek (SMU), Ahmet Diril (UME), Tiejun Wang (NIM), Boris Khlevnoy (VNIIOFI)

1 Introductions

CCT-WG5 met on 19th May 2014 at BIPM in Paris. Actions arising from the discussions at this meeting are listed in Appendix A, the agenda for the meeting is given in Appendix B the attendee list with email contacts are given in Appendix C. The meeting was chaired by Graham Machin and minutes were recorded by Emma Woolliams.

The meeting opened with the participants introducing themselves.

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

2 Review of last minutes

The last two meetings of the CCT-WG5 were at BIPM on 22nd May 2012 and on 18th October 2013 at the Tempmeko conference in Madeira. The minutes of those two meetings were circulated prior to this meeting. Some comments were received and the minutes updated to correct those issues. The minutes are now accepted as a true and accurate record of the meetings.

The action records for both meetings were reviewed. All actions were completed or superseded by subsequent discussions. A short discussion followed the review of action point AP.2012-02. This is described further in the "Any Other Business" section, Section 8, below.

3 Status of supplementary information for the ITS-90 Chapter 6. Radiation Thermometry

Howard Yoon described the work of the TG preparing the supplementary information for the ITS-90. There were two activities of this task group – reviewing and updating the texts for the Supplementary Information for the ITS-90 (red book) and the Techniques for approximating the ITS-90 (blue book).

Supplementary Information for the ITS-90 (red book text)

This text is now complete, agreed and a new version is on the BIPM website.

There was some discussion about the use of specific values for constants (that are updated by CODATA) in scale definitions. The concern was that later it is difficult to explain why the scale uses an outdated value for the physical constant: "it makes us look stupid." However, it was also recognised that it was the job of a scale to 'set in stone' the definition so that the scale itself was not changing in time. Just as the fixed-point temperatures are defined, even if we later realise that improved values could be given, the same should be the case for the constants. In the "red book" text this problem was dealt with using a footnote that stated that while the value was known to be incorrect, it was as defined by an older scale.

Further discussions were about the use of the phrase "Size-of-Source Effect" when "Size-of-Source Characteristic" would be more accurate. It was generally considered that the term SSE was so widely used that it was too late to change.

The document was a considerable rewrite of the previous version. As well as dealing with finite bandwidths and the physical constant definition, the task group removed large parts of the text, including detailed descriptions of specific radiation thermometers and the sections on tungsten strip lamps and effective wavelengths.

Graham Machin thanked Howard Yoon for his editing and chairmanship and all the participants of the task group for getting this completed.

Techniques for approximating the ITS-90 (blue book text)

Considerable new work is required to review and rewrite the Techniques for Approximating the ITS-90 (blue book) text concerning secondary scale realisation below the silver point by radiation thermometry.

The issue is that the ITS-90 is realised below the silver freezing point by using standard platinum resistance thermometers, fixed points of defined temperature and specified interpolation equations. This means that any radiation thermometry scale that is traceable to the ITS-90 must be linked in some way to this definition. This linkage is generally achieved in two broad approaches:

- Through variable temperature blackbodies which incorporate temperature sensors calibrated to the ITS-90 (for the lowest uncertainties these are heatpipe blackbody cavities where the thermometry is performed using SPRTs up to the aluminium freezing point and HT-SPRTs or Au/Pt thermocouples beyond that to the silver freezing point)

- Through fixed point blackbody sources made with high purity ITS-90 fixed point material (In, Sn, Zn, Al or Ag). A high performance radiation thermometer (almost universally equipped with an InGaAs detector) and the use of a Planck or Planckian equivalent interpolating function

These two secondary approaches whilst being fundamentally different should yield equivalent low uncertainty realisation of ITS-90. It was recognised that for straightforward scale realisation, the fixed-point method is generally superior; but for calibrating an industrial radiation thermometers, with a large field of view, there are significant advantages in using the variable temperature blackbody approach.

New text is to be prepared for the "blue book" replacement by the same group led by Howard.

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.

This was followed by a discussion of the additional problems with 10 µm radiation thermometers, where other methods are superior. It was agreed that, while such thermometers are widely used and advice must be given, our focus for now should be on 0.9 µm and 1.6 µm radiation thermometers and temperatures from the indium point to the silver point

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

Howard Yoon presented an outline of the document. Some modifications were made to this outline based on today's decisions. Volunteers were requested to work on the text. Peter Saunders had already agreed to write a section. Andrew Todd, Eric van der Ham and Jörg Hollandt agreed to write the text and Maria-José Martin, Ferruccio Girard and Daniel Cardenas agreed to read the text and offer comments. The following sections were assigned:

1.1	Discussion of ITS-90 and strict definition. And introduction to two methods	Graham Machin with Jörg Hollandt to comment.
1.2	Using Heat pipes and SPRTs (Technique 1)	Andrew Todd, with Jörg Hollandt supporting.
1.3	Radiation thermometer and fixed-point method (Technique 2)	Howard Yoon & Eric van der Ham
1.4	Design of fixed point blackbodies 1.4.1.: Fixed points (incl. recommendations on how to identify when things can go wrong, contamination – and how to look out for it – difference between melt/freeze etc. Or reference to other document with this. 1.4.2: Furnace types	Howard Yoon Mohamed Sadli to write specifications of medium temperature fixed-points
1.5	Interpolation functions and need to use four or five in order to double-check.	Peter Saunders
1.6	Uncertainty discussions	Refer to CCT uncertainty document

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.

4 Radiometric Uncertainty

Emma Woolliams gave a presentation on the history of the radiometric uncertainty document. Some progress has been made but there is still a lot to do.

Eric van der Ham, Mohamed Sadli, Howard Yoon and Andrew Todd volunteered to continue writing the document. Howard Yoon emphasised how important this document will be for CMC reviews when NMIs start to offer calibration services based on filter radiometry – in the same way that the previous CCT-WG5 documents are used in such processes.

Emma Woolliams suggested an approach to complete the report text by working in an intensive period over the summer with everyone making the same week available. Mohamed Sadli was concerned about completing this document before the end of InK-WP1. It is important that the results of InK-WP1 inform the values assigned to uncertainty components in this document. On the other hand, it is also important that this document supports the analysis of InK-WP1

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.

A workshop was held on the morning 20th May 2014 to take the uncertainties report from its current state, consider the structure and organisation and make decisions on how to progress the report to its conclusion.

5 InK WP1 progress

An overview and progress report of InK WP1 was given by Emma Woolliams (see presentation).

There were no comments from participants. Emma Woolliams emphasised that the next steps were

- For remaining participants to keep the measurements on schedule
- For all participants to send measurement reports as soon as completed
- For all participants to measure the temperature step response of the furnace

KRISS is doing some supplementary measurements to test the furnace effects and sensitivity to melting and freezing step. There was some discussion about this and Emma Woolliams agreed a short meeting tomorrow with Yoshi Yamada, Seon Do Lim and Pieter Bloembergen to agree the technical details of those tests.

6 InK WP2 progress

An overview and progress report of InK WP2 was given by Mohamed Sadli with a description of the comparison of radiation thermometers at PTB by Klaus Anhalt (see presentations).

7 New CCT Key comparison above the silver point

Helen McEvoy presented the protocol for the new comparison (see presentation). She thanked everyone for the comments received so far on the protocol and led a discussion on the outstanding issues.

Minor outstanding pieces of information

There have been comments from Ken Hill to ensure it meets the requirements. Needs:

- Serial numbers of test artefacts. These are being provided by different participants. Those instruments that are already at NPL are included. Please could everyone who has their instruments send Helen McEvoy the serial numbers
- Information about LP3: Temperature range for each wavelength. Klaus Anhalt to find out range of LP3 through testing. Please send information about the temperature range – is 3000 °C possible? Also information on packaging for shipping. Yoshi Yamada will test the Chino thermometer before shipping to check whether it will operate to 3000 °C.

Klaus Anhalt described the packaging of LP3. The manufacturer-provided metal box is perhaps not suitable for this shipping, so PTB proposes a new packaging where the metal box is placed inside a wooden crate with additional padding. This will mean that it cannot be moved by hand but will ensure greater care is taken.

- NIST confirmed that the dates in schedule were acceptable.
- Value of all goods for insurance purposes. To be provided by instrument suppliers. Insurance needed during transportation at cost of participant sending artefacts.

There was a discussion on the statements in the protocol about participants being responsible for the equipment. Insurance is needed for the shipping phases. There are no requirements for insurance during laboratory work. It is assumed that participants will take all necessary care and any damage will be dealt with by the group as a whole.

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.

Major discussion item 1: data analysis method

Is the suggested analysis method (using a weighted mean with cut-off) acceptable to the participants and is the choice of cut-off (the best uncertainties in the CCT document) correct?

There was general acceptance of the use of weighted-mean with cut-off. However the choice-of cut-off was considered too low (it is unlikely that any participant will actually achieve "best possible cut-off" and if one comes close to this, the data will be skewed towards that participant). For information the CCPR has a weighted mean with cut-off that is defined as follows:

The CCPR Guidelines G2, available at: http://www.bipm.org/en/committees/cc/ccpr/publications_cc.html . See (paragraph 5.3.1):

> 5.3.1 The cut-off value for the uncertainty, as a default, is determined as the average of the uncertainty values of those participants that reported uncertainties smaller than or equal to the median of all the participants. (For example, if there are 10 participants, the cut-off value will be the average of the 5 smallest values of uncertainty.)

This has been used successfully by the CCPR and is acceptable to this community too. The meeting wondered how this is being dealt with in other CCT comparisons.

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.

Major discussion item 2: two thermometers

- What do we do about having two thermometers?
  - Treat each instrument separately (two reference values)?
  - Average results – what if one instrument performs poorly
  - Measure with LP3 at 900 nm – would mean two instruments are two different wavelengths/scale realisations. But LP3 less stable at 900 nm.

There was considerable discussion on this point. A previous comparison was not allowed to have two KCRVs. Therefore there was some pressure to create a single KCRV for this comparison. However, this requires that the two artefacts perform well and does not allow for a problem with one artefact. In a previous comparison (TRIRAT) there was a problem with one instrument drifting with time.

Although a copper point will be used during this new comparison to test for drift, this cannot test all drift components. The current APMP comparison is run as a star comparison and NMIJ is checking the instrument fully for all possible drift components between participant measurements. So far in the APMP comparison there has been no problem with stability of the Chino radiation thermometer; the new comparison will use an instrument of the same make. The new comparison will additionally use a LP3, and these devices are also generally stable.

The purpose of using two devices is to provide some redundancy. Yoshiro Yamada said that NMIJ statisticians he discussed this with strongly cautioned against obtaining a single KCRV through averaging unless all the correlations were appropriately taken into account.

It was generally considered that the analysis should be performed with two independent KCRVs – one for each radiation thermometer. The degrees of equivalence would be calculated for each KCRV and, if appropriate, these could then be combined by taking either the average or the larger to provide a single degree of equivalence for future regional comparison linkage. A definitive decision was not reached. However, it was recognised that if one artefact drifted, the results from that artefact could be ignored and that if both artefacts performed well then laboratories would generally be expected to have good degrees of equivalence with both artefacts. Having one good and one poor DoE with two good artefacts would suggest inconsistency in the measurement process.

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.

There was further discussion about whether the LP3 should be operated at 650 nm or 900 nm. 650 nm would provide additional information for the main scale realisation and 900 nm provides a separate scale realisation. The decision was made to operate LP3 at 650 nm

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

Further comments on protocol 1

Howard Yoon asked how the data from the fixed-point sources will be used. The fixed-points are used as additional artefacts and will be independently analysed with the assumption that this will provide further, more rigorous testing of the scale realisation uncertainties. For straightforward CMC testing, only the KCRVs from the radiation thermometers will be used. If there are CMCs in the future for provision of, e.g. eutectic sources, then these will be supported by the fixed-point comparison.

The fixed-point comparison is therefore considered supplementary. For each fixed-point a Reference Value (RV) will be separately determined. The Degrees of Equivalence calculated here would be checked against those for the radiation thermometer KCRVs.

Further comments on protocol 2

Yoshiro Yamada said that the existing protocol requires participants to report a measurement at the reference temperatures for the radiation thermometers. At NMIJ the process is to realise the scale from spectral measurements and a full characterisation on the test radiation thermometer. Therefore he would not be able to provide a "measurement". Jörg Hollandt recommended that the protocol was reworded to say that participants should "report a signal at these temperatures" which would allow NMIJ to calculate the expected signal.

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

Yoshiro Yamada expressed some concern about any potential instability or breakage to the fixed-points. It was confirmed that the radiation thermometer comparison takes priority and would continue to schedule even if the fixed-points were damaged. However, several members expressed the feeling that the radiation thermometers were more likely to suffer problems than the fixed-points.

Pieter Bloembergen asked about the stability of the doped eutectic cells. Renato Teixeira said that a similar cell had been tested over 300 hours and had been shown to be stable.

The spectral responsivity of the LP3 radiation thermometer will be measured at the start and end of the comparison at NPL. The spectral responsivity of the Chino thermometer will be measured at the start and end of the comparison by NMIJ. This will enable any drift to be diagnosed.

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.

8 Any other business

Edgar Moreno-Vuelban asked how the thermal imager work will continue. Jörg Hollandt explained that there is now a German standardisation group consisting mostly of industrial partners, which PTB is also part of. Jörg Hollandt has supplied them with all relevant documents and is ensuring that it builds on previous discussions. The standard will be based on the IEC document on radiation thermometry. When the German group has a draft, Jörg Hollandt will circulate it to this CCT-WG5 for comments. The draft will then be sent to Masahiko Gotoh from IEC-WG5 and a subgroup will be set up to turn it into an IEC standard. At that stage participation will be welcome from experts from the CCT.

9 Future of the working group

The CCT will be restructured and CCT-WG5 ceased to exist after this meeting. There will be a new working group set up on non-contact thermometry. This will have a new terms-of-reference, new members and observers and potentially a new chair. Members will have to apply through a formal process. This will be agreed at the CCT at the end of this week.

The formal linkage to the CCPR will be abolished. The original link was established to ensure that radiometry was involved in CCT-WG5. This is now

achieved and many radiometry people are now actively involved in CCT-WG5. The link is no longer needed. Nigel Fox, the CCPR liaison link person was thanked for helping initiate fruitful and enduring dialogue between the radiometry and radiation thermometry communities.

10 Close

The meeting closed at 17:45

11 APPENDIX A: Summary of action points, decisions and recommendations

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.

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.

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.

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.

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.

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

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.

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 radiation thermometers. 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.

12 APPENDIX B: Agenda for the meeting

Agenda for CCT-WG5 Radiation Thermometry

Date: Monday 19th May 2014 pm (and if required Tuesday 20th May 2014 am)

Time: 14:00 to 18:00

Venue: BIPM, Sevres, Room Petit Pavillon

Refreshments at 15:30

Draft agenda

1. Introduction of participants and new members [all] 14:00-14:05
2. Review of last minutes and action record [GM] 14:05-14:15
3. SInf TG progress report [HY] 14:15-14:50
4. Radiometric uncertainty TG progress report [EW] 14:50-15:30
5. Refreshments
6. Progress with InK WP1 assignment of HTFP temperatures [EW] 15:50-16:10
7. Progress with InK WP2 comparison of radiometric methods [KA] 16:10-16:30
8. Key comparison above the silver point protocol [GM+HCM] 16:30-17:40
9. Future of the working group [GM]
10. AOB 17:55-18:00
11. Close of meeting 18:00

NOTE1: It is anticipated that additional discussions on the KC protocol will be required. These will continue on Tuesday 20, 9:30 until 13:00. That meeting is scheduled on level -2 in the "New Pavillion".

NOTE2: If discussions conclude on the KC before 13:00 I propose that The TG for Radiometric uncertainty meet, under chair of EW, to progress the drafting of that document.

On Tuesday 20th May, tea and coffee served in Petit Pavillon at 11:00.

13 APPENDIX C: Participant list and email

Name	Organisation	Email
Graham Machin	NPL, UK	graham.machin@npl.co.uk
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