National Physical Laboratory

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APPENDIX 1

PROTOCOL FOR THE COMPARISON

EURAMET 658 EXTENSION PROJECT TO EXAMINE UNDERLYING PARAMETERS IN RADIANCE TEMPERATURE SCALE REALISATION FROM 156 °C TO 1000 °C

HELEN MCEVOY

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Appendix 1

Protocol for the Comparison:

EURAMET 658 Extension Project to Examine Underlying Parameters in Radiance Temperature Scale Realisation from 156 °C to 1000 °C

Helen McEvoy
Engineering, Materials & Electrical Science

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National Physical Laboratory
Hampton Road, Teddington, Middlesex, TW11 0LW

Approved on behalf of NPL by
Dr Stephanie Bell, Science Area Leader

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PROTOCOL FOR PROJECT TO EXAMINE UNDERLYING PARAMETERS IN RADIANCE TEMPERATURE SCALE REALISATION FROM 156 °C TO 1000 °C

1 RATIONALE

The purpose of this collaboration is to undertake an examination of some underlying parameters in temperature scale realisation using InGaAs-based radiation thermometers (size-of source effect, fixed-point realisation and ambient effects) as well as a comparison of variable-temperature blackbody sources over the temperature range from 156 to 1000 °C.

2 ORGANISATION

The project will be coordinated by:

National Physical Laboratory,
Hampton Road,
Teddington,
Middlesex
TW11 0LW
United Kingdom

Contact:

Helen McEvoy
Phone: +44 20 8943 6183

E-mail: helen.mcevoy@npl.co.uk

Robin Underwood
Phone: +44 20 8943 6950

E-mail: robin.underwood@npl.co.uk

3 PARTICIPANTS

The participants in the project are:

Institute	Contact person
i) PTB, Berlin, Germany	Berndt Gutschwager and Jörg Hollandt Tel: +49 30 34817323 and -7369 E-mail: berndt.gutschwager@ptb.de joerg.hollandt@ptb.de
ii) TUBITAK-UME, Turkey	Aliye Kartal Dogan and Ahmet Diril Tel: +90 262 679 50 00 Ext: 3453 E-mail: aliye.kartal@ume.tubitak.gov.tr ahmet.diril@ume.tubitak.gov.tr
iii) INRiM, Italy	Mauro Battuello Tel: +39 0113977338 E-mail: m.battuello@imgc.cnr.it
iv) CEM, Spain	Maria José Martín Tel: +34 91 807 4771 E-mail: mjmartinh@cem.mytic.es
v) METAS, Switzerland	Anton Steiner Tel: +41 31 32 33 371 E-mail: anton.steiner@metas.ch
vi) LNE, France	Jean-Rémy Filtz Tel: +33 1 30 69 12 82 E-mail: jean-remy.filtz@lne.fr

4 PROJECT END DATE

The measurements are due to be completed by the end of December 2008, with the final project report to be completed by the end of December 2009.

5 CIRCULATION SCHEME

The thermometer will be circulated according to the following schedule:

Institute	Time periods
PTB	1 August 2007 to 30 September 2007
NPL	1 October 2007 to 30 November 2007
CEM	1 December 2007 to 29 February 2008
UME	1 March 2008 to 30 April 2008
METAS	1 May 2008 to 30 June 2008
LNE	1 July 2008 to 30 September 2008
INRiM	1 October 2008 to 30 November 2008

In the last week of each period the laboratory that is completing the measurements should arrange for the thermometers to be transferred to the next institute. Wherever possible, door-to-door transportation should be used to minimise the risk of damage to the instruments. The laboratory completing the measurements is responsible for paying the transport costs for the transfer to the next institute. The institute receiving the thermometers should carry out the check described in 7.4 and confirm to the coordinating laboratory by e-mail or fax that the thermometers have arrived safely. At the end of the circulation the thermometers should be returned to the originating institutes who should then confirm the performance of their instruments.

6 TRANSFER INSTRUMENTS

The two transfer instruments are an LP5, provided by IKE Stuttgart, and a transfer thermometer provided by INRiM, Italy. Both instruments are InGaAs photodiode devices with a peak wavelength of nominally 1.6 μm. Technical information about the thermometers is given in Appendix 1.

Additionally, a zinc point blackbody source, supplied by INRiM, will be circulated along with the transfer thermometers so that the performance and stability of the thermometers can be checked regularly. This zinc point was used in the TRIRAT project, and details can be found in Appendix 1. Instructions for using the zinc point are provided.

7 INITIAL MEASUREMENTS

7.1 – Stabilisation: the stabilisation time for the thermometers is given in Appendix 1. It is recommended that the thermometers be left to stabilise for at least two hours after switch-on before starting measurements. The thermometers should subsequently be left switched on, if possible, for the duration of all the measurements.

7.2 – Lens cleaning: Superficial dust should be blown off the front lens of the thermometer using clean air or other means but otherwise the lens should NOT be cleaned. The protective lens cap should be placed on the front of the thermometer in-between measurements and great care should be taken not to touch the front lens.

7.3 – Positioning: the thermometers should be set up and aligned at the prescribed working distance according to the local procedure, with reference to any specific instructions supplied with the thermometers.

7.4 – Check on arrival at each institute: to make sure that they have not been damaged during transport, a quick check should be made of the thermometers' output when viewing the supplied Zn fixed-point blackbody source. For the INRiM thermometer the working distance should be **330 mm** from the stainless steel flange on the front of the furnace to the front of the objective nose of the thermometer; for the IKE LP5 the working distance should be **610 mm** from the stainless steel flange on the front of the furnace to the front of the objective nose of the thermometer. Instructions for using the Zn point are provided. The results of the check should be e-mailed or faxed to the coordinator.

8 PROBLEMS

Should any problems arise with the operation of the instruments, both the coordinator and the organisation supplying the thermometer should be contacted.

9 REQUIRED MEASUREMENTS

The following gives information about the measurements to be made at each laboratory. Participants should perform as many of the measurements as possible. Measurements should be made according to the usual method used at each laboratory, but following any specific instructions given below. During the measurements the internal instrument temperature (t_{int}), the ambient temperature (t_{amb}) and the relative humidity (RH_{amb}) should be recorded.

Please note:

All the measurements with the IKE thermometer should be made at a distance of **750 mm** from the target to the front of the objective nose.

All the measurements with the INRiM thermometer should be made at a distance of **470 mm** from the target to the front of the objective nose.

9.1 SIZE-OF-SOURCE EFFECT

The size-of-source effect should be made using either the indirect method (i.e. by obscuring the central portion of the field-of-view of the thermometer by means of a blackened disc or spot placed in front of the source) or the direct method (by viewing a stable, uniform source and varying the aperture diameter) or, if the institute wishes, both methods.

If using the indirect method, measurements should be made using spot sizes of both **3 mm and 6 mm diameter** for the IKE LP5 and **6 mm diameter** only for the INRiM thermometer. Measurements should be made using all available apertures of a suitable diameter.

Results - The results shall be presented in the form of a table giving the SSE for each aperture size. For measurements using the indirect method, the table should include columns for the following information: aperture size (mm), 'on spot' thermometer output, 'off spot' output, background signal, SSE, the individual uncertainty components in determining the SSE (u_1, u_2, u_3,…), the total combined uncertainty U_{SSE}, $t_{amb,}$ RH_{amb} and t_{int}.

For measurements using the direct method, the source should be set to a temperature of 500 °C. The results table should include columns for the following information: aperture size (mm), thermometer output, background signal, SSE, the individual uncertainty components in determining the SSE (u_1, u_2, u_3,…), the total combined uncertainty U_{SSE}, $t_{amb,}$ RH_{amb} and t_{int}.

9.2 FIXED-POINT CALIBRATION

The thermometers should be calibrated following the laboratory's usual local procedure using freezing point blackbody sources of In (for the INRiM thermometer), Sn, Zn, Al and Ag (or as many of the fixed-points as are available). At least 3 freeze/melt cycles should be performed with each fixed-point. If suitable fixed-point blackbody sources are not available, variable temperature blackbody sources can be used instead. In this case, the source should be set to within 0.2 °C of the fixed-point temperature and its temperature, as measured by the contact thermometer within the source, should also be recorded over the duration of each set of measurements.

With each thermometer a scan should be performed across the blackbody aperture during a melt and freeze plateau, or across the aperture of the variable temperature blackbody source, to assess the temperature profile. This can be used, if necessary, to perform any corrections due to the size-of-source effect.

Additionally, the thermometer output must be corrected to allow for the size-of-source effect. The correction should be performed according to the laboratory's usual method using the results of the SSE measurements carried out in Section 9.1 and the temperature profile of the fixed-point blackbody aperture. The correction should be from the actual fixed-point blackbody aperture diameter to a reference target of 20 mm diameter.

Results – The following information shall be provided:

a) The blackbody geometry, aperture diameter and emissivity data, and information about the contact sensor within the source (if appropriate).

b) For each fixed-point plateau the average background measurement, the average thermometer output and the average thermometer output corrected for background as well as the standard deviation of the measurements. If using variable temperature blackbody sources the average source temperature for each set of measurements should also be given as well as the standard deviation of the measurements.

c) The ambient conditions $t_{amb,}$ RH_{amb} and $t_{int.}$

d) The thermometer output corrected for SSE to a reference target of 20 mm diameter.

e) The individual uncertainty components in the fixed-point calibration (u_1, u_2, u_3,…) and the total combined uncertainty $U_{calibration}$.

9.3 GAIN RATIO MEASUREMENTS

Gain ratio values should be determined for the settings of amplifier gain used in the fixed-point calibration, by measuring the signal ratios with successive pairs of amplifier gain settings. These measurements may be carried out during a melting or freezing realisation of the appropriate fixed-points or during measurements of the variable temperature blackbodies at appropriate temperatures.

Results – The following information shall be provided:

a) The average background signal and thermometer output signal for measurements made at amplifier gain 1 along with the background-corrected signal;

b) The average background signal and thermometer output signal for measurements made at amplifier gain 2 along with the background-corrected signal;

c) The gain ratio: (background corrected output at amplifier gain 2 / background corrected output at amplifier gain 1)

f) The ambient conditions $t_{amb,}$ RH_{amb} and $t_{int.}$

g) The individual uncertainty components in the measurement of the gain ratio (u_1, u_2, u_3,…) and the total combined uncertainty $U_{gainratio}$.

9.4 MEASUREMENTS USING VARIABLE TEMPERATURE BLACKBODY SOURCES

Measurements should be made at the following temperatures using variable temperature blackbody sources.

The blackbody aperture diameter should be set to 20 mm diameter. If this is not practical the aperture size should be set to an appropriate value, preferably as close as possible to 20 mm diameter. The temperature of the sources should be set to within 0.2 °C of the specified temperatures.

At each temperature a series of measurements should be made of both the thermometer output and the temperature of the source as measured using the contact thermometer within the source. Measurements of the background signal should also be carried out.

The temperatures for the measurements should be:

1. Those corresponding to the In fixed-point (for the INRiM thermometer), then (for both thermometers) the Sn, Zn, Al and Ag fixed-points (if not already carried out under 9.2 above);

2. 200 °C (for the INRiM thermometer), then (for both thermometers) 250 °C, 300 °C and then every 100 °C up to and including 1000 °C if possible.

One complete measurement run should be performed with repeat measurements being carried out at at least five temperatures across the range.

At a minimum of two temperatures for each source (suggest the highest and lowest temperatures) the thermometer should be scanned across the aperture of the blackbody to determine the temperature profile. This will provide information about the temperature uniformity across the source and will be used for any corrections necessary to account for the size-of-source effect.

If the diameter of the blackbody aperture is different from 20 mm, then the thermometer output should be corrected to correspond to the reference target size of 20 mm diameter, using the size-of-source effect results obtained in Section 9.1 and, if necessary, the temperature profile of the furnace.

Results –

The following information should be provided:

a) A description of the blackbody source including blackbody cavity geometry, aperture diameter and emissivity data, and information about the contact sensor within the source.

b) The average thermometer output, the average background signal and the average thermometer output corrected for background at each temperature, the average temperature of the blackbody source and the standard deviation of all the measurements.

c) The results of the scans across the blackbody apertures, including the thermometer output and the blackbody temperature.

d) The thermometer output corrected for SSE to a reference target of 20 mm diameter (if necessary).

e) The ambient conditions t_{amb}, RH_{amb} and $t_{int.}$

f) The individual uncertainty components in the measurements of the blackbody sources (u_1, u_2, u_3,…) and the total combined uncertainty $U_{blackbody}$.

9.5 MEASUREMENTS OF EFFECT OF AMBIENT CONDITIONS

If facilities in the laboratory allow, measurements should be made of the effect of changes in ambient temperature and humidity on the output of each of the thermometers. Measurements should be made while viewing a stable blackbody source (either a fixed-point or variable temperature blackbody) at a temperature of nominally 660 °C. If the laboratory wishes, additional measurements may be made at 232 °C and 962 °C.

The effect of ambient temperature should be measured by recording the output of the thermometer over the range from 18 °C and 26 °C, or over a smaller range if this is more practical. Measurements should be made at intervals of every 2 °C. A set of measurements should be made while viewing a source at 660 °C. If the laboratory wishes, another set of measurements should be made while viewing a source at 232 °C, and a third while viewing a source at 962 °C.

The effect of humidity should be measured at an ambient temperature of 23 °C by recording the output of the thermometer with ambient conditions of 30%, 50% and 70% relative humidity (or at suitable intervals over a smaller range if this is not practical). A set of measurements should be made while viewing a source at 660 °C. If the laboratory wishes, another set of measurements should be made while viewing a source at 232 °C, and a third while viewing a source at 962 °C.

Results –

The following information should be provided:

a) The average thermometer output and background signal for each measurement set at each temperature, the average thermometer output corrected for background and the standard deviation of the measurements. If using a variable temperature blackbody source the average temperature of the source over the duration of the measurements should also be given along with the standard deviation.

b) The average ambient temperature and relative humidity for each measurement set at each temperature, along with t_{int}.

c) The individual uncertainty components in the measurements of the ambient temperature effect (u_1, u_2, u_3,…) and the total combined uncertainty $U_{teffect}$.

d) The individual uncertainty components in the measurements of the relative humidity effect (u_1, u_2, u_3,…) and the total combined uncertainty $U_{RHeffect}$.

10 REPORTING OF THE RESULTS

The following information should be sent to the coordinator within one month of completing the measurements. Please supply both a paper copy and an electronic version.

10.1 DESCRIPTION OF THE EQUIPMENT

All the equipment used for the measurements should be described along with details of the measurement methods, calculations and any assumptions that have been made. The electronic version should be in the form of a Word document.

10.2 RESULTS

The results should be supplied in the form of an Excel spreadsheet / workbook and presented as detailed in Section 9.

10.3 UNCERTAINTIES

The individual uncertainty components for each of the measured parameters should be listed along with the total combined uncertainty of the measurements. All uncertainties should be expressed as k=2; i.e. providing a level of confidence of approximately 95%.

11 APPENDIX 1

11.1 TECHNICAL INFORMATION ABOUT THE THERMOMETERS

11.1.1 IKE LP5

Wavelength: 1568 nm, 36 nm bandwidth

Temperature range: ~230 °C (Sn point) to ~1085 °C (Cu point)

Target size: 2 mm at 750 mm working distance

Working distance: this should be measured from the target to the front of the objective nose of the radiation thermometer

Warm-up time: 1 hour from switch-on

Output: the output is in terms of both photocurrent and temperature. For this comparison only the photocurrent values should be used

Background measurements: these should be performed by placing the lens cap on the front of the thermometer, taking great care not to touch the front lens.

Dimensions: approximately 135 mm high x 175 mm wide x 605 mm long (including objective nose and eyepiece)

11.1.2 INRiM thermometer

Wavelength: 1.5 μm to 1.7 μm

Temperature range: 150 °C to 1000 °C

Target size: 5 mm at 470 mm working distance

Working distance: this should be measured from the target to the front of the objective nose of the radiation thermometer

Warm-up time: 1 hour from switch-on

Output: the output is in terms of voltage

Background measurements: these should be performed by placing the lens cap on the front of the thermometer, taking great care not to touch the front lens.

Dimensions: 170 mm high x 126 mm wide and 400 mm long (including the objective nose)

11.1.3 Zinc point blackbody source

Blackbody dimensions: 9 mm diameter x 61.5 mm long with a 120° end cone

Emissivity: 0.99957 (open aperture)

Dimensions: 150 mm x 260 mm x 315 mm

Weight: 5.7 kg including the ingot