COOMET Key Comparison

(Bilateral)

COOMET.PR-K4.1

Luminous flux

COOMET project 636/UA/14

Technical Protocol

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Content

1 Introduction

This Technical Protocol (TP) describes an international bilateral key comparison on luminous flux, which are transferred by a set of incandescent lamps.

This comparison is conducted by the Euro-Asian Cooperation of National Metrological Institutions (COOMET) as the Regional Metrology Organization (RMO) in accordance with the COOMET project 636/UA/14.

As a prototype of this Technical Protocol was used the Technical Protocol of the EURAMET.PR-K4 comparison prepared by PTB who was also a pilot of the CCPR-K4 key comparison [1].

The National Scientific Centre "Institute of Metrology" (NSC “IM”, Ukraine) acts as a pilot laboratory for this key comparison. All-Russian Research Institute for Optical and Physical Measurements (VNIIOFI, Russia) acts as the laboratory, providing connections comparisons CCPR-K4 (link laboratory).

This bilateral key comparison is intended to determine the Degrees of Equivalence (DoE) for NSC “IM” and the associated expanded uncertainty. The DoE will state the relative difference of the NSC “IM” measurements results to the Key Comparison Reference Value (KCRV), which were determined in the CCPR-K4 key comparisons, initialized by the Comité Consultative de Photométrie et Radiométrie (CCPR). The results of the CCPR-K4 were published in 2001 [3] and shown in Annex A.

Since CCPR-K4, KCRV are maintained by the participants of CCPR-K4. One of the participants (VNIIOFI, Russia) now will be a link-laboratory for the COOMET key comparisons. VNIIOFI will transfer its maintained values by a set of lamps to NSC "IM", who will be a pilot laboratory and will define the DoE

Data analysis, report preparation and results publication will be done following the Guidelines for CCPR «Guidelines for CCPR and RMO Bilateral Key Comparisons» (CCPR-G5, October 10th, 2014) [2].
The participants will submit complete uncertainty budgets with all correlated contributions for a correct analysis of the measurement results. The stated uncertainties must be evaluated and reported according to the "Guide to the Expression of Uncertainty in Measurement" (GUM) [4].

2 Organization of Comparison

2.1 Participants

The participants are VNIIOFI and NSC “IM” (details are presented in the table below). The NSC “IM” result is to be linked to CCPR-K4. VNIIOFI acts as a link laboratory. VNIIOFI participated in CCPR-K4 and provides the link of results between this bilateral KC and CCPR-K4.

NSC "IM" is the laboratory, which requires link to the KCRV (non-link laboratory), and simultaneously acts as a pilot. NSC "IM" is responsible for the preparation of the Technical Protocol, preparation of transfer standards, checking the stability of the transfer standards, registration of the comparisons, preparing Draft A and executing all subsequent work.
VNIIOFI acts as a link laboratory and is responsible for conducting Pre-Draft A procedures. The non-linked laboratory (NSC “IM”) must be able to demonstrate independent traceability to the realization of the quantity, or make clear the route of traceability to the quantity via another named laboratory.

The participants accept the general instructions and the technical protocol written down in this document and commit themselves to follow the procedures strictly.

Once the protocol has been agreed, no change to the protocol may be made without agreement of both participants.

Following the requirements of the Guidelines CCPR-G5 (paragraphs 5.2 – 5.4) [2], a third party (CCPR WG-KC Secretary: Michael Stock, mstock@bipm.org) is designated for the comparison, and all the measurement results, both from the non-link laboratory (NSC “IM”) and the link laboratory (VNIIOFI) are submitted electronically to the third party upon completion of each measurement, to ensure blindness of the comparison. At completion of all measurements, the third party sends all the data received to the link laboratory (VNIIOFI), so that the link laboratory can start Pre-Draft A process. The third party sends to both participants all the raw data received after Draft A is issued.

2.2 Participants details

Institute	Shortcut	Function	Contact Person	Contact Details
All-Russian Research Institute for Optical and Physical Measurement 46, Ozernaya, 119361, Moscow, Russia	VNIIOFI	Link lab	Tatiana Gorshkova	Tel: + 495 437 55 33 Fax: +495 437 31 47 Email: gortb@vniiofi.ru
National Scientific Center “Institute of Metrology” 42, Mironositskaya 61002, Kharkov	NSC “IM”	Pilot lab Non-link lab	Mykola Huriev	Tel: +38 057 704 97 72 Fax: +38 057 700 34 47 Email:ngurev@yandex.ru

2.3 Form of comparison

The comparison will principally be carried out by the calibration of a group of transfer standard lamps. The type of lamps used has to show reasonable stability and robustness.

Both participants will use a set of seasoned lamps which will be provided by NSC "IM". The minimum set of transfer standards used for this comparison should be a group of three lamps. This minimizes the risk of unknown drift and damage and improves the ascertainment of DoE.

The artefacts (lamps) will initially be calibrated by NSC “IM”. Then they will be sent to VNIIOFI to perform calibration. Then they will be returned to NSC “IM” and NSC “IM” will perform the second measurement.

If for some reason the measurement facility is not ready for the measurements according to the agreed schedule, NSC “IM” must contact VNIIOFI immediately to discuss further details and changes of the measurement timetable.

2.4 Timetable

month/year	Activity
04/2015	Development of Technical Protocol and registration of comparisons
05/2015	Calibration of the transfer standards at NSC "IM"
05/2015	Delivery of the transfer standards to VNIIOFI. Measurement at VNIIOFI
05/2015	Delivery of the transfer standards to NSC "IM". Performing repeat measurements at NSC "IM"
06/2015	Measurement reports submission to Third party
07/2015	Pre-Draft A
08/2015	Draft A
09/2015	Draft B submitted to WG-KC for approval

2.5 Handling of artifacts

If possible, the standard lamps should be transported by hand-carriage from the pilot laboratory to the participant and back again to the pilot. The standard lamps should only be handled by authorized persons and stored and packed in such a way as to prevent damage.

The standard lamps should be examined immediately upon receipt at final destination. However, care should be taken to ensure that the lamps and packaging have sufficient time to acclimatize to the actual environment thus preventing any condensation etc. The condition of the lamps and associated packaging should be noted and reported to the pilot laboratory. Please use the form in Annex B.

After the very first calibration at the pilot laboratory, no cleaning of the lamp envelopes should be attempted. No parts other than noted within operating conditions belonging to specific lamp should be removed from or connected to this particular lamp. If a standard lamp appears damaged, a replacement lamp will be provided by NSC “IM”, if possible.

During operation of the standard lamp, any unusual occurrence, e.g. instability of voltage, instability in luminous output etc. should be reported immediately to NSC “IM” before further proceeding in the measurements.

2.6 Transportation of artifacts

It is of utmost importance that the artifacts be transported in a manner in which they will not be lost, damaged or handled by un-authorized persons.

Packaging for the artifacts should be suitably robust to protect the artifacts from being deformed or damaged during transit.

The artifacts should be, as a preference, carried by hand between the participating laboratories. The participants will inform each other via e-mail about completion of the measurements in order to determine the appropriate date of the lamp transportation.

After the measurements, the lamps should be re-packaged in their original transportation cases. The pilot laboratory NSC “IM” is responsible for transportation of the lamps and will pay all associated costs. Each participating laboratory covers the costs of its own measurements. The overall costs of organizing the comparison are covered by the pilot laboratory.

3 Description of the transfer standards

The measurement artifacts are standard lamps of type SIP 107-3500 that are specifically developed to be used as luminous flux standard lamps. A set of these lamps was suggested by NSC "IM" and agreed with VNIIOFI.

The lamps have the following parameters:

- Nominal luminous flux: 3500 lm
- Nominal color temperature: 2800 K
- Nominal voltage: 107 V
- Approximate lamp current: 2.5 A (the exact values will be provided by NSC "IM")
- Polarity: Thread of the lamp cap must be connected to the positive terminal of the DC power source

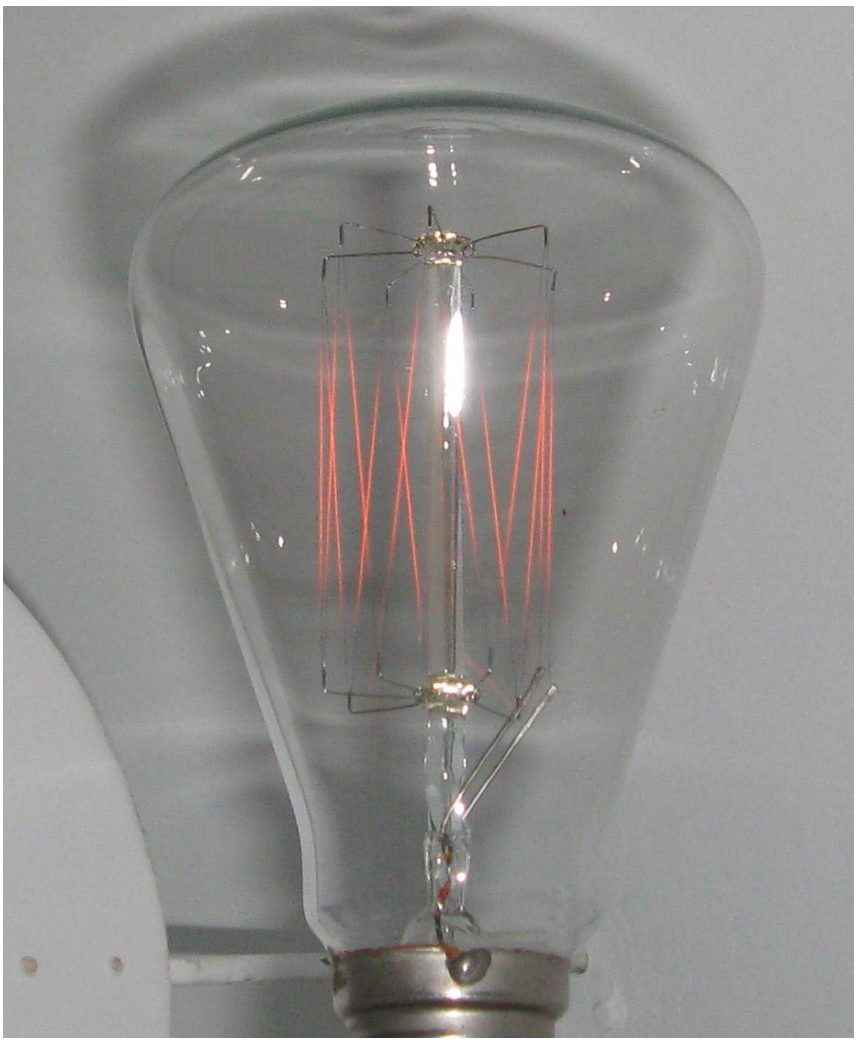

Figure 1**:** Luminous flux transfer standard lamp of type SIP 107-3500.

4 Measurement Conditions

4.1 Traceability

Temperature measurements should be made using the International Temperature Scale of 1990 (ITS-90).

Electrical measurements should be independently traceable to the latest realizations of the DC current and voltage.

4.2 Measurand

The measurand is luminous flux of a lamp. This photometric quantity should be measured for the defined operating conditions of each lamp, where the operating current acts as the setting parameter. The lamp voltage should be measured to monitor the lamp stability.

The measurements should be performed in suitable laboratory conditions, where the room

temperature is maintained between 20 °C and 25 °C. The temperature of the laboratory, the operating DC-current and the lamp voltage during the time of recording the measurement values should be reported.

The luminous flux of the lamps should be measured independently at least 2 times. Each independent measurement should consist of the lamp being realigned in the measurement facility and being switched off and on after a break of at least 1 h for each lamp. The results of each independent measurement set should be reported. It should be noted that each independent measurement may consist of more than one set of measurement values. The exact number of measured values should be that normally used by the participating laboratory to obtain the appropriate accuracy as limited by the noise characteristics of the specific measurement facility. The exact number of measurement values used in the analysis should be stated in the measurement report, but only the mean or final declared value of the set is required to be included. The participants are reminded that values of the luminous flux of the transfer standard lamps will change as a function of the operational burning time and so it is recommended that this is kept to a minimum.

4.3 Electrical conditions

All transfer standard lamps have to be operated with a stable DC power source, whose current output is regulated. The lamp supply voltage must be measured to monitor the stability of the lamp. If not stated elsewhere, the lamp voltages should be measured using a 4-pole technique, with voltage measurement wires connected directly at the lamp cap.

NSC “IM” will fix exact values of the operating current before the first measurement of the lamps. NSC “IM” will provide VNIIOFI with the lamp operating current values, polarity and the lamp voltage values measured during the first round of measurements.

4.4 Measurement instructions

Before connecting to any electrical power supply, the standard lamps should be inspected for damage or contamination of the lamp bulb or cap. Any damage should be documented by photos and a drawing using the appropriate form in Annex B and the pilot laboratory should be informed immediately. The operation time for each lamp is to be recorded using the form attached in the Annex D. This form should be completed and returned to the pilot laboratory as part of the Measurement report.

In both laboratories, all lamps will be measured using an integrating sphere photometer. The lamp must be installed in the center of the sphere vertically, the lamp cap pointing

upwards. The photometer head used with the sphere should not receive direct radiation from the lamp. The lamps should be aligned following the usual laboratory procedure.

After connecting the electrical power to each lamp, the prescribed warm-up procedure should be followed. The procedure will be provided by NSC “IM”. Operational parameters for each lamp (current, voltage, polarity) should be recorded and compared to those supplied with the lamp.

The photometric quantity (luminous flux) of the transfer standards should then be measured together with the electrical values.

The transfer standards used in this comparison should not be used for any purpose other than described in this document nor given to any party other than the predetermined participants in the comparison.

5 Data analysis and reporting

The measurement results of both participants will be sent electronically to a third party (CCPR WG-KC Secretary: Michael Stock, mstock@bipm.org). The results must include: lamp identification number, lamp operating current, lamp voltage, luminous flux values of all independent measurements, combined standard uncertainty of measurements and temperature of the laboratory room during the measurement.

Upon completion of all measurements, the third party will send all the data to the link laboratory (VNIIOFI).

NSC “IM” will send electronically to VNIIOFI the detailed description of measurement method and measurement equipment, as well as the uncertainty budget of the measurement.

VNIIOFI will conduct Pre-Draft A procedures.

At completion of Pre-Draft A, all measurement data will be transmitted to NSC “IM” and NSC “IM” will prepare the Draft A report.

The Degrees of Equivalence (DoE) of NSC “IM” and the associated expanded uncertainty will be evaluated following the approach recommended by the “Guidelines for CCPR and RMO Bilateral Key Comparisons” and taking into account the fact that the Degrees of Equivalence (DoE) of VNIIOFI, published in KCDB [3], is -0.51 % with an expanded uncertainty of 0.66 % (see Appendix A).

6 Literature

[1] Key Comparison K3a of Luminous Intensity and K4 of Luminous Flux with Lamps as Transfer Standards; PTB-Opt-62; ISBN 3-89701-471-8PR.

[2] Guidelines for CCPR «Guidelines for CCPR and RMO Bilateral Key Comparisons» (CCPR-G5, October 10th, 2014).

[3] Database BIPM: http://kcdb.bipm.org/appendixB/appbresults/ccpr-k4/ccpr-k4.pdf.

[4] Guide to the Expression of Uncertainty in Measurement (ISO).

Annex A: Degrees of equivalence of CCPR-K4

The degrees of equivalence of all participants of the CCPR-K4 comparison on luminous flux are shown below as they published in BIPM Key Comparison Database (KCDB) [3]. The values D_i and U_i are the Unilateral Degrees of Equivalence (DoE) and associated expanded uncertainties. VNIIOFI values of D_i and U_i will be used for analysis in the present RMO bilateral comparison.

MEASURAND : Luminous flux

The individual measurements, x_i, of the participating laboratories take the form of ratios which depend on the reference used at the pilot laboratory, the PTB. This is cancelled out by normalization using the key comparison reference value, x_R. This procedure leads to normalized individual measurements: x_i / x_R.

The key comparison reference value, x_R, is calculated as the weighted average of the invidual results x_i, weighted by the inverse square of the individual standard uncertainties, u_i, with the application of a minimum cutoff of 0.30%.
NIM and BIPM are excluded from the calculation of x_R.
The standard uncertainty of x_R is u_R = 0.1%. It is negligible compared to the u_i values.
The degree of equivalence of each laboratory with respect to the reference value is given by a pair of terms: $D_i = (x_i - x_R) / x_R$ and U_i, its expanded uncertainty (k = 2), both expressed in relative units. $U_i = 2u_i$.
The degree of equivalence between two laboratories is given by a pair of terms: $D_{ij} = (x_i - x_j) / x_R$ and U_{ij}, its expanded uncertainty (k = 2), both expressed in relative units. $U_{ij} = 2(u_i^2 + u_j^2)^{1/2}$.

MEASURAND: Luminous flux

The following table displays the **degrees of equivalence**. It includes three parts:

- "white part", list of participants (**Lab *i***);
- "blue part", degrees of equivalence relative to the key comparison reference value;
- "yellow part", degrees of equivalence between pairs of participants.

The pair-wise degrees of equivalence are given as "Lab *i* - Lab *j*"

Select **Lab *j*** BIPM

Lab *i*	D_i	U_i	D_{ij}	U_{ij}
	/ 10^{-2}	/ 10^{-2}	/ 10^{-2}	/ 10^{-2}
BNM-INM*	0.69	0.58	0.37	1.17
CSIR-NML	-0.01	1.06	-0.33	1.47
CSIRO-NML*	0.13	0.58	-0.19	1.17
ETL	0.18	0.68	-0.14	1.23
IEN	-0.06	0.96	-0.38	1.40
IFA	-0.43	1.70	-0.75	1.98
NIM*	-0.22	0.52	-0.54	1.14
NIST	-0.21	0.62	-0.53	1.19
NPL*	0.37	0.40	0.05	1.10
NRC	0.99	2.00	0.67	2.25
OFMET	-0.57	1.38	-0.89	1.72
OMH	0.43	1.30	0.11	1.65
PTB*	-0.42	0.56	-0.74	1.16
SMU	-0.88	2.20	-1.20	2.42
VNIIOFI	-0.51	0.66	-0.83	1.21
INTI**	-0.43	1.00	-0.75	1.43
BIPM**	0.32	1.02		

*cutoff uncertainty (0.30%) applied to those laboratory measurements in the calculation of the reference value, x_R.
**laboratory excluded from the calculation of x_R.

Unless otherwise stated, in the final numbers presented here, rounding has been applied according to ISO-31-0 Annex B Rule B.

Annex B: Inspection of the transfer standards

Has the lamp transportation package been opened during transit ? e.g. Customs…Y / N

If Yes please give details:

Is there any damage to the transportation package?……Y / N.
If Yes please give details:

Are any fingerprints or contaminations visible indicating improper handling? .Y / N
If Yes give details:

Are there any visible signs of damage to the lamp or accessories?…..Y / N
If Yes please give details (e.g. scratches, dust, broken filament, alignment mask moved etc):

Do you believe the standard is functioning correctly ?…Y/ N
If not please indicate your concerns

Operator:
Laboratory:
Date: Signature: ……..

Annex C: Description of the measurement facility

This form should be used as a guide. It is anticipated that many of the questions will require more information than the space allocated, please use separate sheets of paper as appropriate.

Make and type of the photometer (or equivalent)

Laboratory transfer standards used:

Description of measuring technique (please include a diagram):

Establishment or traceability route of primary scale including date of last realization and breakdown of uncertainty:

Description of calibration laboratory conditions: e.g. temperature, humidity etc.

Operating conditions of the lamps: e.g. geometrical alignment, polarity, stray-light reduction etc.

Operator:

Laboratory:

Date: Signature: ……..

Оператор:

Лаборатория:

Дата: Подпись: ……..

Annex D: Record of lamp operating time

Lamp:

Date	Switch-on Local Time	Activity (Test, Alignment, Measure)	Switch-off Local Time	Burn Hrs	Operator initials

Operator:

Laboratory:

Date: Signature: ……..

Annex E: Receipt confirmation

To: Mykola Huriev

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61002 Ukraine, Kharkiv. Str. Mironositska 42

Phone: + 380 57 7079772

Fax: + 38 057 7003447

E-mail: ngurev@yandex.ru

From: Link Laboratory

We confirm having received the standards of the

COOMET.PR-K4.1 Comparison of *Luminous Flux*

After visual inspection

No damage has been noticed;

The following damage must be reported:

Operator:

Laboratory:

Date: Signature: ……..