APMP Key Comparison

Luminous Intensity (APMP. PR-K3.a)

Technical Protocol

2012.12.26

Contents

Revision History

2012.3.31	Draft Ver.1
2012.5.14	Draft Ver.2
2012.5.15	Draft Ver.2.1 (Editorial)
2012.6.22	Draft Ver.3
2012.7.18	Submitted to TCPR Chair
2012.11.8	Re-submitted with minor revisions in response to the CCPR-KCWG review
2012.12.26	Addition of SCL to the participants list

1. Introduction

1.1 Under the Mutual Recognition Arrangement (CIPM MRA) signed in 1999, the metrological equivalence of national measurement standards will be determined by a set of key comparisons chosen and organized by the Consultative Committees of the Comite International des Poids et Mesures (CIPM) working closely with the Regional Metrology Organizations (RMOs).

1.2 In 2007, Technical Committee for Photometry and Radiometry (TCPR) of the Asia Pacific Metrology Programme (APMP), one of the RMOs, proposed several regional comparisons in the field of optical radiation metrology. One of the comparisons on which the agreement was reached was that of luminous intensity, and this document is the technical protocol for the agreed comparison.

1.3 This technical protocol describes general information and technical procedures to be followed for the international comparison of luminous intensity, carried out under the auspices of APMP and denoted as APMP.PR-K3.a, which is registered at the key comparison database (KCDB) of the Bureau International des Poids et Mesures (BIPM).

1.4 This comparison is intended to determine the Degrees of Equivalence (DoE) for each participant with the link to the Key Comparison Reference Value (KCRV), which was determined in the CCPR key comparisons initiated by the Comité Consultative de Photométrie et Radiométrie (CCPR). The DoE states the relative difference of each participant's value from KCRV with the associated expanded uncertainty.

1.5 The latest CCPR key comparison on luminous intensity (CCPR-K3.a), piloted by the PTB, was conducted in 1997-1998 with 17 participants including 4 labs from APMP. The results of the CCPR-K3.a were published in 1999 [1] and are registered in the Appendix-B of the KCDB [2].

1.6 Since the last CCPR-K3.a, the KCRV has been maintained for more than a decade by the participants of the CCPR-K3.a. In this comparison, 3 of them including the pilot laboratory (NMIJ) act as link laboratories, which provide their maintained values to calculate the APMP-KCRV.

1.7 The description of this technical protocol is in accordance with the guidelines defined in CIPM [3] and APMP [4]. Technical procedures including data analysis, report preparation and results publication will be done in accordance with the guideline defined by CCPR [5].

1.8 This technical protocol has been prepared by the National Metrology Institute of Japan (NMIJ), and its content was reached by agreement with all of the other participants.

2. General information

2.1 Participants

2.1.1 Participants for this comparison are formed mainly with NMIs from the full members and associate members of APMP. The details of the participants are shown in Table 1.

2.1.2 The National Metrology Institute of Japan (NMIJ) acts as a pilot laboratory for this comparison. NMIJ, NIM and NMISA act as link laboratories.

2.1.3 By their declared intention to participate in this comparison, the participating laboratories accept the general instructions and the technical protocol written down in this document and commit themselves to follow the procedures strictly.

2.1.4 All the participants must be able to demonstrate independent traceability to the realization of the quantity, or make a clear the route of traceability to the quantity via another NMI.

2.1.5 Once the protocol and list of participants has been agreed, no change in the protocol or list of participants may be made without prior agreement of all participants.

Table 1. Participants' details

Economy	Institute (Acronyms)	Contact Person	Contact Details
China	National Institute of Metrology (NIM)	Liu Hui	No.18, Bei San Huan Dong Lu, Chaoyang, Dist,Beijing,P.R.China, 100013 E-mail: liuhui@nim.ac.cn
Chinese Taipei	Center for Measurement Standards (CMS/ITRI)	Hsueh-Ling Yu Tsung-Ying Chung	Bldg. 16, 321, Sec. 2, Kuang Fu Road, Hsinchu 30011, Chinese Taipei E-mail: hlyu@itri.org.tw ianchung@itri.org.tw
Hong Kong	Standards and Calibration Laboratory (SCL)	Dennis Lee	36/F, Immigration Tower, 7 Gloucester Road, Wan Chai, Hong Kong E-mail: wklee@itc.gov.hk
Indonesia	Research Centre for Calibration, Instrumentation and Metrology (KIM-LIPI)	Helmi Zaini	Kawasan Kompleks PUSPIPTEK, Puslit KIM-LIPI Gdg. 420 Setu, Tangerang Selatan, Banten, Indonesia, 15315 E-mail: mizain@kim.lipi.go.id
India	National Physical Laboratory (NPLI)	Hem Chandra Kandpal	Dr. K.S. Krishnan Road, New Delhi - 110 012

			E-mail: hckandpal@mail.nplindia.ernet.in
Japan (Pilot Lab)	National Metrology Institute of Japan (NMIJ-AIST)	Hiroshi Shitomi	1-1-1 Umezono, Tsukuba, Ibaraki, JAPAN 3058563 E-mail: h-shitomi@aist.go.jp
Malaysia	National Metrology Laboratory (NML-SIRIM)	Mohd Nizam Abdullah	National Metrology Laboratory, SIRIM Malaysia Lot Pt 4803, Bandar Baru Salak Tinggi 43900 Sepang Selangor Darul Ehsan, Malaysia. E-mail: mnizam@sirim.my
New Zealand	Measurement Standards Laboratory (MSL)	Kathryn Nield Neil Swift	69 Gracefield Rd PO Box 31 310 Lower Hutt 5040, New Zealand E-mail: k.nield@irl.cri.nz n.swift@irl.cri.nz
Thailand	National Institute of Metrology (NIMT)	Rojana Leecharoen	3/4-5 Moo 3 Klong 5, Klong Luang Pathumthanee, 12120 Thailand E-mail: rojana@nimt.or.th
Singapore	National Metrology Centre (NMC-A*STAR)	Liu Yuanjie	1 Science Park Drive Singapore 118221 E-mail: liu_yuanjie@nmc.a-star.edu.sg
Vietnam	Vietnam Metrology Institute (VMI)	Cao Xuan Quan	8 Hoang Quoc Viet Road, Caugiay District, Hanoi, Vietnam E-mail: quancx@vmi.gov.vn
Kazakhstan	Kazakhstan Institute of Metrology (RSE "KazInMetr")	Berik Akirov	Orynbor Str., 11, 010000 Astana, Republic of Kazakhstan E-mail: bekonya777@mail.ru
South Africa	National Metrology Institute of South Africa (NMISA)	Rheinhardt Sieberhagen	Private Bag X34, Lynwood Ridge, Pretoria, 0040 South Africa E-mail: rsieberhagen@nmisa.org
Egypt	National Institute for Standards (NIS)	Mohamed Shafik	Tersa St. Elharam, Giza, Egypt P.O. Box 136 Giza Code 12211 E-mail: ms_khalil@yahoo.com

2.2 Form of comparisons

2.2.1 The comparison is principally carried out by the calibration of a group of standard lamps. In the comparison, values of the luminous intensity transferred by the group of standard lamps from each participant to the pilot laboratory (hereinafter called "transfer standards") are compared.

2.2.2 The transfer standards used in the comparison have to show reasonable stability and robustness so as to be capable to transfer the luminous intensity scale maintained at each participating NMI.

2.2.3 The number of the transfer standards used for this comparison should be at least three standard lamps. Using a group of standard lamps minimizes the risk of unknown drift and damage and improves the ascertainment of DoE of the participants.

2.2.4 To have a better link to the KCRV and to minimize the comparison uncertainty in the pilot laboratory due to the difference of lamp types, it is highly recommended that only one type of standard lamp (OSRAM Wi41/G, 31V-6A) be used in this comparison as a transfer standard. A full description of the selected transfer standard is given in section 3.

2.2.5 Each participant is recommended using its own set of transfer standards that are selected by each participant to meet the requirement in 2.2.2. If some participants have difficulty in preparing suitable transfer standards, they can borrow and use a set of standard lamps from the pilot laboratory as transfer standards.

2.2.6 Participants are divided into five groups (Group 1 to 5) according to the time of period allotted for their measurements. Participants are asked to specify a preferred time slot for their own measurements of the transfer standards according to the timetable given in Table 2.

2.2.7 The comparison will take the form of a star-type comparison. The transfer standards will initially be calibrated by a participant. Then they will be sent to the pilot laboratory together with their individual operating conditions described in 3.3.2. After the calibration in the pilot laboratory, they will be returned to the participant and the second calibration will be made to monitor drift. For example, a participant belongs to Group 2 in Table 2 has the first measurement followed by the transportation of the artifacts to the pilot laboratory in the time slot (4), receives the artifacts from the pilot laboratory in (5) and the second measurement in (6).

2.2.8 In the case that a participant uses the transfer standards lent by the pilot laboratory, they will initially be transported from the pilot laboratory to the participant. The specified lamp operating condition will be informed with them. The measurement sequence is the same as 2.2.6. There are two measurement rounds for the participant and one for the pilot laboratory in between. After the second measurement round at the participant, the transfer standards will be sent back to the pilot laboratory. For example, a participant belongs to Group 3 in Table 2 receives the artifacts from the pilot laboratory in the time slot (4), has the first measurement followed by the transportation of the artifacts to the pilot laboratory in (5), receives the artifacts again in (6) and the second measurement followed by the transportation back to the pilot laboratory in (7).

2.2.9 All the data specified in 3.5 should be communicated directly to the pilot laboratory as soon as possible and certainly within 6 weeks of the completion of the measurements by a participant.

2.2.10 Each laboratory has 8 weeks (2 months) for calibration and transportation of transfer standards in its time slot. With its confirmation to participate, each laboratory has to confirm that it is capable to perform the measurements within the time allotted to it. Maximum possible participants in one time slot in Table 2 are generally three (3).

2.2.11 If for some reasons, the measurement facility is not ready or customs clearance takes too much time, the participants must contact the pilot laboratory immediately to discuss further details and changes of the measurement timetable. It may be possible for the participant to continue to take part by submitting or returning the transfer standards to the pilot laboratory at an agreed later date. However, in view of the large amount of work for the pilot laboratory and the need for a strict timetable to complete the comparison in time, this may not be possible. If this is the case, the participants and their results may have to be excluded from the final report. Exclusion may also occur if the results are not available in time to prepare the draft report.

Table 2. *(Draft)* Timetable for the comparison

No.	Start Date	End Date	Activity	Laboratory
1	April, 2012	May, 2012	1) Review/revision of the draft protocol 2) Invitation to participation	All
2	June, 2012	November, 2012	1) Confirmation of the participants 2) Approval of the protocol	All
3	December, 2012	January, 2013	Selection of transfer standards lent for participants	NMIJ
			1) Measurements of transfer standards by participants (Group-1) 2) Transportation of transfer standards from the participants (Group-1) to the pilot lab	(Group-1) NIMT
4	February, 2013	March, 2013	1) Measurements of transfer standards by the pilot lab (for Group-1) 2) Return of transfer standards from the pilot lab to the participants (Group-1)	NMIJ
			1) Measurements of transfer standards by participants (Group-2) 2) Transportation of transfer standards from the participants (Group-2) to the pilot lab	(Group-2) NIS VMI

5	April, 2013	May, 2013	1) Measurements of transfer standards by the pilot lab (for Group-2) 2) Return of transfer standards from the pilot lab to the participants (Group-2)	NMIJ
			1) Measurements of transfer standards by participants (Group-3) 2) Transportation of transfer standards from the participants (Group-3) to the pilot lab	(Group-3) NPLI SIRIM
			Re-measurements of transfer standards by participants (Group-1)	(Group-1)
6	June, 2013	July, 2013	1) Measurements of transfer standards by the pilot lab (for Group-3) 2) Return of transfer standards from the pilot lab to the participants (Group-3)	NMIJ
			1) Measurements of transfer standards by participants (Group-4) 2) Transportation of transfer standards from the participants (Group-4) to the pilot lab	(Group-4) CMS/ITRI NIM KIM-LIPI A*STAR
			Re-measurements of transfer standards by participants (Group-2)	(Group-2)
7	August, 2013	September, 2013	1) Measurements of transfer standards by the pilot lab (for Group-4) 2) Return of transfer standards from the pilot lab to the participants (Group-4)	NMIJ
			1) Measurements of transfer standards by participants (Group-5) 2) Transportation of transfer standards from the participants (Group-5) to the pilot lab	(Group-5) SCL MSL NMISA KazInMetr
			Re-measurements of transfer standards by participants (Group-3)	(Group-3)
8	October, 2013	November, 2013	1) Measurements of transfer standards by the pilot lab (for Group-5) 2) Return of transfer standards from the pilot lab to the participants (Group-5)	NMIJ
			Re-measurements of the transfer standards by participants (Group-4)	(Group-4)
9	December, 2013	January, 2014	Re-measurements of the transfer standards by participants (Group-5)	(Group-5)
10	February, 2014	March, 2014	Data Analysis	NMIJ

11	April, 2014	May, 2014	Pre-Draft A process (1) 1) Verification of reported results 2) Review of uncertainty budgets 3) Review of relative data	All
12	June, 2014	July, 2014	Pre-Draft A process (2) 4) Identification of outliers 5) Consistency check	All
13	August, 2014	September, 2014	Draft A Report	All
14	October, 2014	October, 2014	Draft B Report	All

2.3 Handling of artifacts

2.3.1 Transfer standards used for the comparison (hereinafter called "artifacts") should only be handled by authorized persons and be stored and packed in such a way as to prevent damage. While handling the artifacts, gloves should be worn to prevent contamination.

2.3.2 Artifacts should be examined immediately upon receipt at final destination. However, care should be taken to ensure that the artifacts and packaging have sufficient time to acclimatize to the actual environment thus preventing any condensation etc. The condition of the artifacts and associated packaging should be checked and reported to the pilot laboratory using the form in Annex A with receipt confirmation in Annex B soon after the inspection. If any problems are noted, details should be discussed with the pilot laboratory and the participant responsible for the lamps.

2.3.3 After the very first calibration at the participant laboratory (or the pilot laboratory), no cleaning of any lamp windows, apertures or envelopes should be attempted except for removing the dust by blowing with dry and clean air or inert gas.

2.3.4 After the measurements, the artifacts should be re-packaged in their original cases. All the content of the package should be checked again before shipment.

2.3.5 Any unusual occurrence such as sudden change of lamp voltage or any damage to the artifacts should be notified to the pilot laboratory and/or the participant that owns the lamps immediately before proceeding with any further measurements.

2.3.6 If an artifact appears damaged a replacement, if possible, will be available only from the participant. In case the artifacts belong to the pilot laboratory, a participant should consult the pilot laboratory for a possible replacement.

2.3.7 Participants should inform the pilot laboratory via fax or e-mail of the completion of measurements and should intimate a suitable date for transportation or dispatch.

2.4 Transport of artifacts

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

2.4.2 It is highly recommended that the artifacts should be transported by hand-carrying (in an aircraft cabin) from the participant to the pilot laboratory and back again to the participant.

2.4.3 If transport of the artifacts by the hand-carrying is not possible for a participant for some reason, appropriate shipping agent to ensure the safe and careful transportation of the artifacts should be arranged under the responsibility of the participant.

2.4.4 Packaging for the artifacts should be suitably robust to protect the artifacts from being deformed or damaged during transportation. Shipped packages should be marked as "Fragile".

2.4.5 Appropriate insurance should be taken out by the participant for the artifacts to cover the possible cost of damage that might occur in transportation. The pilot laboratory has no insurance for any loss or damage of the artifacts during transportation.

2.4.6 All artifacts should be accompanied by ATA carnet (where appropriate) or any other custom documentation which can serve similar purposes to the ATA carnet. Documentation identifying the items uniquely is also required. Each participant has to pay attention to the import/export regulations during transport, which may be different among countries.

2.4.7 Participants are responsible for the transport of the artifacts and the costs involved. Transportation of the artifacts both to the pilot laboratory and back to the participant is at each participant's responsibility and cost. Each participant covers the cost for its own measurements, transportation and any customs charges as well as for any damages that may have occurred within its country.

2.4.8 In the case that a participant asks a shipping agent for the transport of the artifacts to the pilot laboratory, "Free House Delivery" or "Free Domicile" option has to be chosen. From the pilot laboratory to the participant, the artifacts will be delivered cash on delivery by the agent designated by the pilot laboratory, unless the participant has arranged a shipping agent with appropriate payment.

2.4.9 In the case that a participant borrows the artifacts from the pilot laboratory, the pilot laboratory will be responsible for the transportation cost (excluding custom charges) for the artifacts when they are shipped from the pilot laboratory to the participant. For the opposite route, each participant should bear all the transportation cost. Any other cost shown in 2.4.7 is borne by each participant.

2.4.10 The overall costs for the organization of the comparison are covered by the pilot laboratory, which means each participant will not be charged additional cost besides that specified in 2.4.7 and 2.4.9.

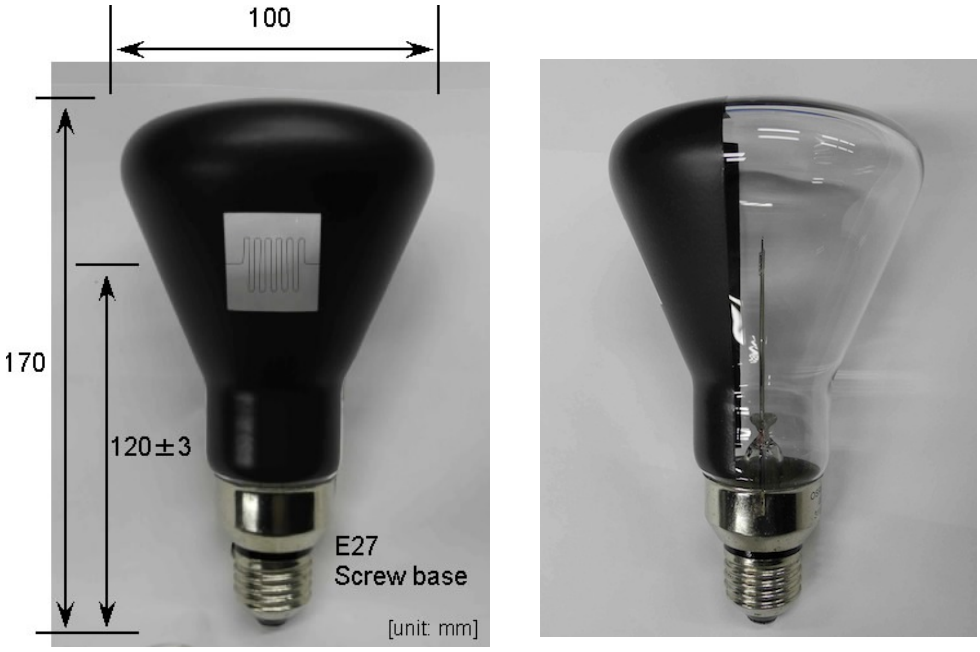
3. Measurement Conditions

3.1 Description of artifacts

3.1.1 The artifacts used for the comparison are specially developed standard lamps for luminous intensity, OSRAM Wi41/G (31V-6A) shown in Fig.1. Each participant should use a batch of the standard lamps consisting of 3 lamps or more.

3.1.2 Additional information on the dimension of the Wi41/G lamps is as follows.

- Bulb diameter: 100 mm
- Total length: 170 mm
- Filament center (from the base): 120 mm
- Lamp base: E27 Edison screw base
- Black mask with opening covered in front side
- Approximate weight: 0.5 kg
- Rated operating current: 6 A
- Rated operating voltage: 31 V
- Approximate luminous intensity at the rating: 300 cd



Front View Side View

Fig. 1: Photo of a luminous intensity standard lamp (OSRAM Wi41/G)

3.2 Traceability

3.2.1 In the comparison, traceability of the calibration to SI base units for the measurement instruments shall be totally guaranteed.

3.2.2 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 Ampere and Volt. Length measurements should be independently traceable to the latest realization of the Meter.

3.2.3 Luminous intensity scale of each participant shall be traced to the latest realization of the candela. If the unit is not independently realized by the participant, the traceability route shall be clearly identified.

3.3 Measurand

3.3.1 Measurand in the comparison is the luminous intensity of a lamp. It should be measured for the defined operating conditions of each lamp, where the operating current acts as the setting parameter.

3.3.2 Each lamp shall be operated at the specified operating condition, which is defined by each participant to achieve the designated distribution temperature or correlated color temperature (CCT). The recommended distribution temperature (or CCT) is 2800 K ± 20 K, taking general uncertainty of distribution temperature into account. In the light of the situation that some NMIs including the participants of the last CCPR-K3.a usually use higher distribution temperature condition (around 2856 K to approximate illuminant A), if needed, alternative distribution temperature (or CCT) up to 2856 K (with maximum possible allowance of 20 K) is accepted for this comparison. In this case, targeted distribution temperature (or CCT) should be clearly stated by a participant.

3.3.3 Laboratory ambient temperature during the calibration shall be maintained at 23 °C ± 2 °C with relative humidity at 50 % ± 20 %. The exact temperature and relative humidity of the laboratory during the calibration shall be reported.

3.3.4 Luminous intensity of the lamps shall be measured independently at least twice. Each independent measurement should consist of the lamp being re-aligned in the measurement facility and being switched off and on after a break of at least 1 hour for each lamp.

3.3.5 It should be noted that each independent measurement may consist of more than one set of measurements, the exact number should be that normally used by the participating laboratory to obtain the appropriate accuracy as limited by the noise characteristics of their specific measurement facility. The exact number of measurements made shall be stated in the measurement report but only the mean or final declared value of the set is required to be included.

3.3.6 It should be reminded that the luminous intensity of a standard lamp will change as a function of the operational burning time and so it is recommended that total burning time for the transfer standards is kept to a minimum.

3.3.7 The measurements should be taken at a sufficient large photometric distance. At the pilot laboratory, all the measurements will be carried out at the photometric distance of 2.7 m.

3.4 Measurement instructions

3.4.1 Luminous intensity of a standard lamp should be calibrated on a photometric bench. The optical axis of the photometric bench should be horizontal and central to the filament of the lamp.

3.4.2 The photometric distance should be measured from the center of the lamp filament to the reference plane of a photometer to be used for measurement along with the optical axis.

3.4.3 The standard lamp should be placed at a base-down position. The optical axis of the lamp should be rectangular to the filament plane and the plane containing optical axis and lamp axis should be vertical. The lamp geometry and coordinates are shown in Fig.2 for clarification.

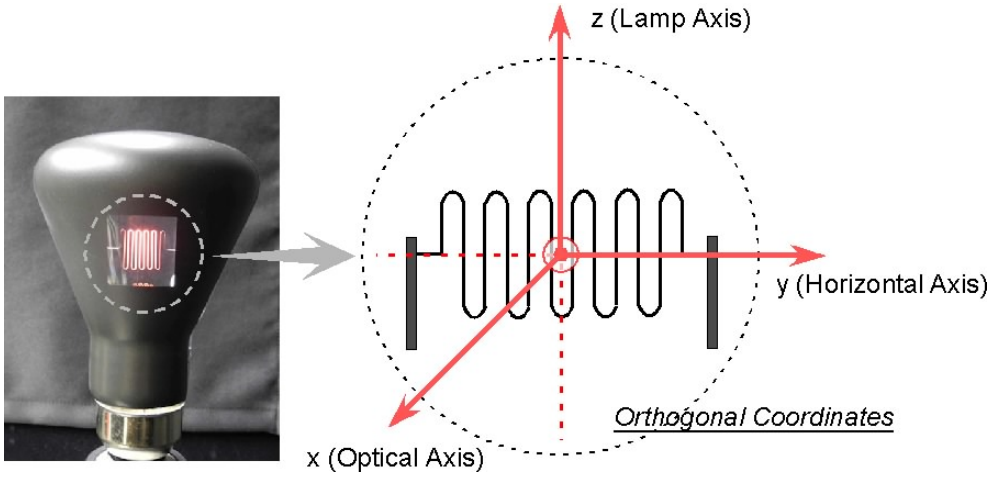


Fig. 2: Lamp geometry and coordinates

3.4.4 Only the direct light passing through an opening in a mask shall be measured.

3.4.5 Before connecting to any electrical power supply, the artifacts should be inspected for damage or contamination of either the window of the lamp, the cap or its supporting mount. Any damage should be documented in detail and the pilot laboratory should be informed immediately.

3.4.6 Lamp current should be ramped up slowly in around a few minutes until it reaches the

specified operating value. After connecting the electrical power to the lamps, the prescribed warm-up procedure for each lamp should be followed. Normally, 7 to 10 minutes is needed until the lamp's current is stabilized. A regulated DC power supply should be used to operate the lamps.

3.4.7 Luminous intensity of the lamps should then be measured together (at the same time if possible) with the electrical values (lamp current and voltage).

3.4.8 The lamp voltage should be measured at the vicinity of the lamp base using four-pole technique with control of the specified current.

3.4.9 The lamp polarity for the DC operation should be specified by each participant. The pilot laboratory uses the same lamp polarity as specified by the participants in the measurement of their lamps.

3.4.10 When the measurement completes, the electrical power supply should be ramped down slowly in the same manner as 3.4.6.

3.4.11 The operation time for each lamp should be recorded as a history of the lamp.

3.4.12 No other measurements should be attempted by the participants nor is any modification to be done on the operating conditions during the course of this comparison. The transfer standards used in this comparison should not be used for any purpose other than described in this protocol nor given to any other party.

3.5 Report of results

3.5.1 On completion of the measurement by a participant in each round (before and after the pilot laboratory's measurement), the results of the measurement shall be sent to the pilot laboratory within six weeks using a form in Annex C as a measurement report.

3.5.2 The signed results of the measurements together with the uncertainty budget table shall be reported to the pilot laboratory by FAX or regular mail. It is recommendable that the report be completed and returned electronically to the pilot laboratory for convenience and rapid response. In case of any differences, the paper form will be the definitive version.

3.5.3 When the artifacts are transported to the pilot laboratory, the information on the lamp operating condition (e.g. lamp No., current, voltage, distribution temperature or CCT etc.) should be provided together. Such information is indispensable for the pilot laboratory to carry out the comparison measurement without any delay.

3.5.4 The record of the operation time for each lamp using Annex D described in 3.4.11 shall be reported to the pilot laboratory as part of the measurement report.

3.5.5 A description of each participant's measurement facility including a schematic diagram or a reference to a published work describing the facility shall be reported using a form in Annex E. The report should also include a description of the participant's traceability route, the date of the last realization of the scale and a description of the measurement technique and procedure with the information of number of repeated measurements described in 3.3.4 and 3.3.5.

3.5.6 In the report, the values of measurement results and operating conditions (especially lamp current and voltage) should be displayed using an appropriate number of decimal places.

3.5.7 Any results obtained by a participant during the course of the comparison shall be sent only to the pilot laboratory that will be responsible for coordinating how the information should be disseminated to other participants. No communication whatsoever regarding any details of the comparison other than the general conditions described in this protocol shall occur between any of the participants or any party external to the comparison without the written consent of the pilot laboratory. In the situation that such communication is required, the pilot laboratory will in turn seek permission of all the participants. This is to ensure that no bias from whatever accidental means can occur.

3.5.8 Following receipt of all measurement reports from the participants, the pilot laboratory will analyze the results and prepare the first draft report on the comparison according to the CCPR guideline [5]. This will be sent to the participants for comments, additions and corrections. Subsequently, the procedure outlined in the guidelines [3, 4, 5] will be followed.

3.6 Measurement uncertainty

3.6.1 Each measurement result shall be followed by a comprehensive uncertainty calculation, including an itemization of all the contributions to the total uncertainty. The uncertainty of measurements shall be estimated according to the ISO Guide to the Expression of Uncertainty in Measurements [6], and the values reported should correspond to a coverage factor of $k = 1$.

3.6.2 The value of each uncertainty contribution shall be reported as an uncertainty budget table as shown in Annex F as an example. The number of degrees of freedom should also be reported.

3.6.3 The followings are the example of the major uncertainty contributions in luminous intensity calibration, which might be considered in the reporting if applicable.

- Uncertainty associated with the reference standard used for the calibration
- Uncertainty associated with random noise during transfer measurement
- Uncertainty associated with lamp alignment
- Uncertainty associated with photometric distance

- Uncertainty associated with spectral mismatch of the photometer to $V(\lambda)$
- Uncertainty associated with non-linearity of the photometer
- Uncertainty associated with stray light
- Uncertainty associated with environmental effects such as the change of temperature and/or humidity
- Uncertainty associated with the error in electrical parameters
- Uncertainty associated with the drift (or ageing) of the lamp
- Uncertainty associated with the instability of whole calibration facilities

3.6.4 It may be appropriate to include other additional parameters, dependent on specific measurement facilities. These should be added with an appropriate explanation and/or reference giving an indication of how they are estimated.

4. Calculation of the DoE

4.1 Procedure and method on data analysis at the pilot laboratory to calculate the APMP-KCRV and DoE will be in accordance with the CCPR guideline [4].

4.2 In this comparison, the transfer standards are measured before and after their transportation. The average of these two measurements will be considered as the final measurement value to be compared. The difference between them will be used to analyze the potential drift (ageing) of the lamps and be considered as a part of uncertainty in the calculation of the APMP-KCRV and the DoE.

4.3 The results of this comparison will be linked to the KCRV determined by CCPR-K3.a through the link laboratories (NMIJ, NIM and NMISA), which are the participants of the last CCPR-K3.a.

4.4 In the same manner as the CCPR-K3.a, the resulting APMP-KCRV will be calculated using the results of link laboratories as weighted average with a minimum cut-off (depending on the number of link laboratories).

4.5 Degree of equivalence (DoE) of each participant's luminous intensity scale will be calculated based on the ratio for each participant's result relative to the pilot laboratory's one, APMP-KCRV calculated in 4.4 and the DoE agreed at the last CCPR-K3.a.

5. References

[1] CCPR Key Comparison K3a of Luminous Intensity and K4 of Luminous Flux with Lamps as Transfer Standards; PTB-Opt-62 (1999)

[2] http: //kcdb.bipm.org/appendixB/default.asp

[3] CIPM MRA-D-05; Measurement comparisons in the context of the CIPM MRA (2011)

[4] APMP–G2; The APMP Guidelines on conducting comparisons (2003)
[5] Guidelines for CCPR Comparison Report Preparation (2009)
[6] ISO/IEC Guide 98-3:2008; Uncertainty of measurement - Part 3: Guide to the expression of uncertainty in measurement (GUM)

Annex A: Inspection of the transfer standards

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

If Yes, please give details:

2) Is there any damage to the transportation package? ……Y / N

If Yes, please give details:

3) Are there any fingerprints or contaminations on the lamps visible indicating improper handling? ……Y / N

If Yes, give details:

4) Are there any visible signs of damage to the lamp? ……Y / N

If Yes please give details (e.g. scratches, broken filament, alignment mask moved etc.):

5) Do you believe the lamps are functioning correctly? ……Y / N

If not, please indicate your concerns:

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

Annex B: Receipt confirmation

To: **Hiroshi Shitomi**
Optical Radiation Section, Photometry and Radiometry Division
National Metrology Institute of Japan (NMIJ, AIST)
AIST-3, 1-1-1 Umezono, Tsukuba, Ibaraki 305-8563, JAPAN
Tel. +81-29-861-5684
Fax. +81-29-861-4860
E-mail: h-shitomi@aist.go.jp

From:

We confirm having received the transfer standards for APMP.PR-K3.a comparison on Luminous Intensity.

After visual inspection,

( ) No damage has been noticed;

( ) The following damage must be reported:

……..……
……..……
……..……
……..……
……..……
……..……
……..……

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

Annex C: Measurement results

The attached measurement summary should be completed for each lamp at each measurement round (before and after the measurement at the pilot laboratory).

1st Round (*Month, Year*)

Lamp No.	Current (A)	Voltage (V)	Distribution Temperature or CCT (K)	Luminous Intensity (cd)

2nd Round (*Month, Year*)

Lamp No.	Current (A)	Voltage (V)	Distribution Temperature or CCT (K)	Luminous Intensity (cd)

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

Annex D: Record of lamp operating time

Lamp No. _____

Date (YY,MM,DD)	Current （A）	Voltage （V）	Operating time (second)	Activity
(ex.) 12.04.30	**(ex.) 5.588**	**(ex.) 30.45**	**(ex.) 950**	**(ex.) Measurement Day-1**

Operator:

Laboratory:

Date: …….. Signature: ……..

Annex E: 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.

1) Make and type of the photometer (or equivalent)

2) Laboratory reference standards used:

3) Description of measuring technique and procedure including number of repetition of measurements (please include a diagram):

4) Establishment or traceability route of primary scale including date of last realization:

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

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

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

Annex F: Uncertainty budget of Measurement

Table. Uncertainty budget for luminous intensity calibrations of transfer standards

	Uncertainty component	Type	Degree of Freedom	Relative standard uncertainty/ %
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
	Relative combined standard uncertainty			
	Relative expanded uncertainty (with coverage factor (k) giving approximately 95 % confidence interval)			

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