Technical protocol of APMP key comparison for the measurement of ^{137}Cs gamma-ray air kerma (APMP.RI(I)-K5)

1. Introduction

The comparison of the high intensity ^{137}Cs gamma-ray air kerma measurement was agreed to be undertaken in APMP TCRI to establish the degree of equivalence. A total of 5 laboratories are scheduled to participate in the comparison, being KRISS the pilot laboratory. Two transfer chambers will be circulated using a star-shaped circulation scheme between the KRISS and the participants. KRISS and NMIJ are the link laboratories to the Key Comparison Reference Value (KCRV).

2. Participants

Institute	Country	Contact person (e-mail)
CIEMAT	Spain	Néstor Cornejo Díaz (nestorarmando.cornejo@ciemat.es)
INER	Taiwan	Yi-Chun Lin (jasmina@iner.gov.tw)
NIM	China	Yanli Zhang (zhangyl@nim.ac.cn) Dehong Li (lidh@nim.ac.cn)
NMIJ	Japan	Tadahiro Kurosawa (tadahiro-kurosawa@aist.go.jp) Norio Saito (norio.saito@aist.go.jp)
KRISS	Korea	Chul-Young Yi (cyyi@kriss.re.kr)

3. Transfer chambers

A brief description of the transfer chambers is given in table 1. The wall materials are 2.5 mm-thick C552 for Exradin A3 and 0.55 mm-thick PMMA with graphite layer of 54 mg/cm^2 for PTW TN23331, respectively. The diameter of the A3 chamber (serial number 110) is 23.5 mm and it is mm for the TN23331 (SN 0833) with 3 mm-thick build up cap on. Photos of the transfer chambers are given in appendix B.

Table 1. Transfer chambers and high voltage ratings for the comparison

Model	Serial No.	Nominal volume (cm^3)	Cavity radius (cm)	Voltage [a)]	Cable connection
Exradin A3	110	3.6	0.95	- 300 V	BNC & Banana plug
PTW TN23331	0833	1	0.345	- 400 V	Triaxial; adaptor for BNC & banna plug

[a)]Negative voltage is to be supplied to the chamber wall with respect to the central electrode being in virtual ground.

4. Reference conditions, measurement procedure and report of results

Considering that we are planning to measure relatively high intensity ^{137}Cs beams, two transfer chambers with 3.6 and 1 cm^3 cavity volumes are selected for the comparison, which will reduce the ion recombination and the beam non-uniformity corrections. The geometrical center of the chamber shall be placed at the reference point of the measurement. The source-to-chamber distance is 1 m. The field shape on the reference plane at 1 m will be circular or rectangular with the field size between 10 cm and 20 cm, where the field is limited to the beam intensity being 50% of that at the center. The ionization current of PTW TN23331 chamber should be measured with the provided build-up cap on. In case of the Exradin A3 (serial number 110), a build-cap is not necessary since the wall is 2.5 mm-thick. The chambers are positioned with the stem perpendicular to the beam axis. The participants do not need to make a correction for the ion recombination. After the measurement is completed, the pilot laboratory will evaluate the effects based on the beam parameters of the participating laboratories. We will use it in the uncertainty evaluation of the comparison.

To acclimatize the chambers for enough time the transfer chambers shall be placed in the laboratory at least 12 hours before the measurement is started. The electrometer and high voltage supply shall be warmed up for at least 2 hours. After the high voltage is applied to the transfer chamber and the signal cable is connected to the electrometer, it is advisable to wait at least 1 hour to stabilize the whole ionizing current measurement system. The background current should be measured before and after the measurement of the ionizing current produced by ^{137}Cs beam. The net ionization current is obtained by subtracting the average background current. The background current is typically in the 0.1% level of the ionization current. At least 10 repeated measurements should be taken to form a set of measurement for each transfer chambers. The ionization current should be normalized to the reference environmental conditions of 293.15 K, 101.325 kPa and 50% relative humidity.

The air kerma calibration coefficient of the transfer chamber to be evaluated at the participating laboratories is:

$$N_K = (\dot{K}/I)\prod_i k_i \qquad (1)$$

where N_K is the air kerma calibration coefficient given in units of Gy/C, $\dot{K}$ is the air kerma rate in Gy/s, I is the net ionization current in A and k_i is the i-th correction factor. The calibration coefficient of each chamber shall be measured at negative polarity only (please, see note of Table 1) and given in units of Gy/C normalized to the reference environmental condition of 293.15 K, 101.325 kPa and 50% relative humidity. Uncertainty shall be evaluated in accordance to the ISO guidance [1].
A template Microsoft excel sheet for reporting the result of measurement is sent to the participating laboratories. The information to be described by the participants for each measurement with the transfer chamber is as follows:

a. Cs-137 source
   - Nominal activity
   - Source dimension, capsule dimension & material (if available)
b. Electrometer
   - Manufacturer & model
   - Operation mode (charge or current)
   - Traceability
c. Pre-calibrated standard chamber used in measurement
   - Manufacturer, model & serial number
   - Traceability
   - Calibration date
   - Calibration distance
   - Air kerma rate during calibration at the laboratory of traceability
   - Calibration coefficient
   - Uncertainty of calibration coefficient (k = 1)
d. Measurement procedure
   - Chamber climatization time at participant's site
   - Date and time of chamber bias voltage loading (yyyy-mm-dd hh:mm:ss)
   - Duration of pre-irradiation
   - Start date and time of measurement (yyyy-mm-dd hh:mm:ss)
   - Finish date and time of measurement (yyyy-mm-dd hh:mm:ss)
   - Number of measurement repetition
e. Measurement results
   - Temperature range during measurement
   - Atmospheric pressure range during measurement

- Relative humidity range during measurement
- Calibration distance (source to the reference point)
- Beam cross-section on the reference plane
- Air kerma rate at the reference point
- Background current
- Net ionization current (background current substracted)
- Calibration coefficient (Gy/C)

f. Uncertainties budget in % (k = 1)

5. Comparison structure and schedule

There will be a star-shaped circulation of the transfer chambers between the KRISS and the participants. KRISS will pay for the transport from KRISS to the airport of the participant's country and, for the return, from Inchon airport in Korea to KRISS. Each participant will pay for the transport from the airport of the participant's country to their institute and, for the return, from their institute to Inchon airport. The participants should pay for the import custom duties. The chambers should stay at the participants' laboratories for no longer than 2 weeks. The three-month gap in the comparison is to avoid rainy season in the East Asian region, which comes in Jun, July and August.

After each participant's calibrations, KRISS will carry out chamber constancy checks by re-calibrating both transfer chambers. These data will form the basis of the uncertainty estimate for chamber stability entering in the data analysis.

The comparison is scheduled to commence in 03-Feb-2014 and expected to be completed in 20-October-2014. In order to avoid successive delay in the comparison schedule, full compliance to the itinerary of shipment back to KRISS is advisable even in the case that the measurements at the participating laboratory are incomplete. A feasible way to deal with the case will be sought after the completion of all scheduled comparison. The proposed schedule is given in Table 2.

Table 2. Proposed schedule of the comparison APMP.RI(I)-K5.

Participant	**Date of chambers leaving KRISS for participant**	**Measurement period at the participating laboratory**	**Date of chamber leaving participant for KRISS**
NMIJ	03-Feb-2014	17-Feb-2014 to 28-Feb-2014	03-Mar-2014
INER	24-Mar-2014	07-Apr-2014 to 18-Apr-2014	21-Apr-2014
CIEMAT	12-May-2014	26-May-2014 to 06-Jun-2014	09-Jun-2014

NIM	22-Sep-2014	06-Oct-2014 to 17-Oct-2014	20-Oct-2014

6. Procedure for handling the results of pilot laboratory

The measurement result of KRISS will be reported to the link laboratory NMIJ within 2 weeks after the measurement, i.e., before the submission of the measurement report by the second participating laboratory. KRISS will repeat the measurement with the transfer chambers before and after every participant's measurement for the consistency check and the results will also be sent to the link laboratories within 2 weeks.

7. Evaluation and publication of the results

After the comparison is completed, the pilot laboratory will evaluate the comparison by analyzing the report of results submitted by the participants. The Key Comparison Reference Value (KCRV) is the CIPM key comparison reference value. The degrees of equivalence of the participating laboratories with respect to the KCRV will be obtained according to the procedure indicated in [2], considering two transfer instruments and two linking laboratories. Further details will be provided in Draft A report.

The pilot laboratory will prepare the Draft A report of the comparison and circulate the report among participants for comments and corrections. Once approved by all participants, the revised version Draft B report will be submitted to APMP TC chair and KCWG of CCRI(I). On approval, the Draft B report will be submitted to BIPM for the inclusion of the degrees of equivalent presented in the report to KCDB. Eventually the Final Report will be published in the Metrologia Tech. Suppl. Series.

References

[1] International Organization of Standard (ISO), *Guide to the expression of uncertainty in measurement*, 2nd ed., Switzerland (1995).

[2] D. T. Burns and P. J. Allisy-Roberts, The evaluation of degrees of equivalence in regional dosimetry comparisons, CCRI(I)/07-04 (2007).

Appendix A

Addresses of the participants

Pilot laboratory

KRISS

Center for Ionizing Radiation
Korea Research Institute of Standards and Science (KRISS)
267 Gajeong-ro, Yuseong-gu, Daejeon 305-340 Korea
http://www.kriss.re.kr/eng/main/index.html

Contact person : Dr. Chul-Young Yi
Tel: +82 42 868 5370 or +82 10 3452 4307
Fax: +82 42 868 5671
e-mail: cyyi@kriss.re.kr

Participating Laboratories (in alphabetical order)

CIEMAT

Laboratorio de Metrología de Radiaciones Ionizantes
(Spanish National Metrology Laboratory for Ionising Radiation)
Avda. Complutense, 40; E2.P0.D13
28040 Madrid
Spain

Contact person : Dr. Néstor Cornejo Díaz
Tel: +34 913466288 ; +34 913466590
Fax: +34 913466442
e-mail: nestorarmando.cornejo@ciemat.es

INER

Institute of Nuclear Energy Research
Health Physics Division
No.1000, Wunhua Rd., Jiaan Village,
Longtan Township,Taoyuan County, 32546, Taiwan(R.O.C.)

Contact person : Dr. Yi-Chun Lin
Tel: +886 3 4711400 ext 7733
Fax: +886 3 4713489
e-mail: jasmina@iner.gov.tw

NIM

National Institute of Metrology
Division of Metrology in Ionizing Radiation
No.18, Northern 3rd Ring Eastern Rd, Chaoyang Dist., Beijing, P.R.China, 100013

Contact person : Dr. Dehong Li
Tel: +86-10-64525024
Fax: +86-10-64214927
e-mail: lidh@nim.ac.cn

Mr. Yuandi Yang
Tel: +86-10-64525001
Fax: +86-10-64214927
e-mail: yangyd@nim.ac.cn

NMIJ

National Metrology Institute of Japan NMIJ
National Institute of Advanced Industrial Science and Technology, AIST
Quantum Radiation Division
1-1-1 Umezono, Tsukuba, Ibaraki 305-8568, Japan

Contact person : Dr. Tadahiro Kurosawa
Tel: +81-29-861-5927
Fax : +81-29-861-5673

e-mail: tadahiro-kurosawa@aist.go.jp

Dr. Norio Saito
Tel: +81-29-861-5656
Fax : +81-29-861-5673
e-mail: norio.saito@aist.go.jp

Appendix B

Fig. 1. A spherical Exradin A3 chamber. No build-up cap is provided since the wall is 2.5 mm-thick. The length of the stem is 28.5 cm and the outer diameter of the chamber is 23.5 mm. Bias is supplied with banana plug and signal is measured with BNC.

Fig. 2. A cylindrical PTW 23331 chamber. A 3 mm-thick PMMA build-up cap is put on the chamber. The length of the stem is 32.7 cm and the outer diameter of the chamber with a build-up cap is 15. 0 mm. Cable can be linked either with a tri-axial connector or using an adapter for connecting the tri-axial connector to BNC-banana plug.

Appendix B (continued)

(a)

(b)

Fig. 3. Postal package of two transfer chamber boxes in a waterproof crushproof protective luggage case. Inside view (a) and outside view (b).