Technical protocol for APMP key comparison of air kerma standards for the CCRI reference qualities in the medium-energy x-ray region (APMP.RI(I)-K3.2013)

Version: 27 May 2015

Prepared by: Chien-Hau Chu, chchu1@iner.gov.tw

1. Introduction

The objective of this key comparison is to establish the degrees of equivalence between the air-kerma standards of the participating NMIs for the CCRI radiation qualities from 100 kV to 250 kV [1], and to support the mutual recognition of calibration certificates for these qualities. Three transfer chambers will be calibrated by each of the participating laboratories for a number of previously selected radiation qualities.

The INER will be the pilot laboratory and the NMIJ and ARPANSA will be the linking laboratories.

2. Participants

The participants are listed in Table1.

Table 1. Participants in the comparison (details in Appendix A)

Participant	Institute	Country	Contact person (E-mail)
1	AEC	Syria	Mamdouh Bero (mbero@aec.org.sy)
2	ARPANSA	Australia	Duncan Butler (Duncan.Butler@arpansa.gov.au)
3	ESR	New Zealand	John Laban (john.laban@esr.cri.nz)
4	INER	Taiwan	Chien-Hau Chu (chchu1@iner.gov.tw)
5	KRISS	Korea	Chul-Young Yi (cyyi@kriss.re.kr)
6	LNMRI-IRD	Brazil	Karla (karla@ird.gov.br)
7	NIM	China	Jinjie Wu (wujj@nim.ac.cn)
8	NIS	Egypt	Ahmed Rashad Elsersy (aelsersy@yahoo.com)
9	NMIJ	Japan	Takahiro Tanaka (takahiro-tanaka@aist.go.jp)
10	NMISA	South Africa	Zakithi Msimang & Sonwabile Arthur Ngcezu (sangcezu@nmisa.org)
11	Nuclear Malaysia	Malaysia	Taiman Bin Kadni (taiman@nuclearmalaysia.gov.my)
12	BATAN	Indonesia	C Tuti Budiantari (tuticb@batan.go.id)

3. Comparison procedure

3.1 Transfer chambers

Three cavity chambers of different types (two are NE 2571 chambers and the other is a PTW 30001 chamber) are to be used as transfer standards for the comparison, as listed in Table 2. No electrometer will be provided. Laboratories will be required to apply the necessary bias voltage and measure the resulting ionization current using their own equipment. The chambers have a TNC or BNT connector, and an adaptor for switching the chamber BNT and TNC connectors as requested by some participants.

At each laboratory, the transfer chambers should be aligned in the beam with the mark/line on their stem facing the source. The transfer chambers have an integral buildup cap which should be removed when starting measurements.

This voltage should be applied at least 30 min before starting measurements. A pre-irradiation of at least 30 min should also be made before any measurements. The leakage current should be measured before and after each measurement.

Table 2. Technical data for the transfer chambers (pictures in Appendix B)

Supplier	Model	Serial number	Volume (cm^3)	Chamber high voltage (V)*	Cable connection
NE	2571	3024	0.69	+250	TNC or BNT
PTW	30001	2340	0.60	+400	BNT
Exradine	A3	139	3.6	+300	BNT

* Central electrode is Positive for all chambers.

3.2. Radiation qualities

The radiation qualities to be used for the comparison are the CCRI reference qualities for the medium-energy x-ray range (100 kV, 125 kV, 180 kV, 250 kV) established by the CCEMRI (currently CCRI) [1]. The conditions of the measurement at the BIPM are shown in Appendix C [2]. The chambers are positioned in the center of the beam with stem of the chamber perpendicular to the beam direction and the mark on the stem facing the radiation source. The distance from the reference point to the source and field size should be required to state. The field size must completely cover the chamber being calibrated. The X-ray qualities (tube potential, filtration, and first HVL) should be also required to state.

The calibration coefficients for the transfer chambers shall be given in terms of air kerma per unit of electric charge (Gy C^{-1}) referring to standard conditions of air temperature, pressure and relative humidity of T = 293,15 K, P = 1013,25 hPa and RH = 50 %. The relative air humidity should be between 20 % and 80 % during the calibrations otherwise a correction to h = 50 % should be applied. Laboratories should state their procedure for controlling or correcting for humidity and the associated uncertainties.

3.3. Course of comparison

There will be a star-shaped circulation of the transfer chambers between the INER and the participating laboratories. However, the chambers will not be returned to INER after each participating laboratory. Instead, **chambers will be passed directly to the next participating laboratory and only returned to INER for chamber constancy checks after every second or third laboratory. The shipment and insurance costs occurring during the whole process will be covered by the INER**. The chambers should stay at the participants' site for **no longer than 3 weeks.**

3.4. Comparison schedule

The comparison is scheduled to commence in July 2015 and expected to be completed within 2 years. The proposed schedule is shown in Table 3.

Table 3. Proposed schedule for the comparison (July 2015 - December 2016)

Participant	Date of calibration at the laboratory	Date of chambers leaving for next laboratory
Pilot(INER)		1-Jul-2015(START)
ESR	18-Jul-2015	8-Aug-2015
Nuclear Malaysia	26-Aug-2015	16-Sep-2015
NMISA	3-Oct-2015	24-Oct-2015
Pilot(INER)	11-Nov-2015	25-Nov-2015
ARPANSA	12-Dec-2015	2-Jan-2016
BATAN	20-Jan-2016	10-Feb-2016
NMIJ	27-Feb-2016	20-Mar-2016
Pilot(INER)	7-Apr-2016	21-Apr-2016
AEC	8-May-2016	29-May-2016
NIM	16-Jun-2016	7-Jul-2016
KRISS	24-Jul-2016	14-Aug-2016
Pilot(INER)	1-Sep-2016	22-Sep-2016
NIS	9-Oct-2016	30-Oct-2016
LNMRI-IRD	17-Nov-2016	9-Dec-2016
Pilot(INER)	27-Dec-2016 (END)	

Notes:

1. The time allowed for measurements for each participant is about 3 weeks.
2. Allowance is made for a transportation time for the chambers of about 2.5 weeks.
3. The time allowed for constancy measurements at the INER is about 2 weeks.

3.5 Submission of calibration results

An **MS-Excel sheet** will be provided by the pilot laboratory to each participant to report their respective radiation qualities, primary standards and calibration results. It is expected that all participating laboratories will submit their calibration results **within 6 weeks** of calibration.
In order to preserve the confidentiality, the pilot shall send their results to the CCRI Executive Secretary prior to reception of results from the other participants. Each participant shall send their results to the pilot only after the pilot's explicit announcement that they are able to receive the reports from the participants. The **MS-Excel sheet** information to be described by the participants for each measurement with the transfer chamber is as follows:

a. Qualities and standard
    - Characteristics of the radiation quality
    - Main characteristics of the primary standard

b. Calibration results
    - Measurement date
    - Temperature range during measurement
    - Atmospheric pressure range during measurement
    - Relative humidity range during measurement
    - Calibration distance (source to the reference point)
    - Beam diameter (At the reference point)
    - Air kerma rate (At the reference point)
    - Relative standard uncertainty of primary standard (k = 1)
    - Calibration coefficient
    - Relative standard uncertainty of calibration coefficient
c. Collection factors
    - Dry air density
    - W/e
    - Collection factors each beam quality
d. Uncertainties budget in % (k = 1)

3.6 Evaluation of measurement uncertainty

All participating laboratories are required to evaluate the uncertainty of their calibration coefficients as Type A and Type B according to the criteria given in the "Guide to The Expression of Uncertainty in Measurement" issued by the Joint Committee for Guides in Metrology (JCGM) and updated in 2008 [3]. The Type A uncertainty is obtained by the statistical analysis of a series of observations; the Type B uncertainty is obtained by means other than the statistical analysis of series' of observations. In order to analyse the uncertainties and take them into account for the degrees of equivalence entered in the BIPM key comparison database (KCDB) [4], the CIPM rules for comparisons require [5] that the participating laboratories submit to the pilot laboratory their detailed uncertainty budgets (with relative standard uncertainties, k = 1). An **MS-Excel sheet** will be provided by the pilot laboratory in which the participants can fill the uncertainty. It should be submitted together with the calibration results.

3.7 Comparison report

The pilot laboratory will prepare a draft report for circulation to all participants for comments and discussion of the results. A revised final report will be submitted to the APMP/TCRI Chairman for approval by the APMP TCRI and then to the CCRI Executive Secretary for revision by the KCWG(I) and CCRI(I). According to the CIPM rules for comparisons [5], after the agreement of the CCRI(I), the Final Report will be sent to the BIPM for inclusion in the KCDB [4].

4. Linking of regional comparisons to international comparisons

To link the APMP/TCRI comparison (a regional comparison) to the results of international comparison at the BIPM, two participating laboratories (NMIJ and ARPANSA) that had made a comparison with the BIPM for the measurement of air kerma rate for medium-energy x-rays are used as "linking laboratories." Then, through the following equation, the measured calibration coefficients for each laboratory, and for each of the CCRI reference radiation qualities, will be converted to ratios relative to the BIPM;

$$R_{\mathrm{NMI,BIPM}} = R_{\mathrm{NMI,Link}} \times R_{\mathrm{Link,BIPM}} \quad . \qquad (1)$$

In this equation,

$R_{\mathrm{NMI,Link}}$ = the mean ratio from the present comparison of the calibration coefficients from a participating NMI to those of the linking laboratory

$R_{\mathrm{Link,BIPM}}$ = the ratio of the linking laboratory and the BIPM obtained in the corresponding quality for the BIPM.RI(I)-K3 key comparison

$R_{\mathrm{NMI,BIPM}}$ = the derived ratio of the participating NMI and the BIPM for this quality.

The evaluation of the uncertainty u_R of each ratio $R_{\mathrm{NMI,BIPM}}$ will take correlation between the standards into account, making use of the guidance given in [6].

5. References

[1] CCEMRI, Qualités de rayonnement, 1972, CCEMRI(I), R15

[2] P.J. Allisy-Roberts, D.T. Burns and C. Kessler, 20011, Measurement Conditions and Uncertainties for the Comparison and Calibration of National Dosimetric Standards at the BIPM, Rapport BIPM-11/04

[3] JCGM, Evaluation of measurement data – Guide to the expression of uncertainty in measurement, 2008, JCGM 100:2008 (GUM 1995 with minor corrections)

[4] KCDB, 2013, Measurement of air kerma for medium energy X rays 2014 – 2016, APMP.RI(I)-K3

[5] CIPM, Measurement comparisons in the CIPM MRA Version 1.5, 2014, CIPM MRA-D-05

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

APPENDIX A. Participants Data

Pilot laboratory

INER

Institute of Nuclear Energy Research
Health Physics Division
No.1000, Wenhua Rd., Jiaan Village,
Longtan District,Taoyuan County, 32546, Taiwan(R.O.C.)
Contact person : Dr. Chien-Hau Chu
Tel: +886 3 471 1400 EXT7741
Fax: +886 3 471 3489
e-mail: chchu1@iner.gov.tw

Participants

AEC

National Radiation Metrology Laboratory,
Protection and Safety Department,
Atomic Energy Commission,
Damascus P.O.Box 6091, Syria
Contact person : Dr. Mamdouh Bero
Tel: 00963-11-2132580
Fax: 00963-11-6112289
e-mail: mbero@aec.org.sy

ARPANSA

Australian Radiation Protection and Nuclear Safety Agency
Ionizing Radiation Standards
619 Lower Plenty Road
Yallambie VIC 3085, Australia
Contact person : Dr. Duncan Butler
Tel: +61 3 9433 2274
Fax: +61 3 9432 1835
e-mail: Duncan.Butler@arpansa.gov.au

ESR

Institute of Environmental Science and Research (ESR) Ltd.
RADIATION STANDARDS SECTION ,
27 Creyke Road, Christchurch 8041, New Zealand
Contact person : Dr. John Laban
Tel: +64 3 366 5059
Fax: +64 3 351 0010
e-mail: john.laban@esr.cri.nz

KRISS

Health Metrology Group
Korea Research Institute of Standards and Science (KRISS)
1 Doryong-Dong Yuseong-Gu Daejeon 305-340 Korea
Contact person : Dr. Chul-Young Yi
Tel: +82 42 868 5370
Fax: +82 42 868 5671
e-mail: cyyi@kriss.re.kr

LNMRI-IRD

Laboratório Nacional de Metrologia das Radiações Ionizantes -LNMRI
Instituto de Radioproteção e Dosimetria –IRD
Avenida Salvador Allende s/no Barra da Tijuca –Rio de Janeiro RJ- Brazil
Contact person : Dr. Karla
Tel: +55 21 2173 2701
Fax: +55 21 2173 2709
e-mail: karla@ird.gov.br

NIM

National Institute of Metrology (NIM)
No.18, Bei San Huan Dong Lu, Chaoyang Dist, Beijing, P.R.China,100029
Contact person : Dr. Jinjie Wu
Tel: +86 10 64525023
Fax: +86 10 64214927
e-mail: wujj@nim.ac.cn

NIS

National Institute for Standards (NIS)
Terssa st. , El-Haram ,Giza , Egypt
Contact person : Dr. Ahmed Rashad Elsersy
Tel: ++202 33860670
Fax:++202 33867451
e-mail: aelsersy@yahoo.com

NMIJ/AIST

National Metrology Institute of Japan (NMIJ),
National Institute of Advanced Industrial Science and Technology (AIST)
Quantum Radiation Division, Ionizing Radiation Section
Central 2, 1-1-1 Umezono, Tsukuba, Ibaraki 305-8568, Japan
Contact person : Dr. Takahiro Tanaka
Tel:+81-29-861-4151

Fax:+81-29-861-5673
e-mail: takahiro-tanaka@aist.go.jp

NMISA

National Metrology Institute of South Africa (NMISA)
CSIR Campus, Build 5, Meiring Naude Road, Brummeria, Pretoria, South Africa
Contact person : Dr. Zakithi Msimang and Sonwabile Arthur Ngcezu
Tel: +27 12 841 3229
Fax:+27 12 841 3367
e-mail: sangcezu@nmisa.org

Nuclear Malaysia

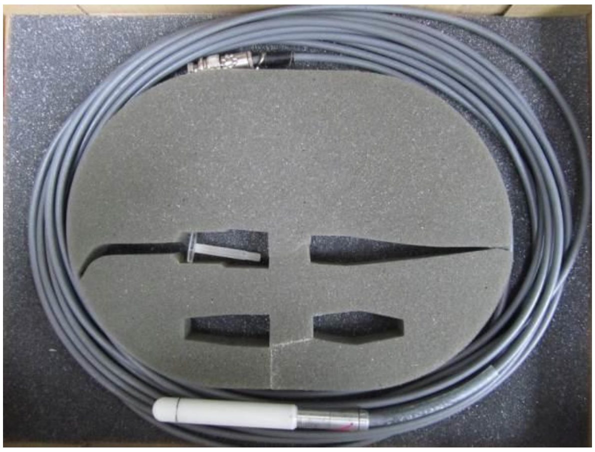
Malaysian Nuclear Agency (Nuclear Malaysia)
Bangi, 43000 Kajang, Selangor Darul Ehsan, Malaysia
Contact person: Dr. Taiman Bin Kadni
Tel.: +603-89282983
Fax: +603-89112164
e-mail: taiman@nuclearmalaysia.gov.my

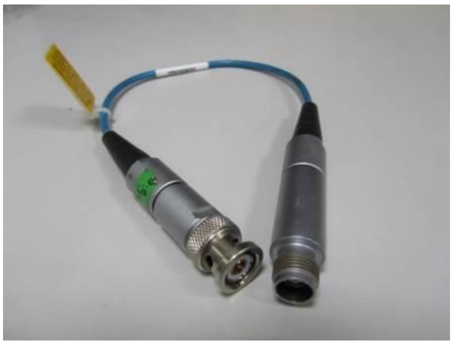
BATAN

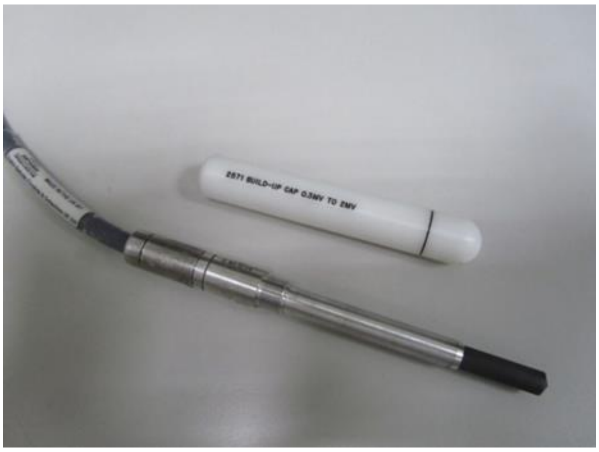
National Radiation Metrology Laboratory/SSDL Jakarta
Center for Technology of Radiation Safety and Metrology,
National Atomic Energy Agency (BATAN),
Jalan Lebak Bulus Raya No. 49, Pasar Jumat Kebayoran Lama Jakarta Selatan, Indonesia
Contact person: Dr. C Tuti Budiantari
Tel: +62 21 7513906 ext 302
Fax: +62 21 7657950
e-mail: tuticb@batan.go.id or tuticb@yahoo.com

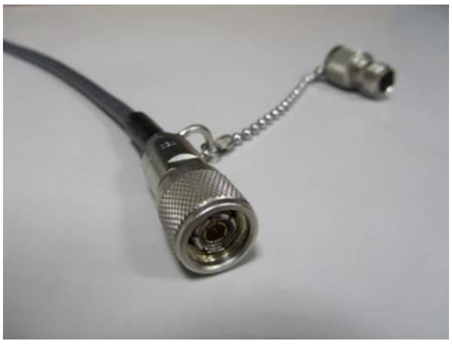
APPENDIX B: Pictures of the transfer chambers

NE 2571

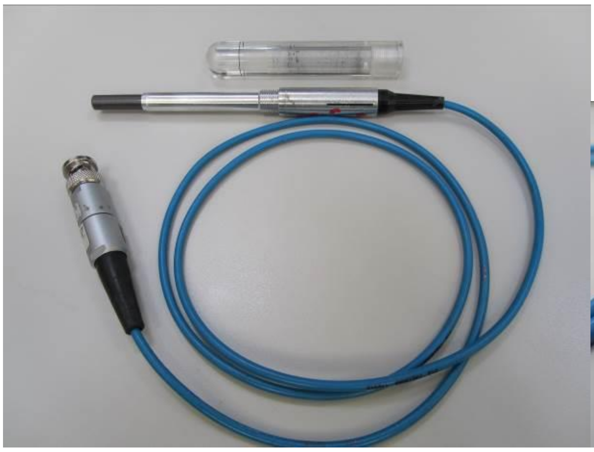


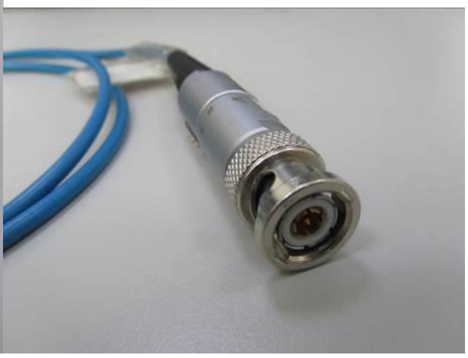




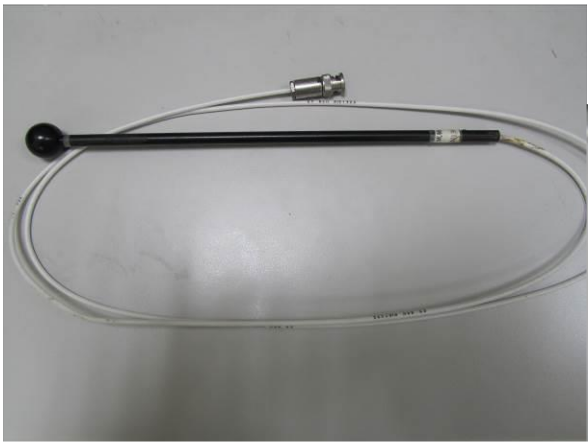
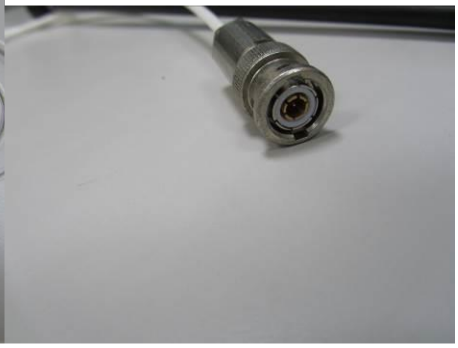


PTW 30001





Exradine A3

APPENDIX C: Conditions of measurement at the BIPM [reference 2]

Distance between focal spot and reference plane of standard: 120 cm
Beam diameter in the reference plane: 9.8 cm
Inherent filtration: ～3 mm Be

Reference qualities (recommended by Section I of the CCEMRI)

X-ray tube voltage /kV	100	135	180	250
Al filtration /mm	3.431	2.228	2.228	2.228
Cu filtration / mm	—	0.232	0.485	1.570
Al half-value layer /mm	4.030	—	—	—
Cu half-value layer /mm	0.149	0.489	0.977	2.484
$\bar{\mu}/\rho^{(1)}/(cm^2 g^{-1})$	0.290	0.190	0.162	0.137
Air-kerma rate/(mGy s^{-1})	0.50	0.50	0.50	0.50

(1) mass air-attenuation coefficient