Technical protocol for APMP key comparison of air kerma standards for the CCRI reference qualities and the ISO 4037 narrow spectrum series in the low-energy x-ray region (APMP.RI(I)-K2)

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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 10 kV to 50 kV [1], and to support the mutual recognition of calibration certificates for these qualities and for the ISO 4037 narrow spectrum series of radiation qualities (15 kV and 40 kV) [2]. Three different transfer chambers will be calibrated by each of the participating laboratories for a number of previously selected radiation qualities.

The NMIJ/AIST will be both the pilot laboratory and the linking laboratory.

2. Participants

The participants are listed in Table 1.

Table 1. Participants in the comparison.

Participant	Institute	Country	Contact person (E-mail)
1	AEC	Syria	Mamdouh Bero (mbero@aec.org.sy)
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11	NIM	China	WU Jinjie (wujj@nim.ac.cn)

3. Comparison procedure

3.1 Transfer chambers

Three cavity chambers of different type are to be used as transfer standards for the comparison, as listed in Table 2. These chambers are provided by the NMIJ/AIST (Magna and AE-1340C) and the ARPANSA (NE 2536). The reference point for each chamber is the front surface of the detector case (NOT the surface of the thin film entrance window). The signal connections of the chambers are a tri-axial BNT plug for the Magna and NE 2536 chambers and a BNC with a 4-mm 'banana' plug for the AE-1340C chamber. **A collecting voltage of -250 V** (negative polarity), supplied at each laboratory, should be applied to the HT electrode of each chamber. This voltage should be applied at least 30 minutes before

starting measurements. A pre-irradiation of at least 30 minutes should also be made before any measurements. The leakage current should be measured before and after each measurement. Photographs of each chamber are presented at the end of this protocol. The Magna chamber is supported by its stem, 100 mm in length, 19 mm wide and 10 mm deep (in the beam direction). The AE-1340C is likewise supported by its cylindrical stem, 178 mm long and 15 mm in diameter. The NE 2536 is generally supported by the chamber casing, 61 mm long, 30 mm wide and 14,5 mm deep. All stated dimensions are indicated in the photographs.
The chambers are transported in an air tight box. of around 500 mm height, 635 mm width, 305 mm depth, and weighing about 8 kg.

Table 2. Technical data for the transfer chambers.

Supplier	Model	Serial number	Volume / (cm^3)	Chamber high voltage / (V)	Cable length / (m)	Cable connection
EXRADIN	Magna[a]	D070313	3,0	-250	1,2	Tri-axial (BNT)
OYOGIKEN	AE-1340C[b]	1042	0,24	-250	4,5	Signal: BNC HV: banana plug
NE	2536/3[c]	R17804	0,3	-250	1,0	Tri-axial (BNT) or Tri-axial (TNC)

[a] Diameter 53,3 mm

[b] Diameter 47 mm

[c] Diameter < 30 mm

3.2. Radiation qualities

The radiation qualities to be used for the comparison are the CCRI reference qualities for the low-energy x-ray range (10 kV, 30 kV, 25 kV, 50 kV(b), 50 kV(a)) and ISO 4037-1 narrow-spectrum series **(15 kV and 40 kV)**.

3.3. Reference conditions

The reference conditions for the chamber calibrations are as follows:

1. **Distance** from the focal spot to the reference plane (the front surface of the chamber): **1.0 m**.
2. **Field size** at the reference plane: **10 cm in diameter**.
3. Air temperature, pressure and relative humidity of T = 293.15 K, P = 1013.25 hPa and h = 50 %.
4. The calibration coefficients for the transfer chambers should be given in terms of air kerma per charge, in units of Gy C^{-1}.

3.4. Course of comparison

There will be a star-shaped circulation of the transfer chambers between the NMIJ and the participants. The **NMIJ will pay for the transport of the chambers to the participants. Each participant will pay for the transport of the chambers back to the NMIJ.** The chambers should stay at the participants' site for **no longer than 3 weeks.**

After each participant's calibrations, the NMIJ will perform chamber constancy checks by re-calibrating all three transfer chambers at all of the CCRI reference qualities. If this is not possible, at least three qualities (10 kV, 25 kV and one of the 50 kV) will be used. These data will form the basis of the uncertainty estimate for chamber stability entering in the data analysis.

3.5. Comparison schedule

The comparison is scheduled to commence at the end of August 2008 and expected to be completed within 2 years. The proposed schedule is shown in Table 3.

Table 3. Proposed schedule for the comparison (August 2008 until March 2010).

Participant	Date of chambers leaving NMIJ for participant	Measurement period at the laboratory	Date of chambers leaving participant for NMIJ
Nuclear Malaysia	18-Aug-2008	1-Sep-2008 to 19-Sep-2008	22-Sep-2008
BARC	5-Jan-2009	19-Jan-2009 to 6-Feb-2009	9-Feb-2009
ARPANSA	9-Mar-2009	23-Mar-2009 to 10-Apr-2009	13-Apr-2009
INER	13-Jul-2009	27-Jul-2009 to 14-Aug-2009	17-Aug-2009
OAP	16-Nov-2009	30-Nov-2009 to 18-Dec-2009	21-Dec-2009
AEC	26-February-2010	12-Apr-2010 to 30-Apr-2010	3-May-2010
IAEA	31-May-2010	14-Jun-2010 to 2-Jul-2010	5-Jul-2010
KRISS	2-Aug-2010	16-Aug-2010 to 3-Sep-2010	6-Sep-2010
NIM	18-Oct-2010	1-Nov-2010 to 19-Nov-2010	22-Nov-2010

Notes:

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

3.6 Submission of calibration results

It is expected that all participating laboratories will submit their calibration results **within 6 weeks** of calibration. An **MS-Excel sheet** will be provided by the pilot laboratory in which information on the participants' radiation qualities, primary standards and calibration results can be submitted.

3.7 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 International Organization for Standardization (ISO) in 1995 [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 correlation into account for the degrees of equivalence entered in the BIPM key comparison database [4], the CIPM requires 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 detail the uncertainty. The sheet should be submitted together with the calibration results.

3.8 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 and to the CCRI(I). After the agreement of the APMP and the CCRI(I), the report will be published as the Technical Supplement in *Metrologia*. In addition, the comparison results will be sent to the BIPM for inclusion in the key comparison database (KCDB).

A weighted mean of the results of each of the ISO reference qualities will provide the regional reference value for these qualities. Although regional degrees of equivalence will be evaluated for the report, they cannot be published in the KCDB for these qualities.

4. Linking of regional comparisons to international comparisons

To link the APMP/TCRI comparison (a regional comparison) to the results of the international comparison at the BIPM, one participating laboratory (the NMIJ) that has made a key comparison with the BIPM for the measurement of air kerma for low-energy x-rays is used as a "linking laboratory." 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 ratio of the air-kerma determinations of a participating NMI and the linking laboratory, which is represented numerically by the corresponding mean ratio of the calibration coefficients from the present comparison

$R_{\mathrm{Link,BIPM}}$ = the ratio of the air-kerma determinations of the linking laboratory and the BIPM obtained in the corresponding quality for the BIPM.RI(I)-K2 key comparison

$R_{\mathrm{NMI,BIPM}}$ = the derived ratio of air-kerma determinations 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 [5].

5. References

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

[2] ISO4037-1, X and gamma reference radiation for calibrating dosemeters and doserate meters and for determining their response as a function of photon energy – Part 1: Radiation characteristics and production methods, 1996.

[3] “Guide to the Expression of Uncertainty in Measurement,” International Organization of Standards, Switzerland (1995)

[4] CIPM, *Guidelines for CIPM key comparisons,* 1999, BIPM, 9 pp.

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

Address

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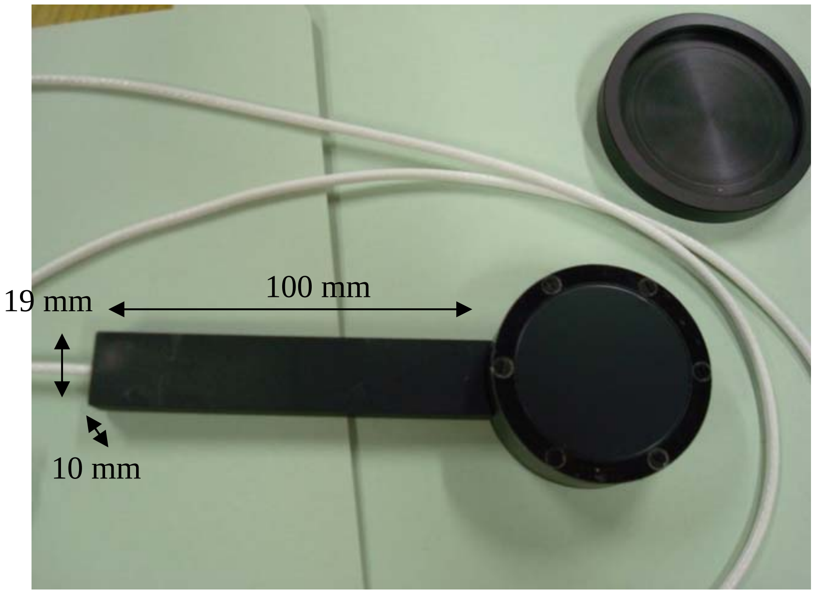
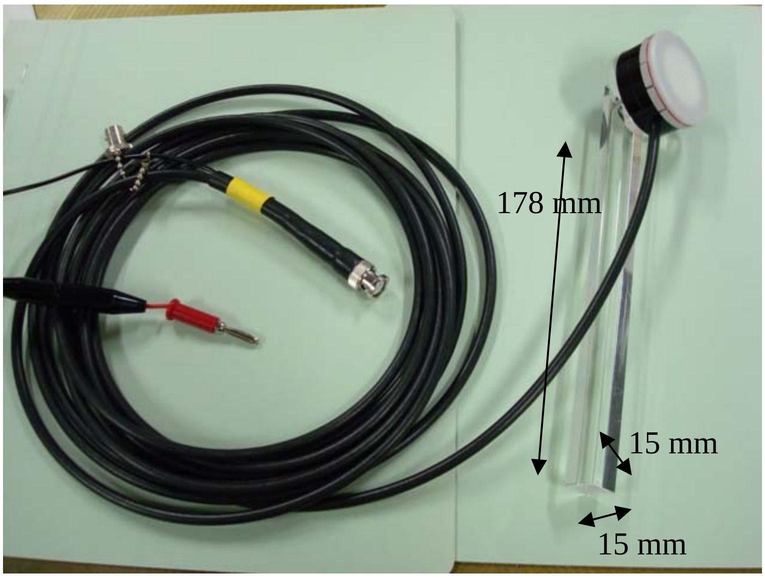
EXRADIN Magna



OYOGIKEN AE-1340C



NE 2536/3