Technical protocol of APMP key comparison for measurement of absorbed dose to water for ^{60}Co (APMP.RI(I)-K4)

1. Introduction

In recent years, the major emphasis in NMIs around the world has shifted from standards for air kerma to standards for absorbed dose to water. The rationale is to establish a better basis for dosimetry that relates directly to the quantity of interest in the clinic, absorbed dose to water [1,2]. The need for a key comparison for ionization chamber calibration in terms of absorbed dose to water came up during the APMP Workshop in 2006 when the previous attempt in 2000 was abandoned as a report could not be completed. The objective of this key comparison is to establish the degrees of equivalence of national standards and to support the CMCs lines of ionization chamber calibration used in radiotherapy for the participants. An indirect comparison of the standards of absorbed dose to water will be undertaken using three ionization chambers as transfer instruments. The results of the comparison will be given in terms of the calibration coefficients of the transfer chambers determined at the participating laboratories. Two of the laboratories (the ARPANSA and PTB) maintain primary standards for absorbed dose to water and their participation in the comparison allows the results to be linked to the key comparison data base (KCDB) of the CIPM MRA.

2. Participants

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Note: Complete addresses are given in Appendix B

3. Procedure

3.1 Comparison methodology

In this comparison, there will be a ring-shaped circulation of the transfer chambers among the participants. The chambers will be continuously tested in INER for at least 3 months before they are delivered to the participants to ensure stable performance of the chambers. Every participant should provide the calibration coefficients of transfer chambers in terms of the absorbed dose to water and air kerma for ^{60}Co. The absorbed dose to water calibration coefficient will be based on the evaluation of participants' measurement results. A three-step process to secure the stability of the chambers during the circulation period is required by:

- checking the ratio of responses of the three chambers in terms of absorbed dose (to water);
- checking the ratio of responses of the three chambers in terms of air kerma;
- checking the calibration coefficients ratio of the absorbed dose to air kerma for each chamber.

These ratios of transfer chambers calibration coefficients should be reported to INER after each participant completes the calibration. **A "Stability check" MS-Excel worksheet** will be provided by INER to let the participants fill in the calibration coefficients of transfer chambers in terms of the absorbed dose to water and air kerma for ^{60}Co. If they are within a suitable range, the chambers can be sent directly to the next laboratory. If the ratios are beyond the range, the chambers would have to be sent back to INER to be measured again.

3.2 Reference conditions

The absorbed dose to water for ^{60}Co is determined at the BIPM under reference conditions [3] defined by the Consultative Committee for Ionizing Radiation (CCRI) as:

- the distance from the source to the reference plane (the center of the detector) is 1 m;
- the field size at the reference plane is 10 cm × 10 cm;
- the reference depth in water is 5 g cm^{-2}.

The above BIPM reference distance and field size are not necessarily required at the participant's site. However, please do specify the exact conditions if they are different from those of the BIPM. The calibration coefficients of the transfer chambers for absorbed dose to water at a reference depth of 5 g cm^{-2} will be expressed in units of Gy/C and referred to standard conditions of 20°C and 101.325 kPa.

3.3 Transfer chambers

The main technical data of the three transfer chambers provided by INER for this comparison are listed in Table 1. These chambers are good representatives commonly used in clinical radiotherapy dosimetry. The chambers are circulated without an electrometer. At each laboratory, the transfer chambers are positioned with the stem perpendicular to the beam direction and with appropriate markings on both the chamber and the envelope (engraved lines or serial numbers) facing the source. A collecting voltage from the manufacturer specifications supplied at each laboratory is applied to each chamber at least 30 min before starting measurement. Each chamber has its own build-up cap for calibration in terms of air kerma. For the absorbed dose to water calibration the waterproof chamber does not need the sleeve in water phantom. **(Never leave the waterproof PTW 30013 chamber in the water phantom after finishing the calibration.)** The pilot laboratory will also provide the commercial waterproof rubber sleeves and the PMMA sleeves made by INER for the non-waterproof Farmer chambers (NE 2571 and PTW 30001) and the adaptors for switching the chamber BNT and TNC connectors as some participants requested.

Table 1. Main technical data of the transfer chambers

Type	Cavity volume	Cavity length	Cavity inside diameter	Wall material	Wall thickness	Connector	**Waterproof**	**Applied voltage***
NE 2571 (S/N 3025)	0.69 cm^3	24 mm	6.3 mm	Graphite	65 mg cm^{-2}	TNC	**No**	**+250 V**
PTW 30001 (S/N 2340)	0.60 cm^3	23 mm	6.1 mm	Acrylic/Graphite	60 mg cm^{-2}	BNT	**No**	**+400 V**
PTW 30013 (S/N 0348)	0.60 cm^3	23 mm	6.1 mm	Acrylic/Graphite	49 mg cm^{-2}	BNT	**Yes**	**+400 V**

***the central electrode is positive**

3.4 Comparison schedule

The comparison is scheduled to begin in April 2009 and expected to be completed within 14 months. The draft comparison protocol will be sent to every participant for review and comments, then the revised protocol is submitted to the CCRI(I) for approval. The total time period for chambers delivery and calibrations is about one month. Each participant should measure the transfer chambers for **no longer than 15 days.** The proposed schedule is shown in Table 2. The calibration coefficient ratios mentioned in Section 3.1 should be reported to INER to determine if the chambers should be sent directly to the next laboratory.

In order to control the progress and time of the whole comparison, INER agreed to take responsibility for the coordination and costs of transportation. To keep the comparison going as scheduled and to make sure it will be completed in Oct. 2010, any laboratory that is not able to perform the measurements according to the approved itinerary must find another participant to exchange their measurement time.

Table 2: Proposed schedule of APMP.RI(I)-K4 comparison

(Apr. 2009 until Oct. 2010)

Participant	Date of chambers arriving at participant	Measurement duration at laboratory	Date of chambers leaving for the next participant
Date of chambers leaving INER for PTB: 27-Apr-2009			
PTB	10-May-2009	11-May-2009 to 25-May-2009	26-May-2009
Nuclear Malaysia	10-Jun-2009	11-Jun-2009 to 25-Jun-2009	26-Jun-2009
AEC	10-Jul-2009	11-Jul-2009 to 25-Jul-2009	26-Jul-2009
INER	10-Aug-2009	Chambers testing	16-Aug-2009
KRISS	31-Aug-2009	01-Sep-2009 to 15-Sep -2009	16-Sep-2009
NMIJ	30-Sep-2009	01-Oct-2009 to 15-Oct-2009	16-Oct-2009
NMISA	31-Oct-2009	01-Nov-2009 to 15-Nov-2009	16-Nov-2009
INER	30-Nov-2009	Chambers testing	11-Jan-2010
Date of chambers leaving INER for PTB: 10-Feb-2010			
DMSC	28-Feb-2010	01-Mar-2010 to 15- Mar-2010	16-Mar-2010
BARC	31-Mar-2010	01-Apr-2010 to 15-Apr-2010	16-Apr-2010
NIM	30-Apr-2010	01-May-2010 to 15-May-2010	16-May-2010
BATAN	31-May-2010	01-Jun-2010 to 15-Jun-2010	16-Jun-2010
INER	30-Jun-2010 Chambers testing	16-Jul-2010 to 30-Jul-2010	31-Jul-2010

ARPANSA	15-Aug-2010	16-Aug-2010 to 30-Aug-2010	30-Aug-2010
NRL	15-Sep-2010	16-Sep-2010 to 30-Sep-2010	1-Oct-2010
INER	15-Oct-2010		

3.5 Calibration results submission

It is expected that all the participating laboratories submit calibration results within 4 weeks after the calibration. The submission must include at least the calibration coefficients (Gy C^{-1}) of the transfer chambers, the absorbed dose rate of the radiation field (mGy s^{-1}), the calibration conditions, the standard traceability and the relative standard uncertainties of absorbed dose measurements and chamber calibrations. Furthermore, it is requested that the relative humidity conditions at the time of calibration are to be stated on the results. Ideally, the relative humidity of the participating laboratories at the time of measurement should be within the range from 30 % to 70 %. To report the results, **a "Results" MS-Excel worksheet** is provided in which information about the national (primary) standards used by the participants and the calibration results can be completed.

3.6 Evaluation of measurement uncertainty

All the participating laboratories are required to evaluate the uncertainty of calibration coefficients as Type A and Type B according to the criteria of the "Guide to The Expression of Uncertainty in Measurement" issued by the International Organization for Standardization (ISO) in 1995 [4]. 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 analyze the uncertainties and take correlations into account for degrees of equivalence entered in the BIPM key comparison database [5], the CIPM has recommended that the participating laboratories submit their detailed uncertainty budgets (preferably with the relative standard uncertainties, $k = 1$) to the pilot laboratory. **The two MS-Excel worksheets "Primary standard uncertainty" and "Chamber calibration uncertainty"** will be provided by the pilot laboratory in which the participants can detail the uncertainty. The participant is allowed to flexibly adjust the analyses items in the uncertainty evaluation worksheets. **The sheets should be submitted together with the calibration results.**

3.7 The comparison report

The pilot laboratory will prepare a draft report to be circulated to all participants for comments and discussion of the results. A revised final report will be the official

report of the comparison and submitted to the APMP/TCRI Chairman and the CCRI(I). After the approval of APMP and CCRI(I), it should be published as the Technical Supplement in Metrologia journal. In addition, the comparison results will be sent to the BIPM for inclusion in the key comparison database (KCDB).

4. The linking of regional comparisons to international comparisons

To link the APMP/TCRI comparison (a regional comparison) with the BIPM (an international comparison), two participating laboratories (PTB and ARPANSA) that had made comparisons with the BIPM for the measurement of absorbed dose to water are to play the role of "linking laboratories." Then, through the following equation, the measured calibration coefficients for each laboratory will be converted to ratios relative to the BIPM;

$$R_{\mathrm{NMI,BIPM}} = R_{\mathrm{NMI,Link}} \times R_{\mathrm{Link,BIPM}} \quad . \tag{1}$$

In this equation,

$R_{\mathrm{NMI,Link}}$ = the ratio of the absorbed dose determinations from a participating NMI to that of the linking laboratory

$R_{\mathrm{Link,BIPM}}$ = the ratio of the linking laboratory and the BIPM obtained in the BIPM.RI(I)-K4 absorbed dose key comparison

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

Originally, the ARPANSA (Australia), which had made a comparison with the BIPM for the standard of absorbed dose to water in 1997 [6], was the only laboratory in the Asia-Pacific region that was eligible to be a linking laboratory. To enhance the accuracy and confidence of the whole comparison linkage with the BIPM, the PTB (Germany) was invited to take part in this APMP.RI(I)-K4 comparison. The PTB had made a bilateral comparison with the BIPM in 2005 [7]. The comparison results ARPANSA/BIPM and PTB/BIPM for absorbed dose to water will be used as the links.

5. References

[1] P. Andreo, "Absorbed dose beam quality factors for the dosimetry of high-energy photon beams," Phys. Med. Biol. 37, 2189-2211 (1992)

[2] D.W.O. Rogers, "The advantages of absorbed-dose calibration factors," Med. Phys. 19, 1227-1239 (1992)

[3] P. J. Allisy-Roberts, D. T. Burns and C. Kessler, "Measuring condition used for the calibration of ionization chambers at the BIPM," Rapport BIPM-2007/06, 20 pp

[4] "Guide to the Expression of Uncertainty in Measurement," International Organization of Standards, Switzerland (1995)

[5] P. J. Allisy-Roberts and D. T. Burns, "Summary of the BIPM.RI(I)-K4 comparison for absorbed dose to water in ^{60}Co gamma radiation", Metrologia 42**,** Tech. Suppl., 06002 (2005)

[6] P. J. Allisy-Roberts, D. T. Burns, J. F. Boas, R. B. Huntley and K. N. Wise, "Comparison of the standards of absorbed dose to water of ARPANSA and BIPM for ^{60}Co gamma radiation," Rapport BIPM-99/17 (2000)

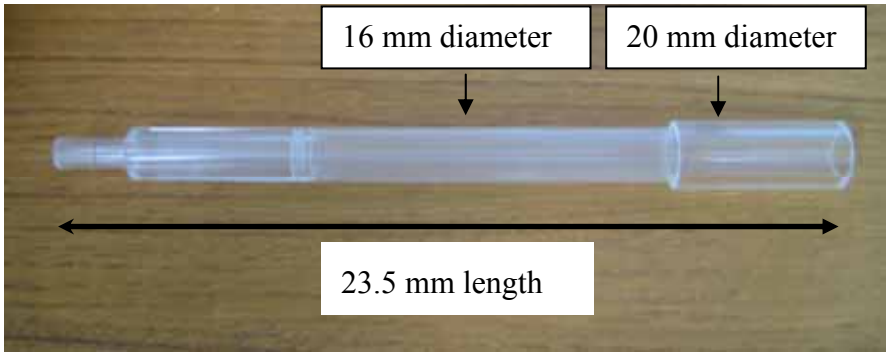
[7] C. Kessler, P. J. Allisy, D. T. Burns, A. Krauss and R.-P. Kapsch, "Comparison of the standards for absorbed dose to water of the PTB, Germany and the BIPM for ^{60}Co γ rays," Metrologia 43**,** Tech. Suppl., 06005 (2006)

APPENDIX A: Pictures of the transfer chambers

NE 2571 chamber
(S/N 3025, non-waterproof)

PTW 30001 chamber
(S/N 2340, non-waterproof)

PTW 30013 chamber
(S/N 0348, waterproof)



PMMA sleeve made by INER

APPENDIX B: Complete addresses of the participants

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