Technical protocol of the radiation therapy comparison

IAEA-SSDL bilateral comparisons for therapy level air kerma and absorbed dose to water measurement standards in ^{60}Co gamma beam

1. Introduction

The performance of laboratories providing calibrations, needs to be verified periodically through comparisons, organized by the IAEA or a Regional Metrology Organization (RMO). In order to maintain confidence in the traceability chain it is recommended for SSDLs, providing calibration service, to participate in this comparison program at least every 5 years, or whenever their reference standards, irradiation setups and/or the measurement technique have changed. The main objective of the SSDL Network is to ensure traceability of measurements for Member States, by providing the link between the end users and the International measurement System (SI). The IAEA Dosimetry Laboratory acts as a central laboratory of the IAEA/WHO SSDL Network and provides calibration, audit and comparison services for the members.

2. International measurement system

The Mutual Recognition Arrangement (MRA) provides the formal recognition of national measurement standards and calibration and measurement capabilities (CMCs) among the Member States of the International Committee for Weights and Measures (CIPM) [1]. By linking to its National Metrology Institute (NMI), any SSDL can take part in RMO comparisons. However, their results cannot be included in the Bureau International des Poids et Mesures (BIPM) key comparison database (KCDB) unless their NMI is a signatory to the MRA and the SSDL has a Designated Institute (DI) status for ionizing radiation standards.

3. Purpose of the comparison program

This ongoing therapy level comparison program of the IAEA, in line with the objectives of the IAEA/WHO SSDL Network Charter [2], aims to verify that SSDLs can carry out calibrations in terms of air kerma (K_{air}) and absorbed dose to water (D_w) within the acceptable limit and within its uncertainty claims. The comparison results, if agreed by the participating SSDL, can be published in open-access literature, for example as an annual summary report on the results of the IAEA/SSDL bilateral comparisons. The published report can be used as supporting evidence for the eligible SSDLs to publish or maintain their relevant CMCs in the KCDB of the CIPM MRA.

A ^{60}Co gamma beam is used for the comparison because most SSDLs are using this radiation quality for therapy level calibrations. Calibration coefficients for linear accelerator based high energy photon beam qualities can be calculated using appropriate radiation quality correction factors (k_Q)[3].

The IAEA is maintaining the K_{air} comparison program in addition to the D_w program because few SSDLs still calibrate the therapy level dosimeters in terms of K_{air} instead of D_w as recommended in [3]. The use of both quantities enables the SSDLs to check the consistency of the results from two different calibration procedures by comparing the ratio of calibration coefficients $N_{K,air}/N_{D,w}$ of the transfer ionization chamber to typical values.

4. Participants

4.1. Pilot laboratory: IAEA

The IAEA signed the MRA under the auspices of the CIPM in 1999. The IAEA maintains a peer reviewed quality management system (QMS) complying with the ISO/IEC 17025:2005 standard [4], and published its revised dosimetry CMC claims in the KCDB in 2016. The calibration of ionization chambers and the charge measurements performed at the IAEA are traceable to the appropriate

primary standards at the BIPM and Federal Office of Metrology in Austria (BEV), respectively. The IAEA maintains secondary standards for the determination of K_{air} free in air and D_w in 5 g/cm^2 depth in ^{60}Co gamma ray beam. It consists of Nuclear Enterprise NE-2611A model ionization chamber and Keithley 6517A electrometers.

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4.2. Participant

The yearly comparison program is announced for members of the SSDL network in the beginning of each year. A participant laboratory should have a traceable reference standard and a calibration procedure for therapy level calibration. An application should be submitted to the IAEA to participate in the comparison program. The number of accepted participants is limited and dependent on the workload. The laboratory which has not participated in the last 5 years or its last result was not acceptable, has priority in the selection.

The application should include full contact information, a shipment address, the preferred type of transfer chamber connection (TNC, BNC or M type) and the preferred time schedule. If a participant intends to use this bilateral comparison result to support CMC claims it should also be stated in the application.

5. Transfer chambers

Each comparison is conducted through the calibration of one of the IAEA transfer chambers specified in Table 1 in terms of K_{air} and/or D_w according to the standard laboratory procedures of the participant. The comparison parameters are the calibration coefficients $N_{K,air}$ and $N_{D,w,}$ of the transfer chamber and its associated uncertainties. The technical details of the transfer chambers are given in Table 1 and photos in the Figures 1 and 2.

Table 1. Technical data of the transfer chambers

Type*	Reference point	Nominal volume	Polarising Voltage**	Wall thickness	Outer diameter
Wellhöfer FC65-G Farmer type chamber	13 mm from the top on its axis (17 mm with build-up cap)	0.65 cm^3	+300 V	81 mg/cm^2 graphite	7.1 mm (15.0 with build-up cap)
PTW 30013 Farmer type chamber	13 mm from the top on its axis (17.6 mm with build-up cap	0.6 cm^3	+300 V	56.5 mg/cm^2 PMMA+graphite	6.1 mm (15.2 with build-up cap)

* More details are on the IBA website and PTW website. Both chamber types are type- tested by the PTB and comply with the IEC 60731:2011 Standard [5]. Their k_Q values for high energy photon beams are available with u_c=0.24% [6]
** This positive polarity is applied on the central electrode, i.e. collector. If an arrangement is used in which the collector is at virtual ground potential, negative polarity should be applied.

Figure 1. Transfer chamber type FC65-G

Figure 2. Transfer chamber type PTW 30013

6. Reference conditions

- The calibration coefficients for the transfer chambers should be given in terms of air kerma and absorbed dose to water at 5 cm^2/g reference depth per charge in units of mGy/nC, corrected to to standard conditions of air temperature and pressure of T = 293.15 K, P = 101.325 kPa.
- The relative air humidity should be between 30% and 70% during the calibrations.
- The recommended source to chamber distance and beam size are 100 cm and 10 cm × 10 cm, respectively.
- No correction for polarity should be applied and no correction for saturation is required if the air kerma rate is less than 2 Gy/s.
- If any additional correction factors are applied, they shall be stated in the data sheet (DOLF.1402).

7. Work flow of the comparison

7.1. Calibrations at the IAEA

For the purpose of a constancy check, the IAEA repeats the calibrations before and after return of the transfer chamber and uses the average of the two calibrations. Details of the IAEA calibration procedure are available in the Appendix of the IAEA calibration certificate [7].

7.2. Shipment

The IAEA schedules each comparison and informs the participating SSDL by email of the shipment of the package. The IAEA covers the shipment costs from the IAEA to participants, including insurance (the insurance value of a transfer chamber is 2000 euro). All other potential costs associated with transportation (customs procedures, deposition fee etc.) shall be paid by the participant. Each participating SSDL is responsible for any damage that may occur within the borders of its country. Participants shall confirm the receipt of the transfer instruments and their correct functioning by email using the IAEA contact.

7.3. Preliminary tests

The procedure to verify the correct functioning of the transfer chamber is as follows.

- Measure your electrometer leakage together with the connected extension cable in the most sensitive range. Please note that the cable should be fitted with its protective cap when it is not used.
- Connect the cable of the transfer chamber to your extension cable, (avoid using adapter(s) as much as possible), switch on the polarizing potential, wait at least 10 minutes and measure the leakage again.
- If the difference between the two leakages is more than 20 fA, report it to the IAEA.
- The sensitivity of the transfer chamber can also be checked in a radiation beam before a full calibration is made. The nominal sensitivity of both types of transfer chambers is about 20nC/Gy.
- Never use or store the transfer chamber where the relative humidity is higher than 80%, and remove it from the water phantom as soon as each D_w measurement is completed.

7.4. Calibration in the participant laboratory

The transfer chambers shall be calibrated by the participant in ^{60}Co beam using their own protocol. The minimum air kerma rate at 1 meter distance from the ^{60}Co source required for the comparison measurements is 30 mGy/min. Participant should provide technical details of the waterproof sleeve in the data sheet if it is used for the D_w measurement. The calibration should be repeated twice. Between these repeated calibrations, the chamber shall be removed from the beam and repositioned.

The laboratory details and calibration data shall be reported to the IAEA using the data sheet DOLF.1402. The participating SSDL has four weeks to complete the calibrations and send the preliminary result by email using the data sheet. This data sheet should be send to IAEA before the chamber is send back.

If the preliminary comparison results are acceptable, the IAEA will inform the participant and asks to send back the transfer chamber together with the signed hard copy of the data sheet. The participant confirms the shipment by sending an email with an enclosed tracking number of the package to the IAEA contact.

If a preliminary comparison result is not within the acceptance limits, the IAEA informs the participant about it, without disclosing the details of the deviations. In this case, additional two weeks are available for the participant to investigate the measurements (setup, calculations, uncertainties etc. or repeat some measurements). However, after that, the transfer chamber should be sent back to the IAEA together with the signed hard copy of the data sheet.

7.5. Uncertainty estimation of the calibration coefficient

The participant should provide a full uncertainty budget of the calibration coefficient including all the components related to the applied calibration method and the environmental conditions at the SSDL. Uncertainty estimations for the comparison measurements performed by the participants should follow the GUM: Guide to the Expression of Uncertainty in Measurement [8], and include those uncertainty components and values which are used for the relevant routine calibrations. Participants can find help for preparing their individual uncertainty budgets in the following references: Table 2 of IAEA Technical Report Series no. 469 [9], Appendix II and III of IAEA-TECDOC-1585 [10], report of EURAMET.RI(I)-K1 and K4 key comparisons [11].

7.6. Data evaluation and analysis

The IAEA calibration coefficients, N_{ref}, are the comparison reference values. The result of the comparison is $R=N_{part}/N_{ref}$, where N_{part} is the calibration coefficient determined by the participant. The IAEA secondary standard is traceable to the BIPM both in terms of K_{air} and D_w. If the participant laboratory is not traceable to BIPM directly, a correction for the difference in traceability chains may be required and this is done during the data analysis at the IAEA.

Differences in the traceability chain will be taken into account by using the published data available about degrees of equivalence between the relevant primary standards. If the traceability chain is the same as that of the IAEA, some uncertainty components are correlated but this is not taken into account in the uncertainty calculation of R. The expanded uncertainty of the comparison result, U_R, is calculated as a square sum of the uncertainties of the calibration coefficients.

7.7. Acceptance limit

The comparison result R is considered to be acceptable if it is: (i) consistent i. e. the expanded uncertainty of the R covers the unit value and (ii) $0.985 \leq R \leq 1.015$. This acceptance limit enables the SSDL to maintain reliable and accurate calibration services for therapy level dosimeters.

The ±1.5% acceptance limit for R is established taking into account: (i) the available calibration uncertainties from the PSDLs; (ii) the reference quality of the transfer chamber; (iii) the good calibration practice at the participating SSDLs [3 and 9] and (iv) the uncertainties of the $N_{ref,}$ determinations. Details of the IAEA uncertainties are available in the Appendix 3A of the IAEA Therapy calibration certificate [7].

7.8. Acceptance of results

The final results are analysed after the re-calibration of the transfer chamber in the IAEA. The stability of the transfer chamber during the comparison is acceptable if the difference in the IAEA values before and after the transportation is less than 0.2%. If the stability of the transfer chamber is questionable after further analysis of the measurement data, a repetition of the comparison with another transfer chamber is offered by the IAEA.

If the comparison result is not within the acceptance limits, the discrepancies require comprehensive investigation of the details before the IAEA issue the report of the comparison results. The process of reconciliation is a collaborative effort with the IAEA attempting to help the SSDL understand the cause of the deviation.

7.9. Report on the comparison

If the stability of the transfer chamber and the comparison results are acceptable, the IAEA prepares the comparison report for the participant. This report is provided only to the participant and the results are not disclosed to any third party. If a participant wants to publish the comparison as a separate publication, the IAEA will assist, upon request.

References

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