Technical protocol of the radiation therapy comparison

IAEA-SSDL bilateral comparisons for radiation 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 validated periodically and one method is to participate in an intercomparisons. In order to maintain confidence in the measurement capability it is recommended for SSDLs, providing this calibration service, to participate in this comparison programme at least once 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 measurement traceability by providing a 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 Network members.

2. International measurement system

In 1999, the International Committee for Weights and Measures (CIPM) established a mutual recognition arrangement (CIPM MRA) [1] for Member States of the Metre Convention and Associate States of the General Conference of Weights and Measures. The CIPM MRA provides a possibility for the eligible SSDLs to get an international approval for their calibration and measurement capabilities (CMCs). To achieve international recognition within the CIPM MRA, a laboratory has to take part in a relevant measurement comparison and demonstrate the quality of their measurements through a quality management system (QMS) in line with the ISO/IEC 17025.

3. Purpose of the comparison programme

This ongoing radiation therapy level comparison programme of the IAEA, in line with the objectives of the IAEA/WHO SSDL Network Charter [2], aims to validate the measurement capabilities of SSDL for calibrations performed in terms of air kerma (K_{air}) and absorbed dose to water (D_w), is within the acceptable limit and within the uncertainty claims of the SSDL. Based on the request, the exercise can be organized as a bilateral comparison (the results are restricted) or the participant may request to use the result to support their CMCs (the results are published). A ^{60}Co gamma beam is used for the comparison.

The comparison results, if agreed by the participating SSDL, can be published in open-access literature for example as a biannual summary report on 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.

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 17025:2017 standard [3] and has some of their dosimetry measurement capabilities published in the KCDB.

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 water at 5 g/cm^2 depth in a ^{60}Co gamma ray beam. It consists of Nuclear Enterprise NE-2611 model ionization chamber.

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4.2. Participant

The IAEA comparison programme is an ongoing service for members of the SSDL Network. A participant laboratory should have a traceable reference standard and a calibration procedure for radiation therapy level calibration. A comparison request form should be submitted to the IAEA to participate in the comparison programme. The number of accepted participants is limited and dependent on the workload and source availability. The laboratory which has not participated in the last 5 years, or its last result was not acceptable, has priority in the selection.

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

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 calibration procedures of the participant. The comparison parameters are the calibration coefficients N_K 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
IBA 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	-400 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 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.
- If any additional correction factors are applied, they shall be stated in the data sheet (DOLF.1402).

7. Workflow 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 the 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. The participants are responsible for the shipment costs related to the return of the transfer instruments back to the IAEA.

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 covered 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 20 nC/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 routine calibration procedure. 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 sent to the IAEA before the chamber is returned.

After the preliminary comparison results are received and reviewed, the IAEA will inform the participant and request for the transfer chamber to be shipped back to the IAEA. The participant confirms the shipment by sending an email with an enclosed tracking number of the package to the IAEA contact.

If the 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.

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 from the uncertainty budgets of the IAEA calibrations (Appendix of the IAEA Calibration Certificate) [7], IAEA Technical Report Series no. 469 [9] or IAEA-TECDOC-1585 [10].

7.6. Data evaluation and analysis

The IAEA calibration coefficients, N(IAEA) are the comparison reference values. The result of the comparison is $R = N(\text{SSDL}) / N(\text{IAEA})$, where N(SSDL) is the calibration coefficient determined by the participant. N is a general symbol for a calibration coefficient and subscript is used to specify the quantity (N_K for K_{air} and $N_{D,w}$ for D_w). The IAEA secondary standard is traceable to the BIPM both in terms of K_{air} and D_w.

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 and this is included in the standard comparison report. However, it is analysed and considered separately if the participant wants to use the comparison to support their CMCs. The degree of equivalence, as determined for the key comparison, is not calculated.

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 radiation 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 radiation therapy calibration certificate [7].

7.8. Acceptance of results

The final results are analysed after the re-calibration of the transfer chamber at 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 the participant wants to use their result to support their CMCs, the participant needs to provide a short procedure of their measurement process to be used for issuing an appendix to the report. The comparison data may be published with the consent of the participants.

References

[1] Mutual recognition of national measurement standards and of calibration and measurement certificates issued by national metrology institutes http://www.bipm.org/en/cipm-mra/cipm-mra-text/

[2] IAEA/WHO Network of Secondary Standard Dosimetry Laboratories, SSDL Network Charter 2nd edition, IAEA, Vienna (2018). https://ssdl.iaea.org/Home/SSDLNetworkCharter

[3] IAEA Technical Report Series no. 398, Absorbed dose determination in External Beam Radiotherapy, IAEA, Vienna (2000). https://www-pub.iaea.org/MTCD/Publications/PDF/TRS398_scr.pdf

[4] ISO/IEC 17025:2017 General requirements for the competence of testing and calibration laboratories, Geneva (2017).

[5] IEC 60731 Ed. 3.0 Dosimeters with ionization chambers as used in radiotherapy, Geneva (2011)

[6] Malcolm et al. Addendum to the AAPM`s TG-51 protocol for clinical reference dosimetry of high energy photon beams. Med. Phys. 41 (4), (2014)

[7] Appendix to IAEA Calibration Certificate: Radiotherapy ionization chamber calibration procedures at the IAEA Dosimetry Laboratory. https://ssdl.iaea.org/Content/DOLP_011_Appendix_3A.pdf

[8] ISO/IEC Guide 98-3:2008, JCGM 100:2008, Evaluation of measurement data- Guide to the Expression of Uncertainty of Measurement, Geneva (2008) http://www.bipm.org/en/publications/guides/gum.html

[9] IAEA Technical report Series no. 469, Calibration of Reference Dosimeters for External Beam Radiotherapy, IAEA, Vienna (2009). http://www-pub.iaea.org/MTCD/publications/PDF/trs469_web.pdf

[10] IAEA-TECDOC-1585, Measurement Uncertainty: A Practical Guide for Secondary Standards Dosimetry Laboratories, IAEA, Vienna (2008). http://www-pub.iaea.org/MTCD/publications/PDF/te_1585_web.pdf