Technical protocol of a brachytherapy comparison

IAEA-SSDL bilateral comparisons for brachytherapy well type standards using ^{60}Co and ^{192}Ir sources

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 brachytherapy 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 SSDLs reference air kerma rate ($\dot{K}_R$) within the acceptable limit and within the uncertainty claims of the laboratory. 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). Laboratories may use the IAEA TECDOC-1274 guidance document when setting up their capability. A ^{60}Co and/or ^{192}Ir source 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 results of the IAEA/SSDL bilateral comparisons. The published report may 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 [4] and has some of their dosimetry measurement capabilities published in the KCDB.

The calibration of well type chambers and the charge measurements performed at the IAEA are traceable to the appropriate primary standards at the PTB Braunschweig (GER) and Federal Office of Metrology in Austria (BEV), respectively. The IAEA maintains secondary standards for the determination of $\dot{K}_R$ for ^{60}Co and ^{192}Ir sources. It consists of model HDR-1000 Plus well type chamber and UNIDOS Tango electrometer.

IAEA contact information:

Email: ssdl @iaea.org
Subject: IAEA/SSDL bilateral comparisons for radiation therapy dosimetry

Postal address:
Dosimetry Laboratory
Mr. Ladislav Czap
IAEA Laboratories Seibersdorf
Friedensstraβe 1
A-2444 Seibersdorf
AUSTRIA.

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 brachytherapy 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 $\dot{K}_R$ according to the standard calibration procedures of the participant. The comparison parameters are the calibration coefficients, N_{KR}, of the transfer chamber and a detailed measurement uncertainty budget. The technical details of the transfer chambers are given in Table 1 and photos in the Figures 1.

Table 1. Technical data of the transfer chambers

Type*	Sweet spot	Nominal volume (cm^3)	Polarising Voltage**	Inner diameter/ Cavity length (mm)	Insert type/ Inner diameter/ Cavity length
Standard Imaging HDR 1000 Plus	~ 50 mm	245	+300 V	102/156	70010 or 70110/35/121

** 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. Well type chamber used for brachytherapy calibration

6. Reference conditions

- The calibration coefficients for the transfer chambers should be given in terms of reference air kerma at a sweet spot determined by the laboratory in units of $(\mu Gy/h).nA^{-1}$ or mGy/nC, corrected to standard conditions of air temperature and pressure, T = 293.15 K, P = 101.325 kPa.
- The relative air humidity should be between 30 % and 70 % during the calibrations.
- If any additional correction factors are applied, they shall be stated in the data sheet (DOLF.1404).

7. Workflow of the comparison

7.1. Calibrations at the IAEA

For a constancy check, the IAEA performs the calibrations before and after return of the transfer chamber and uses the average of the two calibrations to determine the performance of a laboratory. Should the chamber be returned when the source has been changed, the data for the loaded source shall be used and compared with the previous data to establish consistency of the chamber. Details of the IAEA calibration procedure are available in the Appendix of the IAEA calibration certificate [5].

7.2. Shipment

The IAEA schedules each comparison and informs the participating SSDL by email of the schedule and shipment of the package. The IAEA covers the shipment costs from the IAEA to participants, including insurance. All other potential costs associated with transportation (e.g. customs procedures,

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 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 the transfer chambers is about 1.97×10^{10} nA/Bq (7.3 nA/Ci) [6].
- Never use or store the transfer chamber where the relative humidity is higher than 80 %.

7.4. Calibration in the participant laboratory

The transfer chambers shall be calibrated by the participant following their own routine calibration procedure. Each participant shall determine the maximum response source position (sweet spot) with their system. Participant should provide technical details of the insert used during the measurement. The calibration should be repeated twice. Between these repeated calibrations, the source shall be removed from the chamber and repositioned.

The laboratory details and calibration data shall be reported to the IAEA using the data sheet DOLF.1404. 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 IAEA before the chamber is returned. The source model used by a laboratory shall be reported to the IAEA together with the results.

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 detailed 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 at the IAEA are performed following the GUM: Guide to the Expression of Uncertainty in Measurement [7] 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) [5], IAEA-TECDOC-1585 [7].

7.6. Data evaluation and analysis

The IAEA calibration coefficients, N(IAEA) are the comparison reference values. The result of the comparison is $R = N$(SSDL) / N(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_{KR} for *Reference Air Kerma (RAK)*). The IAEA secondary standard is traceable to the PTB. The source geometry factor will be considered where needed for those sources where data is available.

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, are 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) $0.965 \leq R \leq 1.035$. This acceptance limit enables the SSDL to maintain reliable and accurate calibration services for radiation therapy level dosimeters.

The ± 3.5 % 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 and (iv) the uncertainties of the $N_{KR,}$ determinations. Details of the IAEA uncertainties are available in the Appendix B of the IAEA brachytherapy calibration certificate [5].

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] International Atomic Energy Agency, Calibration of Photons and Beta Ray Sources used in Brachytherapy, TECDOC-1274, IAEA, Vienna (2002).
[4] ISO/IEC 17025:2017 General requirements for the competence of testing and calibration laboratories, Geneva (2017).
[5] Appendix to IAEA Calibration Certificate: Brachytherapy well-type chamber calibration procedures at the IAEA Dosimetry Laboratory. https://ssdl.iaea.org/Content/DOLP_012_Appendix_B.pdf
[6] Vandana, S & Sharma, Drdk. (2010). Long term stability of a well type ionization chamber used in calibration of high dose rate brachytherapy sources. Journal of medical physics / Association of Medical Physicists of India. 35. 100-3. 10.4103/0971-6203.62200.
[7] 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
[8] 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
[9] Shipley DR, Sander T, Nutbrown RF. Source geometry factors for HDR ^{192}Ir brachytherapy secondary standard well-type ionization chamber calibrations. Phys Med Biol. 2015 Mar 21;60(6):2573-86. doi: 10.1088/0031-9155/60/6/2573. Epub 2015 Mar 12. PMID: 25761529.