Technical protocol of the radiation protection comparison

IAEA-SSDL bilateral comparisons for radiation protection level air kerma measurement standards

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 protection 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 SSDLs for calibrations performed in terms of air kerma for radiation protection level, is within acceptable limits 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).

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 performed at the IAEA are traceable to the primary standard at the BIPM for ^{137}Cs radiation beam and to PTB for the ISO Narrow beam series X ray radiation qualities. The charge measurement is traceable to the Federal Office of Metrology in Austria (BEV). The IAEA maintains a secondary standard for the determination of air kerma at radiation protection level for the radiation beams in ^{137}Cs,

^{60}Co and X ray (ISO Narrow beam qualities). It consists of PTW LS-01 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 protection level calibrations. 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 chamber and radiation qualities

Each comparison is conducted through the calibration of a transfer chamber in terms of air kerma according to the standard calibration procedure of the participant. The comparison parameters are the calibration coefficients of the transfer chambers and its associated uncertainty. The technical details of the chambers are given in Table 1 and their photos in Figures 1 and 2.

The participant decides on how many radiation qualities to request for the comparison according to the available radiation qualities and calibration services in their laboratories. Table 2 lists all the available radiation beam qualities for the comparison.

Table 1. Technical data for the transfer chambers

Type	**Reference point**	**Nominal volume (cm^3)**	**Polarizing voltage*** **(V)**	**Wall thickness material** (mm)	**Outer diameter (mm)**
Exradin A6, spherical chamber	chamber centre	800	+400	3.0 C552**	120.4
PTW LS01***	chamber centre	1000	+400	3 mm POM (polyoxymethylene)	140

* This positive polarity is applied to the collector. If an arrangement is used in which the collector is at virtual ground potential, then a negative polarity should be applied.
**Shonka air-equivalent plastic
*** Used only for those with M type connectors

Figure 1. Transfer chamber type Exradin A6

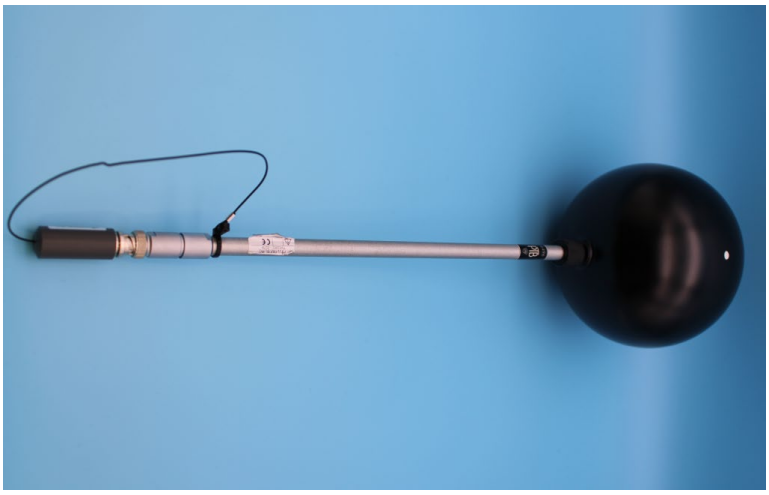

Figure 2. Transfer chamber type PTW 32002 (LS01)

Table 2. Radiation qualities available for the comparison

Radiation quality*	**Tube voltage (kV)**	**Mean energy E (keV)**	**Air kerma rate IAEA (2.5 m distance) (µGy/min)**	**1st HVL IAEA (mm)**	**1st HVL ISO 4037 (mm)**	**IAEA standard traceability**
N-40	40	33	~200	2.69 Al	2.65 Al	PTB
N-80	80	65	~200	0.59 Cu	0.58 Cu	PTB
N-100	100	83	~100	1.09 Cu	1.09 Cu	PTB
N-200	200	164	~200	4.14 Cu	3.91 Cu	PTB
N-300	300	250	~200	6.32 Cu	5.94 Cu	PTB
Gamma ray qualities						
Radiocuclide	**Photon energy (keV)**		**Air kerma rate IAEA (2.5 m distance) (µGy/min)**			**IAEA standard traceability**
^{137}Cs	661.6		~78			BIPM

* ISO 4037 Part 1 Narrow-spectrum X-ray radiation qualities [4]

6. Reference conditions

- The calibration coefficients for the transfer chamber should be given in terms of air kerma per charge in units of µGy/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 selected focus to chamber distance and field size should ensure a uniform irradiation of the transfer chambers.
- The mark on the stem of the chamber shall face the radiation source.
- If any additional correction factors are applied, they shall be stated in the Excel worksheets for data record and evaluation of comparison measurements (DOLF. 1403).

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 [5].

7.2. Shipment

The IAEA schedules each comparison and informs the participating SSDL by email on 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 3000 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 each transfer chamber is as follows.

- Measure your electrometer leakage together with the connected extension cable on the most sensitive range. Please note that the cable should be covered with the protective cap when it is not used.
- Connect the cable of the transfer chamber to your extension cable, 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 50 fA, report it to the IAEA.
- The sensitivities of the transfer chambers can also be checked in a radiation beam before a full calibration is made. The nominal sensitivity value of the Exradin A6 transfer chamber is 26 μC/Gy and 40 μC/Gy for the LS01.

7.4. Calibration in the participant laboratory

The transfer chamber shall be calibrated by the participant in the selected radiation qualities from Table 2, using their own routine calibration procedure. For each radiation quality 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.1403. 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.

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 a 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 [6] and include an estimation of those uncertainty components and values which are used for the relevant routine calibration. 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].

7.6. Data evaluation and analysis

The IAEA calibration coefficients, N_K(IAEA) are the comparison reference values. The result of the comparison is $R = N_K(\text{SSDL}) / N_K(\text{IAEA})$, where N_K(SSDL) is the calibration coefficient determined by the participant. The IAEA secondary standard is traceable to the BIPM for ^{137}Cs radiation beam and to the PTB for the X ray ISO Narrow beam.

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 consistent i. e. the expanded uncertainty of the R covers the unit value, and if $0.97 \leq R \leq 1.03$. This acceptance limit enables the SSDL to maintain reliable and accurate calibration services in terms of air kerma for radiation protection level.

The ± 3.0 % acceptance limit for R is established taking into account (i) the available calibration uncertainties from the PSDLs; (ii) the reference quality of the Exradin type of transfer chambers; (iii) the good calibration practice at participant SSDL [7], and (iv) the uncertainty of the N_{ref} determination. Details of the IAEA uncertainties are available in the Appendix of the IAEA 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 0.5 %. 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] ISO/IEC 17025:2017 General requirements for the competence of testing and calibration laboratories, Geneva (2017)

[4] INTERNATIONAL ORGANIZATION FOR STANDARDIZATION, Radiological protection – X and gamma reference radiation for calibrating dosemeters and doserate meters and for determining their response as a function of photon energy, ISO 4037 Parts 1-3, Geneva (2019).

[5] Appendix of the IAEA Calibration Certificate: Calibration of reference dosimeters for diagnostic radiology at the IAEA Dosimetry Laboratory https://ssdl.iaea.org/Content/DOLP_011_Appendix_3B.pdf

[6] 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

[7] IAEA Safety Report Series No. 16, Calibration of radiation protection monitoring instruments. IAEA, Vienna (2000) http://www-pub.iaea.org/MTCD/Publications/PDF/P074_scr.pdf