GULFMET Technical protocol of the radiation protection comparison

GULFMET.RI(I)-K5: Key Comparison of Radiation Protection Air Kerma Standards in ^{137}Cs gamma radiation

Contents

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1. Introduction

One of the main objectives of the SSDL Network [1] is to ensure traceability of measurements for the Member States, by providing the link between the end-users and the international measurement System (SI). The performance of laboratories providing calibrations needs to be verified periodically through comparisons organized by the IAEA or a Regional Metrology Organization (RMO), such as GULFMET which is linked to the BIPM. In order to maintain confidence in the traceability chain, it is recommended for SSDLs, providing calibration services, 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.

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) [2]. 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 institute is a signatory of the CIPM MRA as NMI (National Metrology Institute) or DI (Designated Institute) for ionizing radiation standards.

3. Purpose of the comparison program

This ongoing radiation protection comparison program organized by GULFMET TC IR, in line with the objectives of the IAEA/WHO SSDL Network Charter [1], aims to verify that SSDLs can carry out calibrations in terms of dose equivalent operational quantities established by the International Commission on Radiological Units (ICRU) for photon radiation within acceptable limits and within its uncertainty claims, and to validate the traceability of the participant's radiation protection level standards.

Since the appropriate operational quantities can be derived from the air kerma free in air by the application of the conversion coefficients published in the ISO 4037 Part 3 [3], the calibration practice of the radiation protection proposed dosimeters in terms of operational quantities at the SSDLs is based on the reference air kerma/kerma rate determination. Because the same conversion coefficients and associated uncertainties are applied, this comparison for the air kerma measurement can additionally support the relevant calibration services of SSDLs in terms of dose equivalent operational quantities. The comparison results, if desired by the participant, can be published in open-access literature, for example as a summary report on the GULFMET Key comparisons, and 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 in the comparison

4.1. Pilot laboratory: KFSHRC's SSDL (Saudi Arabia) hereafter as Pilot Lab

The KFSHRC's SSDL is a member of the IAEA/WHO Network of SSDLs since 1988. The SSDL maintains a peer-reviewed quality management system (QMS) complying with the ISO/IEC 17025:2017 standard [4]. The calibration of ionization chambers performed at the Pilot Lab are traceable to the IAEA whose standards are traceable to the primary standard at the BIPM for ^{137}Cs radiation beam and at the PTB for the ISO Narrow beam series X-ray beam qualities. The charge measurement is traceable to the Federal Office of Metrology in Austria (BEV). The Pilot Lab maintains a secondary standard for the determination of air kerma, ambient dose equivalent, and personal dose equivalent at radiation protection level for ^{137}Cs and ^{60}Co gamma radiation beams, and for the ISO Narrow beam series X-ray radiation qualities. It consists of a PTW 32002 model ionization chamber and a Keysight B2987A electrometer.

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Subject: GULFMET Key Comparisons for Radiation Protection Field

4.2. Postal address:

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4.3. Participants

The supplementary comparison program is announced for the GULFMET members at the beginning of 2022. A participant laboratory should have a traceable reference standard and a calibration procedure for radiation protection levels. An application should be submitted through GULFMET ILC webpage to the GULFMET TC IR secretariat to participate in the comparison program. The number of accepted participants is limited and dependent on the workload. The laboratories which have not participated in the last 5 years to any intercomparison or their last result was not acceptable, have priority in the selection.

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

The list of participants along with their data and the comparison schedule is given in table1.

The PTB, German Primary Standard Dosimetry Laboratory, is participating in this comparison as a linking laboratory as it is holding a key reference value and is linked to BIPM valid comparison [6].

Table 1. *Participants to the GULFMET Radiation Protection Comparison 2022*

No	Lab Name	Country	Role*	Contact person	Contact person (e-mail)
1	IMBIH SSDL	Bosnia and Herzegovina	P	Amra Šabeta	amra.sabeta@met.gov.ba
2	PTB	Germany	K.R	Stefan Pojtinger	*stefan.pojtinger@ptb.de*
3	Jordan SSDL	Jordan	P	Alaa Aladwan	alaa.aladwan@jaec.gov.jo
4	Kuwait SSDL	Kuwait	P	Elham Al Fares	*ealfares2002@yahoo.com*
5	KFSHRC SSDL	Saudi Arabia	P.L	Mehenna Arib	*marib@kfshrc.edu.sa*
6	KACST	Saudi Arabia	P	Mansour Almurayshid	*malmurayshid@kacst.edu.sa*
7	TENMAK-NÜKEN (Ankara-SSDL)	Turkey	P	Çiğdem Yıldız	cigdem.yildiz@tenmak.gov.tr
8	FANR SSDL	United Arab Emirates	P	Samia Mohamed	*samia.mohamed@fanr.gov.ae*
9	Uzbek SSDL	Uzbekistan	P	Azamat Taubaldiev	*t.azamat @nim.uz*

* P: Participant K.R: Key Reference P.L: Pilot Lab,

5. Transfer chamber and radiation qualities

The comparison is conducted through the calibration of one robust reference quality transfer chamber in terms of air kerma according to the participants' laboratory procedure. The comparison parameters are the calibration coefficient of the transfer chamber for the ^{137}Cs gamma radiation and its associated uncertainty. The technical details of the chamber are given in Table 2 and its photo in Figure 1.

Table 2. *Technical data for the transfer chambers*

Type	Reference point	Nominal volume (cm^3)	Polarizing voltage* (V)	Wall thickness material (mm)	Outer diameter (mm)	Connector type
PTW 32002, spherical ionization chamber	Chamber Centre	1000	-300	3.0 POM**	140	TNC

* This negative polarity is applied to the chamber wall.
** polyoxymethylene

Table 3. *Radiation quality available for the comparison*

Radiation quality*	Radionuclide	Mean photon energy (keV)	Air kerma rate Pilot Lab (3 m distance) (mGy/h)	Pilot Lab standard traceability**
S-Cs	^{137}Cs	661.7	13.1	IAEA

* As described in ISO 4037 [5].
** The traceability is established through calibration at the IAEA Dosimetry Lab

Figure 1. Transfer chamber type PTW 32002

6. Reference conditions

- The calibration coefficients for the transfer chambers should be given in terms of air kerma per charge in units of mGy/nC, corrected to standard conditions of air temperature and pressure of T = 20ºC (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 is 300 cm for the ^{137}Cs radiation quality.
- The minimum beam diameter at the chamber position is 20 cm and the beam homogeneity should be 5 % or better, to ensure the uniform irradiation of the transfer chamber.
- The air kerma rates should not be less than 0.5 mGy/h.
- The reference point for positioning the chambers in the beams will be the geometrical center of the chamber’s cavity.
- The mark on the stem of the PTW 32002 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.

7. Workflow of the comparison

7.1. Calibrations at the Pilot Lab

The pilot laboratory will participate in the comparison. For the purpose of a constancy check, it repeats the calibrations before and after the return of the transfer chamber and performs check source measurements using a radioactive check device ^{90}Sr source of type T48010, along with the chamber holding device of type T48001. These data will form the basis of the uncertainty estimate for chamber stability entering in the data analysis. To avoid any conflict of interest, the first results of these calibrations are sent to the IAEA dosimetry laboratory which keeps the data until the final analysis of the comparison results. Details of the pilot laboratory calibration procedure are available in Appendix A.

7.2. Calibrations at the Linking Lab

As stated before, the PTB, German Primary Standard Dosimetry Laboratory, is participating in this comparison as a linking laboratory as it has its degree of equivalence for air kerma published in the BIPM key comparison database (KCDB) [6]. This value will be used to calculate the degree of equivalence for all the participating laboratories, using the BIPM guidelines [7] and their updated version [8].

7.3. Comparison schedule

The comparison schedule is given in table 4. If a participant is not able to perform the measurements according to the approved schedule, it must notify the pilot laboratory and, if possible, find another participant to exchange their time slot.

Table 4. *Workflow of the Comparison*

No.	Participant	Measurement at the Participant's Laboratory	Transfer to the next participant or to the Pilot Laboratory	Done
1	KFSHRC SSDL	May-2022	June-2022	✓
2	KACST (Saudi Arabia)	June-2022	July-2022	✓
3	FANR SSDL (UAE)	July-2022	Aug-2022	✓
4	Jordan SSDL (Jordan)	Aug-2022	Sept-2022	✓
5	KFSHRC SSDL	Sep-2022	Oct-2022	✓
6	PTB PSDL (Germany)	Oct-2022	Dec-2022	✓*
7	TENMAK-NÜKEN (Ankara-SSDL)	April-2023	July-2023	✓**
9	Uzbek SSDL (Uzbekistan)	Jul-2023	Aug-2023	✓
8	IMBIH SSDL (Bosnia & Herzegovina)	August-2023	Sept-2023	✓
10	KFSHRC SSDL	Sept-2023	Nov	✓
11	Kuwait SSDL (Kuwait)	Nov-2023	Dec-2023	
12	KFSHRC SSDL	Dec-2023	-	

*** Returned Dec 2022 to KSA → Unable to clear it → back to PTB in March 2023**
**** Delayed because of Customs clearance**

7.4. Shipment

The Pilot Lab schedules each comparison and informs the participating SSDL using the GULFMET platform on the shipment of the package. In addition, an email is sent to the participant. The pilot Laboratory covers the shipment to the next participant and each participant covers the shipment costs from its own laboratory to the next participant, including insurance (the insurance value of a transfer chamber is 3000 euros). All other potential costs associated with transportation (customs procedures, deposition fee, etc.) shall also 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 instrument and their correct functioning, by the GULFMET ILC webpage and email

7.5. Preliminary tests

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

- The transfer chamber shall be placed in the laboratory at least 12 hours before the measurement is started, to allow it acclimatize with the room temperature.
- The electrometer, with the transfer chamber connected and the high voltage applied, shall be warmed up for at least 2 hours. This will allow the whole ionizing current measurement system stabilize.
- Measure your electrometer leakage together with the connected extension cable on the most sensitive range. Please note that the cable should be terminated 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 Pilot Laboratory
- 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 PTW 32002 transfer chamber is 40 x 10^{-6} C/Gy.
- At least 10 repeated measurements should be taken to form a set of measurement for the transfer chamber.

7.6. Calibration in the participant laboratory

The PTW 32002 S/N 00765 transfer chamber shall be calibrated by the participant for the ^{137}Cs gamma radiation, using the routine calibration procedure. 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 Pilot Lab using the data sheet given in Appendix B. (An excel file will be provided)

The participating SSDL has three weeks to complete the calibrations and send the artefact back to the pilot Laboratory or to the next participant. The participant confirms the shipment using the GULFMET ILC platform with an enclosed tracking number of the package.

The results of the calibrations should be reported through the GULFMET ILC platform and an electronically signed datasheet along with a copy of the calibration certificates, as issued by the SSDL, should be sent to the Pilot Laboratory not later than two weeks after shipment of the artefact.

The results of the calibrations shall not be revealed to any participant during the course of the comparison except to the Pilot Laboratory

All the data will be revealed to all the participants after the comparison.

7.7. 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 [9], 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 in the IAEA TECDOC 1585 [10] and may use also the IAEA Appendix to IAEA calibration certificate [11].

7.8. Data evaluation and analysis

After the comparison is completed, the pilot laboratory will evaluate the comparison by analyzing the report of results submitted by the participants.

The comparison of the national standards will be based on the average of the calibration coefficients in terms of air kerma. The degrees of equivalence for each participating laboratory will be evaluated based on the normalized results of the linking laboratory (PTB) according to its degrees of equivalence published for air kerma quantity in the KCDB [6], according to the procedure given in [8], considering one transfer instrument and one linking laboratory.

Further details will be provided in Draft A report.

7.9. Report on the comparison

If the stability of the transfer chamber is acceptable, the Pilot Lab, in cooperation with the GULFMET secretary, prepares the comparison certificate for each participant. An overall comparison report is prepared by the Pilot Laboratory This report, including all the comparison data, is provided to all the participants and the results are not disclosed to any third party.

7.10. Publication of the comparison results

The pilot laboratory will prepare the Draft A report of the comparison and circulate the report among participants for comments and corrections. Once approved by all participants, the revised version Draft B report will be submitted to BIPM.

The results of the Key comparison will be submitted to an international journal, preferably the Metrologia Journal by the end of May 2023. The head of the Pilot Lab will appear as the first author, and all the contact persons given in table 1, will appear as co-authors, in alphabetical order of the surname. If a participant wants to publish the comparison as a separate publication, the Pilot Lab will assist, upon request and the previously described arrangements regarding the list of authors apply.

8. References

IAEA/WHO Network of Secondary Standard Dosimetry Laboratories, SSDL Network Charter 2nd edition, IAEA, Vienna (2018).

https://ssdl.iaea.org/Home/SSDLNetworkCharter

[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] ISO 4037-3:2019 Radiological protection — X and gamma reference radiation for calibrating dosemeters and doserate meters and for determining their response as a function of photon energy — Part 3: Calibration of area and personal dosemeters and the measurement of their response as a function of energy and angle of incidence. , Geneva (2019)

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

[4] ISO 4037-1:2019 Radiological protection — X and gamma reference radiation for calibrating dosemeters and doserate meters and for determining their response as a function of photon energy — Part 1: Radiation characteristics and production methods, Geneva (2019)

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[7] D. T. Burns (BIPM) and D. Butler (ARPANSA). Updated report on the evaluation of degrees of equivalence in regional dosimetry comparisons, CCRI(I)/17-09. Draft V6 2017-05-09

[8] ISO/IEC Guide 98-3:2008, JCGM 100:2008, Evaluation of measurement data- Guide to the Expression of Uncertainty of Measurement, Geneva (2008). https://www.bipm.org/documents/20126/2071204/JCGM_100_2008_E.pdf

[9] INTERNATIONAL ATOMIC ENERGY AGENCY, Measurement Uncertainty. A Practical Guide for Secondary Standards Dosimetry Laboratories, TECDOC-1585, IAEA, VIENNA (2008). https://www-pub.iaea.org/MTCD/publications/PDF/te_1585_web.pdf

[10] Appendix of the IAEA Calibration Certificate: Radiation Protection Ionization Chamber Calibration Procedures at the IAEA Dosimetry Laboratory https://ssdl.iaea.org/Content/DOLP_011_Appendix_3B.pdf

Appendix A

APPENDIX TO THE KFSHRC'S SSDL CALIBRATION CERTIFICATE

PROCEDURE FOR CALIBRATION OF RADIATION PROTECTION IONIZATION CHAMBER AT THE KFSHRC'S SECONDARY STANDARD DOSIMETRY LABORATORY

A.1. INTRODUCTION

A.1.1. General

Ionization chambers and their electrometers are calibrated at the King Faisal Specialist Hospital and Research Centre (KFSHRC)'s Secondary Standard Dosimetry Laboratory (SSDL) in terms of air kerma free in air (N_K) using ^{137}Cs gamma radiation and ISO 4037 X-ray narrow spectra series [1]. Calibrations are either made for a system composed of an ionization chamber plus an electrometer (from here on called "system calibration") or for an ionization chamber only.

Calibrations are performed using the beam output data that was measured using the SSDL's reference standard chamber of type PTW32002 # 545. This reference standard is calibrated periodically at the IAEA Dosimetry Laboratory (DOL). For calibrations of the ionization chamber only, the current is measured with the SSDL's reference electrometer, of type Keysight B2987A # MY54321163, calibrated also at the IAEA DOL. With system calibrations, the internal bias supply in the electrometer/dosimeter is used for the polarizing voltage. No correction for the possible lack of saturation is applied. The calibration is performed only when the relative air humidity at the SSDL is between 30 % and 70 %.

The air kerma calibration coefficient N_K [mGy/nC] of the chamber alone is determined as the ratio of the air kerma rate $\dot{K}_{air}$ [mGy/s] obtained with the SSDL's reference standard, and the ionization current I [nA] from the chamber under calibration corrected for the influence quantities, pressure (P) and temperature (T). The ambient conditions (temperature, pressure, and humidity), prevailing at the SSDL facility during the calibrations, are monitored continuously. Typically, the temperature fluctuations in the laboratory are within 19°C - 24°C and during measurements within ± 0.5 °C.

The air kerma calibration coefficient N_K [mGy/scale unit] of the system is determined as the ratio of the air kerma rate $\dot{K}_{air}$ [mGy/s] obtained with the SSDL's reference standard, and the reading rate $\dot{M}$ [scale units/s] of the system (electrometer and ionization chamber), corrected for the influence quantities P and T.

A.1.2. Reference conditions

The reference point of the ionization chamber, where the calibration coefficients apply, is considered to be the geometrical center of the collecting volume as defined by the external walls (unless another indication is given). Details on the geometrical centre for each specific chamber are given in the operation manual of the ionization chamber. If the chamber stem has a mark, this mark is oriented towards the radiation source during the calibration. The distance between the reference point and the source is 3.5 m for calibration in ^{137}Cs gamma beams and 2 m for calibration in X-rays (see Figures 1 and 2).

A.2. AIR KERMA CALIBRATIONS

A.2.1. ^{137}Cs gamma radiation

The chamber, with its build-up cap (if applicable), is positioned free in air, so that its reference point is on the central axis of the beam. The chamber reference plane is perpendicular to the central axis of the beam and the reference point of the chamber is 3 m. The useful radiation field size (95 % isodose level) at the reference plane is ∅ = 75 cm. Fig. 1 shows the set-up.

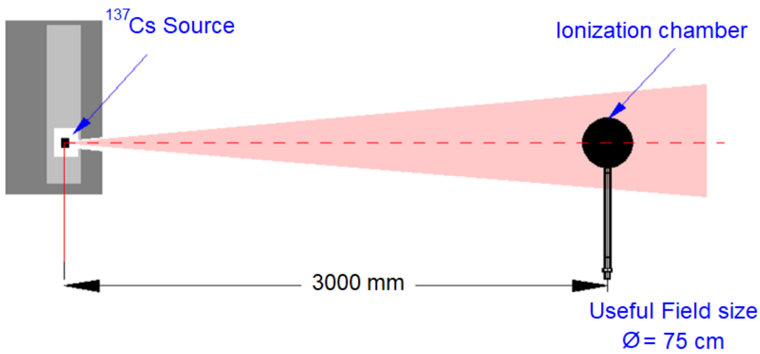

***Fig. 1**: Set-up for calibration in terms of air Kerma for ^{137}Cs gamma radiation.*

A.2.2. X-ray beams

One X-ray tube is used to generate the ISO 4037 narrow-spectrum X-ray beam series reference radiation. The characteristics of the beams, established at the SSDL, are shown in Table I.

The chamber, with its build-up cap (if applicable), is positioned free in air so that its reference point is on the central axis of the beam. The reference plane of the chamber must be perpendicular to the central axis of the beam. The distance from the focus of the X-ray tube to the reference point of the chamber is 2 m. The diameter of the useful radiation field size (95 % isodose level) at the reference plane is ∅ = 26 cm. Fig. 2 shows the set-up.

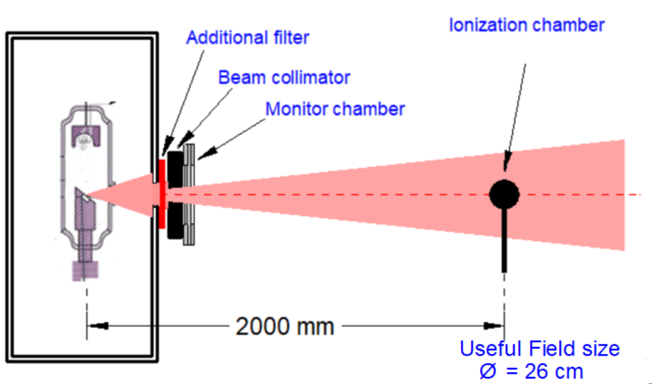

***Fig. 2**: Set-up for calibration in terms of air Kerma for X ray beams.*

Table I: *Beam qualities Established at the SSDL for the ISO 4037 Narrow beams x-rays [1]*

Short name of the Radiation Quality	Tube Potential (kVp)	Additional Filtration thickness in *			1st HVL measured at a distance of 1 m from the focal spot (mm)	2nd HVL measured at a distance of 1 m from the focal spot (mm)
		mm Pb	mm Sn	mm Cu		
N-40	38			0.21	2.630 Al	2.931 Al
N-60	59			0.60	0.240 Cu	0.254 Cu
N-80	80			2.00	0.610 Cu	0.680 Cu
N-100	100			5.00	1.178 Cu	1.176 Cu
N-120	120		1.00	5.00	1.807 Cu	1.865 Cu
N-150	150		2.50		2.482 Cu	2.475 Cu
N-200	200	1.00	3.00	2.00	4.097 Cu	4.184 Cu
N-250	245	3.00	2.00		5.268 Cu	5.299 Cu
N-300	290	5.00	3.00		6.118 Cu	6.188 Cu

*) an inherent filtration of 4 mm Al is added

A.3. CALIBRATION UNCERTAINTIES

The methodology for estimating the uncertainties of calibrations at the KFSHRC's SSDL is based on the recommendations of the ISO [5] and IAEA [6] guides on uncertainty. All sources of uncertainty are identified and classified as Type A or Type B, as per ISO classification.

The uncertainty associated with the SSDL calibrations is a combined standard uncertainty, with a coverage factor of k=2, which for a normal distribution corresponds to a level of confidence of approximately 95 %.

The contributions to the total uncertainty in the calibration coefficient are determined in 2 steps:

a. uncertainties arising from measurements made to determine the output rate (air kerma rate) of the radiation beams, with the SSDL reference instrument (including the stability of the measurement standards), and
b. uncertainties related to the instruments to be calibrated (user's instrument). Instruments calibrated at the SSDL are reference class instruments. Typical uncertainties are assumed for these instruments.

These 2 components are further divided into sub-components and their classification (Type A or Type B) determined. Uncertainty budgets of the SSDL gamma and x-rays calibrations are given in Tables II and III respectively.

A.4. REFERENCES

[1] 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

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, Calibration of Dosimeters Used in Radiotherapy, Technical Report Series No. 374, IAEA, Vienna (1994).

[3] INTERNATIONAL ATOMIC ENERGY AGENCY, International Basic Safety Standards for Protection Against Ionizing Radiation and for the Safety of Radiation Sources, Safety Series No. 115, IAEA, Vienna (1996).

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[5] INTERNATIONAL ATOMIC ENERGY AGENCY, Absorbed Dose Determination in External Radiotherapy: An International Code of Practice for Dosimetry Based on Standards on Absorbed Dose to Water, Technical Reports Series No. 398, IAEA, Vienna (2000).

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Table II: Estimated relative standard uncertainty in the KFSHRC's SSDL calibration in ^{137}Cs gamma radiation: Air kerma rate

Uncertainty components	Type A (%)	Type B (%)
Step 1. Factors influencing only the reference standard:		
1.1 Calibration from IAEA		0.4
1.2 Constancy of the Secondary Standard		0.2
1.3 Dosimeter reading	0.05	0.10
1.4 Temperature and pressure	0.05	0.10
1.5 Uniformity of radiation beam		0.10
Relative Combined Standard Uncertainty in Step 1	0.07	0.48
Step 2. Factors influencing the chamber to be calibrated		
2.1 Dosimeter reading	0.05	0.2
2.2 Temperature and pressure	0.05	0.1
2.3 Uniformity of radiation beam		0.1
2.4 Positioning of the instrument		0.03
Relative Combined Standard Uncertainty in Step 2	0.07	0.25
Relative Combined standard uncertainty (1 + 2)	0.10	0.54
Overall Relative uncertainty	0.55	
3.3 Expanded uncertainty (k=2)	**1.10**	

Table III: Estimated relative standard uncertainty in the KFSHRC's SSDL calibration ISO 4037 Narrow Spectrum Series

Uncertainty components	Type A (%)	Type B (%)
Step 1. Factors influencing only the reference standard:		
1.1 Calibration from IAEA		0.7
1.2 Constancy of the Secondary Standard		0.3
1.3 Dosimeter reading	0.05	0.10
1.4 Temperature and pressure	0.05	0.10
1.5 Monitor Chamber	0.05	
Relative Combined Standard Uncertainty in Step 1	0.09	0.77
Step 2. Factors influencing the chamber to be calibrated		
2.1 Dosimeter reading	0.05	0.2
2.2 Temperature and pressure	0.05	0.1
2.3 Uniformity of radiation beam		0.2
2.4 Positioning of the instrument		0.03
2.5 Monitor Chamber	0.05	
2.6 Beam Quality		0.20
Relative Combined Standard Uncertainty in Step 2	0.09	0.36
Relative Combined standard uncertainty (1 + 2)	0.12	0.86
Overall Relative uncertainty	0.864	
3.3 Expanded uncertainty (k=2)	**1.73**	

APPENDIX B: Intercomparison Report

GULFMET.RI(I)-S1: Comparison of Air Kerma Standards from Radiation Protection level Cs-137 and ISO 4037 Narrow Beam X-ray Series in Range 40 kV to 300 kV

COMPARISON REPORT

Participant :						
SSDL / Institute :						
Calibration Date(s) :	@ Cs137:		@ X-rays:			
SSDL Reerence Chamber :	Type :		Serial Number :		Polarizing Voltage :	
Transfer Chamber :	Type :		Serial Number :		Polarizing Voltage :	
Reference Distance :	@ Cs137:		@ X-rays:			
Electrometer used @ Cs137 :	Type :		Serial Number :		**kelec :**	
Electrometer used @ x-rays:	Type :		Serial Number :		**kelec :**	
monitor:	Type :		Serial Number :		**kelec :**	

Beam code	**Results**				**Measurements Corrected** (2)		**Calibration coefficient**		Transfer chamber calibration coefficients (5)	Correction factors applied in the DOL beam (6)		
	Air kerma rate Cs-137		**Air kerma rate per m.u.** (1) **x-rays ISO N series**		Transfer chamber	Monitor chamber	Transfer chamber (3)	Monitor chamber (4)				
	µGy / min	**Standard uncertainty %**	**µGy / m.u.**	**Standard uncertainty %**	nC / min	nC / min	µGy/nC	µGy/nC	µGy / nC			
Cs-137												
N40												
N80												
N100												
N200												
N300												

(1) If measurements are performed without Monitor chamber, then give Air kerma rate per minute

(2) for influence quantities (leakage, temperature, pressure, electrometer, etc)

(3) As given by the calibration Lab (IAEA, PTW,..).

(4) As given by the calibration Lab (IAEA, PTW,..). If no monitor chamber is available or not used, put "NA"

(5) determined at participant`s beam

(6) indicate type and value (e.g. recombination 1.0005, etc.)

Please send a copy of the calibration certificates as issued by the SSDL

Full Uncertainty Budget

(add rows and columns as needed)

Influence Quantities	Type A	Type B	Distribution	Comments

	Type A	Type B
Combined standard uncertainty		
Combined standard uncertainty Type A and B		