

APPENDIX 3B



ATTACHMENT TO IAEA CALIBRATION CERTIFICATE

IONIZATION CHAMBER CALIBRATION PROCEDURES AT THE IAEA DOSIMETRY LABORATORY

CALIBRATION FOR RADIATION PROTECTION DOSIMETRY ^{60}Co , ^{137}Cs AND ISO-4037 X RAY BEAMS

1. INTRODUCTION

1.1. General

Ionization chambers and electrometers are calibrated at the IAEA Dosimetry Laboratory in terms of air kerma free in air (N_K) and ambient dose equivalent ($H^*(10)$), in ^{60}Co , ^{137}Cs gamma radiation and also 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 by the substitution method or the use of decayed output [2] using the IAEA Reference Standard chamber. This reference standard is calibrated every 3 years, at the BIPM or a Primary Standards Dosimetry Laboratory participating in the Mutual recognition Arrangement (MRA). For calibrations of the ionization chamber only, the current is measured with the IAEA reference electrometer. 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 relative air humidity at the dosimetry laboratory is kept between 30% and 70%. No correction is applied for this influence quantity (see Section 4)..

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 IAEA reference standard, and the ionization current I [nA] from the chamber under calibration corrected for the influence quantities for pressure (P) and temperature (T). The ambient conditions (temperature, pressure and humidity), prevailing at the IAEA Laboratory during the calibrations, are monitored continuously. Typically, the temperature fluctuations are within 18 °C-22 °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 IAEA 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.

The same procedure is followed to determine the ambient dose equivalent calibration coefficient.

1.2. Reference conditions

The reference point of the ionization chamber, where the calibration coefficients apply, is considered to be in the geometrical centre 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 chambers. 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 m (see Figs 1 and 2).

2. AIR KERMA CALIBRATIONS

2.1. ^{137}Cs and ^{60}Co gamma radiation

The chamber, with the build-up cap (where 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. The distance from the source to the reference point of the chamber is 3 m. The size of the radiation field (50% isodose level) at the reference plane is $\varnothing 81$ cm. Fig. 1 shows the set-up.

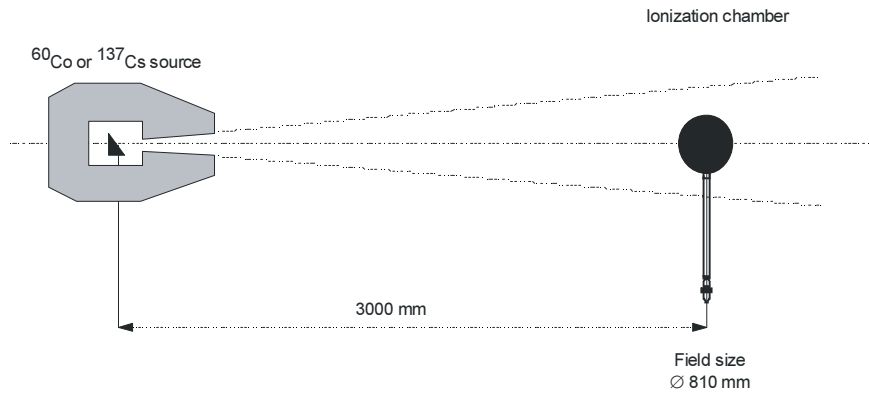


FIG. 1. Set-up for calibration in terms of air kerma for ^{137}Cs and ^{60}Co gamma radiation.

2.2. X rays beams

Two X ray tubes are used to generate the ISO narrow spectrum series X ray reference radiation. The characteristics of the beams are shown in Table 1 [1].

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 3 m. The size of the radiation field (50% isodose level) at the reference plane is $\varnothing 240$ cm. Fig. 2 shows the set-up.

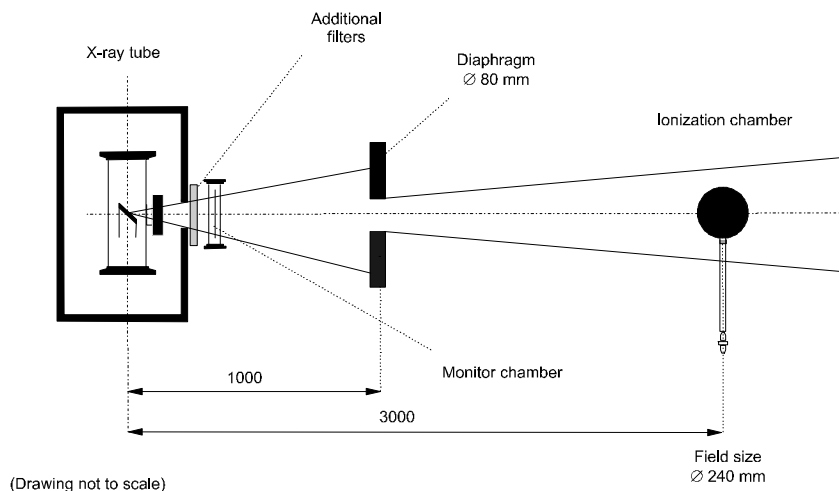


FIG. 2. Set-up for calibration in terms of air kerma for X rays.

The characteristics of the X ray beams used for calibration are given in Table 1.

TABLE 1. X RAY BEAM QUALITIES AT THE IAEA [1]

Quality	No.	H.V. [kV]	Added filtration *				HVL	
			Al [mm]	Cu [mm]	Sn [mm]	Pb [mm]	Al [mm]	Cu [mm]
N40	40	40	1.0	0.22			2.7	
N60	60	60	1.0	0.59				0.24
N80	80	80	1.0	1.85				0.59
N100	100	100	1.0	5.30				1.15
N120	120	120	1.0	5.00	1.0			1.74
N150	150	150	1.0		2.5			2.40
N200	200	200	1.0	2.00	3.0	1.0		4.06
N250	250	250	1.0		3.0	2.5		5.21
N300	300	300	1.0		3.0	5.0		6.19

3. CALIBRATIONS IN TERMS OF AMBIENT DOSE EQUIVALENT

The ambient dose equivalent is an operational quantity. Definitions of operational quantities used in radiation protection dosimetry are given in IAEA Basic Safety Standards [3] and IAEA Safety Series No.16 [4]. The set-up used for the calibration of ionization chambers in terms of ambient dose equivalent is identical to that of air kerma calibrations.

4. USE OF CALIBRATION COEFFICIENTS

The reference instruments calibrated at the IAEA can be used, in another radiation beam, to determine the output rate (air kerma or absorbed dose to water), subject to the provisions listed below:

- a. The humidity conditions should not differ significantly from those prevailing at the IAEA Dosimetry Laboratory. If the relative humidity is outside the range of 30–70%, corrections based on [4] should be made.
- b. The condition of measurement must not differ significantly from those of the calibration at the IAEA. Otherwise, additional corrections may be needed – in particular, of the following:
 - Radiation quality (particularly for X ray beams)
 - Calibration distance and beam dimensions of the radiation beam
 - Radial non-uniformity of the beam over the cross section of the ionization chamber
 - Beam intensity. It should be noted that the calibration coefficients determined at the IAEA are not corrected for the lack of saturation due to recombination. If the instrument is used in beams different from those listed in the calibration certificate, the user is advised to correct for this effect. Additional information on this effect can be found in [1]; and
 - Polarity and scale used during the calibration at the IAEA are reported in the calibration certificate. If the instrument is used with a different polarity or scale from those listed in the calibration certificate, the user is advised to determine the effect of these differences and decide on their effects on the measurements. Additional information on these effects and ways to correct for them can be found in [1].

5. CALIBRATION UNCERTAINTIES

The methodology for estimating the uncertainties of calibrations at the IAEA Dosimetry Laboratory is based on the recommendations of the ISO “Guide to the Expression of Uncertainty in Measurement” [5]. All sources of uncertainty are identified and classified as Type A or Type B, as per ISO classification.

The uncertainty associated to IAEA calibrations is as combined standards 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 two steps:

- a. Uncertainties arising from measurements made to determine the output rate (air kerma rate or absorbed dose to water rate) of the radiation beams, with the IAEA 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 IAEA are reference class instruments. Typical uncertainties are assumed for these instruments.

These two components are to be further divided into sub-components and their classification (Type A or Type B) determined. Uncertainty budgets of IAEA calibrations are given in Tables 2–6.

6. REFERENCES

- [1] INTERNATIONAL ORGANIZATION FOR STANDARDIZATION, X and Gamma Reference Radiation for Calibrating Dosimeters and Doserate Meters and for Determining their Response as a Function of Photon Energy, Parts 1–3, ISO, Geneva (1999).
- [2] INTERNATIONAL ATOMIC ENERGY AGENCY, Calibration of Dosimeters used in Radiotherapy, Technical Reports 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).
- [4] INTERNATIONAL ATOMIC ENERGY AGENCY, Calibration of Radiation Protection Monitoring Instruments, Safety Series No. 16, IAEA, Vienna (2000).
- [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).

TABLE 2. ESTIMATED RELATIVE STANDARD UNCERTAINTY IN THE IAEA CALIBRATION
 ISO-4037 NARROW SPECTRA X RAY BEAM QUALITIES
 CORRESPONDING TO CMC ENTRY: IAEA-RAD-1008

Step 1: Air kerma rate	Type A	Type B
	<i>Uncertainty (%)</i>	
Calibration from PSDL		0.39
Long term stability of the secondary standard		0.29
Temperature and pressure	0.060	0.10
Current	0.060	0.10
Monitor chamber	0.01	
<i>Combined uncertainty in Step 1</i>	0.09	0.51
Step 2: Instrument to be calibrated		
	<i>Uncertainty (%)</i>	
Temperature and pressure	0.06	0.10
Electrometer reading	0.06	0.20
Chamber positioning		0.01
Monitor chamber	0.01	
Beam quality		0.17
Field uniformity		0.12
<i>Combined uncertainty in Step 2</i>	0.09	0.31
Combined relative standard uncertainty (Steps 1 + 2)	0.12	0.59
Overall relative uncertainty		0.60
Expanded relative uncertainty (k=2)		1.2%

TABLE 3. ESTIMATED RELATIVE STANDARD UNCERTAINTY IN THE IAEA CALIBRATION
⁶⁰Co AND ¹³⁷Cs GAMMA RADIATION
CORRESPONDING TO CMC ENTRY: IAEA-RAD-1009 AND IAEA-RAD-1010

Step 1: Air kerma rate	Type A	Type B
	<i>Uncertainty (%)</i>	
Calibration from PSDL		0.25
Long term stability of the secondary standard		0.17
Temperature and pressure	0.030	0.10
Current	0.050	0.10
<i>Combined uncertainty in Step 1</i>	0.06	0.33
Step 2: Instrument to be calibrated		
	<i>Uncertainty (%)</i>	
Temperature and pressure	0.03	0.10
Electrometer reading	0.06	0.20
Uniformity of radiation field		0.10
Chamber positioning		0.01
<i>Combined uncertainty in Step 2</i>	0.07	0.25
Combined standard uncertainty (Steps 1 + 2)	0.09	0.41
Overall relative uncertainty		0.42
Expanded relative uncertainty (k=2)		0.8%

TABLE 4. ESTIMATED RELATIVE STANDARD UNCERTAINTY IN THE IAEA CALIBRATION AMBIENT DOSE EQUIVALENT, ISO-4037 NARROW SPECTRA X RAY BEAMS

CORRESPONDING TO CMC ENTRY: IAEA-RAD-1011

Step 1: Air kerma rate	Type A	Type B
	<i>Uncertainty (%)</i>	
Calibration from BIPM		1.50
Long term stability of the secondary standard		0.23
Temperature and pressure	0.03	0.10
Current	0.06	0.10
Monitor chamber	0.01	
<i>Combined uncertainty in Step 1</i>	0.07	1.52
Step 2: Instrument to be calibrated		
	<i>Uncertainty (%)</i>	
Temperature and pressure	0.03	0.10
Electrometer reading	0.06	0.20
Chamber positioning		0.01
Monitor chamber	0.01	
Beam uniformity		0.12
Beam quality		0.17
<i>Combined uncertainty in Step 2</i>	0.07	0.31
Combined relative standard uncertainty (Steps 1 + 2)	0.10	1.55
Overall relative uncertainty		1.56
Expanded relative uncertainty (k=2)		3.1%

TABLE 5. ESTIMATED RELATIVE STANDARD UNCERTAINTY IN THE IAEA CALIBRATION AMBIENT DOSE EQUIVALENT, ¹³⁷Cs GAMMA RADIATION

CORRESPONDING TO CMC ENTRY: IAEA-RAD-12

Step 1: Air kerma rate	Type A	Type B
	<i>Uncertainty (%)</i>	
Calibration from PSDL		0.52
Long term stability of the secondary standard		0.17
Temperature and pressure	0.03	0.10
Current	0.05	0.10
<i>Combined uncertainty in Step 1</i>	0.06	0.57
Step 2: Instrument to be calibrated		
	<i>Uncertainty (%)</i>	
Temperature and pressure	0.03	0.10
Electrometer reading	0.06	0.20
Uniformity of radiation field		0.10
Chamber positioning		0.05
<i>Combined uncertainty in Step 2</i>	0.07	0.25
Combined standard uncertainty (Steps 1 + 2)	0.09	0.62
Overall relative uncertainty		0.62
Expanded relative uncertainty (k=2)		1.2%

TABLE 6. ESTIMATED RELATIVE STANDARD UNCERTAINTY IN THE IAEA CALIBRATION
 AMBIENT DOSE EQUIVALENT, ⁶⁰Co GAMMA RADIATION
 CORRESPONDING TO CMC ENTRY: IAEA-RAD-1013

Step 1: Air kerma rate	Type A	Type B
	<i>Uncertainty (%)</i>	
Calibration from PSDL		0.33
Long term stability of the secondary standard		0.35
Temperature and pressure	0.03	0.10
Current	0.05	0.10
<i>Combined uncertainty in Step 1</i>	0.06	0.51
Step 2: Instrument to be calibrated		
	<i>Uncertainty (%)</i>	
Temperature and pressure	0.03	0.10
Electrometer reading	0.06	0.20
Uniformity of radiation field		0.12
Chamber positioning		0.05
<i>Combined uncertainty in Step 2</i>	0.07	0.26
Combined relative standard uncertainty (Steps 1 + 2)	0.09	0.57
Overall relative uncertainty		0.58
Expanded relative uncertainty (k=2)		1.2%