APPENDIX 3A

ATTACHMENT TO IAEA CALIBRATION CERTIFICATE

IONIZATION CHAMBER CALIBRATION PROCEDURES AT THE IAEA DOSIMETRY LABORATORY

CALIBRATION FOR EXTERNAL THERAPY DOSIMETRY ^{60}Co AND CCEMRI X RAY GAMMA RADIATON

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, for low and medium energy X rays and for ^{60}Co gamma radiation. Calibrations in terms of absorbed dose to water for ^{60}Co gamma radiation are provided only for SSDLs and hospitals who have adopted a code of practice based on absorbed dose to water, such as IAEA TRS-398 [1]. Calibrations are either made for a system composed of an ionization chamber plus an electrometer (hereinafter referred to as "system calibration"), or for an ionization chamber only.

All therapy calibrations are performed by the substitution method [2] using the IAEA reference standard chamber. This reference standard is calibrated at BIPM[1] every three years. 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 $\dot{\mathbf{K}}_{\mathbf{air}}$ [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 $\dot{\mathbf{K}}_{\mathbf{air}}$ [mGy/s] obtained with the IAEA reference standard, and the reading rate $\dot{\mathbf{M}}$ [scale units/s] of the system (electrometer and ionization chamber), corrected for the influence quantities P and T.

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 always 1 m (see Figs 1 and 2), except for low energy X rays (0.5 m).

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[1] Or a Primary Standards Dosimetry Laboratory participating in the Mutual Recognition Arrangement.

2. AIR KERMA CALIBRATIONS

2.1. ^{60}Co beam gamma radiation

The chamber, with its build-up cap, is positioned free in air so that its reference point is on the central axis of the beam. The chamber axis is perpendicular to the central axis of the beam. The distance from the source to the reference point of the chamber is 1 m. The size of the radiation field (50% isodose level) at the reference plane is 10 cm × 10 cm. Fig. 1 shows the set-up.

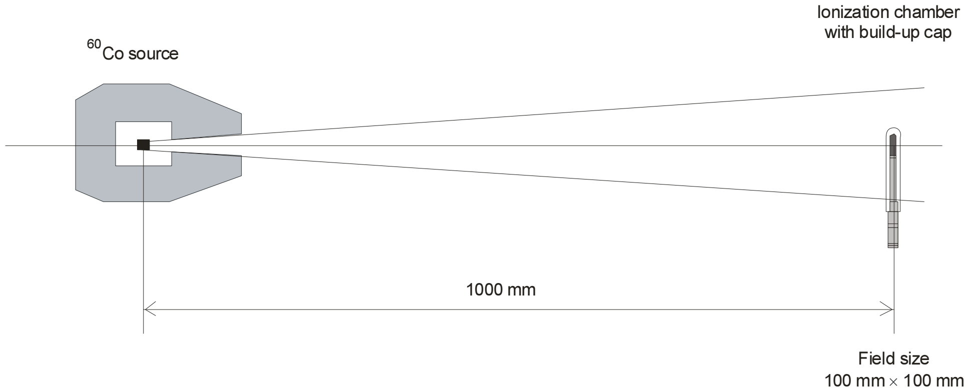

FIG. 1. Set-up for calibration in terms of air kerma for ^{60}Co gamma radiation.

2.2. Medium energy X rays

The chamber, without its build-up cap, is positioned free in air, so that its reference point is on the central axis of the beam. The chamber axis is 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 1 m. The size of the radiation field (50% isodose level) at the reference plane is ∅ 10 cm. Fig. 2 shows the set-up.

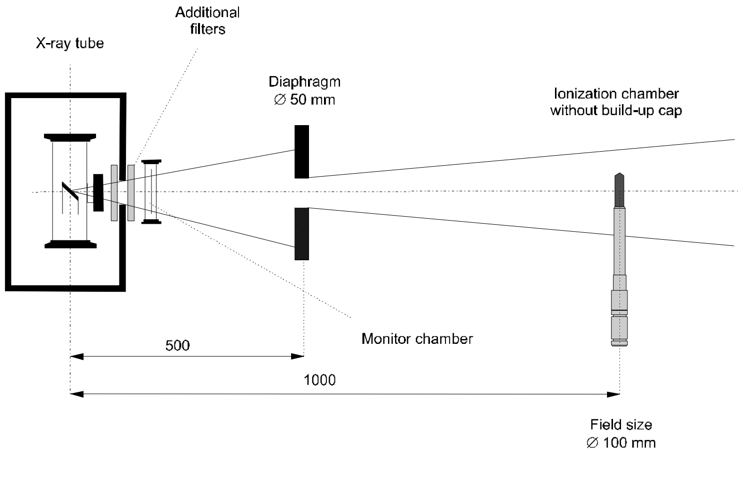

FIG. 2. Set-up for calibration in terms of air kerma for medium energy X rays.

The characteristics of the medium energy X ray beams used for calibration are given in Table 1 [3].

TABLE 1. MEDIUM ENERGY X RAY BEAM QUALITIES

Quality No.		Added filtration*/		HVL	
	H.V.	**Al**	**Cu**	**Al**	**Cu**
	[kV]	**[mm]**	**[mm]**	**[mm]**	**[mm]**
T1	100	0.6	—	3.91	—
T2	135	1.0	0.23		0.50
T3	180	1.0	0.51		1.03
T4	250	1.0	1.65		2.50

*/ The fixed filtration consists of 2.2 mm Be + 3 mm Al + monitor chamber (equivalent to 0.1 mm Al)

2.3. Low energy X rays

The chamber, without its build-up cap, is positioned free in air, so that its reference point is on the central axis of the beam. The chamber axis is 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 50 cm. The size of the radiation field (50% isodose level) at the reference plane is ∅ 9.5 cm.

The characteristics of the low energy X ray beams used for calibration are given in Table 2 [3].

TABLE 2. LOW ENERGY X RAY BEAM QUALITIES

Quality No.		Added filtration*/		HVL	
	H.V.	**Al**	**Cu**	**Al**	**Cu**
	[kV]	**[mm]**	**[mm]**	**[mm]**	**[mm]**
T8	25	0.38		0.24	
T9	30	0.22		0.19	
T10	50	4.02		0.23	
T11	50	1.09		1.06	

*/ The fixed filtration consists of 1.0 mm Be + monitor chamber (equivalent to 0.02 mm Al for quality no. 1).

3. ABSORBED DOSE TO WATER CALIBRATIONS IN ^{60}CO

Calibrations in terms of absorbed dose to water are available only for ^{60}Co gamma radiation.

The chamber, protected by a PMMA sleeve of 1 mm wall thickness, is positioned in the water phantom, so that its reference point is on the central axis of the beam. The chamber axis is perpendicular to the central axis of the beam. The serial number of the chamber on the stem is set so as to point towards the radiation source. The distance from the source to the reference point of the chamber is 1 m. The reference point of the chamber is at 5g/cm² water depth. The size of the radiation field (50% isodose level) at the reference plane is 10 cm × 10 cm. Fig. 3 shows the set-up.

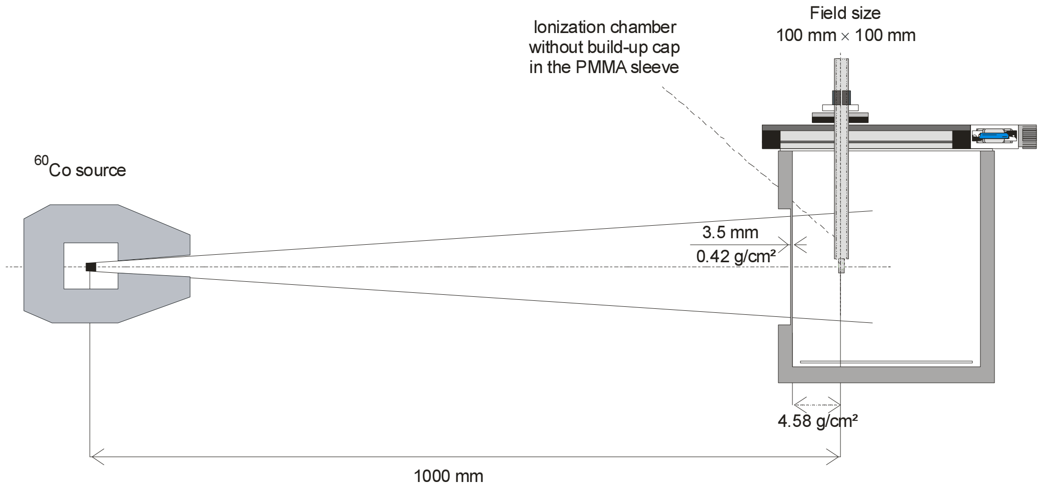

FIG. 3. Set-up for calibrations in terms of absorbed dose to water.

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 be further divided into sub-components and their classification (Type A or Type B) determined. Uncertainty budgets of IAEA calibrations are given in Tables 3–5.

6. REFERENCES

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Absorbed Dose Determination in External Beam Radiotherapy: An International Code of Practice for Dosimetry based on Standards of Absorbed Dose to Water, IAEA TRS-398, Vienna (2000).

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, Calibration of Dosimeters used in Radiotherapy, IAEA TRS-374, Vienna (1994).

[3] BUREAU INTERNATIONAL DE POIDS ET MESURES, Qualités des Rayonnements Ionisants, in Com. Cons. Etalons des Ray. Ionisants (Section 1), **2** R15, BIPM; Sèvres (1972).

[4] BUREAU INTERNATIONAL DE POIDS ET MESURES, Correction d'humidité, in Com. Cons. Etalons des Ray. Ionisants (Section 1) **4**, R(I)6, BIPM; Sèvres (1977).

[5] INTERNATIONAL ORGANIZATION FOR STANDARDIZATION, Guide to the Expression of Uncertainty in Measurement, ISO; Geneva (1995).

TABLE 3. ESTIMATED RELATIVE STANDARD UNCERTAINTY IN THE IAEA CALIBRATION
^{60}Co ABSORBED DOSE TO WATER
CORRESPONDING TO CMC ENTRY: IAEA-RAD-1001

Step 1: Absorbed dose to water rate	Type A	Type B
	Uncertainty (%)	
Calibration from BIPM		0.30
Long term stability of the secondary standard		0.23
Temperature and pressure	0.03	0.10
Current	0.05	0.10
Combined uncertainty in Step 1	**0.06**	**0.40**
Step 2: Instrument to be calibrated		
	Uncertainty (%)	
Temperature and pressure	0.03	0.10
Electrometer reading	0.05	0.20
Chamber positioning		0.10
Combined uncertainty in Step 2	**0.06**	**0.24**
Combined relative standard uncertainty (Steps 1 + 2)	**0.08**	**0.47**
Overall relative uncertainty		**0.48**
Expanded relative uncertainty (k=2)		**1.0%**

TABLE 4. ESTIMATED RELATIVE STANDARD UNCERTAINTY IN THE IAEA CALIBRATION
^{60}Co AIR KERMA
CORRESPONDING TO CMC ENTRY: IAEA-RAD-1002

Step 1: Air kerma rate	Type A	Type B
	Uncertainty (%)	
Calibration from BIPM		0.20
Long term stability of the secondary standard		0.20
Temperature and pressure	0.03	0.10
Current	0.05	0.10
Combined uncertainty in Step 1	**0.06**	**0.32**
Step 2: Instrument to be calibrated		
	Uncertainty (%)	
Temperature and pressure	0.03	0.10
Electrometer reading	0.05	0.20
Chamber positioning		0.01
Combined uncertainty in Step 2	**0.06**	**0.22**
Combined relative standard uncertainty (Steps 1 + 2)	**0.08**	**0.39**
Overall relative uncertainty		**0.40**
Expanded relative uncertainty (k=2)		**0.8%**

TABLE 5. ESTIMATED RELATIVE STANDARD UNCERTAINTY IN THE IAEA CALIBRATION MEDIUM ENERGY X RAY BEAMS, AIR KERMA CORRESPONDING TO CMC ENTRY: IAEA-RAD-1003

Step 1: Air kerma rate	Type A	Type B
	Uncertainty (%)	
Calibration from BIPM		0.21
Long term stability of the secondary standard		0.23
Temperature and pressure	0.03	0.10
Current	0.05	0.10
Monitor chamber	0.01	
Combined uncertainty in Step 1	**0.06**	**0.34**
Step 2: Instrument to be calibrated		
	Uncertainty (%)	
Temperature and pressure	0.03	0.10
Electrometer reading	0.05	0.20
Chamber positioning		0.01
Monitor chamber	0.01	
Difference in beam quality		0.06
Combined uncertainty in Step 2	**0.06**	**0.23**
Combined relative standard uncertainty (Steps 1 + 2)	**0.08**	**0.41**
Overall relative uncertainty		**0.42**
Expanded relative uncertainty (k=2)		**0.8%**

TABLE 6. ESTIMATED RELATIVE STANDARD UNCERTAINTY IN THE IAEA CALIBRATION
LOW ENERGY X RAY BEAMS, AIR KERMA
CORRESPONDING TO CMC ENTRY: IAEA-RAD-1004

Step 1: Air kerma rate	Type A	Type B
	Uncertainty (%)	
Calibration from BIPM		0.20
Long term stability of the secondary standard		0.21
Temperature and pressure	0.03	0.10
Current	0.06	0.10
Monitor chamber	0.01	
Combined uncertainty in Step 1	**0.07**	**0.32**
Step 2: Instrument to be calibrated		
	Uncertainty (%)	
Temperature and pressure	0.03	0.10
Electrometer reading	0.06	0.20
Chamber positioning		0.01
Monitor chamber	0.01	
Beam quality		0.12
Combined uncertainty in Step 2	**0.07**	**0.25**
Combined standard relative uncertainty (Steps 1 + 2)	**0.10**	**0.41**
Overall relative uncertainty		**0.42**
Expanded relative uncertainty (k=2)		**0.8%**