APPENDIX TO IAEA CALIBRATION CERTIFICATE

IONIZATION CHAMBER CALIBRATION PROCEDURES AT THE IAEA DOSIMETRY LABORATORY

MAMMOGRAPHY LEVEL CALIBRATIONS

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 selected mammography radiation qualities [1]. Calibrations are made either for a system composed of an ionization chamber plus an electrometer/control unit or for an ionization chamber only.

All calibrations are performed by the substitution method [2] using the IAEA reference standard ionization chamber calibrated every three years at a Primary Standards Dosimetry Laboratory. When only an ionization chamber is calibrated, the charge is measured using an external voltage supply[1] and the IAEA reference electrometer. The magnitude of the polarizing voltage provided is comparable to that provided by the user's electrometer and the polarity of the charge collected by the chamber is identical to that collected when attached to the user's electrometer. When a system is calibrated, the internal bias supplied by the electrometer/control unit is used. Unless otherwise stated, the value and sign of the polarizing voltage as specified in the instruction manual or by the user are used. In both cases, the magnitude and polarity of the polarizing voltage as well as the polarity of charge collected from the chamber are noted in the calibration certificate.

The air kerma calibration coefficients, N_K[mGy/nC], of ionization chambers calibrated without electrometer are determined as the ratio of air kerma, K_{air}[mGy], obtained with the IAEA reference standard, and charge, C[nC], collected from the chamber under calibration, corrected for the influence quantities P and T.

The air kerma calibration coefficients, N_K[mGy/scale unit], of electrometer/control unit plus chamber (system calibration) are determined as the ratio of air kerma, K_{air}[mGy] obtained with the IAEA reference standard, and the reading, M[scale units], of the electrometer/control unit under calibration, 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 chamber is positioned free in air, so that its reference point is on the central axis of the beam (see Fig. 1). The chamber axis is perpendicular to the central axis of the beam. The distance from the X ray tube focus to the reference point of the chamber is 1 m. The radiation field at the reference plane is circular with a 10 cm diameter. The mammography beam qualities, together with their characteristics, are shown in Tables 1 and 2. The air kerma rates are approximately 1.5–7.0 mGy/s for unattenuated beams and 0.1–0.5 mGy/s for attenuated beams. No correction for lack of saturation is applied.

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[1] The polarizing potential indicated in the certificate is applied to the outer electrode. The potential of the collecting electrode is kept to 0.0 V.

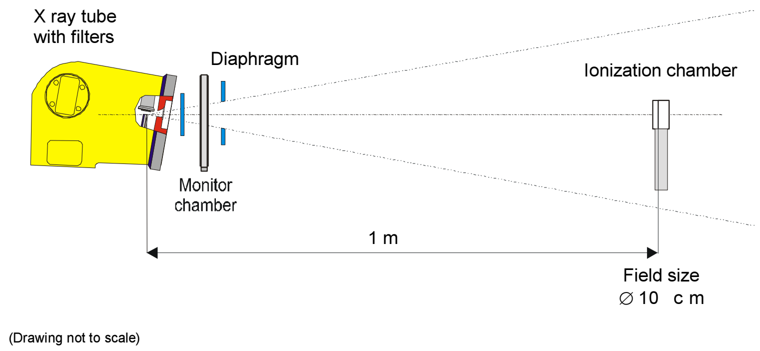

FIG. 1. Reference conditions for calibration in terms of air kerma for mammography X ray beam qualities.

The IAEA standard mammography beam qualities (Mo anode and Mo filter), together with their characteristics, are shown in Table 1. The IAEA Dosimetry Laboratory has established additional beam qualities, given in Table 2 (Mo anode and Rh filter, Rh anode and Rh filter). Calibrations for the additional beam qualities given in Table 2 are conducted only upon special request. Interested SSDLs should submit a request to the SSDL Officer.[2]

TABLE 1. IAEA STANDARD MAMMOGRAPHY RADIATION BEAM QUALITIES

Radiation	**Tube**	**Added filtration**	**1st HVL**	**Homogeneity**
	[kV]	[mm]	[mm Al]	[Al]
		Mo anode		
MoMo-25	25	0.03 Mo	0.323	0.79
MoMo-28	28	0.03 Mo	0.358	0.80
MoMo-30	30	0.03 Mo	0.376	0.80
MoMo-35	35	0.03 Mo	0.411	0.81
MoMo-25x	25	0.03 Mo + 2 Al	0.579	0.97
MoMo-28x	28	0.03 Mo + 2 Al	0.615	0.95
MoMo-35x	35	0.03 Mo + 2 Al	0.706	0.87

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[2] Please send your request and justification for additional beam qualities to the SSDL Officer (E-mail: dosimetry@iaea.org).

[3] Available only upon special request.

* *The beam codes are a combination of the chemical symbol of the anode and filter, respectively, followed by the potential* of the tube in kilovolts and a letter "x" for beams attenuated by 2 mm of aluminium. The inherent filtration is 0.8 mm beryllium for all radiation qualities.

** *Homogeneity coefficient is defined as a ratio of the 1st HVL to the 2nd HVL.*

TABLE 2. ADDITIONAL MAMMOGRAPHY RADIATION BEAM QUALITIES AT THE IAEA DOSIMETRY LABORATORY[3]

Radiation	Tube	Added filtration	1st HVL	Homogeneity
	[kV]	[mm]	[mm Al]	[Al]
Mo anode				
MoMo-23	23	0.03 Mo	0.293	0.78
MoRh-28	28	0.025 Rh	0.417	0.82
MoRh-32	32	0.025 Rh	0.449	0.84
MoMo-30x	30	0.03 Mo + 2 Al	0.641	0.93
Rh anode				
RhRh-25	25	0.025 Rh	0.362	0.78
RhRh-30	30	0.025 Rh	0.444	0.76
RhRh-35	35	0.025 Rh	0.504	0.78
RhRh-40	40	0.025 Rh	0.548	0.78
RhRh-30x	30	0.025 Rh + 2 Al	0.814	0.94
RhRh-35x	35	0.025 Rh + 2 Al	0.883	0.92

2. 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), subject to the provisions listed below:

– 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 [3] should be made.
– The condition of measurement must not differ significantly from those of the calibration at the IAEA. Otherwise, additional corrections may be needed, particularly the:
  - Radiation quality of the X ray beam;
  - 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 or the lack of saturation due to recombination. If the instrument used in beams is 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 [4];
  - 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 [4].

3. 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:

1. 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

2. 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 further divided into sub-components and their classification (Type A or Type B) determined. The uncertainty budgets of IAEA calibrations are given in Tables 2 and 3.

4. REFERENCES

[1] INTERNATIONAL ELECTROTECHNICAL COMMISSION, Medical Diagnostic X-ray Equipment – Radiation Conditions for use in the Determination of Characteristics, IEC 61267, Ed. 2.0 b, Geneva (2005).

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

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

[4] 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).

[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
AIR KERMA, MOLYBDENUM BEAM QUALITIES
CORRESPONDING TO CMC ENTRY: IAEA-RAD-1006

Step 1: Air kerma rate	Type A	Type B
	Uncertainty (%)	
Calibration from PSDL		0.70
Long term stability of the secondary standard		0.23
Temperature and pressure	0.06	0.10
Current	0.06	0.10
Monitor chamber	0.05	
Combined uncertainty in Step 1	**0.10**	**0.75**
Step 2: Instrument to be calibrated		
	Uncertainty (%)	
Temperature and pressure	0.06	0.10
Electrometer reading	0.06	0.20
Chamber positioning		0.01
Monitor chamber	0.05	
Beam quality		0.06
Field in homogeneity		0.06
Non-linearity		0.15
Combined uncertainty in Step 2	**0.10**	**0.28**
Combined relative standard uncertainty (Steps 1 + 2)	**0.14**	**0.80**
Overall relative uncertainty		**0.81**
Expanded relative uncertainty (k=2)		**1.6%**

TABLE 4. ESTIMATED RELATIVE STANDARD UNCERTAINTY IN THE IAEA CALIBRATION
AIR KERMA, RHODIUM BEAM QUALITIES
CORRESPONDING TO CMC ENTRY: IAEA-RAD-1007

Step 1: Air kerma rate	Type A	Type B
	Uncertainty (%)	
Calibration from PSDL		0.45
Long term stability of the secondary standard		0.23
Temperature and pressure	0.06	0.10
Current	0.06	0.10
Monitor chamber	0.05	
Combined uncertainty in Step 1	**0.10**	**0.52**
Step 2: Instrument to be calibrated		
	Uncertainty (%)	
Temperature and pressure	0.06	0.10
Electrometer reading	0.06	0.20
Chamber positioning		0.01
Monitor chamber	0.05	
Beam quality		0.06
Field inhomogeneity		0.06
Non-linearity		0.15
Combined uncertainty in Step 2	**0.10**	**0.28**
Combined relative standard uncertainty (Steps 1 + 2)	**0.14**	**0.60**
Overall relative uncertainty		**0.61**
Expanded relative uncertainty (k=2)		**1.2%**