SIM Comparison of Calibration Coefficients at Radiotherapy Level for Orthovoltage X-ray Beams

Technical Protocol

Pilot laboratory: NIST

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Contents

1. Description of the project

It is the objective of this proposal to compare the calibration coefficients at radiotherapy level for orthovoltage x-ray beams. The comparison is intended for members of the Sistema Interamericano de Metrología (SIM). Five SIM laboratories (NIST, NRCC, ININ, CNEA and LNMRI) have expressed interest in the comparison. Four NIST reference-class transfer ionization chambers of two different models will be calibrated by each of the participating laboratories for four tungsten-anode reference radiation qualities of energies between 100 kV and 300 kV. The reference radiation qualities are recommended by the Consultative Committee for Ionizing Radiation (CCRI(I)). The comparison project was proposed at the SIM MWG6 (Ionizing Radiation) in April 2007 by CNEA/CAE.

2. Participants

Institute	Country	Contact	E-mail of contact person
NIST	United States	Michelle O’Brien	michelle.obrien@nist.gov
NRCC	Canada	John P. McCaffrey	john.mccaffrey@nrc-cnrc.gc.ca
CNEA	Argentina	Margarita Saraví	saravi@cae.cnea.gov.ar
LNMRI	Brazil	Paulo Cunha	pcunha@ird.gov.br
ININ	Mexico	Víctor Tovar	vmtm@nuclear.inin.mx

3. Procedure

3.1 Object of comparison

Calibration of four ionization chambers of two different models and volumes of 0.6 cm^2 against the national standards for air kerma. The calibration coefficient is $N_{K\mathrm{air}} = K_{\mathrm{air}} / I_{\mathrm{corr}}$, where K_{air} is the air-kerma rate and I_{corr} is the measured ionization current corrected for influence quantities.

3.2 Transfer chambers

The transfer ionization chambers are Farmer-type: two are Exradin A12 and two are PTW 30010. Both are thimble-type, fully guarded chambers. The A12 is made of Shonka air-equivalent plastic. The PTW wall material is graphite with a protective acrylic cover, and the electrode is made of aluminum. The reference points of the chambers are the geometrical centers of the volumes. The chambers are aligned in the center of the beam with the white or black mark towards the radiation source. The A12 centroid of the collecting volume is 12.9 mm from the tip of the chamber. The PTW reference point is 13 mm from the chamber tip (on the chamber axis). The chambers are positioned so that the direction of radiation is perpendicular to the chamber axis. The signal connection of the chambers is a triaxial BNC plug. The polarizing potential is applied such that the outer wall of the chamber is negative with respect to the collecting-center electrode. The polarity of the collected charge on the electrometer is negative. The equilibrium caps have been shipped with the chambers for completeness but are not used for the x-ray beams for this comparison. No corrections for saturation are applied. A physical description of the transfer chambers follows in the table.

Type	Serial Number	Sensitive volume (nominal)	Outside diameter	Diameter of inner electrode	Chamber Voltage[a]
A12	XA071361	0.65 cm^3	7.1 mm	1.0 mm	300 V
A12	XA071362	0.65 cm^3	7.1 mm	1.0 mm	300 V
PTW30010	TN30010-0613	0.6 cm^3	6.95 mm	1.1 mm	400 V
PTW30010	TN30010-0614	0.6 cm^3	6.95 mm	1.1 mm	400 V

[a] The polarizing potential is applied such that the outer wall of the chamber is negative with respect to the collecting-center electrode. The polarity of the collected charge on the electrometer is negative.

3.3 Radiation qualities

The reference radiation qualities are recommended by the Consultative Committee for Ionizing Radiation and supported by the BIPM for x-ray comparisons. NIST conducted a recent comparison with the BIPM using these reference radiation qualities (Burns and O'Brien, 2006).

Generating tube potential (kV)	Half-value layer (mm Cu)
100	0.15
135	0.5
180	1.0
250	2.5

3.4 Reference conditions

The calibration coefficients for the transfer chambers should be given in terms of air kerma per charge in units of Gy/C and refer to standard conditions of air temperature, pressure and relative humidity of T = 295.15 K, P = 1013.25 hPa and h = 50 %. The recommended source-to-chamber distance is 100 cm. (See also Appendix B)

3.5 Course of comparison

There will be a star-shaped circulation of the chambers between the NIST and the participants. The NIST pays for all shipping costs and makes all shipping arrangements through a soon to be specified NIST shipping broker. After completion of the calibrations at each facility, the NIST will perform chamber constancy checks, therefore the chambers must be returned to the NIST. The chambers should stay at the participant's site for no longer than 2 weeks. Each technical contact, listed in Appendix A, is requested to communicate with the NIST coordinator, Michelle O'Brien, in the event of any delay. Prior to the start of the comparison, further shipping instructions will be provided to each participant from NIST. It is critical to the success of the comparison that the shipping broker's instructions are followed. The addresses provided in Appendix A, including the telephone and fax numbers will be provided to the shipping broker.

The results should be reported to the coordinator within 4 weeks after the calibration. A spreadsheet will be provided by the NIST in which information about the radiation qualities at the participant's site and the calibration results can be entered (see also Appendix C). The requested uncertainties should be given in accordance with the ISO guide to the expression of uncertainties in measurements (GUM) (ISO, 1993). In addition to the completed spreadsheet, a complete uncertainty budget for the x-ray techniques included in the comparison should be provided to the NIST.

3.6 Prospective time schedule

Participant	Date chamber leaves the NIST for participant	Measurement duration at laboratory	Date chamber leaves participant for the NIST
NRCC	Nov. 9, 2007	Nov. 19 – Nov. 30, 2007	Dec. 3, 2007
CNEA	Feb. 8, 2008	Feb. 18 – Feb. 29,2008	Mar. 3, 2008
LNMRI	Mar. 21, 2008	Mar. 31- Apr. 11, 2008	April 14, 2008
ININ	May 2, 2008	May 12 – May 23, 2008	May 26, 2008

3.7 Procedure for handling the results of the pilot laboratory

The pilot laboratory, the NIST, will participate in the comparison. It will determine its values of the calibration coefficients at the radiation qualities and reference conditions given above. For the purpose of constancy checks, the pilot laboratory will repeat their determination of the calibration coefficients for the radiation qualities described above after every participant's measurements.

3.8 Evaluation of the results

The pilot laboratory will evaluate the comparison on the basis of the results given by the participants in the provided MS-Excel sheet. The results will reveal the degree to which the participating calibration facility can demonstrate proficiency in transferring air-kerma calibrations under the conditions of the said facility at the time of the measurements. The evaluation of the degrees of equivalence will be performed according to the method described by (Burns, Allisy-Roberts, 2007) in CCRI(I)/07-04. The comparison of the calibration coefficients for the four chambers will be based on the average ratios of calibration coefficients measured at the NIST and at each participating laboratory.

3.9 Publication of the results

The pilot laboratory will prepare a draft of a final report for circulation to all participants for comments and discussion of the results. The relevant procedure will be followed to permit the results to be entered in the key comparison database of the BIPM. This or a revised report will be the official report of the comparison. A summary of the report will be published in the NIST Journal of Research.

4 References

D.T. Burns and M. O’Brien (2006). “Comparison of the NIST and BIPM Standards for Air Kerma in Medium-Energy X Rays,” J. Res. Natl. Inst. Stand. Technol. **111**, 385-391.

ISO International Organization for Standardization (1993). *Guide to the Expression of Uncertainty in Measurement*. Geneva, ISBN 92-67-10188-9.

APPENDIX A: Complete addresses of the participants

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Appendix B

SIM Comparison of Calibration Coefficients at Radiotherapy Level for Orthovoltage X-ray Beams

Four NIST reference class chambers have been provided for the SIM comparison of calibration coefficients at radiotherapy level for orthovoltage x-ray beams. The protocol for the comparison involves the calibration of the NIST reference class, transfer ionization chambers, by the participating facility. After the participating facility calibrates the NIST ionization chambers, using their appropriate equivalent beam qualities, the chambers are to be returned to NIST. The participant provides NIST with the results of the calibration coefficients for the NIST chambers found at their facility in units of Gy/C in terms of the HVL for each of the techniques, using the specified spreadsheet. The participant's calibration coefficients should be provided to NIST, normalized to one standard atmosphere and **22 °C** (T = 295.15 K and P = 1013.25 hPa) for a direct comparison with the average of the NIST calibration coefficients. The results will reveal the degree to which the participating calibration facility can demonstrate proficiency in transferring air-kerma calibrations under the conditions of the said facility at the time of the measurements. Questions or concerns should be directed to the NIST contact and no communication concerning the test should exist amongst participants until the results have been issued.

Conditions for all Chambers in the NIST Facility:

The chamber is open to the atmosphere and all measurements were normalized to one standard atmosphere and 22 degrees Celsius (T = 295.15 K and P = 1013.25 hPa). Use of the chamber at other pressures and temperatures requires normalization of the ion currents to these reference conditions. The average charge used to compute the calibration coefficient is based on measurements with the wall of the ionization chamber at the stated potential. The polarizing potential is applied such that the outer wall of the chamber is negative with respect to the collecting-center electrode. The polarity of the collected charge on the electrometer is negative. Leakage corrections are applied. A detailed study of ion recombination was not performed. No recombination correction was applied to the calibration coefficient. If the chamber is used to measure an air-kerma rate significantly different from that used for the calibration, it may be necessary to correct for recombination loss.

Chamber:	**Exradin A12**	**PTW 30010**
Bias (negative charge on electrometer):	300 volts	400 volts
Identifier towards source of radiation:	white line	black line
Orientation:	the stem is perpendicular to the beam direction	
Distance:	100 cm to center of the volume	
Beam diameter at point of measurement:	3 cm diameter	
Air Kerma rates (Gy/s):	1E-03	

Reference Beam Qualities

Generating tube potential (kV)	Half-value layer (mm Cu)
100	0.15
135	0.5
180	1.0
250	2.5

APPENDIX C

SIM Comparison
Report of the results

Participant: (Please fill in the blue cells

Characteristics of the radiation quality as realized at the participants site

Tube voltage kV	1st HVL mm Al	1st HVL mm Cu
100		
135		
180		
250		

Results of calibration

Exradin A12 SN XA071361

Date range of measurements:		
Temperature range (C):		
Pressure range (hPa):		

Tube voltage **kV**	Calibration distance (source to reference point) **mm**	Beam diameter* **mm**	Air-kerma rate* **Gy/s**	Calibration coefficient (Reference: *T* = 295.15 K *P* = 1013.25 hPa *h* = 50 %) **Gy/C**	Relative standard uncertainty of calibration coefficient (coverage *k* =1) **%**
100					
135					
180					
250					

* At the reference point
Remarks:

Exradin A12 SN XA071362

Date range of measurements:		
Temperature range (C):		
Pressure range (hPa):		

Tube voltage **kV**	Calibration distance (source to reference point) **mm**	Beam diameter* **mm**	Air-kerma rate* **Gy/s**	Calibration coefficient (Reference: *T* = 295.15 K *P* = 1013.25 hPa *h* = 50 %) **Gy/C**	Relative standard uncertainty of calibration coefficient (coverage *k* =1) **%**
100					
135					
180					
250					

* At the reference point
Remarks:

APPENDIX C

PTW 30010 SN 613

Date range of measurements:		
Temperature range (C):		
Pressure range (hPa):		

Tube voltage **kV**	Calibration distance (source to reference point) **mm**	Beam diameter* **mm**	Air-kerma rate* **Gy/s**	Calibration coefficient (Reference: *T* = 295.15 K *P* = 1013.25 hPa *h* = 50 %) **Gy/C**	Relative standard uncertainty of calibration coefficient (coverage *k* =1) **%**
100					
135					
180					
250					

* At the reference point

Remarks:

PTW 30010 SN 614

Date range of measurements:		
Temperature range (C):		
Pressure range (hPa):		

Tube voltage **kV**	Calibration distance (source to reference point) **mm**	Beam diameter* **mm**	Air-kerma rate* **Gy/s**	Calibration coefficient (Reference: *T* = 295.15 K *P* = 1013.25 hPa *h* = 50 %) **Gy/C**	Relative standard uncertainty of calibration coefficient (coverage *k* =1) **%**
100					
135					
180					
250					

* At the reference point

Remarks: