Establishment of a Tandem Ionization Chamber System in Standard Mammography Beams

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Abstract. A double-faced tandem ionization chamber system was developed at the Calibration Laboratory of IPEN. It has different collecting electrode materials: aluminium and graphite. The response repeatability and reproducibility and the energy dependence test of this tandem ionization chamber were evaluated. The chamber response stability is within the ±3% limit recommended in international standards. The energy dependence test of the ionization chamber system using the tandem curve obtained, presented agreement with literature results.

1 Introduction

X-ray beam qualities are generally characterized in terms of the beam half-value layers. For the purpose of quality control programs, the half-value layers using absorbers shall be determined periodically. Nevertheless, it is a very high time-consuming technique and it is usually not even carried out by clinics. So, it is important to develop easier and faster procedures to evaluate the radiation qualities.

The tandem system is a practical method for routine checking of the X radiation qualities. It consists in comparing the responses of similar detectors, but with different energy dependencies. The usually common detector types to be utilized as tandem systems are the ionization chambers [1-5] and thermoluminescent dosimeters [6]. Some tandem systems were already tested in diagnostic radiology qualities, mammography and therapy beams [1-5].

The objective of this work is to present an alternative method for checking the standard mammography X-rays qualities, with aluminium and molibdenium filtrations, using a homemade tandem ionization chamber system. The methodology proposed in this work can de used in calibration laboratories and mammography clinics.

2 Materials and Methods

The tandem ionization chamber system was developed at the Calibration Laboratory of IPEN (LCI). This system consists of two ionization chambers of same geometry, but with collecting electrodes of different materials: aluminium and graphite. They are constructed together in the same acrylic body, and each ionization chamber has a sensitive volume of 6.0 cm^3. It is double-faced ionization chamber.

A PTW UNIDOS-E electrometer was utilized for the reading acquisitions of the developed tandem ionization chamber system. For the measurements, the tandem ionization chamber system was polarized with +300 V.

The irradiation systems used in the present work were a Pantak Seifert Isovolt 160HS X-ray equipment with tungsten target, which operates from 5 to 160 kV, and a ^{90}Sr+^{90}Y PTW check device (33 MBq, 1994). An acrylic holder for the geometrical reproducibility between the tandem ionization chamber system and the check source was developed, as presented in Figure 1.

A Radcal RC6M ionization chamber was used to obtain the air kerma rates during the experiments. This ionization chamber was calibrated at Physikalisch-Technische Bundesanstalt (PTB), and it is the reference system for the LCI mammography qualities. The calibration coefficients for the tandem ionization chamber system were obtained from the tandem system and the reference chamber measurements.

The PTB mammography qualities [7] utilized in this work were established at LCI, and they are described in Table 1 (for aluminium additional filtration) and in Table 2 (for molybdenum and aluminium additional filtrations). The effective energies were obtained by calculation based on NIST X-ray mass attenuation coefficients [8]. As the tandem ionization chamber is unsealed, the measurements were corrected for the standard environmental conditions of temperature and pressure.

For the measurements of the ambient temperature and pressure in the X-ray laboratory a Hart Scientific thermometer, 1529 model, and a GE Druck barometer, DPI 142 model were utilized. The relative humidity varied between 50% and 60%, and it was controlled using dehumidifiers and an air-conditioning system.

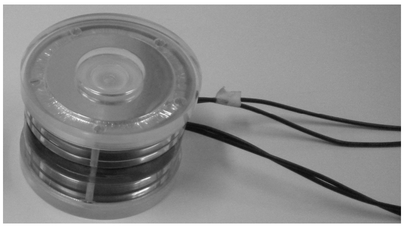

Fig. 1. The tandem ionization chamber with the ^{90}Sr+^{90}Y check source holder

Table 1. PTB mammography radiation qualities implemented at LCI. Aluminium additional filtration

Radiation quality	Tube voltage (kV)	Tube current (mA)	Additional filtration (mmAl)	Half-value layer (mmAl)	Effective energy (keV)	Air-kerma rate (mGy/min)
			Direct beams			
WAV 25	25	10	0.57	0.35	15.4	22.72
WAV 28	28	10	0.57	0.40	16.1	30.40
WAV 30	30	10	0.58	0.43	16.6	34.79
WAV 35	35	10	0.62	0.51	17.5	44.56
			Attenuated beams			
WAH 25	25	10	2.57	0.73	19.8	1.66
WAH 28	28	10	2.57	0.88	21.2	3.00
WAH 30	30	10	2.58	0.97	22.0	4.05
WAH 35	35	10	2.62	1.21	23.8	7.14

Table 2. PTB mammography radiation qualities implemented at LCI. Molybdenum and aluminium additional filtrations

Radiation quality	Tube voltage (kV)	Tube current (mA)	Additional filtration		Half-value layer (mmAl)	Effective energy (keV)	Air-kerma rate (mGy/min)
			(mmAl)	(mmMo)			
			Direct beams				
WMV 25	25	10	---	0.07	0.36	15.6	9.56
WMV 28	28	10	---	0.07	0.37	15.7	11.94
WMV 30	30	10	---	0.07	0.38	15.9	13.48
WMV 35	35	10	---	0.07	0.41	16.3	17.53
			Attenuated beams				
WMH 25	25	10	2.00	0.07	0.56	18.1	0.46
WMH 28	28	10	2.00	0.07	0.61	18.7	0.66
WMH 30	30	10	2.00	0.07	0.68	19.4	0.83
WMH 35	35	10	2.00	0.07	0.93	21.7	1.46

3 Results and Discussion

The tandem ionization chamber was studied in relation to its repeatability and reproducibility tests and energy dependence. For the system repeatability and reproducibility tests the reference distance of 1.0 mm (source to chamber distance) was utilized for the ^{90}Sr+^{90}Y measurements, and 1.0 m (focal spot to chamber distance) for the mammography radiation quality measurements.

3.1 Repeatability and Reproducibility Tests

The repeatability and reproducibility tests (also called short- and medium-term stability tests) were performed using the check source. For the repeatability test 10 successive measurements in the same conditions were taken, and the mean value was obtained. The geometrical reproducibility was guaranteed by the use of the acrylic holder. In this test the highest variation was 0.03% for the aluminum collecting electrode chamber and 0.04% for the graphite collecting electrode chamber, both for positive polarity.

The reproducibility test results are presented in Figure 2 as a set of measurements of the repeatability test. As can be observed, the measurements performed with the tandem ionization chamber system were within ±3%, as recommended in IEC 61674 [9] standard for this test.

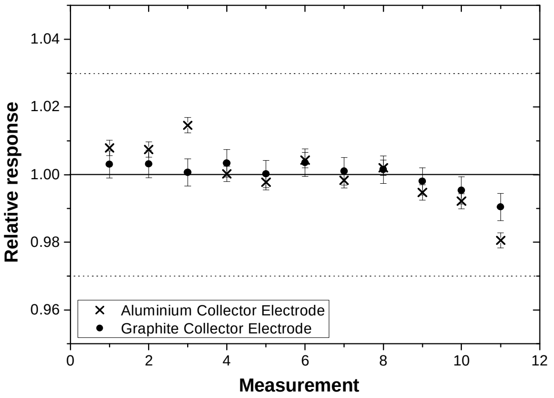

Fig. 2. Reproducibility test of the tandem ionization chamber

3.2 Energy Dependence Test

The tandem ionization chamber energy dependence test was evaluated by its calibration in the mammography radiation qualities. The calibration coefficients and the respective correction factors are presented in Tables 3 and 4. In Figures 3 and 4 are presented the energy dependence test results for the mammography radiation qualities. Table 5 presents the energy dependence maximum variation values. In the case of the WAV and WAH radiation qualities, the energy dependence showed a maximum of 7.2% for the aluminium collecting electrode chamber and a minimum of 1.6% for the graphite collecting electrode chamber. For the WMV and WMH radiation qualities, the tandem ionization chamber presented a maximum variation of 9.1% and a minimum of 0.7%.

Table 3. Calibration coefficients for the tandem ionization chamber. The correction factors were obtained by normalization with the WAV 28 and WAH 28 radiation qualities

Radiation quality	Ionization chamber			
	Aluminium electrode		Graphite electrode	
	Calibration coefficient ($Gy.\mu C^{-1}$)	Correction factor	Calibration coefficient ($Gy.\mu C^{-1}$)	Correction factor
	Direct beams			
WAV 25	2.574 ± 0.025	1.031 ± 0.014	4.381 ± 0.042	0.988 ± 0.013
WAV 28	2.496 ± 0.024	1.000 ± 0.014	4.432 ± 0.043	1.000 ± 0.014
WAV 30	2.431 ± 0.023	0.974 ± 0.014	4.444 ± 0.043	1.003 ± 0.014
WAV 35	2.316 ± 0.023	0.928 ± 0.014	4.501 ± 0.043	1.016 ± 0.014
	Attenuated beams			
WAH 25	2.138 ± 0.027	1.043 ± 0.013	4.618 ± 0.059	0.986 ± 0.016
WAH 28	2.049 ± 0.022	1.000 ± 0.015	4.684 ± 0.050	1.000 ± 0.015
WAH 30	2.003 ± 0.021	0.978 ± 0.015	4.705 ± 0.048	1.005 ± 0.015
WAH 35	1.919 ± 0.019	0.937 ± 0.014	4.769 ± 0.047	1.018 ± 0.015

Table 4. Calibration coefficients for the tandem ionization chamber. The correction factors were obtained by normalization with the WMV 28 and WMH 28 radiation qualities

Radiation quality	Ionization chamber			
	Aluminium electrode		Graphite electrode	
	Calibration coefficient ($Gy.\mu C^{-1}$)	Correction factor	Calibration coefficient ($Gy.\mu C^{-1}$)	Correction factor
	Direct beams			
WMV 25	2.602 ± 0.025	1.009 ± 0.014	4.355 ± 0.042	0.994 ± 0.014
WMV 28	2.580 ± 0.025	1.000 ± 0.014	4.380 ± 0.042	1.000 ± 0.014
WMV 30	2.555 ± 0.025	0.991 ± 0.014	4.380 ± 0.042	1.000 ± 0.014
WMV 35	2.499 ± 0.024	0.969 ± 0.013	4.410 ± 0.043	1.007 ± 0.014
	Attenuated beams			
WMH 25	2.296 ± 0.072	1.028 ± 0.014	4.370 ± 0.137	0.975 ± 0.039
WMH 28	2.233 ± 0.054	1.000 ± 0.034	4.484 ± 0.108	1.000 ± 0.034
WMH 30	2.185 ± 0.046	0.978 ± 0.031	4.521 ± 0.096	1.008 ± 0.032
WMH 35	2.030 ± 0.028	0.909 ± 0.025	4.635 ± 0.065	1.034 ± 0.029

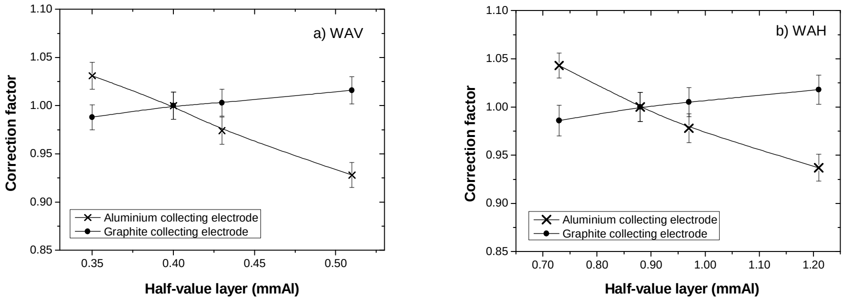

Fig. 3. Energy dependence test of the tandem ionization chamber for (a) WAV and (b) WAH radiation qualities

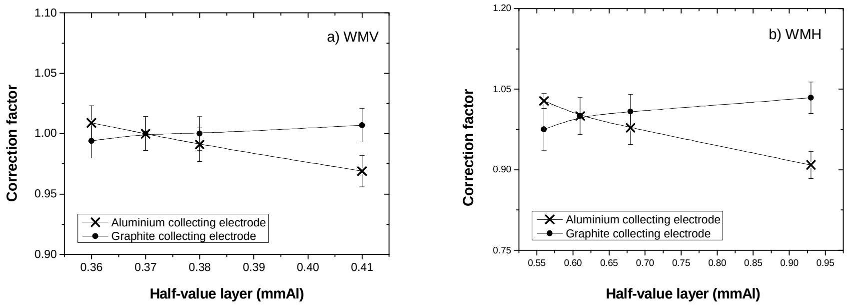

Fig. 4. Energy dependence test of the tandem ionization chamber for (a) WMV and (b) WMH radiation qualities

Table 5. Energy dependence maximum variation values of the tandem ionization chamber

Radiation quality range	Ionization chamber	
	Aluminium electrode	Graphite electrode
WAV	7.2%	1.6%
WAH	6.3%	1.8%
WMV	3.1%	0.7%
WMH	9.1%	3.4%

In IEC 61674 standard [9] the influence quantities for mammography energy range are defined for molybdenum anode tube. But, according to IAEA TRS 457 [10], a good compromise would be to use an X-ray tube with tungsten target and molybdenum filter. As the limits of variation of this test should be within ± 5%, according to IEC 61674 [9], it can be seen from Table 5 that the ionization chamber with graphite collecting electrode is suitable for dosimetry of this type of beam. The ionization chamber with aluminium collecting electrode presented energy dependence within the standard limits only in the case of the WMV quality range.

The results for the ionization chamber with graphite collecting electrode are in agreement with literature [1-3]. The tandem curves obtained from the chamber response ratios are presented in Figure 5 for the WAV and WAH radiation qualities ranges and in Figure 6 for the WMV and WMH radiation qualities ranges. The tandem curve shapes are adequate for mammography energy ranges [5].

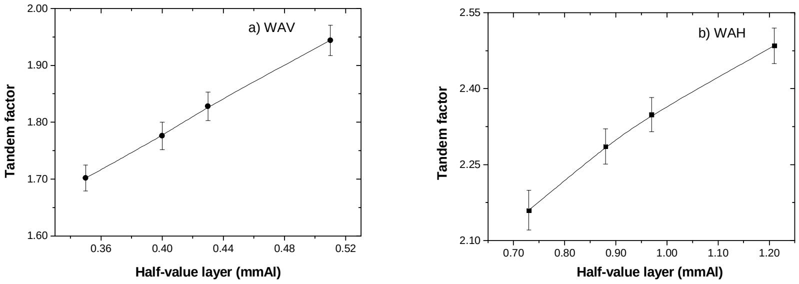

Fig. 5. Tandem curves for (a) WAV and (b) WAH radiation qualities

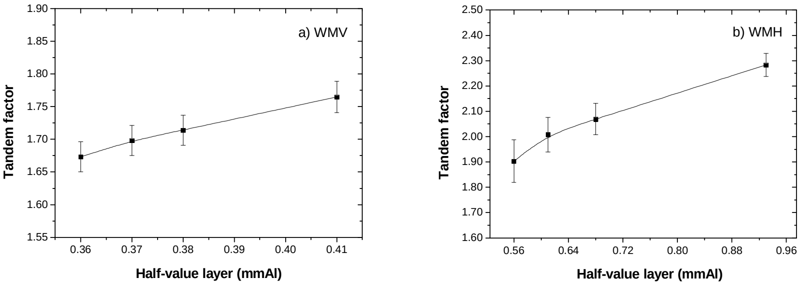

Fig. 6. Tandem curves for (a) WMV and (b) WMH radiation qualities

4 Conclusions

The tandem ionization chamber was tested in standard mammography radiation fields implemented at LCI. The tandem ionization chamber system showed adequate response in terms of stability and energy dependence as specified in international standards. A difference in response was observed for each chamber, due to the different materials in their collecting electrodes. From the energy dependence curves, it was possible to construct tandem curves, which may be used for confirmation/determination of the half–value layers of the radiation beams. Therefore, it can be concluded that the new tandem ionization chamber system can be used to verify the radiation qualities of the mammography beams established at LCI.

5 Acknowledgements

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