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Comparison of air kerma primary standards between SZMDM and OMH in ^{60}Co beam from the standpoint of radiotherapy

ABSTRACT

As the ICRU (International Committee for Radiation Unit) and some international expert bodies concluded that there was a need for an accuracy of ±5% in the delivery of absorbed dose in some treatment situations, dosimetry in radiotherapy generally became very serious metrological task. According to IAEA (International Atomic Energy Association) and WHO investigations in hospitals all over the world, radiotherapists do not use the same radiation beam, even physicists do not measure the same quantity. Due to that, there were some efforts made at the international level to unify measurements starting from ^{60}Co as a calibration beam and air kerma calibration factor for ionization chambers. According to this recommendation, national metrological organizations perform international intercomparisons between the air kerma primary standards. The comparison performed between the air kerma standards of Federal Bureau of Measures and Precious Metals (SZMDM) and Országos Mèrèsügyi Hivatal (OMH) for ^{60}Co gamma radiation is reported. It was the second international comparison between these two national metrological organizations which took place in Budapest in November, 1999. The results obtained with the two standards are in theagreement for ^{60}Co gamma radiation.

Key words: *International comparison; Primary standards; Radiotherapy; Metrology; ^{60}Co beam irradiation*

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INTRODUCTION

Quality control in radiotherapy dosimetry is a subject widely spread, not only to the hospitals and dosimetry laboratories, but to the other relevant authorities responsible for establishing and implementing the Quality Assurance (QA) program, particulary responsible for legal metrology. According to the national laws, obligations and licences, the SZMDM is considered to be the national primary dosimetry laboratory. Primary standards for air kerma, exposure and absorbed dose in water are developed and internationally intercompared. The same status in Hungary has the OMH. These two institutions have a long time colaboration in dosimetry comparisons. In November 1999 comparisons of three physical quantities were performed: air kerma in ^{60}Co gamma beam, exposure to X-ray beam and absorbed dose in water in ^{60}Co gamma beam. According to some recent recommendations, the absorbed dose in water calibration factor is needed, even at the level of national metrological organizations. In this paper, we presented only the results of air kerma primary standards comparison (1,2).

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MATERIALS AND METHODS

A comparison of the primary standards of air kerma of the Federal Bureau of Measures and Precious Metals (SZMDM), Belgrade, Yugoslavia and of the Országos Mèrèsügyi Hivatal (OMH), Budapest, Hungary, has been carried out for ^{60}Co radiation beam. The primary standards of air kerma of the SZMDM and OMH are graphite cavity chambers constructed at the OMH, Budapest. These chambers are cylinder shaped, graphite walled and 1cm^3 cavity volumed, ionisation chambers. The main technical data of the chambers are given in Table 1.

An earlier comparison of SZMDM standards was carried out at the OMH, in 1995, and the result showed the agreement of 0.1% for ^{60}Co radiation (3). These intercomparisons took place at the OMH in November, 1999.

Main technical data of ionization chambers

The standards of air kerma of the SZMDM and OMH constructed and built at the OMH, are used for the Bragg-Gray. Wall and electrode materials of the chambers are pure graphite EK 50 Ringsdorf (SZMDM) and EK 51 Ringsdorf (OMH), with the density of 1.75 gcm^{-3}.

The main technical data of the two chambers are given in Table 1.

Table 1. Characteristics of the SZMDM and OMH standards of air kerma

Dimensions	**(nominal value) [mm]**	**SZMDM**	**OMH**
Chamber	Outer height	19	19
	Outer diemeter	19	19
	Inner height	11	11
	Inner diemeter	11	11
	Wall thickness	4	4
Electrode	Diemeter	2.00	2.00
	Length	10.00	8.97
Volume of	**the air cavity [cm^3]**	1.0142	1.0219
Materials:	Wall ultrapure graphite Ringsdorf density 1.75 gcm^{-3}, impurities less than 1.5 x 10^{-4}	EK 50	EK 51
	Insulator	Poliethylene	PTFE(teflon)

Conditions of comparison

The comparison has been carried out for the ^{60}Co radiation beam of the Gammatron irradiation facility at the Gamma-Beta dosimetry of OMH. The distance from the source to the reference plane was 0.900 m. The field size (50%) in air, at the reference plane was 100^3 cm . The ambient temperature, pressure and relative humidity were 23.4°C, $100 cm^3$ kPa and 40.2%, respectively.

The ionisation current measurement system is based on Kiethley 617 electrometer and General Radio 1404-A standard capacity. The data collection of charge, and environmental parameter evaluation, is PC controlled automatic measuring set, with the usage of IEEE - 488 bus system.

The collection voltage applied to the SZMDM and OMH standards is ± 250 V. The polarity effect I_+/I_- is equal to 1.0021 (SZMDM) and 1.0018 (OMH). The air kerma rate is determined by (3,4,5):

$$\bar{K} = (1/m)(W/e)(1-\bar{g})^{-1}(\mu_{en}/\rho)_{a,c}\ \bar{S}_{c,a}\Pi k_i$$

where:

I/m is the mass ionisation current measured by the standard,

W is the average energy spent by an electron to produce an ion pair in dry air,

e is the electron charge,

$\bar{g}$ is the fraction of energy lost by “bremsstrahlung”.

$(\mu_{en}/\rho)_{a,c}$ is the ratio of the mean mass-energy absorption coefficients of air and graphite,

$\bar{S}_{c,a}$ is the ratio of the mean stopping powers of graphite and air,

Πk_i is the product of the correction factors to be applied to the standard

The data and the correction factors for the OMH and the SZMDM chambers are given in Table 2. The correction factors for axial and radial non-uniformity characterising the OMH beam, during the comparison, were given as k_{an}=0.9998, k_{rn}=1.0005 and were used for both standards.

RESULTS

The correction factors for the SZMDM standard were determined at the SZMDM.

The result of the comparison, $R_K = K_{SZMDM}/K_{OMH}$ is given in Table 3, together with the related standard uncertainties.

Table 3. Result of the SZMDM - OMH comparison of standards of air kerma (^{60}Co beam)

K_{SZMDM} [Gy/h]	K_{OMH} [Gy/h]	R_K
6.679	6.680	0.9999±0.0025

The standard uncertainty of the ratio was calculated as the quadratic sum of the individual standard uncertainties, but without the uncertainty components of the physical constants, because both laboratories used the same values.

The average percentage deviation of the ratio from (3) was 0.01 % for ^{60}Co beam quality. The result of present comparison is nearly 0.2% higher than the value obtained during the 1995 comparison (3).

The results of SZMDM-BIPM comparison (4) in 1991 and OMH-BIPM (5) were:

K_{SZMDM}/K_{BIPM}=0.9982±0.0019 and K_{OMH}/K_{BIPM}=1.0025±0.0024

It can be concluded that the standards of OMH and SZMDM agree well within their uncertainties.

Table 2. Physical constants and correction factors entered in the determination of the air kerma rates K_{SZMDM} and K_{OMH} for OMH ^{60}Co beam, and estimated relative uncertainties in the ratio K_{SZMDM}/K_{OMH}

	OMH			**SZMDM**			**K_{SZMDM}/K_{OMH}**	
	value	uncertainty		value	uncertainty		uncertainty	
		s	u		s	u	s	u
Physical constants								
Dry air density [kgm^{-3}]	1.2049		0.01	1.2049		0.01		
$(\mu_{en}/\rho)_{a,c}$	0.9985		0.05	0.9985		0.05		
$S_{c,a}$	1.0007		0.11	1.0009		0.11		
W/e [J/C]	33.97			33.97				0.03
g	0.0032		0.02	0.0032		0.02		
Correction factors								
k_s recombination loss	1.0027	0.04	0.05	1.0032	0.03	0.03	0.05	0.06
k_h humidity	0.9974		0.03	0.9974		0.03		0.04
k_{st} stem scattering	0.9998	0.01	0.05	0.9998	0.01	0.01	0.02	0.05
k_{at} wall attenuation				1.0165				
k_{sc} wall scattering	1.0157	0.05	0.05	0.999	0.04	0.06	0.07	0.08
k_{CEP} mean origin of e	0.997		0.1	0.998		0.02		0.1
k_{an} axial nonuniform.	0.9998		0.1	0.9998		0.1		0.14
k_{rn} radial nonunif.	1.0005		0.02	1.0005		0.02		0.03
Πk_i	1.01285			1.01314				
Measurement of I/v								
v – volume [cm^3]	1.0219		0.1	1.0142	0.01	0.03	0.01	0.1
I – ion. current [pA]	66.2383	0.01	0.02	65.7023	0.01	0.02	0.01	0.03
Uncertainty								
by quadratic summat		0.07	0.23		0.05	0.18	0.08	0.24
combined			**0.24**			**0.19**	**0.25**	

CONCLUSION

It can be concluded that the air kerma primary standards of SZMDM and OMH agree well within their uncertainties. The whole procedure was performed from strictly metrological standpoint in order to ensure quality assurance in radiotherapy. The very next step after the international intercomparison is a distribution of the accurate measures to the users through the national intercomparisons, as well as through the routine calibration of the measurement instruments. According to the recent recommendations, SZMDM makes all efforts to introduce and establish a new calibration program in radiotherapy, based on the absorbed dose in water calibration (1,6).

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