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Comparison of the air kerma standards of SZMDM and BIPM for ^{60}Co radiation

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Abstract

The comparison performed between the air kerma standards of the Savezni Zavod za Mere I Dragocene Metale and of the Bureau International des Poids et Mesures for ^{60}Co gamma radiation is reported. The results obtained with the two standards are in good agreement.

1. Introduction

A comparison between the air kerma standards of the Savezni Zavod za Mere I Dragocene Metale (SZMDM), Beograd, Yugoslavia, and of the Bureau International des Poids et Mesures (BIPM) has been performed in the ^{60}Co gamma radiation. The SZMDM standard of air kerma is a graphite cavity chamber constructed in the Dosimetry section of the Országos Mérésugyi Hivatal (OMH), Budapest, Hungaria (type ND 1005/A, serial number 8013). Its main characteristics are given in Table 1. Its volume had been determined at the OMH by an ionometric comparison against the OMH standard. The comparison took place at the BIPM in December 1991.

2. Conditions of measurement

The comparison has been performed at the BIPM in the conditions of measurement given in Table 6 of ref. [1].

The air kerma rate is determined for one standard by

$$\dot{K} = \frac{I}{m} \frac{W}{e} \frac{1}{1 - \bar{g}} \left(\frac{\mu_{en}}{\rho}\right)_{a,c} \bar{s}_{c,a} \, \Pi \, k_i \, , \qquad (1)$$

where
I/m is the mass ionization current measured by the standard,
W is the average energy spent by an electron of charge e to produce an ion pair in dry air,
$\bar{g}$ is the fraction of energy lost by bremsstrahlung,

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$(\mu_{en}/\rho)_{a,c}$ 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 physical constants and the correction factors entering in Eq. (1) and the uncertainties associated with the measurement of K are given in Table 7 of ref. [1] for the BIPM standard and in Table 2 of the present report for the SZMDM standard.

The collecting voltage applied to the SZMDM standard is ± 250 V. The polarity effect I_{+250V}/I_{-250V} is equal to 1,001 8.

Some of the correction factors, previously determined at the SZMDM, have been measured again in the BIPM beam for checking purposes. They concern corrections due to the wall (k_{at}, k_{sc}) and the stem scattering (k_{st}); the results are given in Table 3. The correction factor k_s, for the recombination losses, has been roughly checked: the result (1,003 0) is in agreement with the value 1,003 2 determined at the SZMDM. The correction factor k_{rn}, for the radial non-uniformity of the BIPM beam over the section of the SZMDM standard, has been estimated from [2]. The value of $\bar{s}_{c,a}$ applied to the SZMDM standard, (Δ = 17,5 keV, ρ_c = 1,75 g cm^{-3}), has been calculated by the Spencer-Attix method [3] from the data of ICRU [4].

The uncertainty on the measurement of the ionization current is larger at the SZMDM (< 0,1 %) than at the BIPM (0,02 %); likewise the uncertainties given in Table 3 are larger at the SZMDM. The uncertainty on the air kerma rate $\dot{K}_{SZMDM}$ is estimated to be 0,26 % for the determination at the SZMDM and to 0,2 % for the determination at the BIPM (see Table 2).

3. Results

The result of the comparison is given in Table 4; the air kerma rates determined by the SZMDM and the BIPM standards are in very good agreement. Their ratio $R = \dot{K}_{SZMDM}/\dot{K}_{BIPM}$ is equal to 0,998 2. Some of the uncertainties in $\dot{K}$ which appear in both determinations (such as air density, W/e, μ_{en}/ρ, $\bar{g}$, $\bar{s}_{c,a}$, k_h, ...) cancel for the uncertainty in ratio R, which is estimated to be 0,2 %. A detailed analysis is given in Table 2.

Four national laboratories which are in possession of an air kerma standard of this type have performed comparisons at the BIPM during the last decade. All the results agree within 0,3 %. This confirms that graphite cavity chambers of the type used in the present comparison are adequate as primary standards for ^{60}Co gamma radiation.

Table 1 - Characteristics and dimensions of the SZMDM standard ionization chamber type ND 1005/A, serial number 8013

Dimensions (nominal values)	(mm)
Outer height	19
Outer diameter	19
Inner height	11
Inner diameter	11
Wall thickness	4
Electrode	
diameter	2
length	10
Volume of the air cavity*	1,014 2 cm^3

Materials

Wall ultrapure graphite EK50 Ringsdorf, of density 1,75 g cm^{-3} and with impurities of about $1,5 \times 10^{-4}$

Insulator polyethylene

* Measured by the Országos Mérésügyi Hivatal (OMH), Budapest.

Table 2 - Physical constants and correction factors entering in the determination of air kerma rate $\dot{K}_{SZMDM}$, for the BIPM ^{60}Co beam.
The uncertainties are given as standard deviations (in %).

		values	$\dot{K}_{SZMDM}$ uncertainty		$\dot{K}_{SZMDM}/\dot{K}_{BIPM}$ uncertainty*	
			s_i	u_j	s_i	u_j
Physical constants						
dry air density						
(273,15 K, 101 325 Pa)	(kg m^{-3})	1,293 0		0,01		
$(\mu_{en}/\rho)_a/(\mu_{en}/\rho)_c$ [5]		0,998 5		0,05		
$\bar{s}_{c,a}$ [5]		1,000 9				0,03
W/e [5]	(J C^{-1})	33,97		0,11**		
$\bar{g}$ (fraction of energy						
lost by bremsstrahlung) [5]		0,003 2		0,02		
Correction factors						
k_s recombination losses		1,003 2	0,026	0,03	0,03	0,03
k_h humidity		0,997		0,03		
k_{st} stem scattering		0,999 8	0,01	0,01	0,01	0,02
k_{at} wall attenuation						
k_{sc} wall scattering		1,012 4	0,03	0,08	0,03	0,11
k_{CEP} mean origin of electrons						
k_{an} axial non-uniformity		0,997		0,1		0,12
k_{rn} radial non-uniformity		1,000 3		0,02		
Measurement of I/vρ						
v volume	(cm^3)	1,014 2	0,01	0,03	0,02	0,04
I ionization courant						
corrections concerning ρ			0,01	0,01	0,02	0,02
(temperature, pressure,						
air compressibility)						
Uncertainty on $\dot{K}_{SZMDM}$						
quadratic sum			0,04	0,19		
combined uncertainty			0,19			
Uncertainty on $\dot{K}_{SZMDM}/\dot{K}_{BIPM}$						
quadratic sum					0,05	0,18
combined uncertainty					0,19	

* See Table 7 of ref. [1] for a detailed analysis of the uncertainty on $\dot{K}_{BIPM}$.

** Uncertainty on the product W/e $\bar{s}_{c,a}$ entering in the determination of air kerma [6].

Table 3 - Determination at the SZMDM and BIPM
of some correction factors of the SZMDM standard

	at SZMDM			at BIPM		
	value	uncertainty		value	uncertainty	
		s_i	u_j		s_i	u_j
k_{at} k_{sc}	1,016 5	0,04	0,06	1,012 4	0,03	0,08
k_{CEP}	0,997		0,02			
k_{st}	0,999	0,03	0,03	0,999 8	0,01	0,01

Table 4 - Result of the SZMDM-BIPM comparison of air kerma

Date of measurement	$\dot{K}_{SZMDM}$ mGy/s	$\dot{K}_{BIPM}$ mGy/s	$\dot{K}_{SZMDM}/\dot{K}_{BIPM}$*
1991-12-09	10,147	10,166 4	
1991-12-10	10,149		
			0,998 2 ± 0,001 9
1991-12-11	10,148		
1991-12-16		10,166 6	

Each air kerma rate value is the mean of 60 measurements.
The leakage current of the SZMDM standard is of the order of 0,01 %.
The standard deviation of a daily mean value of the ionisation current of the SZMDM standard is 0,01 %.

* See Table 2 for the analysis of the uncertainty of $\dot{K}_{SZMDM}/\dot{K}_{BIPM}$.

References

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