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

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Abstract

The comparison performed between the air kerma standards of the Ustav Dozimetrie Zareni 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 Ustav Dozimetrie Zareni (UDZ), Praha, and of the Bureau International des Poids et Mesures (BIPM), Sèvres, has been performed in ^{60}Co gamma radiation. The UDZ standard of air kerma is a graphite cavity chamber constructed in the Dosimetry section of the Orszagos Mérésugyi Hivatal (OMH), Budapest, Hungaria (type ND 1005/A, serial number 8105). Its main characteristics are given in Table 1. Its volume had already been determined at the OMH by an ionometric measurement. The comparison took place at the BIPM in September 1992.

2. Conditions of measurement

The comparison has been performed at the BIPM under the conditions of measurement given in Table 6 of [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 (1) and the uncertainties associated with the measurement of $\dot{K}$ are given in Table 7 of [1] for the BIPM standard and in Table 2 of the present report for the UDZ standard.

The collecting voltage applied to the UDZ standard is ± 300 V. The polarity effect I_{+300V}/I_{-300V} is equal to 1,002 4 ± 0,000 4.

The correction factors relevant to the UDZ standard concerning the wall, the stem scattering and the recombination losses have been determined at the UDZ. The correction factor k_{rn}, for the radial non-uniformity of the BIPM beam over the section of the UDZ standard, has been estimated from [2]. The value of $\bar{s}_{c,a}$ applied to the UDZ 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 in the air kerma rate $\dot{K}_{UDZ}$, determined at the BIPM, is estimated to be 0,23 % (see Table 2).

3. Results

The result of the comparison is given in Table 3; the air kerma rates determined by the UDZ and the BIPM standards are in good agreement. Their ratio $\dot{K}_{UDZ}/\dot{K}_{BIPM}$ is 0,999 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 when evaluating the uncertainty of the ratio $\dot{K}_{UDZ}/\dot{K}_{BIPM}$, which is estimated to be 0,23 %. A detailed analysis is given in Table 2.

Another determination of the volume of the UDZ standard was performed at the OMH by a mechanical measurement. The result differs from the value given in Table 1 by 0,2 %.

During the comparison at the BIPM, the ionization currents of the BIPM and UDZ standards were measured with the BIPM equipment. In addition, the ionization current of the UDZ standard was measured with the UDZ electrometer (Keithley 617): the value was 0,16 % lower than the one measured by the BIPM equipment. After the comparison, the UDZ electrometer has been checked at UDZ.

Five national laboratories which are in possession of a similar air kerma standard have performed comparisons at the BIPM during the past decade. All the results agree to 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 UDZ standard ionization chamber type ND 1005/A, serial number 8105

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 (cm^3)*	1,018 8

Materials

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

Insulator polyethylene

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

Table 2

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

			$\dot{K}_{UDZ}$ values	$\dot{K}_{UDZ}$ uncertainty		$\dot{K}_{UDZ}/\dot{K}_{BIPM}$ 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		1,001 6	0,02	0,03	0,03	0,03
k_h	humidity		0,997 0		0,03		
k_{st}	stem scattering		0,999 7	0,01	0,01	0,01	0,02
k_{at}	wall attenuation						
k_{sc}	wall scattering		1,013 1	0,02	0,12	0,02	0,15
k_{CEP}	mean origin of electrons						
k_{an}	axial non-uniformity		0,999 8		0,1		0,12
k_{rn}	radial non-uniformity		1,000 3		<0,01		0,02
Measurement of I/vρ							
v	volume	(cm^3)	1,018 8		0,10	0,01	0,10
I	ionization current						
corrections concerning ρ (temperature, pressure, air compressibility)				0,01	0,01	0,02	0,02
Uncertainty in $\dot{K}_{UDZ}$							
quadratic sum				0,03	0,23		
combined uncertainty					0,23		
Uncertainty in $\dot{K}_{UDZ}/\dot{K}_{BIPM}$							
quadratic sum						0,04	0,22
combined uncertainty							0,23

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

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

Table 3

Result of the UDZ-BIPM comparison of air kerma standards

Date of measurement	$\dot{K}_{UDZ}$ (mGy/s)	$\dot{K}_{BIPM}$ (mGy/s)	$\dot{K}_{UDZ}/\dot{K}_{BIPM}$*
1992-09-09		8,914 7	
1992-09-15	8,907 5		0,999 2 ± 0,002 3
1992-09-16		8,915 0	

Each air kerma rate value is the mean of 60 measurements. It is corrected for decay and air absorption between source and standard and given for the reference date 1992-01-01, using the recently compiled value for the ^{60}Co half life of (1925,5 ± 0,5) d [7].

The leakage current of the UDZ standard is of order 0,01 %.

The standard deviation of the mean value of the ionisation current of the UDZ standard is 0,01 %.

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

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