Rapport BIPM-04/17

MEASURING CONDITIONS USED FOR THE CALIBRATION OF IONIZATION CHAMBERS AT THE BIPM*

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December 2004

BUREAU INTERNATIONAL DES POIDS ET MESURES

F-92310 Sèvres

*This report supersedes the *Rapport BIPM-01/04* of M. Boutillon, P. J. Allisy-Roberts, D.T. Burns

Table of contents

Abstract. Information is presented on the experimental conditions used at the BIPM in the x- and γ-radiation beams for the calibration of secondary standards in terms of air kerma, absorbed dose in water and ambient dose equivalent, together with the uncertainties involved in the determination of these dosimetric quantities.

I. Introduction

The BIPM calibrates secondary standards (ionization chambers) for countries that are Member States of the Metre Convention. It works with a single, designated laboratory in each country for a given type of measurement. The calibrated instruments are then normally used as national references. For this reason, the chambers should be instruments of good quality; in particular, with respect to leakage currents and both short- and long-term stability. Their calibration coefficients must not vary significantly with the conditions of irradiation.

Calibrations of ionization chambers are performed at BIPM

- in terms of air kerma in the low- and medium-energy x-ray ranges and in ^{60}Co and ^{137}Cs gamma radiations,
- in terms of absorbed dose to water in ^{60}Co gamma radiation,
- in terms of ambient dose equivalent in ^{60}Co and ^{137}Cs gamma radiations.

The present report documents the conditions of measurement at the BIPM, the values for the physical constants and correction factors, and the estimated uncertainties in the determination of calibration coefficients.

II. General remarks

The reference plane is specified in terms of a distance from the radiation source or, in the case of low-energy x-rays, from the beam exit window. The reference point is the intersection of the beam axis with the reference plane.

For chamber types other than parallel plate, the chamber is positioned with its axis in the reference plane and with the stated point of measurement of the chamber at the reference point. For calibration in gamma radiation the chamber is used with the build-up cap provided. The orientation of the chamber is such that the number or text inscribed on the stem is facing the radiation source, unless a different orientation is indicated. Parallel-plate chambers are calibrated with the outer surface of the entrance window in the reference plane, unless a different surface is indicated, and with the entrance window centred on the beam axis.

All chambers are irradiated for at least thirty minutes, with the polarizing potential applied, before any measurements are made.

Note that the secondary standard chamber type NE2611 differs from the older type NE2561 in that the insulation ring near the top of the body of the NE2561 is eliminated. In the NE2561, the graphite cap is at the polarizing potential. The NE2611 is designed to work with modern electrometers with the case, chamber cap and body, and outer braid at earth potential. The electrometer amplifier floats at the polarizing potential and the central electrode and guard of the chamber are also at this potential.

The leakage current is normally measured before and after each set of measurements and a correction applied based on the mean value. A chamber for which the relative leakage current is high, and in particular for which the leakage is also variable, might be considered unsuitable for calibration. In this case, a study note is issued.

The irradiation facilities at the BIPM are temperature controlled (close to 20 °C) at the level of around 100 mK. For air kerma measurements in ^{60}Co and ^{137}Cs, an additional, passive enclosure is used to give temperature stability below 50 mK. The BIPM reference conditions for air temperature and pressure are T_0 = 293.15 K and P_0 = 101.325 kPa, respectively. Relative humidity is controlled within the range 47 % to 53 % and consequently no humidity correction is applied.

No correction is applied for the effect of ion recombination; the air kerma rate is stated in the certificate. For the chamber types calibrated in gamma radiation the radial non-uniformity correction for the BIPM beams is small and is stated in the certificate, although no correction factor is applied. In x-rays, chambers of larger dimensions may be calibrated and the appropriate correction factor is always applied.

III. Calibration in terms of air kerma (x-rays, ^{60}Co, ^{137}Cs)

The transfer chamber is operated in air at the stated reference distance. The calibration coefficient N_K is defined by the relation

$$N_K = \dot{K}_{\text{BIPM}} / I \,, \qquad (1)$$

where : $\dot{K}_{\text{BIPM}}$ is the air kerma rate at the reference point, measured with the BIPM standard, and I is the ionization current of the transfer chamber under the BIPM reference conditions of air temperature, pressure and humidity. The value of I is given by

$$I = I_{exp} \, (TP_0)/(T_0 P) \,, \qquad (2)$$

where : I_{exp} is the ionization current measured at temperature T (expressed in K) and pressure P (expressed in Pa).

The calibration coefficient for exposure, N_X, is given by

$$N_X = N_K (1 - g)/(W/e) \,, \qquad (3)$$

where g is the fraction of electron energy lost by bremsstrahlung [1], W is the mean energy expended to produce an ion pair in dry air, and e is the electron charge [1,2].

Details of the conditions of measurement at the BIPM and the uncertainties in the determination of $\dot{K}_{\text{BIPM}}$ are given in Tables 1 to 6 for x-rays, in Tables 7 and 8 for ^{60}Co and in Tables 9 and 10 for ^{137}Cs. In these tables, the relative standard uncertainties estimated by statistical methods (Type A) are denoted by s_i and those estimated by other means (Type B) are designated by u_i.

IV. Calibration in terms of absorbed dose to water (^{60}Co)

The transfer chamber is placed in its waterproof sleeve and positioned in the BIPM cubic water phantom of side 30 cm. Its axis is placed in the reference plane, at the reference depth of 5 g cm^{-2} in water. This depth includes the window of the phantom (PMMA, 0.476 g cm^{-2}) and is corrected for the change in water density with temperature. As well as correctly orienting the chamber, the mark on the sleeve is rotated so as to point towards the radiation source, unless a different orientation is indicated.

The calibration coefficient, $N_{D,\mathrm{w}}$, is determined using the relation

$$N_{D,\mathrm{w}} = \dot{D}_\mathrm{w} / (I_\mathrm{w} k_\mathrm{pf}), \qquad (4)$$

where :
$\dot{D}_\mathrm{w}$ is the absorbed dose rate to water at the reference point, measured by the BIPM standard at a depth of 5 g cm^{-2} in water;
I_w is the ionization current measured by the transfer chamber under the BIPM reference conditions of air temperature, pressure and humidity;
k_pf = 0.9996 is a correction factor applied to I_w for the non-equivalence with water of the PMMA window of the phantom. The conditions of measurement at the BIPM are given in Table 7. The physical constants and correction factors used in the ionometric determination of the absorbed dose rate to water at 5 g cm^{-2} are given in Table 11 along with their estimated relative uncertainties.

V. Calibration in terms of ambient dose equivalent (^{60}Co, ^{137}Cs)

The transfer chamber is positioned in air, with its axis in the reference plane.

The calibration coefficient, N_H is determined using the relation

$$N_H = \dot{H}^* / I_H \quad , \qquad (5)$$

where :
$\dot{H}^*$ is the ambient dose equivalent rate. For ^{60}Co radiation, $\dot{H}^*$ is measured by the BIPM standard. For ^{137}Cs, $\dot{H}^*$ is deduced by calculation from the measurement of air kerma rate,
I_H is the ionization current measured by the transfer chamber under the BIPM reference conditions of air temperature, pressure and humidity.

The conditions of measurement at the BIPM are given in Tables 7 and 9 for ^{60}Co and ^{137}Cs, respectively. The physical constants and correction factors used in the ionometric determination of the ambient dose equivalent are given in Tables 12 and 13 for ^{60}Co and ^{137}Cs radiation, respectively.

VI. Use of calibration coefficients

A secondary standard calibrated in the BIPM beam can be used in another beam, taking the calibration coefficients N_K , $N_{D,\mathrm{w}}$ or N_H , obtained from (1), (4) and (5), respectively, to determine K, D_w or H in that beam, subject to certain provisions;

(a) The humidity conditions must not differ significantly from those of the calibration at BIPM. Otherwise, if the relative humidity is outside the range 30 % to 70 %, the curves given in [3] should be used.

(b) The conditions of measurement must not differ significantly from those of the calibration at the BIPM. Otherwise, additional corrections may be necessary (see for example [4] and [5]). Particular attention should be paid to:

- the radiation quality, particularly in the x-ray range;
- the distance from the source;

- the dimensions of the radiation field, in particular as regards the radiation scattered by the stem and the support, for calibration in terms of air kerma;
- the intensity of the ionization current, which can produce a change in the ion recombination;
- the radial non-uniformity of the beam over the cross-section of the chamber [6, 7].

VII. Calibration uncertainties

The uncertainties associated with dosimetry measurements made at the BIPM are analysed in accordance with the GUM [8]. The uncertainty budget for the respective dosimetry standard is given in Tables 3, 6, 8, 10, 11, 12 and 13. The BIPM standard uncertainties are combined with the uncertainties associated with the chamber under calibration to give the combined standard uncertainty of the calibration coefficient. This value is given in the calibration certificate.

The uncertainty associated with BIPM calibrations is a combined standard uncertainty without the application of a coverage factor *k*. This long-standing practice of not applying a coverage factor is considered to facilitate the combination of the BIPM and NMI uncertainties and thus simplify the subsequent dissemination of the standard to the customers of the NMI.

The BIPM dosimetry measurements fulfil the criteria of section G6.6 of the GUM [8]. In particular, for the purpose of calculating the expanded uncertainty for their end result at a specified level of confidence, a NMI can assume that the effective degrees of freedom for a BIPM calibration is sufficient to be able to use a coverage factor $k = 2$ for a level of confidence of approximately 95 %. Any exceptions are noted in the calibration certificate.

Table 1. X-rays (10 kV to 50 kV)

Conditions of measurement at the BIPM

Distance between beryllium window of x-ray tube and reference plane of standard: 50 cm
Beam diameter in the reference plane: 8.4 cm
Air filtration : 59.4 mg cm^{-2} (50 cm at 293.15 K and 100 kPa); beryllium filtration: ≅ 3.0 mm

Reference qualities (recommended by Section I of CCEMRI [9, 10])

X-ray tube voltage /kV	10	30	25	50(b)	50(a)[(2)]
filtration /(mm Al)	0	0.208	0.372	1.008	3.989
half-value layer /(mm Al)	0.037	0.169	0.242	1.017	2.262
μ/ρ [(1)] /(cm^2 g^{-1})	14.84	3.66	2.60	0.75	0.38
air kerma rate /(mGy s^{-1})	1.00	1.00	1.00	1.00	1.00

(1) mass air attenuation coefficient
(2) the more-filtered of the two 50 kV radiation qualities

Table 2. X-rays (10 kV to 50 kV)

Physical constants and correction factors used in the BIPM determination[(1)] of the air kerma rate

Dry air density (273.15 K, 101.325 kPa) = 1.2930 kg m^{-3}

W/e = 33.97 J C^{-1}

Measuring volume: 1.200 41 cm^3

	X-ray tube voltage /kV	10	30	25	50(b)	50(a)
Correction factors						
k_{sc}	scattered radiation[(2)]	0.9962	0.9972	0.9973	0.9977	0.9979
k_{fl}	fluorescence[(2)]	0.9952	0.9971	0.9969	0.9980	0.9985
k_e	electron loss	1.0000	1.0000	1.0000	1.0000	1.0000
k_s	ion recombination	1.0006	1.0007	1.0007	1.0007	1.0007
k_{pol}	polarity	1.0005	1.0005	1.0005	1.0005	1.0005
k_a	air attenuation[(3)]	1.1957	1.0451	1.0319	1.0091	1.0046
k_d	field distortion	1.0000	1.0000	1.0000	1.0000	1.0000
k_l	transmission through edges of diaphragm	1.0000	1.0000	1.0000	1.0000	1.0000
k_p	transmission through walls of standard	1.0000	1.0000	1.0000	1.0000	1.0000
k_h	humidity	0.998	0.998	0.998	0.998	0.998
$1-g$	bremsstrahlung	1.0000	1.0000	1.0000	1.0000	1.0000

(1) details on the determination of the air kerma rate are given in [11]
(2) new values adopted October 2003
(3) values at 293.15 K and 101.325 kPa for an attenuation length of 10.0 cm

Table 3. X-rays (10 kV to 50 kV)

Estimated relative standard uncertainties in the BIPM determination of air kerma rate

		$100\ s_i$ [1]	$100\ u_i$
Physical constant			
dry air density		–	0.01
(273.15 K, 101.325 kPa)			
W/e	$/(\mathrm{J\ C^{-1}})$	–	0.15
g		–	0.01
Correction factors			
k_{sc}	scattered radiation	–	0.03
k_{fl}	fluorescence	–	0.05
k_{e}	electron loss	–	0.01
k_{s}	ion recombination	0.01	0.01
k_{pol}	polarity	0.01	–
k_{a}	air attenuation	0.02	0.01
k_{d}	field distortion	–	0.07
k_{l}	transmission through edges of diaphragm	–	0.01
k_{p}	transmission through walls of standard	0.01	
k_{h}	humidity	–	0.03
Measurement of $I/v\rho$			
v	volume /cm^3	0.03	0.05
I	ionization current correction concerning ρ	0.02	0.02
	(temperature, pressure, air compressibility)		
	positioning of standard	0.01	0.01
Relative standard uncertainty in $\dot{K}_{\mathrm{BIPM}}$			
quadratic sum		0.05	0.19
combined uncertainty		0.20	

[1] s_i represents the relative standard Type A uncertainty, estimated by statistical methods;
u_i represents the relative standard Type B uncertainty, estimated by other means.

Table 4. X-rays (100 kV to 250 kV)

Conditions of measurement at the BIPM

Distance between focal spot and reference plane of standard: 120 cm

Beam diameter in the reference plane: 9.8 cm

Inherent filtration: ≅ 3 mm Be

Reference qualities (recommended by Section I of the CCEMRI [9])

X-ray tube voltage /kV	100	135	180	250
additional filtration /(mm Al)	3.431	2.228	2.228	2.228
/(mm Cu)	–	0.232	0.485	1.570
half-value layer /(mm Al)	4.030	–	–	–
/(mm Cu)	0.149	0.489	0.977	2.484
μ/ρ [(1)] /(cm^2 g^{-1})	0.290	0.190	0.162	0.137
air kerma rate /(mGy s^{-1})	0.50	0.50	0.50	0.50

[(1)] mass air attenuation coefficient

Table 5. X-rays (100 kV to 250 kV)

Physical constants and correction factors used in the BIPM determination[1] of the air kerma rate

Dry air density (273.15 K, 101.325 kPa) =1.2930 kg m^{-3}

W/e = 33.97 J C^{-1}

Measuring volume: 4.6554 cm^3

	X-ray tube voltage /kV	100	135	180	250
Correction factors					
k_{sc}	scattered radiation[2]	0.9952	0.9959	0.9964	0.9974
k_{fl}	fluorescence[2]	0.9985	0.9992	0.9994	0.9999
k_e	electron loss[2]	1.0000	1.0016	1.0043	1.0073
k_s	ion recombination	1.0010	1.0010	1.0010	1.0010
k_{pol}	polarity	1.0002	1.0002	1.0002	1.0002
k_a	air attenuation[3]	1.0099	1.0065	1.0055	1.0047
k_d	field distortion	1.0000	1.0000	1.0000	1.0000
k_l	transmission through edges of diaphragm	0.9999	0.9998	0.9997	0.9996
k_p	transmission through walls of standard	1.0000	1.0000	0.9999	0.9988
k_h	humidity	0.998	0.998	0.998	0.998
$1-g$	bremsstrahlung	0.9999	0.9999	0.9998	0.9997

(1) details on the determination of the air kerma rate can be found in [12]
(2) new values adopted October 2003
(3) values at 293.15 K and 101.325 kPa for an attenuation length of 28.15 cm

Table 6. X-rays (100 kV to 250 kV)

Estimated relative standard uncertainties in the BIPM determination of air kerma rate

		$100\ s_i$[1]		$100\ u_i$
Physical constant				
dry air density (273.15 K, 101.325 kPa)		–		0.01
W/e	$/(\mathrm{J\ C^{-1}})$	–		0.15
g		–		0.01
Correction factors				
k_{sc}	scattered radiation	–		0.03
k_{fl}	fluorescence	–		0.03
k_e	electron loss	–		0.09
k_s	ion recombination	0.02		0.01
k_a	air attenuation	0.02		0.01
k_d	field distortion	–		0.07
k_l	transmission through edges of diaphragm	–		0.01
k_p	transmission through walls of standard	0.01		–
k_h	humidity	–		0.03
Measurement of $I/v\rho$				
v	volume /cm^3	0.01		0.05
I	ionization current correction	0.02		0.02
	concerning ρ (temperature, pressure, air compressibility)			
	positioning of standard	0.01		0.01
Relative standard uncertainty in $\dot{K}_{\mathrm{BIPM}}$				
quadratic sum		0.04		0.20
combined uncertainty			0.21	

[1] s_i represents the relative standard Type A uncertainty, estimated by statistical methods;
u_i represents the relative standard Type B uncertainty, estimated by other means.

Table 7. ^{60}Co gamma radiation

Conditions of measurement at the BIPM

Measurement of air kerma and absorbed dose	
source activity (2005-01-01) (approximate value)	23 TBq
source dimensions	
diameter	20 mm
length	5.6 mm
contribution of incident scattered radiation (in terms of energy fluence)	14 %
distance from source to reference plane	1 m
beam section in the reference plane[(1)]	10 cm × 10 cm
reference depth for absorbed dose measurement	5 g cm^{-2}
Measurement of ambient dose equivalent	
source activity (2005-01-01) (approximate value)	0.2 TBq
source dimensions	
diameter	5 mm
length	6 mm
contribution of incident scattered radiation (in terms of energy fluence)	8 %
distance from source to reference plane	3.5 m
beam diameter in the reference plane	80 cm

[(1)] The photon fluence rate at the centre of each side of the 10 cm × 10 cm field is 50 % of the photon fluence rate at the centre of the square.

Table 8. ^{60}Co gamma radiation

Physical constants and correction factors used in the BIPM determination[1] of the air kerma rate, and their estimated relative standard uncertainties

Physical constant		**value**	100 s_i	100 u_i
dry air density /(kg m^{-3}) (273.15 K, 101.325 kPa)		1.2930	–	0.01
$(\mu_{en}/\rho)_a/(\mu_{en}/\rho)_c$		0.9985	–	0.05
stopping power ratio $\bar{s}_{c,a}$		1.0010	–	0.11 [2]
W/e	/(J C^{-1})	33.97	–	
g	fraction of energy lost by bremsstrahlung	0.0032	–	0.02
Correction factors				
k_s	ion recombination	1.0015	0.01	0.01
k_h	humidity	0.9970	–	0.03
k_{st}	stem scattering	1.0000	0.01	–
k_{at}	wall attenuation	1.0398	0.01	0.04
k_{CEP}	mean origin of electrons	0.9922	–	0.01
k_{sc}	wall scattering	0.9720	0.01	0.07
k_{an}	axial non-uniformity	0.9964	–	0.07
k_{rn}	radial non-uniformity	1.0016	0.01	0.02
Measurement of $I/v\rho$				
v	volume /cm^3	6.8028 [3]	0.01	0.03
I	ionization current correction concerning ρ (temperature, pressure, air compressibility)		0.01	0.02
Relative standard uncertainty in $\dot{K}_{BIPM}$				
quadratic sum			0.03	0.17
combined uncertainty			0.17	

[1] details on the determination of air kerma rate are given in [13]

[2] the uncertainty of the product of the stopping power ratio and W/e is estimated to be the same for determinations of air kerma and absorbed dose [14]. The present value supersedes that quoted in the Rapport BIPM-96/1, as agreed by the CCRI in 1999 [15]

[3] standard CH5-1

Table 9. ^{60}Co gamma radiation

Physical constants and correction factors used in the BIPM ionometric determination[1] of the absorbed dose rate to water at 5 g cm^{-2}, and their estimated relative standard uncertainties

Physical constant		**value**	100 s_i	100 u_i
dry air density /(kg m^{-3}) (273.15 K, 101.325 kPa)		1.2930	–	0.01
$(\mu_{en}/\rho)_w/(\mu_{en}/\rho)_c$		1.1125[2]	0.01[2]	0.14[2]
stopping power ratio $\bar{s}_{c,a}$		1.0030	–	} 0.11[3]
W/e /(J C^{-1})		33.97	–	
Correction factors				
k_p	fluence perturbation	1.1107	0.05	0.17
k_{ps}	polythene envelope of the chamber	0.9994	0.01	0.01
k_{pf}	front face of the phantom	0.9996	–	0.01
k_{rn}	radial non-uniformity	1.0051	0.01	0.03
k_s	ion recombination	1.0015	0.01	0.01
k_h	humidity	0.9970	–	0.03
Measurement of $\boldsymbol{I/v\rho}$				
v	volume /cm^3	6.8810[4]	0.19	0.03
I	ionization current correction concerning ρ (temperature, pressure, air compressibility)		0.01	0.02
positioning			0.03	–
Relative standard uncertainty in $(\dot{D}_w)_{BIPM}$				
quadratic sum			0.20	0.21
combined uncertainty			0.29	

(1) details on the determination of absorbed dose to water are given in [14]

(2) included in the uncertainties for k_p

(3) the uncertainty of the product of the stopping power ratio and W/e is estimated to be the same for determinations of air kerma and absorbed dose [14]. The present value supersedes that quoted in the Rapport BIPM-96/1, as agreed by the CCRI in 1999 [15]

(4) standard CH4-1.

Table 10. ^{60}Co gamma radiation

Physical constants and correction factors used in the BIPM determination(1) of the ambient dose equivalent rate, and their estimated relative standard uncertainties

Physical constant		**value**	100 s_i	100 u_i
dry air density /(kg m^{-3}) (273.15 K, 101.325 kPa)		1.2930	–	0.01
$(\mu_{en}/\rho)_w/(\mu_{en}/\rho)_c$		1.1109	–	0.10
stopping power ratio $\bar{s}_{c,a}$		1.0010	–	0.11(2)
W/e	/(J C^{-1})	33.97	–	
Q	(quality factor)	1		
Correction factors				
k_p	fluence perturbation	0.9931	–	0.16
k_s	ion recombination	1.0014	0.01	0.01
k_h	humidity	0.9970	–	0.03
k_{st}	stem scattering	1.0000	0.01	–
k_{rn}	radial non-uniformity	1.000	–	0.01
Measurement of $I/v\rho$				
v	volume /cm^3	6.8116(3)	0.01	0.03
I	ionization current correction concerning ρ (temperature, pressure, air compressibility)		0.02	0.02
Relative standard uncertainty in $\left(\dot{H}^*\right)_{BIPM}$				
quadratic sum			0.03	0.22
combined uncertainty			0.23	

(1) details on the determination of the ambient dose equivalent are given in [16]

(2) the uncertainty of the product of the stopping power ratio and *W/e* is estimated to be the same for determinations of air kerma and absorbed dose [14]. The present value supersedes that quoted in the Rapport BIPM-96/1, as agreed by the CCRI in 1999 [15]

(3) standard CH2.

Table 11. ^{137}Cs gamma radiation

Conditions of measurement at the BIPM

Source details	
source activity (2005) (approximate value)	0.8 TBq
source dimensions	
diameter	12 mm
length	23 mm
contribution of incident scattered radiation (in terms of energy fluence)	30 %
Measurement of air kerma	
distance from source to reference plane	1 m
beam diameter in the reference plane	11 cm or 20 cm
Measurement of ambient dose equivalent	
distance from source to reference plane	3 m
beam diameter in the reference plane	60 cm

Table 12. ^{137}Cs gamma radiation

Physical constants and correction factors used in the BIPM determination(1) of the air kerma rate, and their estimated relative standard uncertainties

Physical constant		**value**	100 s_i	100 u_i
dry air density /(kg m^{-3}) (273.15 K, 101.325 kPa)		1.2930	–	0.01
$(\mu_{en}/\rho)_a/(\mu_{en}/\rho)_c$		0.9990	–	0.05
stopping power ratio $\bar{s}_{c,a}$		1.0104	–	} 0.11(2)
W/e	/(J C^{-1})	33.97	–	
g	fraction of energy lost by bremsstrahlung	0.0012	–	0.02
Correction factors				
k_s	ion recombination	1.0014	0.01	0.01
k_h	humidity	0.9970	–	0.03
k_{st}	stem scattering	0.9998	0.01	–
k_{at}	wall attenuation	1.0540	0.01	0.04
k_{CEP}	mean origin of electrons	0.9972	–	0.01
k_{sc}	wall scattering	0.9535	0.01	0.15
k_{an}	axial non-uniformity	0.9981	–	0.07
k_{rn}	radial non-uniformity	1.0070	0.01	0.03
Measurement of $I/v\rho$				
v	volume /cm^3	6.8344 (3)	0.01	0.10
I	ionization current correction concerning ρ (temperature, pressure, air compressibility)		0.03	0.02
Relative standard uncertainty on $\dot{K}_{BIPM}$				
quadratic sum			0.04	0.24
combined uncertainty			0.24	

(1) details on the determination of the air kerma rate are given in [7]

(2) the uncertainty of the product of the stopping power ratio and W/e is estimated to be the same for air kerma and absorbed dose determination [14]. The present value supersedes that quoted in the Rapport BIPM-96/1, as agreed by the CCRI in 1999 [15]

(3) standard CH5-2.

Table 13. ^{137}Cs gamma radiation

Estimated relative standard uncertainties used in the BIPM determination(1)
of the ambient dose equivalent rate

Parameters	100 s_i		100 u_i
air kerma rate $\dot{K}_{\mathrm{BIPM}}$	0.04		0.24
ratio $\dot{H}^*/\dot{K}$ (2)	–		0.45
Relative standard uncertainty in $(\dot{H}^*)_{\mathrm{BIPM}}$			
quadratic sum	0.04		0.51
combined uncertainty		0.51	

(1) details on the determination of the ambient dose equivalent rate $\dot{H}^*$ are given in [17]

(2) the calculated value of the ratio $\dot{H}^*/\dot{K}$ for the BIPM beam is 1.2161 Sv Gy^{-1}

References

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