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

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

I. Introduction

The BIPM calibrates national reference 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 current and both short- and long-term stability. Their calibration coefficients should not vary significantly with the conditions of irradiation.

Calibrations of ionization chambers are performed at the 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 appropriate polarizing potential applied, before any measurements are made.

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 lack of saturation; the air-kerma rate is stated in the certificate. For the thimble 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. For calibrations at radiation-protection levels in terms of ambient dose equivalent, the radial non-uniformity correction for the BIPM beams is stated in the certificate although no correction is 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

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

where $\dot{K}_{\mathrm{BIPM}}$ 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

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

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

When requested, the calibration coefficient for exposure, N_X, is given by

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

where g is the fraction of electron energy lost in radiative processes in air [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 $\dot{K}_{\mathrm{BIPM}}$ are given in Tables 1 to 6 for x-rays, in Tables 7 and 8 for ^{60}Co and in Tables 11 and 12 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, a reference 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

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

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 9 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

$$N_H = \dot{H}^*(10)/I_H \quad , \qquad (5)$$

where :
$\dot{H}^*(10)$ is the ambient dose equivalent rate. For ^{60}Co radiation, $\dot{H}^*(10)$ is measured by the BIPM standard. For ^{137}Cs, $\dot{H}^*(10)$ 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 11 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 [3] and in Table 10 for ^{60}Co and in Tables 12 and 13 for ^{137}Cs.

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 , $N_{D,w}$ or N_H , obtained from (1), (4) and (5), respectively, to determine K, D_w or $H^*(10)$ in that beam, subject to certain provisions that are listed here.

(a) The humidity conditions must not differ significantly from those of the calibration at the BIPM. If the relative humidity is outside the range 30 % to 70 %, the data given in [4] 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 [5] and [6]). 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 with regard to 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 [7, 8].

VII. Calibration uncertainties

The uncertainties associated with dosimetry measurements made at the BIPM are analysed in accordance with the GUM [9]. The uncertainty budgets for the dosimetry standards are 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 [9]. 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 [10, 11])

X-ray tube voltage /kV	10	30	25	50 (b)	50 (a) [(2)]
Al filtration /mm	0	0.208	0.372	1.008	3.989
Al half-value layer /mm	0.037	0.169	0.242	1.017	2.262
$\bar{\mu}/\rho$ [(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 of the air-kerma rate [(1)]

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 4 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	saturation	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
$1-g$	radiative loss	1.0000	1.0000	1.0000	1.0000	1.0000

(1) details on the determination of the air-kerma rate are given in [12].
(2) values adopted October 2003 [13].
(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

Symbol	Parameter / unit	Relative standard uncertainty [1] s_i	u_i
Physical constants			
ρ_a	dry air density (0°C, 101.325 kPa) / kg m^{-3}	–	0.01
W/e	mean energy per charge / J C^{-1}	–	0.15
g	fraction of energy lost in radiative processes	–	0.01
Correction factors			
k_{sc}	scattered radiation	–	0.03
k_{fl}	fluorescence	–	0.05
k_e	electron loss	–	0.01
k_s	saturation	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/υ			
I	ionization current (T, P, air compressibility)	0.02	0.02
υ	volume	0.03	0.05
	positioning of standard	0.01	0.01
Combined uncertainty of the BIPM determination of air-kerma rate			
quadratic summation		0.05	0.19
combined relative standard uncertainty		0.20	

[1] expressed as parts in 10^2.
s_i represents the relative uncertainty estimated by statistical methods, type A
u_i represents the relative uncertainty estimated by other methods, type B.

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 [10])

X-ray tube voltage /kV	100	135	180	250
Al filtration /mm	3.431	2.228	2.228	2.228
Cu filtration /mm	–	0.232	0.485	1.570
Al half-value layer /mm	4.030	–	–	–
Cu half-value layer /mm	0.149	0.489	0.977	2.484
$\bar{\mu}/\rho$ [(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 of the air-kerma rate (1)

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	saturation	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
$1-g$	radiative loss	0.9999	0.9999	0.9998	0.9997

(1) details on the determination of the air-kerma rate can be found in [14].
(2) values adopted October 2003 [13].
(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

Symbol	Parameter / unit	Relative standard uncertainty [(1)] s_i	u_i
Physical constants			
ρ_a	dry air density (0°C, 101.325 kPa) / kg m^{-3}	–	0.01
W/e	mean energy per charge / J C^{-1}	–	0.15
g	fraction of energy lost in radiative processes	–	0.01
Correction factors			
k_{sc}	scattered radiation	–	0.03
k_{fl}	fluorescence	–	0.03
k_e	electron loss	–	0.09
k_s	saturation	0.02	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 / υ			
I	ionization current (T, P, air compressibility)	0.02	0.02
υ	volume	0.01	0.05
	positioning of standard	0.01	0.01
Combined uncertainty of the BIPM determination of air-kerma rate			
quadratic summation		0.04	0.20
combined relative standard uncertainty		0.21	

(1) expressed as parts in 10^2.
s_i represents the relative uncertainty estimated by statistical methods, type A
u_i represents the relative uncertainty estimated by other methods, type B.

Table 7. ^{60}Co gamma radiation

Conditions of measurement at the BIPM

Measurement of air kerma and absorbed dose	
source activity (2007-01-01) (approximate value) (1)	116 TBq
source dimensions	
diameter	20 mm
length	14 mm
contribution of incident scattered radiation (in terms of energy fluence)	21 %
distance from source centre to reference plane	1 m
beam section in the reference plane (2)	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 centre to reference plane	3.5 m
beam diameter in the reference plane	80 cm

(1) the reference beam was changed to the CIS Bio unit in November 2007 [15].
(2) 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 [16].

Table 8. ^{60}Co gamma radiation

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

Symbol	Parameter / unit	Value	Relative standard uncertainty [(2)] s_i	u_i
Physical constants				
ρ_a	dry air density (0°C, 101.325 kPa) / kg m^{-3}	1.2930	–	0.01
$(\bar{\mu}_{en}/\rho)_{a,c}$	ratio of mass energy-absorption coefficients	0.9989	0.01	0.04
$s_{c,a}$	ratio of mass stopping powers	1.0010	}	0.11 [(3)]
W/e	mean energy per charge / J C^{-1}	33.97		
g	fraction of energy lost in radiative processes in air	0.0031	–	0.02
Correction factors				
k_g	re-absorption of radiative loss	0.9996	–	0.01
k_h	humidity	0.9970	–	0.03
k_s	saturation	1.0022	0.01	0.02
k_{st}	stem scattering	1.0000	0.01	–
k_{wall}	wall attenuation and scattering	1.0011	}	– [(4)]
k_{an}	axial non-uniformity	1.0020		
k_{rn}	radial non-uniformity	1.0015	–	0.02
Measurement of I/υ				
υ	effective volume / cm^3	6.7967 [(5)]	–	0.08 [(4)]
I	ionization current (T, P, air compressibility)	–	–	0.02
	short-term reproducibility (including positioning and current measurement) [(6)]	–	0.01	–
Combined uncertainty of the BIPM determination of air-kerma rate				
quadratic summation			0.02	0.15
combined relative standard uncertainty			0.15	

(1) details on the determination of air kerma are given in [17] and [18] with the new correction factors in [15].
(2) expressed as parts in 10^2.
s_i represents the relative uncertainty estimated by statistical methods, type A
u_i represents the relative uncertainty estimated by other methods, type B.
(3) uncertainty value for the product $s_{c,a}$ W/e, as agreed by the CCRI [19].
(4) the uncertainties for k_{wall} and k_{an} are included in the determination of the effective volume [15].
(5) for standard CH5-1, the measured volume 6.8028 cm^3 reduced by the factor 1.0009 [15].
(6) over a period of 3 months. The long-term reproducibility over a period of 15 years, u_{rep} is 0.0004.

Table 9. ^{60}Co gamma radiation

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

Symbol	Parameter / unit	Value	Relative standard uncertainty (2) s_i	u_i
Physical constants				
ρ_a	dry air density (0°C, 101.325 kPa) / kg m^{-3}	1.2930	–	0.01
$(\bar{\mu}_{en}/\rho)_{w,c}$	ratio of mass energy-absorption coefficients	1.1125 (3)	0.01 (3)	0.14 (3)
$s_{c,a}$	ratio of mass stopping powers	1.0030	}	0.11 (4)
W/e	mean energy per charge / J C^{-1}	33.97		
Correction factors (5)				
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	1.0056	0.01	0.03
k_s	saturation	1.0017	0.01	0.01
k_h	humidity	0.9970	–	0.03
Measurement of I/υ				
υ	volume / cm^3	6.8810 (6)	0.19	0.03
I	ionization current (T, P, air compressibility)	–	–	0.02
	short-term reproducibility (including positioning and current measurement) (7)		0.02	–
Combined uncertainty of the BIPM determination of absorbed-dose rate to water				
quadratic summation			0.20	0.21
combined relative standard uncertainty			0.29	

(1) details on the determination of absorbed dose to water are given in [20].
(2) expressed as parts in 10^2.
s_i represents the relative uncertainty estimated by statistical methods, type A
u_i represents the relative uncertainty estimated by other methods, type B.
(3) included in the uncertainties for k_p.
(4) uncertainty value for the product $s_{c,a}$ W/e, as agreed by the CCRI [19].
(5) values for the CIS Bio beam.
(6) standard CH4-1.
(7) over a period of 3 months. The long-term reproducibility over a period of 15 years, u_{rep} is 0.0006.

Table 10. ^{60}Co gamma radiation

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

Symbol	Parameter / unit	Value	Relative standard uncertainty [(2)] s_i	u_i
$\dot{K}_{BIPM}$	air-kerma rate at 3.5 m	–	0.10	0.20
$\dot{H}^*(10)/\dot{K}$	ratio of the ambient dose equivalent to air kerma / Sv Gy^{-1}	1.143	–	0.22
Combined uncertainty of the BIPM determination of ambient dose equivalent rate				
quadratic summation			0.10	0.30
combined relative standard uncertainty			0.32	

[(1)] details on the determination of the ambient dose equivalent rate $\dot{H}^*(10)$ are given in [3].
[(2)] expressed as parts in 10^2.
s_i represents the relative uncertainty estimated by statistical methods, type A
u_i represents the relative uncertainty estimated by other methods, type B.

Table 11. ^{137}Cs gamma radiation

Conditions of measurement at the BIPM

Source details	
source activity (2007) (approximate value)	0.6 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 centre to reference plane	1 m
beam diameter in the reference plane	11 cm or 20 cm
Measurement of ambient dose equivalent	
distance from source centre 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 of the air-kerma rate (1), and their estimated relative standard uncertainties

Symbol	Parameter / unit	Value	Relative standard uncertainty (2) s_i	u_i
Physical constants				
ρ_a	dry air density (0°C, 101.325 kPa) / kg m^{-3}	1.2930	–	0.01
$(\bar{\mu}_{en}/\rho)_{a,c}$	ratio of mass energy-absorption coefficients	0.9990	–	0.05
$s_{c,a}$	ratio of mass stopping powers	1.0104	} –	0.11 (3)
W/e	mean energy per charge / J C^{-1}	33.97		
g	fraction of energy lost in radiative processes in air	0.0012	–	0.02
Correction factors				
k_h	humidity	0.9970	–	0.03
k_s	saturation	1.0014	0.01	0.01
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/υ				
υ	volume / cm^3	6.8344 (4)	0.01	0.10
I	ionization current (T, P, air compressibility)	–	–	0.02
	short-term reproducibility (including positioning and current measurement) (5)	–	0.02	–
Combined uncertainty of the BIPM determination of air-kerma rate				
quadratic summation			0.04	0.24
combined relative standard uncertainty			0.24	

(1) details on the determination of air kerma are given in [21].
(2) expressed as parts in 10^2.
s_i represents the relative uncertainty estimated by statistical methods, type A
u_i represents the relative uncertainty estimated by other methods, type B.
(3) uncertainty value for the product $s_{c,a}$ W/e, as agreed by the CCRI [19].
(4) for standard CH5-2.
(5) over a period of 3 months. The long-term reproducibility over a period of 15 years, u_{rep} is 0.0004.

Table 13. ^{137}Cs gamma radiation

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

Symbol	Parameter / unit	Value	Relative standard uncertainty (2) s_i	u_i
$\dot{K}_{BIPM}$	air-kerma rate	–	0.04	0.24
$\dot{H}^*(10)/\dot{K}$	ratio of the ambient dose equivalent to air kerma / Sv Gy^{-1}	1.216	–	0.45
Combined uncertainty of the BIPM determination of ambient dose equivalent rate				
quadratic summation			0.04	0.51
combined relative standard uncertainty			0.51	

(1) details on the determination of the ambient dose equivalent rate $\dot{H}^*(10)$ are given in [21].
(2) expressed as parts in 10^2.
s_i represents the relative uncertainty estimated by statistical methods, type A
u_i represents the relative uncertainty estimated by other methods, type B.

References

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