Comparison BIPM.RI(I)-K8 of high dose-rate ^{192}Ir brachytherapy standards for reference air kerma rate of the NIM and the BIPM

C Kessler[1], Wang Ji[2], Wang Peiwei[2], Wang Kun[2], Han Jinpeng[2]

[1]Bureau International des Poids et Mesures, F-92312 Sèvres Cedex, France
[2] National Institute of Metrology, Beijing, China

Abstract

An indirect comparison of the standards for reference air kerma rate for ^{192}Ir high dose rate (HDR) brachytherapy sources of the National Institute of Metrology (NIM), China, and of the Bureau International des Poids et Mesures (BIPM) was carried out at the NIM in October 2024. The comparison result, based on the calibration coefficients for a transfer standard and expressed as a ratio of the NIM and the BIPM standards for reference air kerma rate, is 1.0027 with a combined standard uncertainty of 0.0045.

1. Introduction

The Brachytherapy Standards Working Group (BSWG(I)), created under the recommendation made by the Consultative Committee for Ionizing Radiation CCRI(I), proposed at their meeting of November 2005 to start a comparison of primary standards for reference air kerma rate (RAKR) of ^{192}Ir. To meet the needs of the National Metrology Institutes (NMIs), a new ongoing key comparison was registered in the BIPM key comparison database (KCDB 2025) under the reference BIPM.RI(I)-K8. As no primary facility for brachytherapy is available at the BIPM, the measurements take place at the NMI using one of the two BIPM transfer standards, a thimble-type transfer ionization chamber or a well-type ionization chamber.

The National Institute of Metrology (NIM) took part in the comparison in October 2024. The comparison was carried out after the implementation of the recommendations of the ICRU Report 90 (ICRU 2016) at the NIM. The comparison result is evaluated considering the implementation of the ICRU 90 at both laboratories.

As the NIM provides traceability for HDR ^{192}Ir sources calibrating only well-type chambers, the present comparison was run using only the BIPM well-type chamber and the result is given in terms of the ratio of the calibration coefficient determined at the NIM and the reference value used by the BIPM. The BIPM reference value is the mean of the calibration coefficients determined by the BIPM during the comparisons with the NMIs that have participated calibrating the thimble chamber (VSL, NPL, PTB and NRC) during the period 2009-2014 (KCDB 2025).

The long-term stability of the well chamber is established by measurements at the BIPM using a ^{137}Cs source.

The comparison result, approved by the CCRI(I), is analyzed and presented in terms of degrees of equivalence for entry in the BIPM key comparison database.

2. Characteristics of the transfer instrument

The transfer instrument, belonging to the BIPM, used to undertake the comparison, was a Standard Imaging HDR 1000 Plus well chamber. The main characteristics of the transfer instrument are listed in Table 1.

Table 1. Characteristics of the BIPM transfer chamber

Characteristic/Nominal values		Standard Imaging HDR 1000 Plus	Standard Imaging Insert 70010
Dimensions	Inner diameter / mm	102	35
	Cavity length / mm	156	121
	Bottom of insert to reference point / mm	50 (sweet-spot)	
Air cavity	Volume / cm^3	245	
Voltage applied	Polarity to outer electrode / V	+ 300	

3. Determination of the NIM reference value

The NIM designed and constructed two similar spherical graphite cavity ionization chambers, identified as NIM-Ir100-1 and NIM-Ir100-2. A full description of the NIM-Ir100-1 can be found in Han *et al.* (2025). The chamber NIM-Ir100-2, fully characterized by the NIM, was adopted as the primary standard and it was the one used to determine the reference air kerma rate for the present comparison.

The volume of the standard NIM-Ir100-2 was determined from dimensional measurements of the diameter of the sphere, wall thickness, electrode diameter and length, using a coordinate measuring machine (CMM), model LEITZ PMM-C-8106, before the pieces were assembled. The volume of the ionization chamber was determined to be 102.49 cm^3, with a relative standard uncertainty of 3 parts in 10^4.

The main characteristics of the standard are listed in Table 2.

Table 2. Characteristics of the NIM primary standard

Characteristic/Nominal values		NIM-Ir100-2
Dimensions	Inner diameter / mm	58.01
	Wall thickness / mm	3.0
Electrode	Length / mm	29.9
	Diameter / mm	1.99
Volume	Air cavity / cm^3	102.49
Graphite density	/ g cm^{-3}	1.85
Voltage applied to collecting electrode / V		+ 600

The RAKR is determined using the equation

$$\dot{K}_R = \frac{I_{\text{corr}}}{\rho_{\text{air}} \cdot V_{\text{air}}} \left(\frac{W_{\text{air}}}{e}\right) \frac{1}{(1-\bar{g})} \left(\frac{\bar{S}}{\rho}\right)_{\text{air}}^{\text{graph}} k_{\text{fl}} \left(\frac{\bar{\mu}_{\text{en}}}{\rho}\right)_{\text{graph}}^{\text{air}} \prod_i k_i \left(\frac{d}{d_{\text{ref}}}\right)^2 (k_{\text{air}} k_{\text{catheter}} k_{\text{dec}} k_h) \qquad (1)$$

where

$\dot{K}_R$	is the RAKR at the chosen reference time t_{ref},
I_{corr}	is the measured ionization current (i.e., measured charge per unit of time) with leakage, temperature, and pressure corrections applied,
V_{air}	is the volume of the air cavity,
ρ_{air}	is the density of dry air at normal pressure and temperature,
W_{air}	is the mean energy expended by an electron of charge e to produce an ion pair in dry air,
$\bar{g}$	is the fraction of secondary electron energy lost to bremsstrahlung in air,
$(\bar{S}/\rho)_{\text{air}}^{\text{graph}} k_{\text{fl}}$	is the product of the ratio of the mean electron-fluence-weighted electron mass stopping power of graphite to that of air and the fluence perturbation correction factor (determined by Monte Carlo simulation),
$(\bar{\mu}_{\text{en}}/\rho)_{\text{graph}}^{\text{air}}$	is the ratio of the mean photon-energy-fluence-weighted photon mass energy-absorption coefficient of air to that of graphite (determined by Monte Carlo simulation),
$\prod_i k_i$	is the product of all remaining correction factors listed in Table 3, but not explicitly listed in equation (1), determined by measurements (polarity effect, stem scatter, radial non-uniformity of the beam and ion recombination correction factors) and by Monte Carlo simulation (axial non-uniformity and wall, including central electrode, correction factors),
$(d/d_{\text{ref}})^2$	normalizes the current measured at the centre-to-centre source-to-chamber distance d = 1.2 m to the reference distance d_{ref} = 1 m,
k_{air}	is the combined air attenuation and scatter correction factor which corrects for air attenuation and scatter between the source and the point of measurement,
k_{catheter}	is the catheter attenuation correction factor which corrects for the attenuation of the photons emitted from the HDR ^{192}Ir source by the polypropylene catheter inside the lead collimator,
k_{dec}	is the decay correction factor which corrects the measured ionisation current at the time of measurement to the reference time t_{ref}, and
k_h	is the humidity correction factor.

The values used for the physical constants, the correction factors entering in the determination of the RAKR and the associated uncertainties are given in Table 3; the essential details of the NIM primary standard and details of the reference air kerma rate determination are briefly described in the following paragraphs. The method to determine the reference air kerma rate is also described in Han *et al.* (2025).

Table 3. Physical constants and correction factors with their relative standard uncertainties of the NIM standard for the ^{192}Ir radiation beam

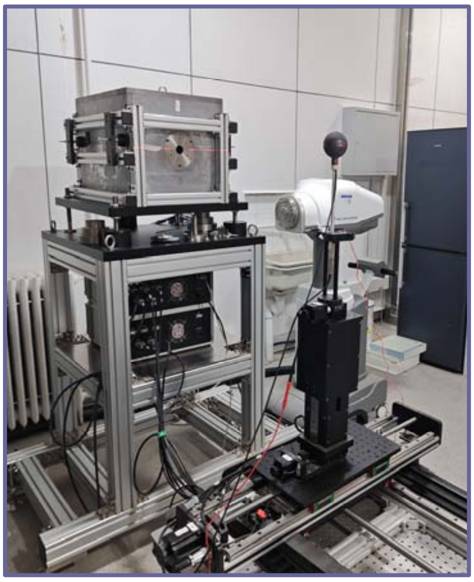
NIM		values	uncertainty [(1)]	
Physical Constants			$100\,u_{i\mathrm{A}}$	$100\,u_{i\mathrm{B}}$
ρ_{air}	dry air density [(2)] / kg m^{-3}	1.2930	-	0.01
$(\overline{\mu}_{\mathrm{en}}/\rho)^{\mathrm{air}}_{\mathrm{graph}}$	ratio of mass energy-absorption coefficients	1.0024	0.07	0.07
$(\overline{S}/\rho)^{\mathrm{graph}}_{\mathrm{air}}\cdot k_{\mathrm{fl}}$	product of mass stopping power ratio and fluence perturbation correction [(3)]	1.0070	0.04	0.07
W_{air}/e	mean energy per charge / J C^{-1}	33.97	-	
$\overline{g}$	fraction of energy lost in radiative processes	0.0012	-	0.02
Correction factors				
k_{pol}	polarity	0.9995	0.02	-
k_{stem}	stem scattering correction	0.9966	-	0.05
k_{ion}	ion recombination [(4)]	1.0015	0.10	0.15
k_{wall}	wall correction	1.0377	0.02	0.08
k_{an}	axial non-uniformity	1.0003	0.02	0.07
k_{rn}	radial non-uniformity	0.9995	0.03	0.07
k_{air}	air attenuation and scatter correction	1.0149	-	0.15
k_{catheter}	catheter attenuation correction	1.0021	0.01	0.03
k_h	humidity	0.9970	-	0.03
k_{dec}	decay correction	-	-	0.02
R_{angular}	angular response	-	-	0.05
d	distance source-chamber centre / mm	1200.0	0.01	0.10
Measurement of I / V				
V_{air}	chamber volume / cm^3	102.49	-	0.03
I	ionization current / A [(5)]	-	0.11	0.11
Relative standard uncertainty				
	quadratic summation		0.18	0.32
	combined uncertainty of $\dot{K}_R$		0.36	

(1) Expressed as one standard deviation
$u_{i\mathrm{A}}$ represents the relative standard uncertainty estimated by statistical methods, type A
$u_{i\mathrm{B}}$ represents the relative standard uncertainty estimated by other means, type B
(2) Calculated density of dry air (0% relative humidity, 273.15 K, 101.325 kPa)
(3) Due to correlated uncertainties between the stopping power ratio and W_{air}/e, the uncertainty in W_{air}/e has been included in the combined uncertainty for the product $W_{\mathrm{air}}/e\cdot(\overline{S}/\rho)^{\mathrm{graph}}_{\mathrm{air}}\cdot k_{\mathrm{fl}}$
(4) Ion recombination correction factor for a typical ionization current of 30 pA
(5) Includes the electrometer correction, capacitors, temperature, pressure, and the associated uncertainties of these quantities involved in the current measurement process

Positioning

At the NIM, the primary standard cavity chamber is set up on a moveable carriage in front of a lead housing where the radiation source is inserted, as shown in Figure 1. The front face of the housing has a conical aperture of 20 mm to collimate the beam.

Figure 1. Set-up for the calibration of HDR brachytherapy source at the NIM



The HDR ^{192}Ir brachytherapy source is inserted from the afterloader into the lead housing through a polypropylene catheter with an inner diameter of 1.4 mm and an outer diameter of 2 mm.

The collimated beam is directed towards the primary standard cavity chamber, which is set up at a centre-to-centre source-to-chamber distance of 1.2 m. Both the source-to-chamber distance and aperture size were chosen to give a uniform field over the circular cross section of the ionization chamber. The measured ionization current is corrected to standard atmospheric conditions and to 1 metre distance. Conversion and correction factors listed in equation (1) are applied to determine the reference air kerma rate for a reference time and date. For the present comparison, the reference air kerma rate was derived from the mean of fourteen separate measurements performed during the period September-October 2024.

Applied voltage and polarity correction (k_{pol})

A collecting voltage of 600 V (positive polarity) is applied to the collecting electrode of the chamber at least 30 min before any measurements are made. The outer electrode (graphite sphere) is earthed, i.e., negative charge is usually collected. A correction factor of 0.9995 is applied to account for the polarity effect with a standard uncertainty of 2 parts in 10^4.

Ion recombination (k_{ion})

The ion recombination correction factor was determined from measurements made at the NIM in medium-energy x-ray beams, using the Niatel-Boutillon method (Boutillon 1998). The recombination correction factor k_{ion} can be expressed as

$$k_{\text{ion}} = 1 + k_{\text{init}} + k_{\text{vol}} I_V \qquad (2)$$

where k_{init} is the initial recombination, k_{vol} is the volume recombination coefficient and I_V is the current measured for the applied voltage V. Using equation (2), the correction factor k_{ion} for losses due to ion recombination for the ^{192}Ir source, applied to the measured current to determine the reference air kerma rate, was found to be 1.0015 with a relative standard uncertainty of 1.8 parts in 10^3.

Charge and leakage measurements

The charge Q, collected by the primary standard, is measured using a Keithley 6517B electrometer.

The measured ionization current was corrected for the leakage current. This correction was in relative value less than 5 parts in 10^4.

Ambient conditions

The measurements are normalized to 293.15 K and 101.325 kPa. Relative humidity was around 50 %.

Attenuation and scattering in the chamber wall (k_{wall})

Monte Carlo techniques (EGSnrc code) were used to simulate the source, collimation system and ionization chamber and to determine the wall correction factor for photon attenuation and scattering in the graphite wall of the standard, k_{wall}.

The simulated ^{192}Ir source spectrum (Bé *et al*. 1999) included all photons contributing at least 0.1 % to the ^{192}Ir spectrum. The value for k_{wall} is 1.0377 with a standard uncertainty of 8 parts in 10^4.

Radial non-uniformity correction (k_{rn})

The correction for radial non-uniformity, k_{rn}, for the NIM standard is estimated from the measured radial beam profile. This correction is 0.9995 with a standard uncertainty of 8 parts in 10^4.

Axial non-uniformity correction (k_{an})

The axial non-uniformity correction factor, k_{an}, was calculated using Monte Carlo techniques; the correction of 1.0003 is applied with a standard uncertainty of 7 parts in 10^4.

Catheter attenuation correction ($k_{catheter}$)

The catheter attenuation correction factor corrects for the attenuation of the photons emitted from the HDR ^{192}Ir source by the polypropylene catheter inside the lead housing. The catheter attenuation correction factor was calculated using Monte Carlo simulations. The value for the correction factor, $k_{catheter}$, was found to be 1.0021 with a standard uncertainty of 3 parts in 10^4.

Air attenuation and scattering between the source and the chamber (k_{air})

The correction factor for air attenuation and scattering between the source and the chamber was measured using a multiple-distance method (Sander and Nutbrown 2006). The air attenuation and scatter correction factor, k_{air}, was determined to be 1.0149 at standard temperature and pressure with a standard uncertainty of 1.5 parts in 10^3.

The main characteristics of the NIM ^{192}Ir source are listed in Table 4.

Table 4. Characteristics of the NIM ^{192}Ir source

Afterloader unit	KL-HDR-C
Manufacturer of source	HTA Co., Ltd
Source serial number	0124IR001013
Estimated content activity of source	370 GBq at 2024-09-19, 00:00 UTC
Capsule material and dimensions	Stainless steel, AISI 304, 1.1 mm diameter, 6.5 mm length
Source pellet dimensions	0.68 mm diameter, 3.9 mm length

4. Determination of the BIPM reference value

The BIPM does not possess an ^{192}Ir source. The reference value for the well-type HDR 1000 Plus ionization chamber is based on measurements made using the ^{192}Ir sources of the four laboratories participating in the BIPM.RI(I)-K8 comparison during the period 2009-2014. The stability of the well chamber is monitored using a sealed source of ^{137}Cs. The long-term reproducibility of the chamber established using this source is less than 1 part in 10^3 in relative value.

To derive a reference value for the well chamber, the BIPM determined its calibration coefficient at each NMI that participated in this on-going key comparison through calibration of the thimble-type NE 2571 ionization chamber. Using the NMI ^{192}Ir source, the calibration coefficient for the well-type chamber $N_{K,\mathrm{BIPM}}^{\mathrm{w}}$ was evaluated as

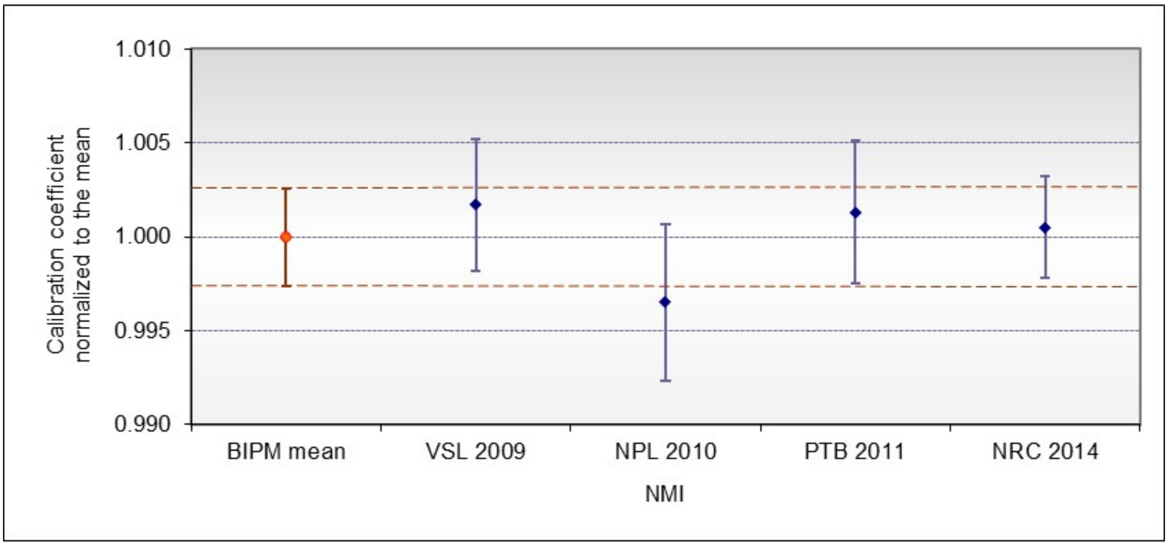
$$N_{K,\mathrm{BIPM}}^{\mathrm{w}} = \frac{\dot{K}_{R,\,\mathrm{BIPM}}}{I_{\mathrm{w}}} \tag{3}$$

where $\dot{K}_{\mathrm{R,\,BIPM}}$ was the RAKR for the NMI source evaluated from the ionization current I^{th} determined by the NMI using the BIPM NE 2571 thimble chamber and its calibration coefficient, $N_{K,\mathrm{BIPM}}^{\mathrm{th}}$, determined by the BIPM ($\dot{K}_{\mathrm{R,\,BIPM}} = I^{\mathrm{th}} N_{K,\mathrm{BIPM}}^{\mathrm{th}}$), as described in the protocol for this on-going key comparison[a].

The well chamber current, I_{w}, measured at the sweet-spot, was appropriately corrected to the reference conditions of measurements and normalized to the reference ambient conditions.

The mean of the well chamber calibration coefficients determined by the BIPM at each NMI that calibrated the NE 2571 chamber during the period 2009-2014 is taken as the reference value for the well chamber. To date, four NMIs (VSL, NPL, PTB and NRC) have participated in the BIPM.RI(I)-K8 comparison by calibrating the NE 2571 chamber (Alvarez *et al*. 2014a, Alvarez *et al*. 2014b, Kessler *et al*. 2015 and Kessler *et al*. 2014). The normalized calibration coefficients determined by the BIPM at these NMIs are shown in Figure 2. The standard deviation of the mean is 1.2 parts in 10^3; the evaluation of the standard uncertainty is explained in Section 7 and is represented in the graph by the dotted line.

Figure 2. Normalized BIPM calibration coefficient for the well chamber



The uncertainty bars represent one standard uncertainty

[a] The value $N_{K,\mathrm{BIPM}}^{\mathrm{th}}$ for ^{192}Ir is calculated from the calibration coefficient determined at the BIPM in the ^{60}Co reference beam and a correction factor that accounts for the energy dependence of the chamber; this factor was calculated using a Monte Carlo code (Mainegra-Hing and Rogers 2006) to simulate the chamber response from 100 keV to ^{60}Co beams.

5. Comparison measurements at the NIM

The HDR 1000 Plus well chamber, together with its electrometer and probes for temperature, pressure and humidity, is used as a transfer system to determine a comparison result for those NMIs that do not provide calibrations of thimble-type ionization chambers. The ionization current of the well chamber was measured at the NIM and the BIPM calibration coefficient was derived from these measurements and the NIM determination of RAKR, as described in Section 3.

The essential details of the current measurements are reproduced here.

Sweet-spot

At the NIM, measurements at nine dwell positions for the ^{192}Ir source with steps of 1 mm were done to determine the sweet-spot of the well chamber. A second series of measurements at six dwell positions for the ^{192}Ir was done, confirming the sweet-spot previously determined.

Charge and leakage measurements

At the sweet spot, five series of 20 charge measurements over 60 s each were made on three different days, the source being retracted to the afterloader and repositioned at the sweet-spot between each series. Each day, measurements were also made at ±1 mm of the sweet-spot to confirm the position of the source. The standard deviation of the mean value of the five series was estimated to be less than 5 parts in 10^4.

Leakage current was measured before and after each series of measurements. The leakage correction, relative to the ionization current, was less than 1 part in 10^4.

Ambient conditions

The measurements are normalized to 293.15 K and 101.325 kPa. No humidity correction is applied.

Decay correction

The measurements are corrected for the decay of the source to the reference date of 2024-10-07, 16:00 UTC. The half-life for ^{192}Ir is 73.827 days with u_c = 0.013 days, taken from Bé *et al.* (1999).

6. Results of the comparison

The individual calibration coefficients of the well chamber will not be disclosed as this transfer chamber will be calibrated by other NMIs participating in this ongoing comparison.

The calibration coefficient $N_{K,\mathrm{NIM}}^{\mathrm{w}}$ for the NIM is determined as

$$N_{K,\mathrm{NIM}}^{\mathrm{w}} = \frac{\dot{K}_{R,\,\mathrm{NIM}}}{I_{\mathrm{w}}} \tag{4}$$

where $\dot{K}_{\mathrm{R,NIM}}$ is the NIM reference air kerma rate and I_{w} is the well chamber ionization current, both corrected to the reference date 2024-10-07 16:00 UTC. The reference air kerma rate used for the present comparison was 33.602 mGy/h with a relative standard uncertainty of 3.6 parts in 10^3.

As noted in Section 4, at the time of producing this report, four NMIs had participated in the BIPM.RI(I)-K8 comparison using the NE 2571 chamber (VSL, NPL, PTB and NRC). Taking the mean, $\bar{N}_{K,\mathrm{BIPM}}^{\mathrm{w}}$, of the four values determined by the BIPM at these NMIs, it is possible to evaluate the comparison result for the NIM expressed as

$$R_{K,\mathrm{NIM}}^{\mathrm{w}} = N_{K,\mathrm{NIM}}^{\mathrm{w}} / \bar{N}_{K,\mathrm{BIPM}}^{\mathrm{w}} \tag{5}$$

For the NIM, the comparison result $R_{K,\mathrm{NIM}}^{\mathrm{w}}$ is 1.0027.

7. Uncertainties

As explained in Section 6, the BIPM calibration coefficient for the well chamber for ^{192}Ir beams is the mean of the calibration coefficients obtained at each NMI. Table 5 summarizes the uncertainty u_i corresponding to each calibration and the uncertainty of the mean value u, taking correlation into account.

Table 5. Relative standard uncertainty associated with the BIPM well chamber calibration at the NMIs

Relative standard uncertainty	u_i
$N^{\text{w}}_{K,\text{BIPM}}$ at the VSL (1st comparison 2009)	0.0035
$N^{\text{w}}_{K,\text{BIPM}}$ at the NPL (1st comparison 2010)	0.0042
$N^{\text{w}}_{K,\text{BIPM}}$ at the PTB (1st comparison 2011)	0.0038
$N^{\text{w}}_{K,\text{BIPM}}$ at the NRC	0.0027
$\overline{N}^{\text{w}}_{K,\text{BIPM}}$ (a) for ^{192}Ir	0.0026

(a) Correlation between the four determinations has been taken into account

The relative standard uncertainties associated with the well-type chamber calibration at the NIM are listed in Table 6.

Table 6. Relative standard uncertainties associated with the well chamber calibration at the NIM

Relative standard uncertainty	NIM $u_{i\text{A}}$	NIM $u_{i\text{B}}$
^{192}Ir air kerma determination		
Reference air kerma rate $\dot{K}_R$	0.0018	0.0032
Calibration of the well-type chamber		
Ionization current measured with well chamber, I_{w}	0.0002	0.0002
Positioning of source	0.0005	
Temperature, pressure correction	---	0.0001
Short-term stability	0.0005	---
$N^{\text{w}}_{K,\text{NIM}}$	0.0019	0.0032

From Tables 5 and 6, the combined standard uncertainty u_c for the comparison result $R^{\text{w}}_{K,\text{NIM}}$ is 4.5 parts in 10^3.

8. Discussions

Since 2019 and following the decision of the CCRI(I), the BIPM and the participating laboratories started to implement the recommendations of the ICRU 90. Some laboratories have also implemented some improvements to their standards, and the resulting changes adopted by the NMIs to update the comparison results are summarized in Table 7.

Table 7. Comparison results updated with the changes implemented by the NMIs

Year of participation	NMI	NMI change	Comparison result pre-2019	Updated comparison result
	BIPM	0.9913		
2009	VSL [a]	0.9943	0.9873	0.9903
2010	NPL [a]	1.0029	0.9989	1.0106
2011	PTB [a]	0.9883	1.0003	0.9973
2014	NRC [a]	0.9955	0.9966	1.0009
2015	NMIJ [b]	0.9917	1.0036	1.0040
New participation in the BIPM.RI(I)-K8				New comparison result
2019	VSL [a]			0.9926
2022	NPL [b]			1.0045
2023	PTB [b]			1.0022
2024	LNHB [b]	0.9955	---	0.9990
2024	NIM [b]		---	1.0027

[a] results obtained using the thimble chamber

[b] results obtained using the well-type chamber

9. Degrees of equivalence

Following a decision of the CCRI(I), the BIPM determination of the dosimetric quantity is taken as the key comparison reference value (KCRV) (Allisy *et al.* 2009).

For each NMI i having a comparison result $R_{K,i}$ (denoted x_i in the KCDB) with combined standard uncertainty, u_i, the degree of equivalence with respect to the key comparison reference value is given by a pair of terms:

the relative difference $D_i = \left(N_{K_R,\text{NMI}i} - N_{K_R,\text{BIPM}}\right)/N_{K_R,\text{BIPM}} = R_{K,i} - 1$ (6)

and its expanded uncertainty $U_i = 2\,u_i$. (7)

The results for D_i and U_i, are expressed in mGy/Gy. Table 8 gives the values for D_i and U_i for the NMIs that have participated to date, taken from the KCDB of the CIPM MRA (1999) and this report. These data are presented graphically in Figure 3.

Table 8. **Degrees of equivalence**

For each laboratory *i*, the degree of equivalence with respect to the key comparison reference value is the difference D_i and its expanded uncertainty U_i. Tables formatted as they appear in the BIPM key comparison database

BIPM.RI(I)-K8

	Lab *i*	D_i	U_i
		/ (mGy / Gy)	
a)	NRC	0.9	10.0
b)	NMIJ	4.0	10.8
a)	VSL	-7.4	11.0
b)	NPL	4.5	8.6
b)	PTB	2.2	20.2
b)	LNHB	-1.0	14.2
b)	NIM	2.7	9.0

a) results obtained using a thimble-type chamber

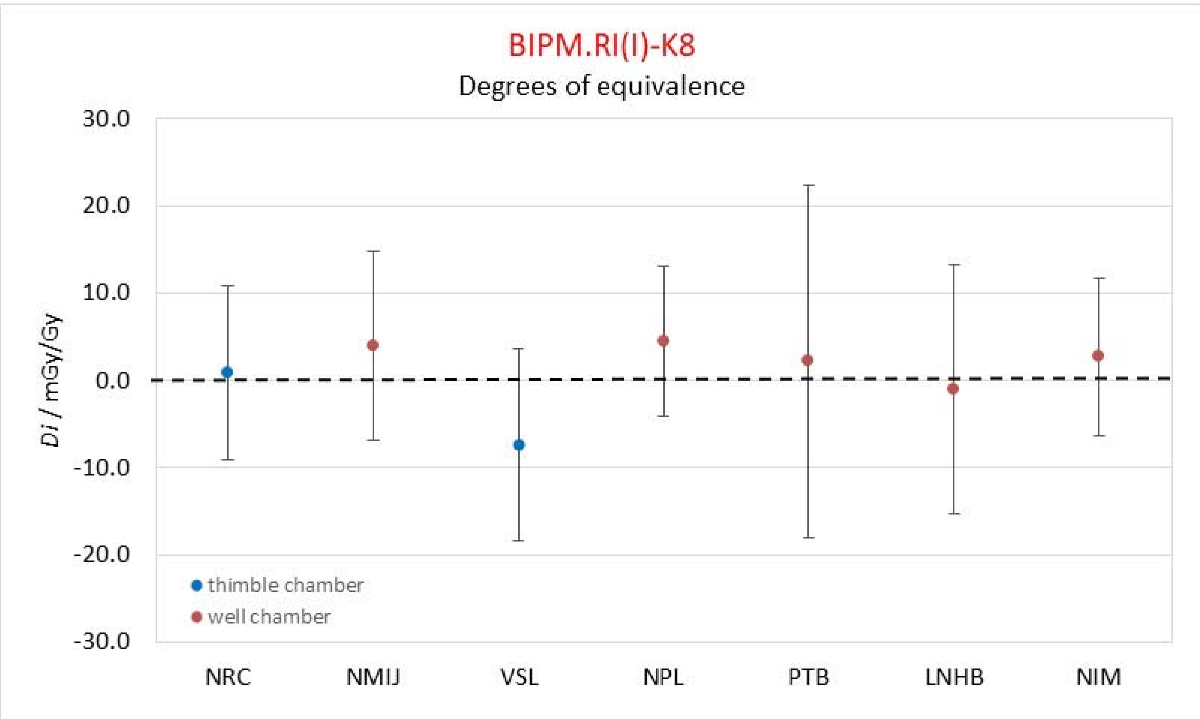
b) results obtained using a well-type chamber

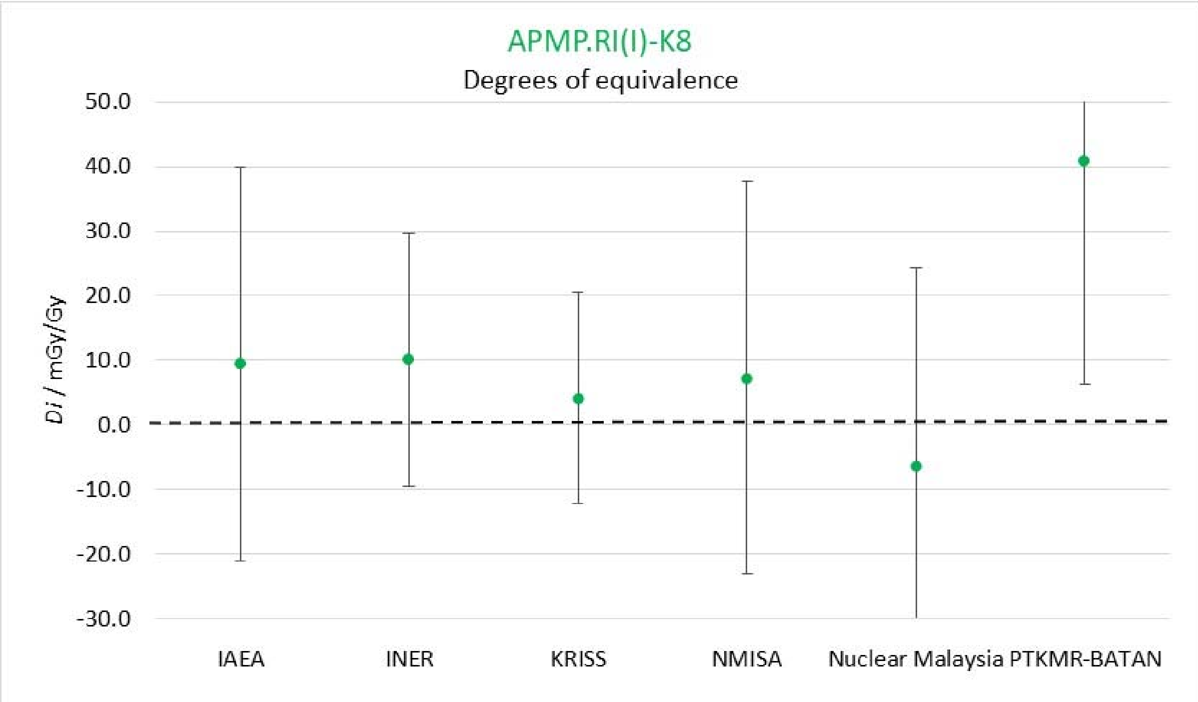
APMP.RI(I)-K8

Lab *i*	D_i	U_i
	/ (mGy / Gy)	
IAEA	9.4	30.4
INER	10.1	19.6
KRISS	4.2	16.4
NMISA	7.3	30.4
Nuclear Malaysia	-6.4	30.8
PTKMR-BATAN	40.8	34.4

Note that the data presented in Table 8, while correct at the time of publication of the present report, become out-of-date as NMIs make new comparisons. In addition, revised validity rules for comparison data have been agreed by the CCRI(I) so that any results older than 15 years are no longer considered valid and have been removed from the KCDB. The formal results under the CIPM MRA are those available in the key comparison database.

Figure 3. **Graph of degrees of equivalence with the KCRV**





8. Conclusion

The NIM standard for the reference air kerma rate for ^{192}Ir gamma radiation compared with the BIPM reference value gives a comparison result of 1.0027 with a combined standard uncertainty u_c of 0.0045, in agreement, within the expanded uncertainty, with the other NMIs that have taken part in the BIPM.RI(I)-K8 comparison.

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