

## **Dosimetry comparisons and calibrations at the BIPM 2001 to 2003**

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### **1. Introduction**

Comparisons and calibrations at the BIPM are made in terms of the quantities air kerma, absorbed dose to graphite, absorbed dose to water and ambient dose equivalent, to date for 29 NMIs and the IAEA. The radiations used are low-energy (10 kV to 50 kV) and medium-energy (100 kV to 250 kV) x-ray beams, a 1 TBq  $^{137}\text{Cs}$  source and three  $^{60}\text{Co}$  sources (currently about 190 TBq, 22 TBq and 0.15 TBq), the smallest activity source being used for ambient dose equivalent. The results of the comparisons are published usually as *BIPM Rapports* and a summary appears periodically in *Metrologia*. Comparisons reported at the last meeting are summarized in [1]; comparison reports that have been published since are cited here in full [2 to 12] while for those comparisons not yet published, draft reports are cited [13 to 20].

Ten comparisons in terms of air kerma or absorbed dose and eighty-one calibrations of secondary standards have been carried out at the BIPM since the last meeting of Section I of the CCRI in 2001 (Table 1). The medium-energy x-ray system was re-established at the end of 2001 following the breakdown and the subsequent installation of new high voltage generators. The  $^{60}\text{Co}$  ambient dose equivalent beam has been re-established following its relocation and re-orientation.

Collaboration has continued with the IAEA on periodic TLD irradiations at the  $^{60}\text{Co}$  radiation quality.

### **2. Comparisons of air kerma standards for $^{60}\text{Co}$**

Four comparisons of air kerma standards using the 30 TBq  $^{60}\text{Co}$  source have been carried out since the 2001 CCRI(I) meeting. These have been made with the SZMDM (Yugoslavia), NIM (China), NCM (Bulgaria) and the IRD (Brazil) [21 to 24]. A comparison is planned with the BNM-LNHB for November 2003.

As usual, several experiments were undertaken at the same time as the comparisons to assess, variously, the recombination effect, the wall effect (to compare with calculations), the stem effect, orientation and polarity effects.

The BIPM has been running Monte Carlo calculations to determine the correction factors that are appropriate for its cavity chamber standard in the new  $^{60}\text{Co}$  beam. Some of the results form a separate discussion paper [25] for the CCRI(I) meeting and the outcome of the meeting is awaited before the various comparison results are presented for publication in the BIPM key comparison database (KCDB).

Table 1 Comparisons and calibrations at the BIPM from May 2001 to April 2003

Year	Country	X-rays		<sup>137</sup> Cs		<sup>60</sup> Co		
		Air kerma 10 to 50 kV	Air kerma 100 to 250 kV	Air kerma	Ambient dose equivalent	Air kerma	Absorbed dose to water	Ambient dose equivalent
2001	Yugoslavia	(SZMDM) <sub>1</sub>				<b>SZMDM</b>	(SZMDM) <sub>1</sub>	
	China		<b>NIM</b>			<b>NIM</b>		
	Brazil	(IRD) <sub>1</sub>		(IRD) <sub>1</sub>		(IRD) <sub>1</sub>	(IRD) <sub>1</sub>	
	IAEA	(IAEA) <sub>1</sub>		(IAEA) <sub>1</sub>	(IAEA) <sub>1</sub>	(IAEA) <sub>2</sub>		
	Greece Sweden			(SRPI) <sub>2</sub>		(HRICL) <sub>1</sub>	(HRICL) <sub>1</sub>	
2002	Bulgaria	(NCM) <sub>2</sub>	(NCM) <sub>2</sub>	(NCM) <sub>1</sub>	(NCM) <sub>1</sub>	<b>NCM</b>		
	Egypt		(NIS) <sub>2</sub>			(NCM) <sub>1</sub>	(NIS) <sub>3</sub>	
	Austria		<b>BEV</b>			(NIS) <sub>2</sub>		
	Rep. Korea		(KRISS) <sub>1</sub>	(KRISS) <sub>1</sub>		(KRISS) <sub>1</sub>	(KFDA) <sub>1</sub>	
	Hungary					(OMH) <sub>1</sub>	<b>OMH</b>	
	Argentina		(CRRD) <sub>2</sub>			(CRRD) <sub>2</sub>	(OMH) <sub>1</sub>	
	Italy	(ENEA) <sub>2</sub>	(ENEA) <sub>4</sub>			(CRRD) <sub>2</sub>	(CRRD) <sub>2</sub>	
	Brazil	(IRD) <sub>1</sub>	(IRD) <sub>2</sub>			(IRD) <sub>1</sub>	(IRD) <sub>1</sub>	
	Australia	(ARPANSA) <sub>2</sub>	<b>ARPANSA</b>					
	South Africa	(CSIR-NML) <sub>1</sub>	(CSIR-NML) <sub>1</sub>	(CSIR-NML) <sub>1</sub>		(CSIR-NML) <sub>1</sub>	(CSIR-NML) <sub>1</sub>	
	IAEA		(IAEA) <sub>1</sub>	(IAEA) <sub>2</sub>	(IAEA) <sub>2</sub>			(IAEA) <sub>2</sub>
	France		(BNM-LNHB) <sub>2</sub>					
	Netherlands		<b>NMi</b>					
2003	USA		<b>NIST</b>					
	Brazil					<b>IRD</b>	(IRD) <sub>1</sub>	
	Argentina				(CRRD) <sub>1</sub>			(CRRD) <sub>1</sub>
	Sweden	(SRPI) <sub>2</sub>	(SRPI) <sub>2</sub>		(SRPI) <sub>1</sub>	(SRPI) <sub>2</sub>	(SRPI) <sub>2</sub>	(SRPI) <sub>1</sub>

**COMPARISONS**  
(CALIBRATIONS)<sub>number of chambers</sub>

The results of all published air kerma comparisons (BIPM.RI(I)-K1) will be used as the basis of the MRA Appendix B entries [26] once the CCRI(I) has agreed to the values, uncertainties and degrees of equivalence.

### 3. Comparisons of air kerma standards for <sup>137</sup>Cs

Since the last Section I meeting, no comparisons of air kerma standards have been carried out using the 1 TBq <sup>137</sup>Cs source at the BIPM. This may be associated with the uncertainty over cavity-chamber wall corrections at the moment. Indeed, the BIPM has been running Monte Carlo calculations for the wall corrections and these will be presented at the CCRI(I) meeting in May 2003 [27].

Since the installation of the <sup>137</sup>Cs source at the BIPM there have been a total of nine comparisons. A compilation of the results will be published as a BIPM report with joint authorship, once the participating NMIs have agreed, as the basis for an entry in the KCDB.

#### **4. Comparisons of air kerma standards for low-energy x rays**

One low-energy x-ray comparison of air kerma standards has been made since the last CCRI(I) meeting. However, the results indicated a problem with the NMI standard and its resolution is pending further experimental work at the NMI concerned.

The BIPM has reported previously the Monte Carlo calculations of electron loss, photon scatter and fluorescence corrections made for the BIPM free-air chamber standard for low-energy x rays. Further calculations have been made using different codes to produce better estimates for the values and particularly to estimate the uncertainties. These result in changes for the BIPM standard [28], although they are within the expanded uncertainties, and will be implemented on a date to be agreed by the CCRI(I).

A paper, updating the proposal to the CCRI(I) in 2001 and compiling the published results of comparisons for eleven NMIs, has been submitted to the CCRI(I) as the basis for an entry to the KCDB for BIPM.RI(I)-K2 [29].

#### **5. Comparisons of air kerma standards for medium-energy x rays**

There have been five comparisons in medium-energy x-ray beams since the replacement of the high-voltage generators and the re-commissioning of the x-ray beams at the end of 2001. These were for the NIM (China), BEV (Austria), APRPANS (Australia), NMI (Netherlands) and the NIST (USA) [30 to 34]. NPL has also proposed a direct comparison with their transportable medium-energy free-air chamber at the BIPM and it is hoped to conduct this comparison once the practicalities have been resolved.

The BIPM has reported previously the Monte Carlo calculations of electron loss, photon scatter and fluorescence corrections made for the BIPM free-air chamber standard for medium-energy x rays. Further calculations have been made to produce better estimates for the values and particularly to estimate the uncertainties. These result in changes for the BIPM standard [28], although they are within the expanded uncertainties, and will be implemented on a date to be agreed by the CCRI(I).

A paper, updating the proposal to the CCRI(I) in 2001 and compiling the published results of comparisons for eleven NMIs has been submitted to the CCRI(I) as the basis for an entry to the KCDB for BIPM.RI(I)-K2 [35].

#### **6. Comparisons of absorbed dose standards for $^{60}\text{Co}$**

One new comparison of an absorbed dose standard in terms of absorbed dose to water has been made with the OMH (Hungary) in the last two years. Their primary standard is a graphite calorimeter and the comparison was made using two OMH ionization chambers as transfer instruments [36]. A comparison is planned with the BNM-LNHB (France) in November 2003.

The result of all published BIPM comparisons of absorbed dose to water will be presented to the CCRI(I) as the basis of the BIPM.RI(I)-K4 entry to Appendix B of the MRA once the participants have agreed.

In addition to the comparisons of absorbed dose at the BIPM, a set of three transfer standards has continued to circulate around those NMIs with absorbed dose to water primary standards for  $^{60}\text{Co}$  radiation as the key comparison CCRI(I)-K4. The three transfer standards have been followed at the BIPM over the four year period of the comparison and two of these have indicated a stability suitable for their use in this comparison. The results of this comparison will be presented to the CCRI(I). A paper is in preparation [37].

The absorbed dose comparison at high-energies, CCRI(I)-S3, has continued with the ARPANSA and the METAS making measurements in their linear accelerator beams. The five transfer standards used in this comparison have also been measured periodically at the BIPM. There are now three participants with results in this comparison and it is expected that another participant will make measurements for this comparison during the coming year.

The commissioning of the new  $^{60}\text{Co}$  source now installed at the BIPM is taking longer than anticipated because of the heavy load of comparisons and particularly of calibrations over the last two years. Some time was made, during the summer of 2001, for the NPL to make measurements in the new beam with their portable graphite calorimeter [38] and significant progress was made during the summer of 2002 with support again from the NPL [39]. The beam has also been used for recombination measurements both for the BIPM standard, the Brazilian primary standard [24] and for the CSIR-NML (South Africa) secondary standard, the latter during a secondment during 2002 from the CSIR-NML [40]. However, the 22 TBq source will remain in use for comparisons and calibrations until the new beam is fully characterized.

## **7. Calibrations in terms of air kerma, absorbed dose to water and ambient dose equivalent**

Twenty-four of the eighty-one secondary standard calibrations made at the BIPM since the last CCRI(I) meeting (Table 1) were re-calibrations. In general, the values are consistent with the statistical uncertainty of a calibration (0.07 %).

## **8. Conclusion**

Although slightly fewer comparisons were made in the last two years, principally because of updates to the dosimetry facilities, the situation with regard to up-to-date comparisons and calibrations continues to improve. Table 2 shows the numbers of comparisons and calibrations made over the last 12 years.

With the recommendation under the MRA that comparisons are undertaken at least every 10 years, the BIPM needs to be prepared to undertake an average of 10 comparisons and 20 calibrations between CCRI meetings to enable the NMIs to maintain the degrees of equivalence of their national standards.

At the last CCRI(I), a comparison and calibration programme was presented as a proposal [1]. Within this proposal, twenty-six comparisons and at least 60 calibrations were seen as necessary at the BIPM during the four following years to 2005, to support the NMIs in updating their results. Progress towards this goal is on schedule.

Table 2 Numbers of BIPM comparisons and calibrations since 1992

Year	Comparisons	Calibrations
1992/1993	5	31
1994/1995	8	54
1996/1997	17	37
1998/1999	18	35
2000/2001	13	16
2002/2003 to date	10 (+3 planned)	81

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