

## Dosimetry comparisons and calibrations at the BIPM 2005 to 2007

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### 1. Introduction

Comparisons and calibrations at the BIPM are made in terms of the quantities air kerma, absorbed dose to water, absorbed dose to graphite and ambient dose equivalent, to date for 30 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 0.7 TBq  $^{137}\text{Cs}$  source and three  $^{60}\text{Co}$  sources (namely, Picker, CIS-Bio and NBS, currently about 100 TBq, 18 TBq and 0.1 TBq, respectively), the smallest activity source being used for ambient dose equivalent. The results of the comparisons are published usually as *BIPM Rapports* or a *Metrologia Technical Supplement*. Comparisons reported at the last meeting are summarized in [1]; comparison reports that have been published since are cited here in full [2 to 6] while for those comparisons awaiting publication, draft reports are cited [7 to 16].

Eleven comparisons (eight in terms of air kerma and three in terms of absorbed dose) and thirty-three calibrations of secondary standards have been carried out at the BIPM since the last meeting of Section I of the CCRI in 2005 (Table 1). Although the Picker source is the present CCRI reference beam, the CIS-Bio  $^{60}\text{Co}$  source was also used for the comparisons with the ITN (Portugal), GUM (Poland), PTB (Germany), OMH (Hungary), NMi (Netherlands) and the ENEA (Italy).

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

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

Three comparisons of air kerma standards using the Picker  $^{60}\text{Co}$  source have been carried out since the 2005 CCRI(I) meeting. These have been made with the ITN (Portugal), the OMH<sup>1</sup> (Hungary) and the GUM (Poland) [17, 18, 19]. Measurements were also made in the CIS-Bio  $^{60}\text{Co}$  beam. A new comparison with the NPL (UK) is scheduled for later in 2007 and possibly also with the NMi.

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

Although three earlier comparisons and one carried out during this period have been published [2, 3, 4, 18], five others are in various stages of preparation for publication [7, 8, 9, 17, 19] and should be completed in the near future.

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<sup>1</sup> Since March 2007, the OMH has changed its name and its new acronym is the MKEH.

The BIPM has been running Monte Carlo calculations to determine the correction factors that are appropriate for its cavity chamber standard in the CIS-Bio  $^{60}\text{Co}$  beam and this source has been used in all three comparisons to verify the consistency of the BIPM air kerma standard. This work will be presented to the CCRI(I) in May 2007 and published shortly thereafter as the new realization of the reference beam for the air kerma standard.

Table 1 Comparisons and calibrations at the BIPM from May 2005 to April 2007

Year	Country	X-rays		$^{137}\text{Cs}$		$^{60}\text{Co}$		
		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
2005	Portugal					<b>ITN (1)</b>	ITN (1)	
	Netherlands						<b>NMi (3)</b> <sup>1</sup>	
	Germany						<b>PTB (3)</b>	
	South Africa	CSIR (1)	CSIR (1)	CSIR (1)	CSIR (1)	CSIR (1)	CSIR (1)	CSIR (1)
	Argentina		CRRD (2)			CRRD (2)	CRRD (2)	
	IAEA			IAEA (3)	IAEA (3)	IAEA (3)		IAEA (3)
2006	Hungary					<b>OMH (3)</b>		
	Poland			<b>GUM (1)</b>		<b>GUM (1)</b>		
	Belgium	<b>LSDG (1)</b>	<b>LSDG (3)</b>					
	Japan		<b>NMIJ (3)</b>					
	Korea					KRISS (1)	KRISS (1)	
	Switzerland					METAS (2)		
	France		LNHB (2)					
2007	Canada	<b>NRC (4)</b>						
	Italy						<b>ENEA</b>	
	Egypt	NIS (1)	NIS (2)			NIS (2)	NIS (1)	
	Argentina				CRRD (1)			CRRD (1)
<b>Measurements planned for 2007</b>								
2007	Brazil							
	IAEA	IAEA (2)	IAEA (2)			IAEA (2)	IAEA (2)	
	France		<b>LNHB</b>					
	UK	<b>NPL</b>	<b>NPL</b>		<b>NPL</b>	<b>NPL</b>	<b>NPL</b>	<b>NPL</b>

CALIBRATIONS (number of chambers)

COMPARISONS (number of chambers)

<sup>1</sup> calorimeter + 3 transfer chambers

The Draft B report [20] that summarizes the comparisons published in the past 10 years will be presented to the CCRI(I) in May 2007. The approval of the meeting is required before the various comparison results are presented for publication in the BIPM key comparison database (KCDB) in accordance with the CIPM MRA [21].

The BEV (Austria), NIST (USA), ARPANSA (Australia), NRC (Canada), VNIIM (Russian Federation) and the UDZ (Czech Republic) will normally need to schedule their air kerma comparisons or take part in RMO comparisons before the next CCRI(I) meeting in 2009 in order to comply with the recommendation for a fifteen-year cycle<sup>2</sup> of comparisons.

<sup>2</sup> Note that results older than 10 years have to be indicated as such in the KCDB.

### **3. Comparisons of air kerma standards for $^{137}\text{Cs}$**

Since the last Section I meeting, only one comparison of air kerma standards has been carried out using the  $^{137}\text{Cs}$  source at the BIPM and the draft comparison report is under discussion [19]. From the earlier comparisons, the reports of the NPL and the ENEA are awaiting completion [7, 10]. The declaration of the new determination of the BIPM air kerma standard is awaiting confirmation of some further experimental results but once approved by the CCRI(I), a compilation of the nine sets of comparison results will be presented in a Draft B summary comparison report, as the basis for the entry of degrees of equivalence in the KCDB.

A comparison with the NPL is scheduled for later in 2007. In principle, the BEV, LNE-LNHB, ENEA, NIST, MKEH and the VNIIM will each need to schedule a  $^{137}\text{Cs}$  comparison before 2009.

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

Two low-energy x-ray comparisons of air kerma standards have been made since the last CCRI(I) meeting with the LSDG (Belgium) and the NRC (Canada) and the reports are being prepared [22, 23]. A comparison with the NPL is planned for 2007.

The report for the comparison conducted in 2005 with the NMIJ is in discussion [11].

Six NMIs will need to schedule new comparisons before 2009 in order to comply with the recommendation for a fifteen-year cycle of comparisons (GUM, NMI, NIST, METAS, ENEA, VNIIM).

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

Two comparisons of air kerma standards with the LSDG (Belgium) and the NMIJ (Japan) have been made since the last CCRI(I) meeting [24, 25]. Comparisons with the LNE-LNHB (France) and the NPL (UK) are scheduled for 2007.

The reports for the four comparisons conducted latterly for the NIM (China), BEV (Austria), ARPANSA (Australia) and the NMI (Netherlands) are all in preparation or in draft form [12 to 15].

The report for the comparison with the NIST (USA) has been published [6].

Five NMIs will need to schedule new comparisons before 2009 in order to comply with the recommendation for a fifteen-year cycle of comparisons (GUM, ENEA, MKEH, NRC, VNIIM).

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

Three new comparisons of the absorbed dose standards in terms of absorbed dose to water have been made with the NMI (Netherlands), the PTB (Germany) and the ENEA (Italy) in the last two years. The comparison with the NMI was made directly with their water calorimeter and using three ionization chambers as transfer instruments [26]. The comparisons with the PTB and the ENEA were made exclusively using transfer instruments [27, 28]. The opportunity was taken to make measurements also in the CIS-Bio  $^{60}\text{Co}$  beam. However, the Picker beam was used in the final result for each of these comparisons pending the approval of the CCRI(I) to change to the new beam.

One other earlier comparison report is still to be finalized [16] and this result will be added to the KCDB once the uncertainty budget has been analyzed.

A comparison with the NPL is scheduled for 2007. The BEV, ARPANSA, NIST and the NRC will need to schedule new comparisons before 2009 in order to comply with the recommendation for a fifteen-year cycle of comparisons.

In addition to the comparisons of absorbed dose at the BIPM, a set of three transfer standards has circulated 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 during and since the comparison period and two of these have indicated a level of stability suitable for their use in this comparison. The results of this comparison will be presented to the CCRI(I) separately [29].

There are now three participants (the NPL, ARPANSA and the METAS) with results in the absorbed dose comparison at high-energies, CCRI(I)-K6. The five transfer standards used in this comparison have also been measured periodically at the BIPM. The Draft A report will be written with the participants during the coming year.

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

Twenty-three of the thirty-three 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 %).

A report has been published with the details of the re-implementation of the  $^{60}\text{Co}$  ambient dose equivalent reference beam that is used for radiation protection level calibrations [30].

Following the implementation of the BIPM QS for dosimetry calibrations, two internal and two external audits have been carried out since the last CCRI(I) meeting. The auditors declared satisfaction with the QS and no non-conformities were identified although some minor modifications have been implemented in accordance with their suggestions.

## 8. Conclusion

The number of comparisons has increased during the last two years, as anticipated. Table 2 shows the numbers of comparisons and calibrations made over the past few years.

Table 2 Number 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	9	87
2004/2005	7	35
2006/2007	11	33

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

Although this average has been achieved during the past two years, there has been a slippage since 2001 so that at least another 26 comparisons will need to be undertaken by 2009, three of which have already been scheduled and some of which may be satisfied by regional comparisons. There is also a small but inevitable backlog of comparison reports that are pending.

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