Dosimetry comparisons and calibrations at the BIPM 2003 to 2005

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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}Cs source and three ^{60}Co sources (currently about 140 TBq, 23 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* 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 9] while for those comparisons not yet published, draft reports are cited [10 to 20].

Four comparisons (three in terms of air kerma and one of absorbed dose) and two sets of pilot measurements in terms of air kerma and thirty-seven calibrations of secondary standards have been carried out at the BIPM since the last meeting of Section I of the CCRI in 2003 (Table 1). The ^{60}Co ambient dose equivalent beam has been re-established following its relocation and re-orientation [21]. The new ^{60}Co source is now commissioned [22] and will be used for the comparisons planned to take place during the remainder of 2005 with the ITN (Portugal), GUM (Poland), PTB (Germany), OMH (Hungary) and the NMi (Netherlands).

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

2. Comparisons of air kerma standards for ^{60}Co

Two comparisons of air kerma standards using the 23 TBq ^{60}Co source have been carried out since the 2003 CCRI(I) meeting. These have been made with the LNE[1]-LNHB (France) and the ENEA (Italy) [23, 24].

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. Measurements were also made in the 140 TBq Co-60 beam as part of the ENEA air kerma comparison.

Although four earlier comparisons have been published [2, 5, 6, 8], five others are in various stages of preparation for publication [14, 15, 18, 19, 20] and should be completed in the near future.

[1] Since February 2005, the French national metrology institutes have been regrouped under the auspices of the Laboratoire national de métrologie et d'essais (LNE) which replaces the Bureau national de métrologie (BNM).

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}Co beam.

Table 1 Comparisons and calibrations at the BIPM from May 2003 to April 2005

Year	Country	X-rays		^{137}Cs		^{60}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
2003	Brazil	**LNMRI**	**LNMRI**					
	France					**BNM-LNHB**	**BNM-LNHB**	
	Greece			(HIRCL)$_1$		(HIRCL)$_2$	(HIRCL)$_1$	
	Korea					(KFDA)$_1$	(KFDA)$_1$	
2004	Finland	(STUK)$_2$	(STUK)$_1$			(STUK)$_1$	(STUK)$_1$	
	Spain		(CIEMAT)$_1$	(CIEMAT)$_1$		(CIEMAT)$_3$	(CIEMAT)$_2$	
	Norway	(NRPA)$_2$	(NRPA)$_1$	(NRPA)$_1$	(NRPA)$_1$	(NRPA)$_3$	(NRPA)$_2$	
	IAEA	(IAEA)$_1$	(IAEA)$_1$			(IAEA)$_3$	(IAEA)$_3$	
	France		(BNM-LNHB)$_1$					
	Japan	**NMIJ**						
	Italy					**ENEA**		
	Measurements planned for 2005							
2005	Portugal					**ITN**		
	IAEA			(IAEA)	(IAEA)	(IAEA)	(IAEA)	
	South Africa					(CSIR-NML)	(CSIR-NML)	
	Poland					**GUM**		
	Germany						**PTB**	
	Hungary					**OMH**		
	Netherlands						**NMi**	

COMPARISONS
(CALIBRATIONS)$_{\text{number of chambers}}$

The results together with the experimental determinations of the correction factors for the air kerma standard form a separate paper [22]. The approval of the meeting is awaited before the various comparison results are presented for publication in the BIPM key comparison database (KCDB) [25] in accordance with the CIPM MRA [26].

The BEV, NIST, NMi, and the UDZ (Czech Republic) will need to repeat their air kerma comparisons before the next CCRI(I) meeting in order to comply with the recommendation for a ten-year cycle of comparisons.

3. Comparisons of air kerma standards for ^{137}Cs

Since the last Section I meeting, no comparisons of air kerma standards have been carried out using the 1 TBq ^{137}Cs source at the BIPM. Three earlier comparison reports are awaiting completion [15, 16, 19]. The delays are partly 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 a new determination of air kerma will be presented to the CCRI(I) in due course [27].

Once this new value is approved, a compilation of the nine sets of comparison results will be presented to the CCRI(I), as the basis for the entry of degrees of equivalence in the KCDB. However, in principle, the BEV, LNE-LNHB, NIST and OMH will need to repeat their comparisons before the next CCRI(I) meeting.

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 with the NMIJ and the report is being prepared [28]. Some measurements were also made in the frame of a pilot study for the LNMRI.

All the previously published comparisons for eleven NMIs have been published in the KCDB for the comparison designated as BIPM.RI(I)-K2 [29]. These results incorporated the changes in the BIPM standard that were reported to the last CCRI(I) meeting and which have been published [30].

The NRC, GUM and the NMi will need to repeat their comparisons before the next CCRI(I) meeting in order to comply with the recommendation for a ten-year cycle of comparisons.

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

Although no medium-energy x-ray comparisons of air kerma standards have been made since the last CCRI(I) meeting, some measurements were made in the frame of a pilot study for the LNMRI.

The results from all the previously published comparisons for eleven NMIs have now been published in the KCDB in the comparison designated as BIPM.RI(I)-K3 [31]. The summary report incorporated the changes in the BIPM standard that were reported to the last CCRI(I) meeting and which have been published [30].

The reports for the five comparisons conducted latterly for the NIM (China), BEV (Austria), APRPANSA (Australia), NMi (Netherlands) and the NIST (USA) are all in preparation or in draft form [10 to 14].

The GUM (Poland) will need to repeat their comparison before the next CCRI(I) meeting in order to comply with the recommendation for a ten-year cycle of comparisons.

6. Comparisons of absorbed dose standards for ^{60}Co

The results of all published BIPM comparisons of absorbed dose to water are now represented in the KCDB with the summary report approved by the CCRI(I) [32]. One new comparison of an absorbed dose standard in terms of absorbed dose to water has been made with the LNE-LNHB in the last two years. Their primary standard is a graphite calorimeter and the comparison was made using three LNE-LNHB ionization chambers as transfer instruments [33]. One other comparison report is still to be finalized [17] and this result will be added to the KCDB once the uncertainty budget has been analyzed.

Comparisons are scheduled with the PTB and the NMi for the autumn of 2005. The BEV and the ENEA will need to repeat their comparisons before the next CCRI(I) meeting in order to comply with the recommendation for a ten-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}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 [34].

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 for the participants during the coming year.

The new ^{60}Co source at the BIPM is now fully commissioned [22, 35, 36] and will be used for all future air kerma comparisons and calibrations. The water phantom has been constructed and is in place for comparisons and calibrations pending the final calculations for the absorbed dose to water standard. The beam has been used in the last two years to confirm recombination measurements for the BIPM, the LNE-LNHB (France) [23] and the ENEA (Italy) [24] primary standards and for preliminary assessments of air kerma. However, the 22 TBq source was used for each of these comparisons pending the approval of the CCRI(I) to change to the new beam.

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

Twenty-one of the thirty-seven 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 %). The BIPM report on calibration conditions has been updated [37].

A major task that has been completed since the last CCRI(I) meeting is the full implementation of the BIPM QS, and in particular, the QS for dosimetry calibrations. The dosimetry QS was peer reviewed in December 2003 with a

second internal audit in 2004. The next internal audit is scheduled for September 2005.

8. Conclusion

Although slightly fewer comparisons have been made in the last two years, 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.

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

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 comparisons and 20 calibrations between CCRI meetings to enable the NMIs to maintain the degrees of equivalence of their national standards. At the CCRI(I) in 2001, a comparison and calibration programme was presented as a proposal [38]. 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. Although this goal has been achieved, there is a small backlog of comparison reports that are pending and at least another fourteen comparisons will need to be undertaken by 2007.

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