Dosimetry comparisons and calibrations at the BIPM 1999 to 2001

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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 for 28 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 two ^{60}Co sources (currently 30 TBq and 0.2 TBq), the smaller 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 which have since been published are cited here in full [2 to 10] while for those earlier comparisons not yet published, draft reports are cited [11 to 19].

Twelve comparisons in terms of air kerma or absorbed dose and twenty-one calibrations of secondary standards have been carried out at the BIPM since the last meeting of Section I of the CCRI in 1999 (Table 1). No x-ray comparisons were undertaken during the year 2000 due to the breakdown of the negative HT generator which supplied both the low-energy and medium-energy x-ray tubes. The low-energy x-ray system is now re-established (see CCRI(I)01-07) and two comparisons have been undertaken recently; the medium-energy x-ray system should be re-established before the end of 2001.

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

Table 1 Comparisons and calibrations at the BIPM from May 1999 to April 2001

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
1999	Norway	$(NRPA)_1$	$(NRPA)_1$	$(NRPA)_1$		$(NRPA)_2$	$(NRPA)_2$	
	UK			**NPL**				
	Argentina		$(CRRD)_2$		$(CRRD)_1$	$(CRRD)_2$	$(CRRD)_2$	$(CRRD)_1$
	Belgium						**LSDG**	
	India					**BARC**	$(BARC)_2$	
2000	Netherlands						**NMi**	
	Spain			$(CIEMAT)_2$		$(CIEMAT)_2$		
	Slovakia					**SMU**		
	Switzerland						**METAS**	
	Germany			**PTB**		**PTB**		
2001	Japan			**AIST**		**AIST**		
	Russia						**VNIIFTRI**	
	Austria	**BEV**						
	Hungary	**OMH**						

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

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

Four comparisons of air kerma standards using the 30 TBq ^{60}Co source have been carried out since the 1999 CCRI(I) meeting. These have been made with the BARC (India), the SMU (Slovakia), the PTB (Germany) and the AIST[1] (Japan) [20 to 23].

The comparison with the BARC was made indirectly using two transfer standards. The comparisons with the SMU, PTB and the AIST were all direct comparisons using the primary standards of the NMIs. Several experiments were undertaken at the same time as the comparisons to assess, variously, the recombination effect, the wall effect, the stem effect, orientation effects and polarity effects.

The PTB standard is new, comprised of three ionization chambers of differing shape. When the comparison result is evaluated in terms of the correction factors previously used with similarly shaped chambers, it agrees with the previous (1989) comparison result. However, the PTB has re-evaluated its correction factors, using both Monte Carlo calculations and experimental measurements and this produces a significant difference in the comparison result. This is a discussion item for the CCRI(I) meeting.

The results of all published air kerma comparisons (BIPM.RI(I)-K1) will be used as the basis of the MRA Appendix B entries [24] once the CCRI(I) has agreed to the values, uncertainties and degrees of equivalence.

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

Since the last Section I meeting, two further comparisons of air kerma standards have been carried out using the 1 TBq ^{137}Cs source at the BIPM. These were made with the PTB and the AIST [22, 23].

The NPL (UK) standard for ^{137}Cs was also re-measured in the BIPM gamma beams and correction factors for recombination loss were assessed to support the earlier comparison.

Since the installation of the ^{137}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 key comparison database.

[1] National Institute of Advanced Industrial Science and Technology, previously known as the ETL.

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

Since the low-energy x-ray facility has been re-established, two comparisons of air kerma standards have been made, one with the BEV (Austria) and the other with the OMH (Hungary) [25, 26].

Both comparisons were carried out in March 2001, using primary-standard free-air chambers. In addition, both the BEV and the OMH made indirect comparisons using transfer cavity chambers. The results should be available for presentation at the CCRI(I) meeting once the participating NMIs have agreed.

The BIPM has reported previously the Monte Carlo calculations of photon scatter and electron loss corrections made for the BIPM free-air chamber standards. These changes have not yet been implemented for the BIPM standards, partly because the new values are within the uncertainties of the previous values. Calculations of photon scatter and electron loss corrections for other free-air chambers have also been reported [27] and several NMIs are now using these values; the OMH has used the new values for their standard in the present comparison.

A paper compiling the previously published results will be submitted to the CCRI(I) as the basis for an entry to the key comparison BIPM.RI(I)-K2 database.

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

No comparisons have been possible during this period due to the breakdown of the high-voltage generator. The medium-energy x-ray system should be commissioned by the end of 2001 and comparisons are already planned for the ARPANSA (Australia), the BEV and the NIST (USA). The NPL has also proposed a direct comparison with their transportable medium-energy free-air chamber at the BIPM.

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

Four new comparisons of absorbed dose standards have been made in the last two years. Each of these has been in terms of absorbed dose to water, with the LSDG (Belgium), NMi (Netherlands), METAS[2](Switzerland) and the VNIIFTRI (Russian Federation). The standards are all either graphite or water calorimeters [28 to 31].

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.

[2] Swiss Federal Office of Metrology and Accreditation, formerly the Swiss Federal Office of Metrology (OFMET).

In addition to the comparisons of absorbed dose at the BIPM, a set of three transfer standards has been circulating 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 over the two year period of the comparison and indicate a stability appropriate for their use in this comparison. The results of this comparison will be presented to the CCRI(I). A paper is in preparation [32].

The absorbed dose comparison at high-energies, CCRI(I)-S3, has started with the NPL making measurements in their linear accelerator beams. The five transfer standards used in this comparison have also been measured periodically at the BIPM. The ARPANSA has expressed an interest in taking part in this comparison during the coming year.

A 250 TBq ^{60}Co source has now been installed at the BIPM and will be commissioned over the summer months during which time a direct comparison of absorbed dose with the NPL using a portable graphite calorimeter will also take place as a trial comparison. The 30 TBq source will continue to be used 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

Thirteen of the twenty-one secondary standards calibrated at the BIPM since the last CCRI(I) meeting (Table 1) had been calibrated previously at the BIPM between 1993 and 1996. 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 improvements 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 10 years and Table 3 gives the dates of the most recent comparisons and calibrations.

Table 2 Numbers of BIPM comparisons and calibrations since 1990

Year	Comparisons	Calibrations
1990/1991	2	19
1992/1993	5	31
1994/1995	8	54
1996/1997	17	37
1998/1999	18	35
2000/2001 to date	10 (+3)	4 (+9)

Table 3 Most recent comparisons and calibrations of radiation dosimetry standards at the BIPM
[Comparisons are in bold, * indicates scheduled for 2001 and calibrations are given as ( )]

Laboratory	**Country / Region**	**Air Kerma**				**Absorbed Dose**[1]	**Ambient Dose *H****
		10 kV to 50 kV	**100 kV to 250 kV**	**Cs-137**	**Co-60**	**Co-60**	**Cs-137 / Co-60**
AIST	Japan	**1972**		**2001**	**2001**		
ARPANSA	Australia		**1988***		**1997**	**1997w**	
BARC	India		**1975**		**1999**	(1999w)	
BEV	Austria	**2001**	**1982***	**1995**	**1995**	**1994w**	
BNM-LNHB	France	(1985)	**1998**	**1995**	**1993**	**1993g/w**	
CIEMAT	Spain	**1979**	(1991)	(2000)	(2000)	(1993w)	
CMI	Czech Rep.		(1994)		**1992**/(1994)	(1992w)	
CRRD	Argentina		(1999)		(1999)	(1999)	(1999)
CSIR	South Africa	(1999)	**1976**/(1994)		(1994)	(1994w)	
ENEA	Italy	**1998**	**1998**	**1998**	**1998**	**1994g/w**	
GUM	Poland	**1994**	**1994**	(1996)	**1996**		
IAEA	International	(1998)	(1998)	(1996)	(1998)	(1998w)	(1994)
KRISS	Rep. Korea				**0000**		
LNMRI	Brazil	(1993)	(1997)	(1995)	**1995**/(1997)	(1997/w)	
LSDG	Belgium					**1999w**	
METAS	Switzerland	**1998**			(1997)	**2000w**	
NIM	China				(1984)		
NIRH	Denmark	(1995)	(1995)		(1995)	(1995w)	
NIST	USA	**1998**	**1991**	**1994**	**1996**	**1997w**	
NMi	Netherlands	**1996**	**1991**		**1996**	**2000w**	
NPL	UK	**1997**	**1997**	**1999**	**1997**	**1997g/w**	
NRC	Canada	**1966**	**1998**		**1998**	**1998w**	
NRPA	Norway	(1999)	(1999)	(1999)	(1999)	(1999w)	
OMH	Hungary	**2001**	**1998**	**1994**	**1994**	(1994w)	
PTB	Germany	**1999**	**1999**	**2000**	**2000**	**1989w**	
SMU	Slovakia				**2000**		
SRPI	Sweden	(1998)	(1998)	(1995)	(1998)	(1998w)	
STUK	Finland	(1997)	(1997)		(1997)	(1997w)	
VNIIM	Russian Fed.	**1998**	**1998**	**1997**	**1997**	**2001w** VNIIFTRI	

[1] g refers to graphite and w refers to water

The grey boxes in Table 3 indicate comparisons which are now more than ten years old. This table shows that although the comparisons for all seventeen air kerma primary standards in ^{60}Co are current, two will need to be re-compared before the next CCRI(I). A proposal for comparisons and calibrations to be undertaken before the next CCRI(I) meeting is presented in Table 4.

Ten out of fourteen medium-energy x-ray standards comparisons are current, two comparisons are planned and two standards are probably no longer in use;

Table 4 Proposed programme of comparisons and calibrations at the BIPM for 2001-2003

[Comparisons are in bold and calibrations are given as ( ) with previous dates]

Laboratory	**Country / Region**	**Air Kerma**				**Absorbed Dose[1]**	**Ambient Dose *H****
		10 kV to 50 kV	**100 kV to 250 kV**	**Cs-137**	**Co-60**	**Co-60**	**Cs-137 / Co-60**
AIST	Japan	**1972**					
ARPANSA	Australia		✓				
BARC	India		**1975**				
BEV	Austria		✓				
BNM-LCIE	France	**1997***					
CIEMAT	Spain	**1979**	(1991)			(1993w)	
CMI	Czech Rep.		(1994)		**1992**/(1994)	(1992w)	
CSIR	South Africa		**1976**/(1994)		(1994)	(1994w)	
GUM	Poland			(1996)			
IAEA	International	(✓)			(✓)	(✓)	(✓)
KRISS	Rep. Korea				**0000**		
LNMRI	Brazil	(✓)	(1997)	(1995)	(✓)	(✓)	
METAS	Switzerland				(1997)		
NIM	China				(1984)		
NIRH	Denmark	(1995)	(1995)		(1995)	(1995w)	
NIST	USA		✓				
NMi	Netherlands		**1991**				
NRC	Canada	**1966**					
OMH	Hungary					(1994w)	
PTB	Germany					**1989w**	
SRPI	Sweden			(✓)			
STUK	Finland	(1997)	(1997)		(1997)	(1997w)	

✓ already planned * to be repeated

however, two other standards will need to be re-compared before the next CCRI(I). Ten out of thirteen low-energy x-ray standards are current, one may no longer exist and the other two need to be compared in the near future to be eligible for entry as a key comparison result.

There are now twelve absorbed dose to water standards and all but one of the comparisons are current with one further standard to be compared before the next CCRI(I). There are now nine air kerma standards in ^{137}Cs and all of them have been compared within the last ten years with one standard needing comparison before the next CCRI(I). In the near future, the Republic of Korea and China may be ready to undertake air kerma comparisons for ^{60}Co. This implies a programme of up to thirteen comparisons during the next two years.

The situation with regard to the calibration of secondary standards is also reasonably satisfactory. Of the 48 secondary standards for all the radiation qualities maintained by sixteen NMIs and the IAEA which are calibrated at the BIPM, nineteen have not been calibrated within the last 5 years. Together with the eleven standards which will become due for calibration, this implies a work-load of at least another 30 calibrations during the next two years. Subsequently, an average of 10 comparisons and 20 calibrations is foreseen between CCRI meetings.

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