EUROMET Project 813

Comparison of air kerma and absorbed dose to water measurements of Co-60 radiation in radiotherapy

Identifiers in Appendix B of the key comparison database (KCDB):

EUROMET.RI(I)-K1
EUROMET.RI(I)-K4

Technical Protocol

(approved by CCRI(I))

Pilot laboratory: (OMH)

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1. Description of the project

In the EUROMET, the CMC lines of ionisation chamber calibration used in radiotherapy, in terms of air kerma (K_{air}) and absorbed dose to water (D_w), are under the inter RMO approval process and will be published very soon. The degrees of equivalence of relevant primary standards have not yet been published for Co-60 radiation. Although, the laboratories having primary standards regularly take part in the ongoing BIPM.RI(I)-K1, BIPM.RI(I)-K4 key comparisons, during these comparisons the primary standard cavity chamber for air kerma or a transfer standard for absorbed dose to water are used to measure the BIPM Co-60 radiation beam. To support the CMC lines of participants the calibration of the transfer standards, similar to the real items of service using their own irradiation facilities, is the best method for primary and secondary laboratories equally. In these comparisons establishing the degrees of equivalence of national standards will be based on the delivered calibration coefficients by the participants. Calibration coefficients of high quality therapy dosemeters as transfer instruments with small additional uncertainty components related to the calibration procedure, together with detailed uncertainty budgets of the conventional true

values can deliver realistic pictures from the realisation of these fundamental dosimetry quantities and the calibration measurement capabilities of each participants.

Under the project two key comparisons will be run in parallel for measurements of the two quantities. Almost the same protocol will cover them. Two sets of transfer instruments (PTW UNIDOSE 2.3 with PTW 30001 and Wellhöffer FC65-G chambers, and PAM 2001 electrometer with NE 2561 and OMH ND 1006 chambers) will be calibrated in terms of absorbed dose to water at 5 cm depth in standards water phantom. In term of air kerma free in air all the four chambers with both electrometers will be calibrated. The N_{Kair} and N_{Dw} calibration coefficients will be the comparison parameters. Detailed uncertainty budgets of the calibration coefficients and national standards, or traceability descriptions if they are not primary standards, are required separately for the two quantities. More details are in **Appendix C.**

After approving the draft B by the CCRI(I) the degrees of equivalence of participants will appear in the regional part of the equivalence matrix that will be published in Appendix B of MRA.

2. Short history

In October 1999, national metrology laboratories worldwide signed a Mutual Recognition Arrangement (MRA: 'Arrangement on the mutual recognition of the equivalence of national standards and of calibration certificates issued by national metrology institutes') with the aim of establishing a basis for the mutual recognition of calibrations. In this context, BIPM has published on its homepage a list of Calibration and Measurement Capabilities (CMC-lists) of the institutes which have signed the MRA. Calibration services can, however, only be included if a quality management system according to ISO standard 17025 has been established. Quality assurance and confidence in the capabilities of other laboratories can only be ensured by the successful participation in a comparison in which the degree of equivalence with other national metrology institutes or calibration laboratories has been determined.

The idea of a new supporting comparison for ionisation chamber calibration in terms of air kerma and absorbed dose to water used in therapy, came up during the EUROMET TC meeting in Helsinki in 2003. The previous similar EUROMET project No. 335 had been performed in 1996 before the MRA came into force. In consideration of some further reasons the TC agreed not to use that as a supporting comparison in the future. In the meantime new k_{wall} correction factors of primary standard cavity chambers of air kerma, and new water calorimeters of absorbed dose to water have been introduced at PSDLs, hence the relevant CMC lines of participants are not currently perfectly coherent.

The outcomes of this comparison project (calibration coefficients of transfer chambers, transparent traceability, and well documented uncertainty calculations) can validate and

extend the degrees of equivalence data bases for these fundamental quantities for Co-60. The status and technical details of the project were discussed and finalised at the last EUROMET meeting in Paris in September 2004. Participation from other RMOs was also encouraged at this meeting. The call for registration was sent to all members of EUROMET and representatives of SIM, APMP and COOMET also. Four laboratories from SIM and one from the COOMET have been registered.

3. Participants

Table 1

	Contact person	Country	Institute	E-mail address
1	Wilhelm Tiefenboeck	Austria	BEV	w.tiefenboeck@metrologie.at
2*	Jean-Marc Bordy F. Delaunay	France	BNM-LNHB*	Bordy@ortolan.cea.fr DELAUNAY@ortolan.cea.fr
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8	Ahmed Megzifene	International org.	IAEA	a.meghzifene@iaea.org
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12	Mr. Cosme N. M. da Silva Carlos J. da Silva	Brazil	LNMRI	 carlos@ird.gov.br
13	Dr. Gerhard Stucki	Switzerland	METAS	gerhard.stucki@metas.ch
14**	Juliana Mintcheva	Bulgaria	NCM**	ncm@sasm.orbitel.bg
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19	Hans Bjerke	Norway	NRPA	Hans.Bjerke@nrpa.no
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21	Hans-Michael Kramer	Germany	PTB	Hans-Michael.Kramer@ptb.de
22	Antons Lapenas	Latvia	RMTC	alap@latnet.lv
23	Jozef Dobrovodsky	Slovakia	SMU	dobrovodsky@smu.gov.sk
24	Jan-Erik Grindborg	Sweden	SSI	Jan-Erik.Grindborg@ssi.se
25	Mr. Ilkka Jokelainen	Finland	STUK	ilkka.jokelainen@stuk.fi
26**	Alexander Oborin	Russia	VNIIM**	oav@vniim.ru

Note: Complete addresses are given in Appendix B.
* Linking laboratories for to the BIPM Key Comparisons Reference Values
**air kerma comparison only

4. Procedure

4.1 Object of comparison

Calibrations of four different types of transfer ionisation chambers using two electrometers in Co-60 beams against the national standards of absorbed dose to water and air kerma. Each chamber is placed with its reference point at the depth of 5 g/cm^2 in a water phantom and free in air at the reference distance in the Co-60 beam, where the conventional true values of reference absorbed dose to water rate and air kerma rate have been established by the appropriate national standards respectively. The calibration coefficients are $N_{Dw} = D_w/I_{corr}$ and $N_{Kair}=K_{air}/I_{corr}$ where I_{corr} is the measured ionisation current corrected for influence quantities, in order to correspond to the reference conditions for the calibration. D_w and K_{air} are the reference absorbed dose to water rate and air kerma rate respectively. More details are in the **Appendix C**

4.2 Description of transfer instruments

The main technical data of the transfer chambers are listed in the table 2. Each chamber has its own build-up cap for calibration in terms of air kerma. For the absorbed dose to water calibration the waterproof chambers do not need PMMA sleeves in the water phantom whereas the NE 2561 and the PTW 30001 chambers have their own PMMA sleeves outer diameter is 18 mm. *(Never leave the waterproof FC-65 G and ND 1006 chambers in the water phantom after finishing the calibration.)* As the chambers and electrometers have different signal and high voltage arrangements, for the air kerma calibration, adaptors and extension cables are provided to connect all the four chambers to both electrometers. *(When using the TRIAX-BNC adapters, the chamber should be isolated from the electrical ground and the adapters and chamber should never be touched after switching on the collecting voltage.)* The reference points of the chambers are the geometrical centre of the sensitive volumes. The chambers should be aligned in the beam with the black cross on their head (marking the middle of the sensitive lengths) facing the radiation source. (*In case of ND 1006 chamber, never clamp the plastic part of the stem.)* Pictures of the chambers and the appropriate build-up cap, sleeve and adaptor are shown in **Appendix A**.

Table 2: Main technical data of the transfer chambers

Type serial number	Nom. N_{Dw} Gy/μC	Nom. volume cm^3	Collecting Voltage **	Wall material	Wall thickness g/cm^2	Diam. of head mm	Stem diameter/length mm	Waterp oof
NE 2561 # 084	101	0,33	+200	Graphite	0,09	8,4	12,6/180	No
PTW 30001 #2118	54	0,60	+400	PMMA	0,045	7,0	12,6/130	No
Wellhöffer FG-65 C #518	45	0,65	+300	Graphite	0,068	7,0	8,6/80	Yes
ND 1006 #8503	120	0,28	+250	Delrin	0,07	8,0	10,0/*300	Yes

*perpendicular aluminium part of the stem
** the central electrode is positive

The **PTW UNIDOSE 2.30** 10002 #20381 dosemeter is used through it's RS 232 output by a small data collection and evaluation program name: ***UnidoseRS232*.** Use your own temperature and pressure probes and use the keyboard to put these data in. The **PAM 2001** #2306 electrometer has own measuring program name:***PAMW2003*** and build in barometer. The attached PT 200 temperature probe #2306 is watertight. After removal of the metal cylinder it can be immersed into water up to the marking label.

Each time when the *UnidoseRS232* and *PAMW2003* programs are used, the measured ionisation current and further related 9 items of data are stored in a text file on the hard disk of the enclosed **notebook (NEC Versa** #1233200045) connected to the electrometers. The leakage currents of all required configurations (8) should be less than 10 fA, applying the appropriate polarisation voltages in table 2 and waiting minimum 30 minutes. If not, please try to identify the problematic component and call the pilot laboratory immediately + 36 1 4585945.

4.3 Reference conditions

Dose rate of the collimated Co-60 radiation beam in the range of 0,2 mGy/s-50 mGy/s and 100 cm^2 beam cross section at the reference plane shall be used during the calibrations. The recommended source-chamber distance (reference point of chamber from the focus point of Co-60 source) is 100 cm.

The calibration coefficients for the transfer chambers shall be given in terms of absorbed dose to water and air kerma per unit charge in units of Gy/μC referring to standard conditions of air temperature, pressure and relative humidity of $T = 293{,}15$ K, $P = 101{,}325$ kPa and $h = 50$ %. Participants do not need to apply any correction for the incomplete charge collection as their dose rates have been surveyed in advance. The relative air humidity should

be between 20 % and 80 % during the calibrations otherwise a correction to h = 50 % should be applied.

4.4 Course of comparisons

To ensure the highest reliability of transfer standards control, the time consuming star-shaped circulation of the chambers between OMH and the participant laboratories have been chosen. The CNEA-CAE, LNMRI and the NRC they will receive the transfer instruments from the NIST and should return them to the NIST. The participant countries should pay for the transportation and insurance of the transfer instruments' package back to OMH, in case of Canada, Argentina and Brazil back to the NIST. The estimated value of package is 30 000 Euro. Taking into consideration the 26 participants, **the transfer standards should stay at the participants site for no longer than 3 weeks to perform the 2 × 8 air kerma and 2 × 4 absorbed dose to water calibrations**. **The results of all participants should be reported to the OMH within 4 weeks after the calibrations**. **To report the results, four excel sheets in Appendix C are provided in which information about the national (primary) standards used by the participants and the calibration results can be completed.** The example sheets of uncertainty budget in the '**results_813** excel file (**Appendix C**). for realisation of air kerma and absorbed dose to water, and for calibration of user instruments in primary and secondary laboratories serve only for orientation of participants. The requested uncertainties should be given in accordance with the ISO Guide to the expression of uncertainties in measurements (GUM) (ISO 1993, revised 1995).

The comparison measurements are scheduled to commence in February 2005 and expected to be completed in January 2008. The proposed schedule is shown in table 3. The pilot lab and the participants should be communicate about the details of transportation (using the code of of package and web side of company) by E-mail or by phone to the keep the deadlines in table 3.

Transportation time for the chambers from the OMH to a participant by TNT was calculated as one week in each direction. Duration of constancy measurements at OMH laboratory is one week.

To keep the timetable on course for the three year program, if a laboratory is not able to perform the measurements according to the approved itinerary it must find another participant to exchange their time slot.

Table 3: Proposed schedule of measurements of participants

	Participant	Date of chamber leaving OMH for participant	Measurement duration at laboratory	Date of chamber getting back from participant
1	BNM-LNHB	1-March-2005	07-March-2005 to 25- March -2005	04-Apr.-2005
2	CIEMAT	11- Apr.-2005	18-Apr-2005 to 06-May-2005	16-May-2005
3	CMI	23-May-2005	30-May-2005 to 17-Jun-2005	27-Jun-2005
4	RMTC	04-Jul-2005	11-Jul-2005 to 29-Jul-2005	08-Aug-2005
5	SSI	15-Aug-2005	22-Aug-2005 to 9-Sept-2005	19-Sept-2005
6	STUK	26-Sept-2005	03-Oct-2005 to 21-Oct-2005	31-Oct-2005
7	NRPA	07-Nov-2005	14-Nov-2005 to 02-Dec-2005	12-Dec-2005
8	SMU	19-Dec-2005	26-Dec-2005 to 13-Jan-2006	23-Jan-2006
9	IAEA	30-Jan-2006	06-Feb-2006 to 24-Feb-2006	06-March-2006
10	HIRCL	13-March-2006	20-March-2006 to 07-Apr-2006	17-Apr-2007
11	NCM	24-Apr-2006	01-May-2006 to 19- May -2006	29-May.-2006
12	IRB	05-Jun-2006	12-Jun-2006 to 30- Jun -2006	10-Jul.-2006
13	GUM	17-Jul-2006	24-Jul-2006 to 11-Aug -2006	21-Aug.-2006
14	VNIIM	28-Aug-2006	04-Sept-2006 to 22- Sept -2006	02-Oct.-2006
15	PTB	9-Oct-2006	16-Oct-2006 to 03- Nov -2006	13-Nov-2006
16	BEV	20-Nov-2006	27-Nov-2006 to 15-Dec -2006	25-Dec.-2006
17	METAS	02-Jan-2007	08-Jan-2007 to 26- Jan-2007	05-Febr.-2007
18	NMI	12-Febr-2007	19-Febr-2007 to 09- March -2007	19-March.-2007
19	NPL	26-March-2007	02-Apr-2007 to 20- Apr -2007	30-Apr.-2007
20	ENEA	7-May-2007	14-May-2007 to 01- Jun -2007	11-Jun-2007
21	NIST	18-Jun-2007	25-Jun-2007 to 13- Jul-2007	23-Jul.-2007
22	NRC	30-Jul-2007	06-Aug-2007 to 24-Aug -2007	03-Sept.-2007
23	LNMRI	10-Sept-2007	17-Sept-2007 to 12-Oct -2007	22-Oct.-2007
24	CNEA-CEA	29-Oct-2007	05-Nov-2007 to 23-Nov-2007	03-Dec.-2007
25	LMRIR	10-Dec-2007	17-Dec-2007 to 04-Jan-2008	17-Jan.-2008

4.5 Procedure for handling the results of the pilot and linking laboratories

The pilot laboratory will participate in the comparison as one of the linking laboratories. The other linking laboratory is the BNM-LNHB. The OMH will determine the transfer chambers' calibration coefficients in February 2005. The report on these measurements will be sent to the EUROMET TC-IR Chair not later than 15 March before the first laboratory (BNM-LNHB) would send their results back. Both results will be sent to the executive secretary of CCRI(I). This procedure should be a measure of confidence. As the linking laboratories do not yet have published degrees of equivalence, the linking values for this double EUROMET key comparisons will be calculated by the Key Comparison Working Group of CCRI(I). These will be based on the calibration coefficients measured at OMH and BNM-LNHB and the results of these linking laboratories from the BIPM.RI(I)-K1 and K4 key comparisons performed in 2002 and 2003.

Although, the transfer instruments have high stability performance in laboratory circumstances, for purpose of constancy checks, the pilot laboratory will measure the leakage and air kerma calibration coefficient of each chamber after receiving it from each participant.

4.6 Evaluation of the results

The pilot laboratory will evaluate the comparison on the basis of the results given by the participants in the provided MS-Excel sheets. The indirect comparison of the national standards will be based on the average of the eight calibration coefficients in terms of air kerma and the average of the four calibration coefficients in terms of absorbed dose to water. The degrees of equivalence will be evaluated based on the corrected results of linking laboratories according to their degrees of equivalence having been approved by the CCRI(I) and published for both quantities in the KCDB. *(This method pre-supposes the high stability reproduction of air kerma and absorbed dose to water reference values at the two linking laboratories between their BIPM key comparisons and the date of their measurements within this EUROMET 813 project.)*

The results in the KCDB are based on the BIPM.RI(I)-K1 key comparison for air kerma and BIPM.RI(I)-K4 and CCRI(I)–K4 key comparisons for absorbed dose to water. The evaluation procedures will be similar to those used by the BIPM for the determination of the degree of equivalence for the above mentioned key comparisons. More details of the evaluation will be given in the first draft of the report on the results.

4.7 Publication of the results

To support the relevant CMC lines of EUROMET member secondary standard laboratories, as soon as possible once these 12 laboratories. (marked yellow in table 3) have finished their measurements **in August 2006, an interim evaluation will be made**. The Draft A report will be circulated in confidence to these 12 participants and the Draft B containing proposals for degrees of equivalence of the results will be prepared by the KCWG of the CCRI(I) and submitted for approval to the CCRI(I) by the end of October 2006. This interim Draft B report can only be published using relative data.

After finishing the whole program with all the participants in January 2008, the pilot laboratory will prepare an amended Draft A including the results of Argentina, Brazil, Portugal and the primary laboratories. The Draft A will be circulated for comments and discussion of the results and once agreement is reached by all the participants, the revised report Draft B, will be produced as the official final report of the EUROMET project. This will be submitted to the EUROMET TC-IR Chairman and the KCWG of CCRI(I) to have the proposals for the degrees of equivalence included. After the approval of Draft B by the CCRI(I,) the results and the report will be sent to for inclusion of the degrees of equivalence in the KCDB. The report will be submitted to the *Technical Supplement* of *Metrologia* for publication.

5. References

1. ISO International Organisation for Standardisation (1993). “Guide to the Expression of Uncertainty in Measurement. Geneva, ISBN 92-67-10188-9.
2. ISO International Organisation for Standardisation (1996). “X and gamma reference radiation for calibrating dosemeters and dose rate meters and for determining their response as a function of photon energy – Part 1: Radiation characteristics and production methods.” ISO 4037-1:1996(E).
3. IAEA TRS No. 398 “Absorbed Dose Determination in External Beam Radiotherapy”
4. EUROMET Guide 3 Version 2.7“Guidelines on Conducting Comparisons”
5. “Guidelines for CIPM key comparisons” modified in October 2003

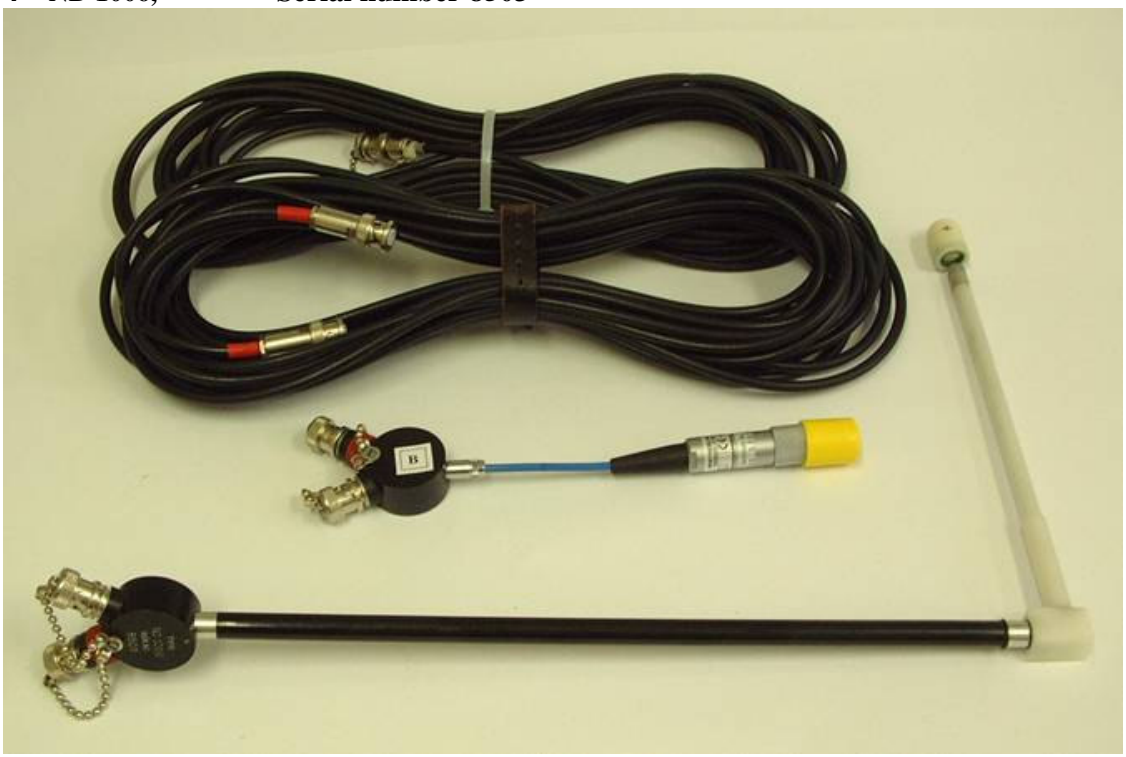
APPENDIX A: **Pictures of the transfer chambers**

1. NE 2561, Serial number 084

2. PTW 30001, Serial number 2118

Wellhöffer FG-65 C, Serial number 518

4 ND 1006, Serial number 8503



UNIDOSE, Serial number 20381

PAM 2001 Serial number 2306