# EURAMET Project 1285

## Comparisons of air kerma and absorbed dose to water standards in $^{60}$Co radiation beams for radiotherapy

**Proposed identifier in Appendix B of the BIPM key comparison database (BIPM KCDB):**

## EURAMET.RI(I)-K1.1
## EURAMET.RI(I)-K4.1

# Technical Protocol

*(submitted to **EURAMET** and **CCRI(I)**)*

**Pilot laboratory: METAS**


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# Contents



## 1. Description of the project

In the project the comparisons for air kerma (EURAMET.RI(I)-K1.1) and for absorbed dose to water (EURAMET.RI(I)-K4.1), both quantities measured in $^{60}$Co radiotherapy beams, will take place in parallel. The comparisons aim basically supporting the participants' calibration and measurement capabilities (CMC) of the quantities mentioned above in the context of the CIPM - Mutual Recognition Arrangement (CIPM-MRA) [1- 5].
In order to do so, transfer standards for air kerma and absorbed dose to water are circulated among the participants. The circulating items are two ionisation chambers and one dedicated electrometer. The participants will determine the calibration coefficients of the transfer standards $N_{K\mathrm{air}}$ and $N_{D\mathrm{w}}$ through comparison with their national standards in their respective $^{60}$Co beams [6]. The calibration coefficients will be corrected for reference conditions as well as for leak current, saturation and the electrometer range used. But no correction for polarity effects has to be applied as the ionisation chambers will be measured with a unique electrometer configuration for the polarity and the voltage level. Detailed uncertainty budgets for the calibration coefficient determinations will be given by the participants [7]. All applied corrections to the calibration coefficient calculation will be documented in written form.

Particular attention will be given to the differing dose rates of the $^{60}$Co beams among the participants, ranging from 0.1 Gy/min to 1.2 Gy/min.

BEV has planned to replace its $^{60}$Co source through out 2013/2014 and, thus, wants to do two series of measurements, one series with the old source in 2013 and a second series with the new source in 2014.

The measurements will be linked with the ongoing BIPM.RI(I)-K1 and BIPM.RI(I)-K4 comparisons, through BEV, LNE-LNHB and VSL for EURAMET.RI(I)-K1.1 and through BEV, LNE-LNHB and METAS for EURAMET.RI(I)-K4.1 [8].

## 2. Participants

**Table 1:** Participants

| | Contact person | Country | Institute | E-mail address |
|---|---|---|---|---|
| 1 | Dr. Anton Steiner | Switzerland | METAS | anton.steiner@metas.ch |
| 2 | Dipl. Ing. Andreas Steurer | Austria | BEV | Andreas.Steurer@bev.gv.at |
| 3 | Dr. Frank Delaunay | France | LNE_LNHB | Franck.DELAUNAY@cea.fr |
| 4 | Dr. Jacco de Pooter | Netherlands | VSL | JdPooter@vsl.nl |
| 5 | Cristina García Mulas | Spain | CIEMAT | cristina.garcia@ciemat.es |
| 6 | Liviu-Cristian Mihailescu | Belgium | SCK-CEN | lmihaile@sckcen.be |

## 3. Procedure

### 3.1 Object of the comparison

The calibration of two ionisation chambers against the national standards of air kerma and of absorbed dose to water in $^{60}$Co radiotherapy beams will be carried out. The ionisation chambers will be used sequentially each with the also circulating electrometer. The chambers are placed free in air for the air kerma measurements and in water at the depth of 5 g/cm$^2$ for the absorbed dose to water measurements at the reference distance in the $^{60}$Co beams where the conventional true values of air kerma and absorbed dose to water rates are established by the corresponding national standards. The calibration coefficients are calculated from $N_{K\mathrm{air}}=\acute{K}_{\mathrm{air}}/I_{\mathrm{corr}}$ and $N_{D\mathrm{w}}=\acute{D}_{\mathrm{w}}/I_{\mathrm{corr}}$. $I_{\mathrm{corr}}$ is the measured ionisation current corrected for reference conditions as well as for leak current and saturation. $\acute{K}_{\mathrm{air}}$ and $\acute{D}_{\mathrm{w}}$ are the established air kerma and absorbed dose to water rates of the $^{60}$Co sources respectively under reference conditions [6].

### 3.2 Description of the transfer instruments

The circulating electrometer is a PTW UNIDOS webline T10022, SN000308. The belonging ionisation chambers are also from PTW; one is watertight and one not; their technical data are given in table 2.

**Table 2:** Technical data of the ionisation chambers

| Type, serial number | Nom. $N_{Dw}$ (Gy/μC) | Nominal volume ($cm^3$) | Collecting Voltage (V) | Wall material | Water-proof | Wall thickness ($g/cm^2$) | inner Diam. of head (mm) | Stem diameter/ length (mm) |
|---|---|---|---|---|---|---|---|---|
| **PTW T30006,** SN036 | 50 | 0.6 | +400 | PMMA | Yes | 0.0565 | 6.1 | 12.6/132.6 |
| **PTW T30004,** SN286 | 50 | 0.6 | +400 | Graphite | No | 0.0785 | 6.1 | 12.6/132.6 |

*Each chamber has its own build-up cap made in POM for the calibration in terms of air* kerma. For the absorbed dose to water calibration the waterproof chamber PTW T30006 does not need a PMMA sleeve in the water phantom whereas the PTW 30004 chamber has to be protected with its PMMA sleeve. Do not leave the chambers in the water after the measurements are finished.

The chambers are measured with the accompanying electrometer PTW UNIDOS webline T10022 (SN000308) in the already defined configuration for the two chambers (Collecting voltage +400 V, mode " ∫ Current dt, Range LOW/MEDIUM (*to be selected)*, Integration time 60 s "). The chambers should be aligned in the beam with the black line on their stem facing the radiation source and the marking on the build-up cap being on the beam axis, both markings defining together the reference point of the chamber. Pictures of the chambers and the appropriate build-up caps and sleeve, if any, are shown in Appendix A.

With $^{60}Co$ dose rates varying from 0.1 Gy/min to 1.2 Gy/min participants may be required to use different, i.e. the most appropriate, ranges of the electrometer for optimum measurements. The corresponding electrometer correction factors are given Appendix B.

Each laboratory uses its own temperature and pressure measurement equipment.

### 3.3 Reference conditions

The chambers are basically placed in the usual reference configuration in the $^{60}Co$ beams where the conventional true values of air kerma and absorbed dose to water rates are established. Thus the source-chamber distance, i.e. the distance between the chamber reference point and the focus point of the $^{60}Co$ source, is 100 cm along the central beam axis. A 10 cm x 10 cm beam cross section at the reference plane perpendicular to the beam axis and specified by the photon fluence rate at the mid-point of each side of the square being 50 % of the photon fluence rate at the centre is used. For the determination of $N_{K\mathrm{air}}$ the chamber is placed free in air, for $N_{D\mathrm{w}}$ the reference point of the chamber is placed at the depth of 5 $g/cm^2$ in a water phantom.

The calibration coefficients of the ionisation chambers $N_{K\mathrm{air}}$ and $N_{D\mathrm{w}}$ shall be given in terms of air kerma and absorbed dose to water per unit charge in the units of Gy/μC referring to standard conditions of air or water temperature, air pressure and relative humidity, i.e. $T$ = 293,15 K, $P$ = 101,325 kPa and $H$ = 50 %rh. The relative humidity of the environment should be between 20 %rh and 80 %rh, otherwise a correction to $H$ = 50 %rh should be applied.

The calibration coefficients of the chambers shall be corrected further for leak current and saturation but not for polarity effects. The saturation correction may be either calculated (e.g. equations according to Boag [6]) or determined from adequate measurements according to the procedure normally used in the laboratory (e.g. two voltage method). The chosen method will be documented and reported with the results.

### 3.4 Course of the comparison

To ensure the highest possible reliability of the transfer standards, a partly star-shaped circulation of the instruments between METAS and the other participants is chosen. Each participant will pay for the transportation and insurance for sending the instruments to the next laboratory as scheduled. The transfer standards should stay at the participant's site for 4 weeks maximum in order to perform 2 x 5 air kerma and 2 x 5 absorbed doses to water measurement sets allowing for leak current and statistical evaluations. The results will be reported to METAS within 2 months after the measurements. Each participant will deliver detailed uncertainty budgets for the calibration coefficient determinations of the transfer standards in accordance with the ISO Guide to the expression of uncertainties in measurements (GUM 1995 [7]).

The comparison measurements are scheduled from March 2013 to November 2014; the schedule is given in table 3.

**Table 3:** Schedule for the measurements at METAS and BEV

| | Participant | Measurement duration at laboratory |
|---|---|---|
| 1 | METAS | March / Mai 2013 |
| 2 | LNE-LNHB | June 2013 |
| 3 | BEV | Mid-August / Mid-September 2013 |
| 4 | METAS | November 2013 |
| 5 | SCK-CEN | March 2014 |
| 6 | VSL | Mid-May / Mid-June 2014 |
| 7 | CIEMAT | July 2014 |
| 8 | BEV | September 2014 |
| 9 | METAS | November 2014 |

Transportation time for the instruments from one participant to next is estimated being one week by door to door delivery. The participants will communicate about transportation details by e-mail or by phone. The addresses for delivering the equipment to the participants are given in Appendix C.

Any delay in the schedule should be communicated to the pilot as well as to the other participants as to decide about the further course of the comparison. Due to the customs formalities between the European Community and Switzerland, the transfer instruments will travel with an ATA carnet that has to be kept strictly always with the instruments.
In the case of failure of one or both ionisation chambers the pilot laboratory may provide one replacement for each chamber type.

### 3.5 Calibration coefficient determination

The participants will proceed in their own way to determine the calibration coefficients of the chambers. Similarly to the uncertainty budgets detailed description of the procedure applied will be given.
As an example the procedure used at METAS is described below. It illustrates the span of measurements allowing for leak current and statistical evaluations.
At METAS the ionisation chambers are connected to the electrometer at least two hours before doing any measurements. Due to the actual strength of the METAS Cobalt source (1.2 Gy/min) the electrometer mode is set to " ∫ Current dt, Range Medium, Integration time 60 s " with a collecting voltage of +400 V. Then, first ten leak current measurements are acquired each with 60 s integration time, followed by the opening of the source and a 10 Gy pre-irradiation period. Thereafter, twenty-five irradiation measurements each with 60 s integration time are done. After these measurements, the irradiation is stopped and a five minute waiting time is allowed for before a second series of ten leak current measurements is taken. Air or water temperature and air pressure are measured at halftime of each 60 s integration period. The air density correction $k_{TP}$ is, thus, applied to each acquired charge value. The calculated saturation correction $k_S$ is also applied to each charge value. The mean of the leak current measurements before and after the irradiation will be subtracted from the mean of the irradiation measurements. The electrometer range correction $k_{EM}$ is based on an electrical calibration of the electrometer done at METAS; the corresponding calibration factors are given in Appendix B.
At METAS the $^{60}$Co measurements are always preceded and followed by control current measurements using always the same specific dedicated radioactive $^{90}$Sr control device. Furthermore METAS will repeat the measurements after the 2013 circulation part as well as at the end of the comparison thus allowing for constancy checks and consolidation of the reported measurements.

### 3.6 Handling the results

METAS will measure the transfer standards for the first time in March/Mai 2013. The report on these measurements will be sent to the EURAMET TC-IR Chair and to the CCRI(I) Executive Secretary before any further participant will deliver its measurement results. This procedure should be a measure of confidence as to ensure the impartiality of METAS as pilot laboratory.

The participants will send their results with detailed descriptions of the procedures and uncertainty budgets to the pilot laboratory by email within two months after having finished their measurements.

The pilot laboratory will evaluate the comparison on the basis of the results reported by the participants.

### 3.7 Evaluation of the results

The arithmetic means of the delivered results in terms of air kerma and absorbed dose to water for both circulating ionisation chambers respectively are proposed to define the base lines against which the participants' calibration coefficient values may be compared in the context of this comparison. Further details for data analysis will be discussed among the participants on the basis of Draft A report.

The pairwise comparison of participants can also be reflected through the ratios of the corresponding calibration coefficient values in terms of air kerma ($N_{K\text{airP1}}/N_{K\text{airP2}}$) and in terms of absorbed dose to water ($N_{D\text{wP1}}/N_{D\text{wP2}}$) for both circulating ionisation chambers respectively.

The degree of equivalence in terms of air kerma for CIEMAT and METAS can be calculated from the ratios defined above linked to the VSL, BEV and LNE-LNHB results from their respective BIPM.RI(I)-K1 exercises [9,10,12]. The resulting ratios will allow for linking the CIEMAT and METAS results in terms of air kerma to BIPM. The primary standards of the three linking laboratories stayed unchanged throughout the mentioned comparisons.

The degree of equivalence in terms of absorbed dose to water for CIEMAT can be calculated from the ratios defined above linked to the BEV, LNE-LNHB and METAS results from their respective BIPM.RI(I)-K4 exercises [11,13,14]. The resulting ratios will allow for linking the CIEMAT results in terms of absorbed dose to water to BIPM. The primary standards of the three linking laboratories stayed unchanged throughout the mentioned comparisons.

BEV will decide following the Draft A discussion on the level of significance of the results obtained with their new $^{60}$Co source.

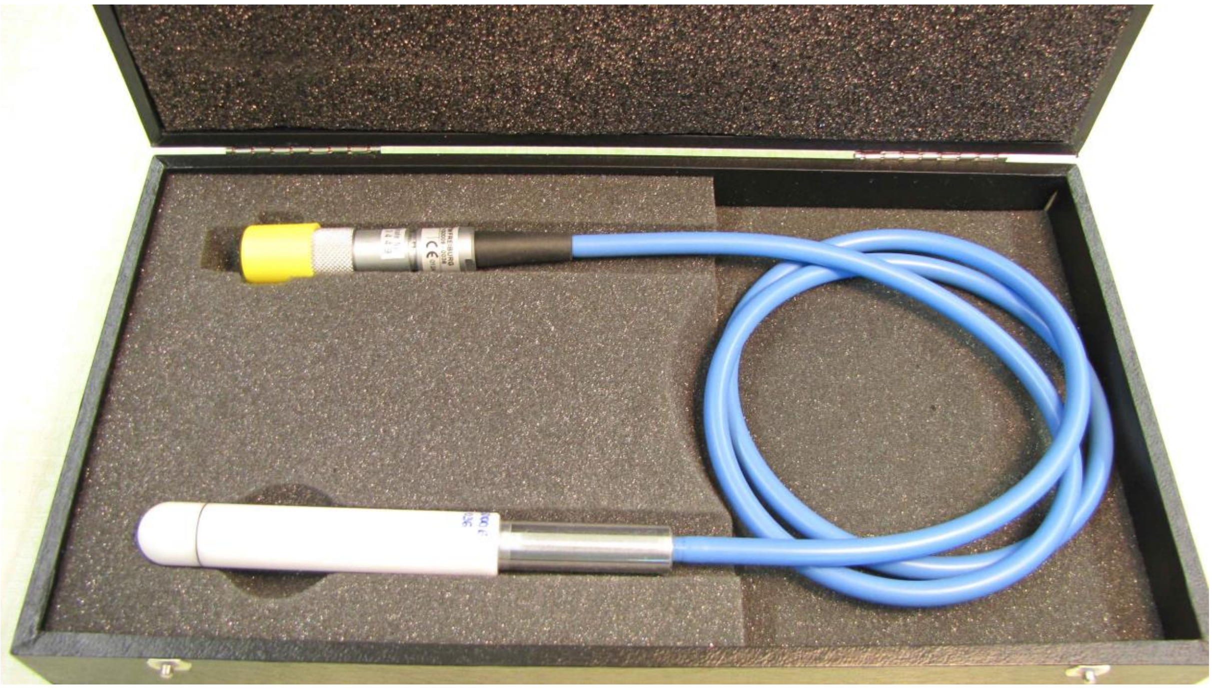
### 3.8 Publication of the results

METAS, as the pilot laboratory, will prepare a Draft A report being circulated for comments and discussion among the participants. The revised report Draft B will be produced as the official final report of the EURAMET project. It will be submitted to the EURAMET TC-IR Chair and the KCWG of CCRI(I). The approved report will finally be submitted to the *Technical Supplement* of *Metrologia* for publication.

## 4. References


1. CIPM MRA – Mutual recognition of national measurement standards and of calibration and measurement certificates issued by national metrology institutes, Paris, 14 October 1999
2. CIPM MRA Technical Supplement revised in October 2003
3. CIPM MRA-D-04 - Calibration and Measurement Capabilities in the context of the CIPM MRA
4. MRA-D-05, Measurement comparisons in the CIPM MRA, CIPM, October 2012 (V.1.3)
5. EUROMET, Guide 3, Guidelines on Conducting Comparisons (V.2.7)
6. IAEA, TRS No. 398, Absorbed Dose Determination in External Beam Radiotherapy, IAEA, VIENNA, 2000, ISSN 1011–4289, June 2006 (V.12)
7. BIPM, JCGM 100:2008, Evaluation of measurement data - Guide to the expression of uncertainty in measurement (GUM 1995)
8. EUROMET Project 813, Comparison of air kerma and absorbed dose to water measurements of $^{60}$Co radiation in radiotherapy (http://kcdb.bipm.org/appendixB/appbresults/EUROMET.RI(I)-K1/EUROMET.RI(I)-K1_Technical_Protocol.pdf)
9. Kessler C., Allisy-Roberts P.J., de Prez L.A., van Dijk E., Comparison of the standards for air kerma of the VSL and the BIPM for $^{60}$Co gamma radiation, Metrologia, 2010, 47, Tech.Suppl. 06015.
10. Kessler C., Allisy-Roberts P.J., Steurer A., Tiefenboeck W., Gabris F. 2010, Comparison of the standards for air kerma of the BEV and the BIPM for $^{60}$Co gamma radiation, Metrologia, 2010, 47, Tech.Suppl. 06006.
11. Kessler C., Allisy-Roberts P.J., Steurer A., Baumgartner A., Tiefenboeck W., Gabris F. 2010, Comparison of the standards for absorbed dose to water of the BEV, Austria, and the BIPM for $^{60}$Co gamma radiation, Metrologia, 2010, 47, Tech.Suppl. 06017.
12. Kessler C., Burns D.T., Delaunay F., Donois M., Key comparison BIPM.RI(I)-K1 of the air kerma standards of the LNE-LNHB, France, and the BIPM in $^{60}$Co gamma radiation, Metrologia, 2013, 50, Tech. Suppl. 06018.
13. Kessler C., Burns D.T., Delaunay F., Donois M., Key comparison BIPM.RI(I)-K4 of the standards for absorbed dose to water of the LNE-LNHB, France, and the BIPM in $^{60}$Co gamma radiation, to be published.
14. 13. Kessler C., Burns D.T., Vörös S., Hofstetter-Boillat B., Key comparison BIPM.RI(I)-K4 of the standards for absorbed dose to water of the METAS, Switzerland, and the BIPM in $^{60}$Co gamma radiation, comparison running.

**APPENDIX A:** **Pictures of the electrometer, the ionisation chambers and the packing**


METAS electrometer for EURAMET comparison
UNIDOS webline
PTW


UNIDOS webline
PTW
METAS


METAS

## APPENDIX B: Correction factors for the electrometer ranges

| | Calibration factor for positive charges | Calibration factor for negative charges |
|---|---|---|
| **LOW** | **0.9999** | **0.9987** |
| **MED** | **1.0006** | **1.0005** |
| **HIGH** | **1.0000** | **0.9998** |

| | Combined standard uncertainty for positive charges | Combined standard uncertainty for negative charges |
|---|---|---|
| **LOW** | **0.0003** | **0.0005** |
| **MED** | **0.0003** | **0.0003** |
| **HIGH** | **0.0004** | **0.0003** |

## APPENDIX C: Delivery addresses of the participants

| | Institute | Delivery address |
|---|---|---|
| 1 | METAS | Anton Steiner<br><br>Federal Institute of Metrology METAS<br>Laboratory Radiotherapy<br>Lindenweg 50<br>3084 Wabern, Switzerland<br><br>Tel. +41 58 387 03 71<br>Tel. reception desk +41 58 387 01 11<br>Fax reception desk +41 58 387 02 10 |
| 2 | BEV | Dipl. Ing. Andreas Steurer<br><br>BEV - Bundesamt für Eich- und Vermessungswesen<br>Gruppe Eichwesen - Abteilung E1 - Elektrizität und Strahlung<br>Referat Ionisierende Strahlung, Radioaktivität<br>Arltgasse 35<br>1160 Wien, Austria<br><br>Tel. +43 1 21110-6379<br>Fax +43 1 21110-6000<br>Tel. Sekretariat: +43 1 21110-6320 |
| 3 | LNE_LNHB | Marc Donois / Frank Delaunay<br><br>CEA-Saclay<br>Bt 534 - PtC 104<br>91191 Gif-sur-Yvette Cedex, France<br><br>Tel. +33 1 69 08 89 82 / 84 05<br>Fax +33 1 69 08 47 73 |
| 4 | VSL | Jacco de Pooter<br><br>VSL<br>Thijsseweg 11<br>2629 JA Delft, The Netherlands<br><br>Tel. +31 15 2691623<br>Fax +31 15 2691500 |
| 5 | CIEMAT | Cristina García Mulas<br><br>National Metrology Laboratory for Ionising Radiations. CIEMAT<br>Avda. Complutense, 40; E2.P0.D16<br>28040 Madrid, Spain<br><br>Tel. +34 913466097 ó +34 913466849<br>Fax +34 913466442 |

| | | |
|---|---|---|
| 6 | SCK-CEN | Liviu-Cristian Mihailescu<br><br>SCK-CEN (Studiecentrum voor Kernenergie - Centre d'Etude de l'Energie Nucleaire)<br>Radiation Protection Dosimetry and Calibrations group (RDC)<br>GKD building<br>Boeretang 200<br>2400 Mol, Belgium<br><br>Tel. +32 14 33 23 89<br>Tel. +32 494 469 541 |