EURAMET DOSEtrace supplementary comparison

EURAMET project No. 1467

BIPM KCDB: EURAMET.RI(I)-S18

Technical Protocol

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1. Introduction

International Committee for Weights and Measures (CIPM) Mutual Recognition Arrangement (MRA) is a multilateral agreement between National Metrology Institutes (NMI) and Designated Institutes (DI). CIPM MRA provides mutual recognition of calibration and test certificates and national measurement standards. Key and supplementary comparisons are organized within CIPM MRA framework to support member Calibration and Measurement Capabilities (CMC) [1].

Ambient dose equivalent, *H**(10), is an operational quantity used in ionizing radiation dosimetry for area monitoring. It was introduced by ICRU [2] and adopted by European Union in Council Directives 96/29/EURATOM and 2013/59/EURATOM. A EURAMET supplementary comparison of calibration coefficients for *H**(10) for photon radiation, EURAMET.RI(I)-S11, was organized between 2013 and 2014, with 16 NMIs and DIs and the International Organization taking part [3]. However, many NMIs and DIs still do not have published CMCs for *H**(10), so there is still a need to organize follow-up comparisons.

The aim of this comparison is to compare calibration coefficients for *H**(10) for photon radiation. For this purpose, a transfer chamber will be provided. The chamber will be circulated between the partners, and will periodically be returned to the pilot for stability checks. The comparison will be performed for 5 radiation qualities (3 mandatory and 2 additional) which are to be established in accordance with ISO 4037-1 [4].

The radiation qualities chosen for the comparison are:

- N-40 (mandatory)
- N-100 (mandatory)
- N-200 (additional)
- S-Cs (mandatory)
- S-Co (additional)

Dose rate will be within the range between 0.5 mSv/h and 10 mSv/h. The recommended value is 6 mSv/h.

This comparison can be used to validate calibrations in ambient dose equivalent/rate. Due to the similar calibration procedures, calibrations in personal dose equivalent/rate penetrating and superficial can also be validated by this comparison.

This comparison is intended to validate calibrations in X-ray radiation qualities from 50 kV to 420 kV, as well as qualities S-Cs and S-Co. Even though radiation quality N-40 (40 kV) is included in the protocol, this comparison is not intended to be used for validation of X-ray radiation qualities from 10 kV to 40 kV, due to the different procedures involved in low energy X-ray calibrations.

The comparison will be performed for N-series X-ray radiation qualities, but calibrations in other standard qualities established in accordance with ISO 4037-1 [4] (H-series, W-series, L-series) use similar procedures, so the comparison can be appropriate for validation of these additional radiation qualities.

The comparison will be coordinated by VINS as the pilot laboratory. PTB will provide expertise in comparison organization and will provide transfer chamber. Results will be evaluated by SMU and VINS, with support of HMI/IRB-SSDL and SCK • CEN/LNK. Final report will be sent to BIPM to be reviewed by CCRI(I), and the results will be submitted for inclusion in the Key Comparison Data Base (KCDB) and publication in Metrologia.

This comparison protocol was prepared according to EURAMET guidelines [5].

2. Participants

Thirteen NMIs and DIs will take part in the comparison:

- VINS, Vinča Institute of Nuclear Sciences – pilot
- GUM - Central Office of Measures/Glowny Urzad Miar
- HMI/IRB-SSDL - Secondary Standard Dosimetry Laboratory of the Ruder Boskovic Institute
- IMBiH - Institute of Metrology of Bosnia and Herzegovina
- INM - National Metrology Institute of the Republic of Moldova
- IRCL/GAEC-EIM - Ionizing Calibration Laboratory/Greek Atomic Commission - Helenic Institute of Metrology
- IST-LPSR-LMRI - Instituto Superior Técnico
- MIRS/IJS/F-2,O-2 - Metrology Institute of the Republic of Slovenia/Jozef Stefan Institute/Low and Medium Energy Physics F2, Environmental Sciences O2
- NSC-IM, National Scientific Centre Institute of Metrology
- PTB, Physikalisch-Technische Bundesanstalt
- SCK • CEN/LNK, Studiecentrum voor Kernenergie, Centre d'Étude de l'énergie Nucléaire / The Laboratory for Nuclear Calibrations
- SMU, Slovak Institute of Metrology
- TAEK, Türkiye Atom Enerjisi Kurumu

3. Transfer standard

Secondary standard ionisation chamber Seibersdorf HS01 [6] S/N 112 will be used as the transfer standard. The chamber is shown in Fig. 1. The chamber is of spherical shape and has a nominal volume of 1 l. The outer diameter of the chamber is 140 mm. Chamber voltage should be set to +300 V and applied to the collecting electrode (inner electrode).

The chamber has BNC connector for current measurement and Lemo connector for the high voltage (HV) supply. Adapter with a Lemo (FFA.1S.304.CLAC52) connector to a banana plug (4 mm pin plug) is used for HV. Connectors and adapters are shown in Fig. 2. An adapter to TNC connector will be provided as well.

Figure 1: HS01 S/N 112, Secondary standard chamber for *H*(10)* (Photo credit Bildstelle PTB).

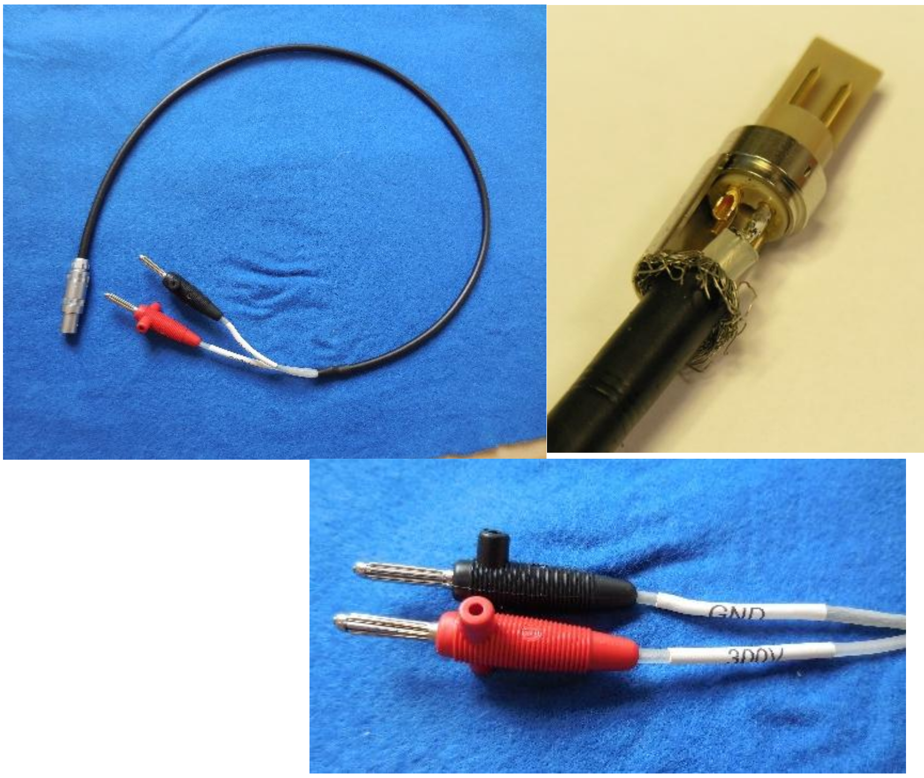

Figure 2: Cable for high voltage connection and details of the connectors.

4. Linearity of the transfer chamber

Due to the fact that it is not possible to determine a dose rate that can be realized by all the participants, the pilot laboratory will perform linearity test with respect to dose rate before the start of the official part of the comparison. Linearity test will be performed in N-100 radiation quality. The dose rate range will be sufficient to include all the dose rates used by the participants for their own calibrations. Participants' results will be corrected for the nonlinearity of the transfer chamber if necessary, based on the linearity test results.

Within the expected dose rate range, the linearity correction is expected to be negligible.

5. Stability of the transfer chamber

Stability of the transfer chamber will be checked by performing calibrations in all radiation qualities by VINS. First calibration will be performed before any other participant performs calibration and the last after all participants have finished calibrations. Two additional calibrations will be performed according to the time schedule, in-between the other partner's calibrations.

The stability checks will be used to enlarge measurement uncertainty. In case of the large deviations of calibration coefficients in subsequent stability checks, or other malfunctions of the transfer chamber, the comparison will be stopped. In that case, the possibility to continue or restart the comparison with a new transfer chamber will be evaluated.

6. Advice on handling and organising the transport of the transfer standard

Each comparison participant will arrange the transport of the chamber by himself. The transport and insurance costs including export charges will be covered by the sender. The receiver will cover import cost. The value for the insurance of the chamber is 12000 €.

Transport container must be shipped by ground. Air pressure change during air transport may damage the equipment. If chamber is hand carried, it can be transported by plane inside passenger cabin. In this case, all costs until the delivery of the chamber are covered by the sender.

The transport container contains:

1. Transfer chamber HS01
2. BNC connector for current measurements and Lemo connector for HV supply
3. Adapter with a Lemo (FFA.1S.304.CLAC52) connector to a banana plug (4 mm pin plug)
4. Adapter to TNC connector.

After the chamber is received, each comparison participant must check the chamber and auxiliary equipment for any damages and inform the pilot about the equipment condition.

After finishing the measurements, comparison pilot should be notified. The pilot institute will then confirm the next shipping address, in case of schedule changes.

7. Tests and procedures to be carried out before measurements

Transfer standard will be used with the electrometers provided by the participants. The measurement system should be left in the measurement room to reach thermal equilibrium, preferably overnight. The transport container should be left closed during this process, especially in cold weather.

The transfer chamber should be used according to installation instructions provided inside the transport container. The electrometer has to be switched on at least one hour before measurements and chamber should be used with a collecting voltage of +300 V applied to the collecting electrode (inner electrode). Even though pre-irradiation of protection level chambers is not necessary, pre-irradiation for at least 10 minutes is recommended. Before measurements, measurement system should be zeroed and at least 10 leakage measurements taken to ensure that the leakage current is less than 0.1 % of the anticipated signal.

8. Calibration method, calibration conditions

Comparison of calibration coefficients will be performed for three mandatory radiation qualities and two additional radiation qualities. The mandatory radiation qualities are N-40, N-100 and S-Cs. Additional radiation qualities are N-200 and S-Co. All radiation qualities will be realised in accordance with ISO 4037-1 [4]. Participants may perform reference measurements in terms of air kerma free-in-air or in terms of ambient dose equivalent. The participants have to state the used conversion coefficients and the method of their determination (e.g. spectrometry or ISO 4037-3 [7]). Recommended dose rate is 6 $mSvh^{-1}$ for all radiation qualities. Participants may use different dose rates, in which case the results might be corrected for transfer chamber linearity.

The chamber should be oriented in such way that the Type number and S/N are pointed towards the radiation source.

The air-kerma rate at the point of test should not vary by more than 5 % over the entire sensitive volume of the transfer chamber. The chamber must be irradiated completely. Chamber readings must be corrected for air density (reference conditions: air pressure 101.325 kPa, ambient temperature 20.0 °C, relative air humidity 50 %). Leakage current correction must be performed if leakage is higher than 0.1 % of the signal. Participants may perform additional corrections, according to their own procedures. Correction for polarity effects is not necessary, because the transfer chamber will be used with a unique configuration for the polarity and voltage.

The calibration coefficient in Sv/C is given by

$$N_{\mathrm{H}} = \frac{H^*(10)}{Q_{cor}}$$

where $H^*(10)$ is the conventional true value of ambient dose equivalent and Q_{cor} collected charge for transfer standard measurements, corrected to the reference conditions.

9. Necessary data and measurement uncertainty

Each participant will prepare the calibration report containing the following data: method of determination of $H^*(10)$, description of the used equipment, description and picture of calibration setup, determination of calibration coefficients and the uncertainty budgets for each radiation quality and any corrections used.

The measurement results and uncertainty budgets will be reported in the excel form which will be provided by VINS. The uncertainty will be determined in accordance with the BIPM Guide to the expression of uncertainties in measurements [8]. Principal uncertainty components are shown in Table 1. Comparison participants should list all other significant contributions to the uncertainty. All contributions to the overall uncertainty which are lower than 0.1 % (k = 1) may be neglected. National/reference standard stability should be reported as calibration coefficient uncertainty type A.

Table 1: Uncertainty budget reporting form

Reference *H*10* measurements				
Source of uncertainty	$u_{i,\mathrm{A}}$	$u_{i,\mathrm{B}}$	$u_{i,\mathrm{A}}^2 + u_{i,\mathrm{B}}^2$	Comment
Calibration coefficient of the national/reference standard				
Collected charge / ionization current				
Air density correction				
Source to chamber distance				
Conversion coefficient				
Other sources of uncertainty				
Combined uncertainty, *H*(10)*				
Transfer chamber measurements				
Source of uncertainty	$u_{i,\mathrm{A}}$	$u_{i,\mathrm{B}}$	$u_{i,\mathrm{A}}^2 + u_{i,\mathrm{B}}^2$	Comment
Collected charge / ionization current				
Air density correction				
Source to chamber distance				
Other sources of uncertainty				
Combined uncertainty,*Q/I*				
Combined uncertainty, N_H	$u = \sqrt{\sum_i \left(u_{i,\mathrm{A}}^2 + u_{i,\mathrm{B}}^2\right)} =$			

10. Evaluation and communication of the results

VINS and all the participants that are performing evaluation of the comparison results will send their calibration reports to CCRI secretary electronically within 1 month after having finished the measurements. All partners will send the calibration reports to VINS within 1 month after having finished the measurements. Reports will be provided in hard copy in a closed envelope, signed by the person in charge of the comparison within the participating institute. Results will additionally be provided electronically.

Comparison evaluation will be performed by SMU and VINS, with support of HMI/IRB-SSDL and SCK • CEN/LNK. VINS will send the calibration reports from all comparison participants electronically to the participants performing evaluation, but not before they have sent their own calibration reports to the CCRI secretary.

The comparison reference value $C_i(N_H)$ will be determined for each radiation quality as the weighted mean of the calibration coefficients, $N_{H,}$ reported by the participants which have traceability to their own primary standards for K_a or $H^*(10)$ – PTB and GUM for all radiation qualities, SMU for S-Cs and S-Co and IST-LPSR-LMRI for S-Co.

The Degrees of Equivalence with the comparison reference value will also be evaluated.

11. Organisation and time schedule

The comparison will have 13 participants in total. The shipping addresses are provided in Appendix A, along with the contact names, telephone numbers and e-mail addresses.

The comparison will start in VINS in February 2019 and the measurements are scheduled to finish in December 2020. Before the first calibration, VINS will perform dose rate dependence test. The calibration results will be reported to the CCRI secretary as VINS official comparison results within 1 month after having finished the measurements and will also serve as the first point for stability checks.

Other participants will be divided in 3 blocks and each participant will have 1 month to receive the transfer chamber, perform the comparison and ship the chamber to the next participant. After each block, transfer chamber will be returned to VINS for stability check. Two months are planned for each stability check in order to compensate for any delays by other partners. Additionally, 4 months at the end of the schedule are planned for any unpredicted delays.

VINS will inform all the participants about the progress of the comparison at the beginning and at the end of each block.

The comparison time schedule is shown in Table 2.

Table 2: Time schedule

Feb	19	VINS
Mar	19	PTB
Apr	19	HMI/IRB-SSDL
May	19	MIRS/IJS/F-2,O-2
Jun	19	SMU
Jul	19	VINS – quality check
Aug	19	
Sep	19	IRCL/GAEC-EIM
Oct	19	GUM
Nov	19	SCK • CEN/LNK
Dec	19	IST-LPSR-LMRI
Jan	20	VINS – quality check
Feb	20	
Mar	20	IMBIH
Apr	20	TAEK
May	20	INM
Jun	20	NSC-IM
Jul	20	VINS – quality check
Aug	20	
Sep	20	
Oct	20	
Nov	20	
Dec	20	

12. Agreement on the presentation of the results

All the participating laboratories agree to keep the comparison results and all the measurement data confidential until the comparison is finished. The results and data can be submitted only for evaluation purposes as described in this protocol, or to the CCRI secretary. Any publication, communication or oral presentation of the results will be considered breach of the confidentiality.

After the comparison is finished, all the data and the comparison results will be made available to all the participants. SMU will prepare the Draft A of the comparison report with the support of VINS and other participants. Participants will have two months to comment on Draft A. Once all the participants agree with the Draft A, VINS will submit Draft B to EURAMET for review. The revised Draft B will be used as the report for EURAMET project, and will be sent to BIPM for review by CCRI(I) and inclusion in KCDB.

Any presentation of the results is done in joint authorship, except for publication in Metrologia, which will be authored by the participants preparing the final report.

13. References

[1] International Committee for Weights and Measures, 2003. Mutual recognition of national measurement standards and of calibration and measurement certificates issued by national metrology institutes

[2] International Commission on Radiation Units and Measurements, 1993. Quantities and Units in Radiation Protection Dosimetry, ICRU Report 51

[3] Hupe, O., Díaz, N.A.C., 2018. EURAMET supplementary comparison of ambient dose equivalent H*(10) in 137Cs and ISO Narrow Beam Series N-60 x-ray beams at low dose rates, *Metrologia, 55, Technical Supplement*, pp. 1-132

[4] International Organization for Standardization, 1996. X and gamma reference radiation fields for calibrating dosemeters and doserate meters and for determining their response as a function of photon energy - Part 1: Radiation characteristics and production methods, ISO 4037-1.

[5] EURAMET Guide No. 4, EURAMET Guide on Comparisons, Version 1.0 (05/2016)

[6] Duftschmid, K. E., Hizo, J., Strachotinsky, Ch., 1992. A secondary standard ionisation chamber for the direct measurement of ambient dose equivalent H*(10), *Radiation Protection Dosimetry, 40(1),* pp. 35–38

[7] International Organization for Standardization, 1999. X and gamma reference radiation for calibrating dosemeters and doserate meters and for determining their response as a function of photon energy - Part 3: Calibration of area and personal dosemeters and the measurement of their response as a function of energy and angle of incidence, ISO 4037-3.

[8] BIPM, JCGM 100:2008, Evaluation of measurement data - Guide to the expression of uncertainty in measurement (GUM 1995)

Appendix A

Addresses of the participants

Pilot laboratory

VINS / RS

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PTB

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