EURAMET supplementary comparison of the ambient dose equivalent rate for photon radiation

EURAMET project No. 1132

BIPM KCDB: EURAMET.R(I)-S11

Technical Protocol

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1. Introduction

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 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 is established. However, 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 is determined.

In the last few decades a great change has taken place in the field of radiation protection dosimetry: The concept of radiation protection quantities developed by ICRU between 1985 and 1993 was adopted by the European Union in Council Directive 96/29/Euratom. The ambient dose equivalent $H^*(10)$ was introduced as the operational quantity for area monitoring. With the transfer of this directive into the national law of the EU member states, the national standard laboratories must be able to realise and disseminate this unit.

In the last years the comparison for personal dose equivalent $H_p(10)$ initiated by the Physikalisch-Technische Bundesanstalt (PTB) was performed as a supplementary comparison using the radiation qualities N-15 and 0°, N-20 and 45°, N-30 and 75°, N-60 and 0°, N-120 and 0°. This comparison could be used to some extend for the ambient dose equivalent, $H^*(10)$, as well, because the quantity $H_p(10)$ on the slab phantom is for 0 ° radiation incidence nearly identical to $H^*(10)$ in the case of unidirectional radiation incidence [1].

It remains that it is quite important to perform an international comparison with the focus on the special needs for calibration of area dosemeters: large radiation fields and low dose rates (10 µSv/h and 1 mSv/h) at the mostly used radiation qualities S-Cs and N-60 (only at 1 mSv/h) of the ISO narrow spectrum series.

Measurements at S-Cs with 500 nSv/h are very demanding, because of the very low current to be measured when using an ionisation chamber. Therefore, this measurement is not an official part of this comparison but can be done optionally.

For this comparison, a secondary standard ionisation chamber for $\dot{H}^*(10)$ with a large active volume of 10 litre will be used as a transfer instrument [2]. The aim of this comparison is to compare the calibration factor of the transfer instrument. The circulation of the chamber will be effected in cloverleaf shape, after sending to three participants, the chamber will be sent back to the pilot laboratory for testing.

This supplementary comparison can support the following types of CMCs:

- Branch: Dosimetry
- Quantity: ambient dose equivalent and ambient dose equivalent rate
- Source: X-ray, 50 kV to 420 kV, S-Cs

For this, it is essential that the participants can perform all the measurements at all given irradiation conditions. Especially due to the fact that these conditions reflect the

most sophisticated challenges for a calibration in terms of ambient dose equivalent rate.

The measurements are done with the radiation qualities of S-Cs and the N-series according to ISO 4037, but this comparison can also support the CMC entries for S-Co and the W-series according to ISO 4037. The reason is that the methods for determining the quantity value are similar in the energy range from N-60 up to S-Cs and further on to S-Co. At radiation qualities with lower energies the difficulties increase – here the 10% percentile and not the mean energy is the relevant quantity – and, therefore, radiation qualities with lower 10% percentiles as that for N-60 cannot be supported by this comparison.

These complex problems at lower energies are also seen in the comparison number 738 for $H_p(10)$. This fact indicates again, that this comparison cannot support the lower energy X-ray radiation qualities (below 50 kV), especially the H-series.
For those entries, a special comparison, facing the problems at lower X-ray energies, is needed.

The comparison will be coordinated by the PTB as the pilot laboratory, which will also evaluate the results. After the agreement of the CCRI(I) to the official final report, it should be published in Metrologia. In addition, the results will be sent to BIPM for inclusion in the Key Comparison Data Base (KCDB).

2. Measuring conditions

The object of the comparison is the calibration of an ionisation chamber in terms of the ambient dose equivalent rate, $\dot{H}^*(10)$. As transfer instrument, a secondary standard chamber for $\dot{H}^*(10)$ [2] is used, see figure 1.

Figure 1: HS10, Secondary standard chamber for $\dot{H}^*(10)$.

Figure 2: Holder to mount the chamber onto the experimental table.

The homogeneity of the doserate distribution across the beam diameter at the measuring point should be about 5 % and better. For calibration purposes the chamber must be irradiated completely

Technical specification of the ionisation chamber:

- Ionisation chamber HS10, see figure 1.
- Outer diameter of about 274 mm.
- The chamber voltage should be +400 V (chamber wall).
- Special holder for the chamber for mounting on the experimental table, see figure 2.
- BNC connector for current measurement,
  and Lemo connector for the high voltage supply.
- For the high voltage: Adaptor with a Lemo (FFA.1S.304.CLAC52) connector to a banana plug (4 mm pin plug), see figure 3.

Figure 3: Cable for high voltage connection and details of the connectors.

3. Measuring programme and quantity to be measured by the participants

Each participant should calibrate the transfer chamber at the radiation qualities S-Cs and N-60 of the ISO narrow spectrum series [5]. The calibration factor in Sv/C is given by

$$N_{\mathrm{H}} = \frac{\dot{H}^{*}(10)}{I}$$

I = current measured by the ionisation chamber with the current measuring instruments of the participant, corrected for the environmental influences and the leakage current.

$\dot{H}^{*}(10)$ = conventional quantity value of the ambient dose equivalent rate determined by the participant.

Measurements should be performed at the following radiation qualities and doserates:

N-60 and 1 mSv/h
S-Cs and 10 µSv/h
S-Cs and 1 mSv/h.

Optional Measurement: S-Cs and 0.5 µSv/h (NOT official part of the comparison) These measurement results are not used to support the CMC entries, but will be given as an informative annex in the report.

The comparison reference value $C_i(N_H)$ will be determined at each radiation quality and for each doserate as the arithmetic mean of the calibration factor N_H given by the participants. Only values from participants with traceability for K_a to their own primary standard will contribute to the comparison reference value.

4. Duties

Duties of the pilot laboratory

- The pilot laboratory must supply the detailed information about the transfer chamber.
- The pilot laboratory will participate in the comparison. It will determine its values of the calibration factor at the radiation qualities listed in chapter 3 in January 2013. The report on these measurements will be sent to the CCRI Secretary at the latest 6 weeks after the end of the measurements. This procedure should be a measure of confidence.
- The pilot laboratory will evaluate the comparison on the basis of the results and measuring reports obtained by the participants. The pilot laboratory will calculate the reference value for each radiation quality according chapter 3.
- The pilot laboratory will prepare a draft of a final report for circulation to all participants for comments and discussion of the results. This or a revised report will be the official report of the comparison and will be submitted to the EURAMET TC-IR Chairman and the CCRI(I). After the agreement of EURAMET and CCRI(I) it should be published. A summary thereof should be submitted to Metrologia for publication. In addition, the results will be sent to BIPM for inclusion in the Key Comparison Data Base (KCDB).

Duties of the laboratories participating

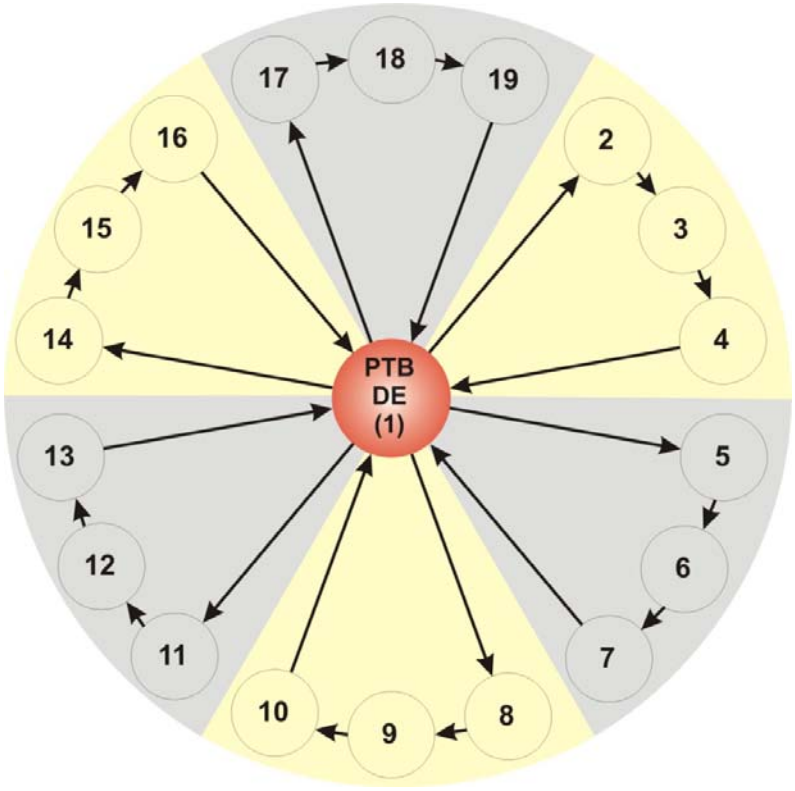
Each participant must send to the pilot laboratory (PTB) a report in a closed envelope describing the measurements which have been carried out for the comparison. The report must be signed by the person in the laboratory who has been in charge of the comparison and must comprise the following details:

- Method of determination of the conventional quantity value of the ambient dose equivalent rate, $\dot{H}^*(10)$. Short description of the measuring devices used for the determination including information about the traceability to primary standards and their quality assurance.
- Detailed description of the determination of the conventional quantity value of $\dot{H}^*(10)$ including all corrections used. Specification of the uncertainty, the confidence level (recommended: two standard deviations, $k = 2$) and the principal components of the uncertainty.
- Description of the calibration measurements, if possible with pictures of the experimental set-up.
- Determination of the calibration factor for each radiation quality used including a complete uncertainty budget according to GUM [3][4] (recommended coverage factor $k = 2$).
- Together with the transfer system, the pilot laboratory will send a form. In this form, the participant has to document all parameters and measurement results. The form should be part of the measuring report.
- All the data required in the report must be send in electronic form in addition to the paper version.

The measuring report is to be sent to the pilot laboratory at the latest 4 weeks after the end of the measurements.

5. Organisation and participants

In total, 17 laboratories have affirmed their participation: The contact persons and addresses of the participants are listed in Appendix A. The circulation of the transfer chamber will be performed in cloverleaf shape. Each participant will send the transfer chamber to the next participant, mentioned by the pilot laboratory. After three participants the transfer chamber will be send back to the pilot laboratory for intermediate testing. Each participant has 1 month time to perform the measurements and to send the system to the next participant. This period of time must be observed by each participant in order to avoid an extension of the duration of this comparison. The circulation scheme is shown in figure 4.



1	DE	PTB
2	AT	BEV
3		none
4	GR	IRCL/GAEC-EIM
5	NO	NRPA
6	SE	SSM
7	FI	STUK
8	PT	ITN
9	ES	CIEMAT
10	CZ	CMI
11	BG	BIM
12	RO	IFIN-HH
13	HU	MKEH
14	NL	VSL
15	SI	IJS
16	LT	VMT/FTMC
17	IT	ENEA-INMRI
18	Int.Org.	IAEA
	?	?

Figure 4: List of participants and circulation scheme.

The comparison will extend over a period of time of about 2.5 year. The pilot institute will inform the participants on the progress of the comparison by newsletters sent by e-mail. The list of the participants with their e-mail addresses is given in Appendix A. In addition, the responsible TC Chairman should be informed about the progress by newsletters.

The following time schedule (table 1) has to be agreed between the 17 participants. The start of the comparison is January 2013. The prospective end of the measurements is November 2014.

Table 1: Time schedule

Time	Participant/Country	testing the system	remarks
01 / 2013	PTB / DE		1
02 / 2013	BEV / AT		2
03 /2013	none		(schedule changed)
04 /2013	IRCL/GAEC-EIM / GR		4
05 / 2013		PTB / DE	
06 / 2013	NRPA / NO		5
07 / 2013	SSM / SE		6
08 / 2013	STUK / FI		7
09 / 2013		PTB / DE	
10 / 2013	ITN / PT		8
11 / 2013	CIEMAT / ES		9
12 / 2013	CMI / CZ		10
01 / 2014		PTB / DE	
02 / 2014	BIM / BG		11
03 / 2014	IFIN-HH / RO		12
04 / 2014	MKEH / HU		13
05 / 2014		PTB / DE	
06 / 2014	VSL / NL		14
07 / 2014	IJS / SI		15
08 / 2014	VMT/FTMC / LT		16
09 / 2014		PTB / DE	
10 / 2014	ENEA-INMRI / IT		17
11 / 2014	IAEA / Int. Org.		3 (schedule changed)
12 / 2014		PTB / DE	

6. Agreement on the presentation of the results

After the end of the comparison, all data and reports delivered by the participants should be made available to each participant.

Before finishing the comparison, each laboratory participating obliges not to reveal any measuring data whatsoever and in any way, neither by publication (e.g. in the Annual Report of one´s own laboratory or in a paper) nor orally.

The participants agree that after the end of the comparison, any presentation of results is always done in joint authorship, except for publication in Metrologia, following the rule that only the participants preparing the final report will be mentioned as authors.

Because of the long duration of the comparison the first participant will have to wait for the results for a very long time. To reduce this time and to give some initial information, first results should be announced before the end of the comparison in the following manner: As soon as the reports with the results of the participants of the first cloverleaf (four participants) have been submitted to the pilot laboratory (about Mid 2013), the results will be evaluated. For every radiation quality, the mean value from the calibration factors given will be calculated. The calibration factor of each participant normalized to this mean value will then be presented. A graphics including these data will be sent to the participants by e-mail.

7. Transport

Each participant must arrange the transport of the system himself. The cost of dispatch and insurance including customs charges have to be borne by the participant who is sending to the next participant.

The value for the insurance of the equipment, including the transfer chamber, is about 12000 €.

For the challenging time schedule it is necessary to inform the pilot institute immediately after arrival of the system and after finishing the measurements. The pilot institute will coordinate, to whom the chamber has to be sent next.

It is necessary that the ionisation chamber is send via overland and not via air, because of the air pressure change during flight the chamber could be destroyed.

The transport container contains:

- The transfer ionisation chamber,
  with BNC connector for current measurement,
  and Lemo connector for the high voltage supply.
- Adaptor with a Lemo (FFA.1S.304.CLAC52) connector to a banana plug (4 mm pin plug).

- Special holder for the chamber for mounting on the experimental table.

After the receipt of the chamber the participant has to check the chamber for damage and has to inform the pilot laboratory immediately about the arrival of the system and its condition.

8. References

[1] Ankerhold, U., Ambrosi, P. and Eberle, T., *A chamber for determining the conventionally true value of $H_p(10)$ and H*(10) needed by calibration laboratories*, Radiation Protection Dosimetry 96, 133-137 (2001)

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

[3] European Cooperation for Accreditation, EAL. *Expression of the Uncertainty of Measurements in Calibration*. EA-4/02 M:1999 (previously EAL-R2), (December 1999)

[4] ISO/IEC Guide 98-3:2008; Uncertainty of measurement - Part 3: *Guide to the Expression of Uncertainty in Measurement* (GUM:1995) (Geneva: ISO), BIPM JCGM 100:2008; *Guide to the Expression of Uncertainty in Measurement* (GUM)

[5] International Organization for Standardization. Standardisation. *X and gamma reference radiations and calibrating dosemeters and doserate meters and for determing 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 (Geneva: ISO) (1999).

Appendix A

Addresses of the participants

Pilot laboratory

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Participants

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