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Experience of the calibration laboratory during the implementation of a new working standard for the calibration of electrometers with ionization chambers for teleradiotherapy

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Laboratory accredited by the Polish Centre for Accreditation, accreditation No AP 155*

*** an actual scope of accreditation No AP 155 is available on the PCA website: www.pca.gov.pl**

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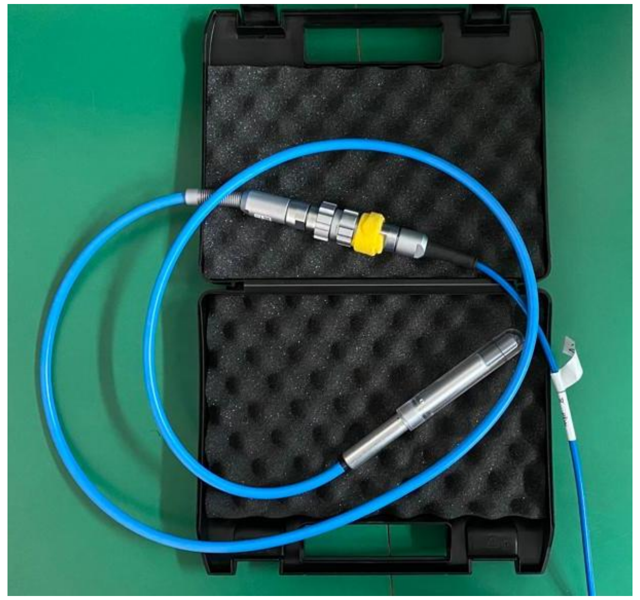
Introduction

In 2023, two UNIDOS Romeo electrometers of type TM10053, together with two ionization chambers of type TM30013, were implemented at the Secondary Standards Dosimetry Laboratory (SSDL) in Poland as working standards for calibration of electrometers with ionization chambers for teleradiotherapy in a Co-60 gamma ray beam, in terms of the absorbed dose to water.

Our laboratory has been accredited in the aforementioned field of calibration by the Polish Centre for Accreditation for the conformity with the ISO/IEC 17025 standard “General requirements for the competence of testing and calibration laboratories” [1] since 28 May, 2014 (accreditation No. AP 155).

In this work, we will share our experience during the implementation of one of the aforementioned working standards. As part of this implementation, all the activities required by our laboratory's management system in accordance with the relevant requirements of the ISO/IEC 17025:2017 standard were carried out.

UNIDOS Romeo electrometer of type TM10053, PTW


Ionization chamber of type TM30013, PTW

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Activities performed by the Secondary Standards Dosimetry Laboratory (SSDL) in Warsaw in Poland during the implementation of the new working standard:

- calibration of the working standard against the reference standard in a Co-60 gamma ray beam in terms of the absorbed dose to water ranging from 0.15 Gy to 3.3 Gy;
- evaluation of measurement uncertainty for CMC expressed as the expanded uncertainty having a coverage probability of approximately 95 %;
- development of a method for evaluating measurement uncertainty for calibration of customer’s electrometers with ionisation chambers when they are calibrated against a new working standard;
- validation of the software, i.e. the spreadsheet used when determining the calibration factor of the customer's electrometers with ionisation chambers when they are calibrated against a new working standard.

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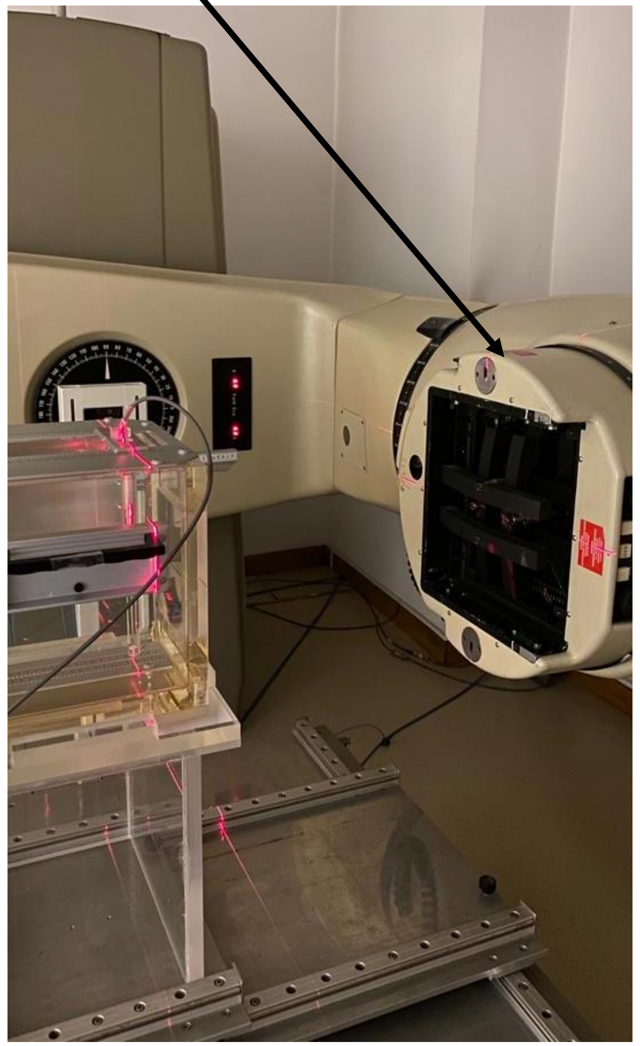
Calibration of the working standard against the reference standard

- calibration of the working standard against the reference standard was performed on 13 June, 2023;
- calibration was carried out in the water phantom PTW-Freiburg, type 4322 in a collimated gamma-ray beam emitted by a Co-60 source: the cross-section of the beam in the plane of measurement was 10 cm × 10 cm;
- calibrations was carried out in terms of the absorbed dose to water ranging from 0,15 Gy to 3,3 Gy;
- calibration was carried out in accordance with our calibration instruction which was accredited by the PCA; this instruction is based on the IAEA report [2];
- during the calibration the water phantom is positioned on the measuring bench in a way that the ionization chamber is positioned at an appropriate distance from the radiation source (SCD = 100.0 cm);
- the ionization chamber is placed in the holder PTW-Freiburg, type 4333/ U13 dedicated to the calibrated ionization chamber type; the holder allows the ionization chamber to be placed in the water phantom so that the reference point of the ionization chamber is at the correct depth in the water phantom (i.e., $z_{ref} = 5.0\ g/cm^2$);
- the reference standard that was used to calibrate the new working standard: an electrometer KEITHLEY type of 6517A with ionization chamber NE Technology type of NE 2571;
- results: The calibration coefficient for the calibrated chamber is given in the table below (for conditions: P = 1013 hPa, T = 20 °C, H = 50%, for the polarization voltage of the chamber V_{pol} = +400 V, for a dose power of 0.23 Gy/min for the measurement range "Charge":



Calibration set in a ^{60}Co gamma ray beam of the Theratron 780E unit at the Polish SSDL

Reference value - dose absorbed to water: D_w	Indication of the calibrated dosimeter: M	Calibration coefficient * $N_{D,w} = D_w/M$	Expanded uncertainty: $U(N_{D,w})$
23.357 cGy	4.341 nC	5.381 cGy/nC	0.079 cGy/nC

where the indication M is corrected for the following influencing quantities: pressure, temperature.

* The result within the scope of PCA accreditation No. AP 155.

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Evaluation of measurement uncertainty for CMC

As stated in the publication: ILAC-P14:09/2020 „ILAC Policy for Measurement Uncertainty in Calibration" [3]:
„A **CMC** is a **calibration and measurement capability** available to customers under normal conditions:
a) as described in the laboratory's scope of accreditation granted by a signatory to the ILAC Arrangement; or
b) as published in the BIPM key comparison database (KCDB) of the CIPM MRA."

„The CMC quoted shall include the contribution from a best existing device to be calibrated such that the CMC claimed is demonstrably realisable.
Note 1: The term "best existing device" is understood as a device to be calibrated that is commercially or otherwise available for customers, even if it has a special performance (stability) or has a long history of calibration.
Note 2: When it is possible that the best existing device can have a contribution to uncertainty from repeatability equal to zero, this value may be used in the evaluation of the CMC. However other fixed uncertainties associated with the best existing device shall be included.
Note 3: In exceptional instances, such as evidenced in very limited number of CMCs in the KCDB, it is recognized that a "best existing device" does not exist and/or contributions to the uncertainty attributed to the device may significantly affect the uncertainty. If such contributions to uncertainty from the device can be separated from other contributions, then the contributions from the device may be excluded from the CMC statement. For such a case, however, the scope of accreditation shall clearly identify that the contributions to the uncertainty from the device are not included."

According to the scope of our accreditation No. AP 155 (Issue No. 8, 09 May, 2022) **the measurement uncertainty for CMC is 1.5 %** for calibration of ionizing radiation dosimeters in a Co-60 gamma ray beam in terms of the absorbed dose to water ranging from 0.15 Gy to 3.3 Gy.

Note:
The measurement uncertainty for CMC is the expanded uncertainty with a probability of expansion of approx. 95 %.
The value expressed as a percentage is the relative measurement uncertainty and refers to the percentage of the contribution to the value of the measurand.

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Evaluation of measurement uncertainty for CMC

- evaluation of measurement uncertainty for CMC when using the new working standard was performed on 27 June, 2023;
- data of the "best existing device" for which the value of the CMC measurement capability was calculated: UNIDOS Webline with ionization chamber type 30013 from PTW Freiburg;
- sources of uncertainty were identified to calculate the CMC's measurement capability;
- for each source of uncertainty, the following data were provided:
  - ✓ input quantity estimate,
  - ✓ standard uncertainty,
  - ✓ method of determining the uncertainty of measurement of the estimate of the input quantity,
  - ✓ probability distribution,
  - ✓ sensitivity coefficient,
  - ✓ contribution to the composite standard uncertainty.
- the final value of the CMC measurement capability was determined according to the formula that takes into account identified sources of uncertainty;

Exemplary components of the uncertainty of one of the coefficient which affects the value of measurement uncertainty for CMC of Polish SSDL:

Components of the uncertainty of k_{other} coefficient	Symbol of quantity	Estimate of the value: x_i	Standard uncertainty: $u(x_i)$	Relative standard uncertainty
Correction factor connected with the long term stability of the working standard	$k_{stabiliy}$	1.0000	0.0012	0.12 %
Correction factor connected with the nonlinearity of the indications of the working standard	$k_{nonlinearity}$	1.0000	0.0005	0.05 %
Correction factor connected with the long term accuracy of the electrometer of the working standard	$k_{electrometer\ accuracy}$	1.0000	0.0024	0.24 %
Correction factor connected with the sensitivity fluctuation of the electrometer of the working standard during the measurement session	$k_{electrometer\ sensitivity}$	1.0000	0.001	0.10 %
Correction factor connected with the deviation of the phantom position from the reference position	$k_{phantom\ position}$	1.0000	0.0012	0.12 %
Correction factor connected with the deviation of the ionization chamber position from the reference position in the water phantom	$k_{chamber\ position}$	1.0000	0.0015	0.15 %

- the value of measurement uncertainty for CMC for the new working standard was the same (i.e., CMC of 1.5 %) as the one determined for the other standards in our laboratory and included in the scope of accreditation No. AP 155.

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Evaluation of measurement uncertainty for CMC

- The Polish SSDL Management System assumes that:
  - the value of CMC measurement capability is determined for each type of calibration performed at PWWD;
  - when determining the CMC measurement capability in PWWD, current requirements are taken into account, including accreditation requirements;
  - the value of the CMC measurement capability is redetermined by the SSDL employee each time there are factors that may affect its value, i.e. when there is a change in the calibration method, a change in the "best existing device", a change in the standards used for calibration, etc.

    Thus, once determined value of CMC measurement capability for a given type of calibration is valid until there is a change of any factor that may affect the value of CMC measurement capability.

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Development of a method for evaluating measurement uncertainty for calibration of customer's electrometers with ionisation chambers

- development of a method for evaluating measurement uncertainty for calibration of customer's electrometers with ionisation chambers when using the new working standard was performed on 27 June, 2023;
- formulas describing the mathematical relationship between the menzurand (output quantity) and input quantities - adequate to the applicable calibration method that is within the scope of our accreditation - have been defined;
- the tables including information for each source of uncertainty about: input quantity estimate, standard uncertainty, method of determining the measurement uncertainty of the input quantity estimate, probability distribution, sensitivity coefficient, contribution to the composite standard uncertainty;
- the final value of the CMC measurement capability was determined according to the formula that takes into account identified sources of uncertainty;
- the final formula according to which the uncertainty value of the calibration coefficient of the user's dosimeter will be determined when it will be calibrated against a new working standard;
- the uncertainty of the calibration coefficient is assumed to be the expanded uncertainty with a probability of expansion of about 95% and $k = 2$;
- the numerical value of the expanded uncertainty is given in the calibration certificate with at most two significant digits.

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Development of a method for evaluating measurement uncertainty for calibration of customer's electrometers with ionisation chambers

- List of documents used to development of a method for evaluating measurement uncertainty for calibration of customer's electrometers with ionisation chambers in a Co-60 gamma ray beam in terms of the absorbed dose to water:
  - ✓ „EA-4/02 M:2013 Evaluation of the Uncertainty of Measurement in Calibration";
  - ✓ "Measurement Uncertainty. A Practical Guide for Secondary Standard Dosimetry Laboratories". IAEA-TECDOC-1585;
  - ✓ „ILAC-P14: 09/2020 ILAC Policy for Measurement Uncertainty in Calibration";
  - ✓ Technical Reports Series No. 277, „Absorbed Dose Determination in Photon and Electron Beams. An International Code of Practice." IAEA, Vienna, 1997;
  - ✓ Technical Reports Series No. 374, „Calibration of Dosimeters Used in Radiotherapy". IAEA, Vienna, 1994;
  - ✓ Technical Reports Series No. 398, „Absorbed Dose Determination in External Beam Radiotherapy. An International Code of Practice for Dosimetry Based on Standards of Absorbed Dose to Water" IAEA, Vienna, 2000;
  - ✓ Technical Reports Series No. 469, „Calibration of Reference Dosimeters for External Beam Radiotherapy." IAEA, Vienna, 2009.

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Validation of the software

- The Polish SSDL Management System assumes that the SSDL employee, prior to the first use of the software for evaluating measurement uncertainty in calibration, shall validate it by placing appropriate records in form PR22.5_P3_F3 *Software validation*.

- In order to prevent unauthorized access to or unauthorized changes in the software records, the software shall be protected by an appropriate password made available to authorized SSDL personnel.

- The validation procedure is repeated each time there is any change in the software that affects the calculation results.

- Completed PR22.5_P3_F3 *Software validation* forms are retained at SSDL for 5 years counting from the date the software is no longer used by SSDL personnel.

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Validation of the software

- According to the Polish SSDL Management System the following data **should be placed in form** PR22.5_P3_F3 *Software validation*:
  - ✓ the name of the software to be validated (e.g., the name of the file that is the spreadsheet that will be used to perform the calculations necessary to evaluating the measurement uncertainty in the calibration performed);
  - ✓ the software requirement (e.g., the correspondence between the results from the spreadsheet and the results obtained using the calculator);
  - ✓ the validation procedure (e.g., in the case of spreadsheet validation:
    - ❖ the identifier of the currently applicable document containing a detailed description of the method of evaluating the uncertainty of measurement in the calibration of a given type,
    - ❖ the source data,
    - ❖ the results of intermediate and final calculations made using the calculator and the spreadsheet);
  - ✓ information on whether the software requirement is met, e.g. in the case of a spreadsheet: "The results from the spreadsheet are consistent with the results obtained using the calculator - the requirement is met.”;
  - ✓ a statement about the suitability of the software for the intended use (if the software requirement is met);
  - ✓ other relevant information about the software validation performed.

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Important issues and conclusions

Implementing a new working standard is a multi-step process.
It requires a lot of measurements, time and staff involvement.

There was no need to modify the scope of accreditation No. AP 155 since the value of measurement uncertainty for CMC for the new working standard was the same as the one determined for the other standards in our laboratory and included in the scope of accreditation No. AP 155.

The aspects of implementing a new working standard for calibrations of electrometers with ionization chambers for teleradiotherapy may be helpful for other calibration laboratories that plan to join the process of obtaining accreditation in a similar field of calibration for compliance with the requirements of the ISO/IEC 17025:2017 standard.

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References

[1] INTERNATIONAL ORGANIZATION FOR STANDARDIZATION, General requirements for the competence of testing and calibration laboratories, ISO/IEC 17025:2017, ISO, Geneva (2017)

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, Absorbed Dose Determination in External Beam Radiotherapy, Technical Reports Series No. 398, IAEA, Vienna (2020)

[3] ILAC-P14:09/2020 „ILAC Policy for Measurement Uncertainty in Calibration”

Thank you for your attention.