

Publishable Summary for 22NRM07 GuideRadPROS

Harmonisation, update and implementation of standards related to radiation protection dosimeters for photon radiation

Overview

Photon dosimeters are used for measuring radiation doses to protect people from the harmful effects of ionising radiation. However, the recent update of the basic standard for photon reference radiation fields in radiation protection, ISO 4037:2019, has presented significant challenges to calibration laboratories and industry, such as high costs and increased need for manpower. This project provides protocols and guidance to calibration laboratories, metrology institutes, standardisation bodies and regulators for a harmonised approach to radiation protection measurements and calibrations. Proposals to update ISO 4037:2019 and future needs for type testing and possible implementation of new radiation protection quantities according to ICRU Report 95 will also be provided, leading to compatible procedures and requirements.

Need

Photon dosimeters are almost universally used in all radiation practices, covering personal and environmental monitoring, and emergency response, to assess the protection of people from harmful effects of ionising radiation. In the EU, the requirements for dose assessment and monitoring are set in Council Directive 2013/59/Euratom, which is implemented in national legislations. Comparable world-wide requirements are given in IAEA Safety Standard Series No. GSR Part 3: General Safety Requirements.

Radiation protection dosimeters measure ambient dose equivalent, directional dose equivalent, or personal dose equivalent. These dosimeters are tested and calibrated in photon reference fields according to the ISO 4037:2019 standard series. In the 2019 update of this standard, many changes were introduced. The new requirements result in high costs and manpower to establish such reference fields and therefore, small laboratories and emerging metrology institutes have not been able to fully implement the standard.

Furthermore, there is a need to provide guidance to implement ISO 4037 series and to provide missing data regarding ^{241}Am reference fields, high voltage measurements of X-ray units and the associated uncertainty estimates. In addition, harmonised procedures for traceable X-ray spectrometry are needed.

The type testing of the dosimeters is done against the IEC standards but there are many standards with conflicting requirements for the same type of dosimeter. There are also standardisation gaps, due to recent or upcoming developments in measurement technology, such as use of spectrodosimetry, new technologies related, e.g., to the use of machine learning, artificial intelligence, and other methods based on computation. Therefore, the standards must be harmonized, and future standardisation needs must be analysed.

Finally, ICRU report 95 proposed new operational quantities to replace the current quantities. This will require a revision of the type test standards and characterisation study of existing dosimeters to see whether software and/or design modifications are necessary.

Objectives

The overall objective is to support standardisation in photon-based radiation protection dosimetry, related to ISO 4037 standard series, IEC standards and the changes due to new operational quantities of ICRU Report 95.

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European Partnership

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The specific objectives are:

1. To develop harmonised approach to X-ray spectrometry in concordance with the ISO 4037 standard series, evaluate the discrepancies between measured and calculated half value layer (HVL) of X-ray spectra and to produce data to update requirements for reference X-ray fields. To produce data for ²⁴¹Am reference fields to be included in this standard series and evaluate methods to determine X-ray tube high voltage (HV).
2. To develop cost effective procedures and guidance for the calibration of dosimeters and determination of their response as a function of photon energy to enable smaller metrology institutes and other calibration laboratories to implement the ISO 4037 standard series with respect to the actual quantities and the ICRU Report 95 quantities. To provide training to emerging metrology institutes and to produce open e-learning materials on the calibration procedures.
3. To produce guidance on validated procedures for harmonized type testing based on IEC standards (e.g., IEC 61526, IEC 60846-1, IEC 60846-2, IEC 61017, IEC 60532, and IEC 62387) for the commonly used radiation protection dosimeters with valid metrological solutions for situations where requirements in existing standards deviate and standardisation gaps exist for radiation protection dosimeters for photon radiation.
4. To assess future standardisation needs related new and upcoming technologies and to produce a guidance document for the implementation of the new operational quantities of ICRU Report 95 into standards and regulations based on the results of Objective 1,2 and 3 to disseminate this to policymakers, manufacturers, regulators, metrology networks, standardisation bodies and laboratories.
5. To collaborate with ISO and IEC and the users of their dosimetry standards (including the EMN on radiation protection and the IAEA) to ensure that project outputs align with their needs. Produce guidance on the implementation of new operational quantities of ICRU Report 95 into standards and regulations and recommendations for incorporation of this information into future standards. To disseminate project outcomes for inclusion into ISO 4037.

Progress beyond the state of the art and results

Harmonised approach to X-ray spectrometry and implementation of ISO 4037

Support will be given to calibration laboratories to build up their spectrometry methods by guidance documents and training on characterising the spectrometers and unfolding the measured X-ray spectra to implement the ISO 4037 standard series. Data have been collected and measured to carefully characterize different ²⁴¹Am sealed sources. This, in the future, will be used in the standard to harmonize this radiation field and to reduce the uncertainties in type testing and calibration of the dosimeters. In addition, methods have been investigated to reduce the uncertainties in HVL values of reference X-ray fields, and information on methods of X-ray tube high voltage determination are tested. Furthermore, conversion coefficients for operational quantities for monoenergetic photons have been re-evaluated. All this will facilitate the accurate implementation of such reference fields.

Training on requirements of ISO 4037 and calibration in reference fields

Hands-on training and e-learning material will be produced to support calibration laboratories to implement photon reference fields according to the ISO 4037 standard series and to apply changes due to new quantities of ICRU Report 95 in the calibration fields. The training needs and the status of applying both ISO 4037 and ICRU report 95 were identified with an online questionnaire to laboratories, authorities, manufacturers, and other stakeholders. Based on the questionnaire, an online training was tested with consortium members and stakeholders to develop material for the hands-on training that will be organized in May 2025.

Validated procedures for harmonized type testing standards

Analysis of the standards and overview of inconsistencies will be performed to provide recommendation for harmonisation to IEC. A survey was done to assess the status of type testing practices in Europe and the type testing requirements were discussed with the stakeholder committee. A document is prepared e.g. for manufacturers to identify relevant legal requirements for dosimeters and dose measurements in different countries. Identification of missing data in the performance of state of the art and commonly used active

dosimeters used in individual and area (workplace/environmental) monitoring was done, based on the literature review on their performance, manufacturer specifications of IEC compliant dosimeters and based on the aggregated calibration data on most commonly used dosimeters in different European countries. A measurement campaign to collect the missing data is ongoing.

Assess future standardisation needs and produce guidance to implement new quantities into the standards

An analysis of the state-of-the-art and upcoming technologies in dosimetry will be done. The incompatibilities of these technologies with respect to the requirements from the existing IEC standards will be evaluated and the potential needs for new or updated standards considering the new technologies will be identified and analysed. Special attention will go to the practical implementation of computational dosimetry and spectrodosimeters to the future IEC standards. Finally, the impact of ICRU Report 95 to the ISO 4037 standard series and IEC standards will be evaluated and reported.

Outcomes and impact

Key dissemination and communication activities

The project has started to strongly engage the stakeholders within the project scope to update requirements both for setting up the laboratory calibration x-ray beams and for type testing of radiation protection dosimeters. In addition, the project and its progress has been presented in several scientific conferences and workshops. The goals of the project have been presented to several national radiation protection authorities and regulators. Project has been introduced to technical committees of standardization bodies (IEC, ISO, DKE). Active interaction with European Metrology Network for Radiation Protection is manifested via position and conference papers, where the project has provided input. The project is presented in the web pages of the Network.

The impact of new quantities of ICRU 95 were discussed with industrial and regulatory stakeholders in a dedicated workshop. In the same workshop, type testing requirements for the future radiation dosimetry techniques were discussed and the feedback is used to refine the contents of the technical work to establish requirements for the future type testing practices. The project participants discussed the effect of ICRU 95 quantities in a dedicated workshop, organized by IAEA in October 2024. In addition, the industrial partner of the project organized a technical visit to their R&D and manufacturing premises to discuss the impact of implementation of new quantities and the deficiencies identified in the present standards.

Within the project, technical visits have been organized among participating laboratories to discuss practical aspects of calibration beam quantification with spectrometry and practicalities of implementing the new radiation protection quantities.

A project web page has been developed and set up at <https://lmri-met.github.io/sites-guideradpros/>.

Outcomes for industrial and other user communities

The revision of the ISO 4037 standards and the adoption of the ICRU Report 95 operational quantities have an impact on realization of radiation beam qualities and the value of the conversion coefficients from air kerma to dose equivalents, respectively. The new operational quantities introduced in ICRU Report 95, the ambient dose and personal dose, have a different energy and angle dependence with respect to the incident radiation field compared to the current quantities. Thus, these new quantities require changes in the characteristics of the measuring equipment. These changes will have consequences for all industrial stakeholders, including calibration laboratories, dosimeter manufacturers, dosimetry services and users of ionizing radiation in industry, research and medical applications where radiation protection measurements are needed. The change affects the legal dose limits given in Council Directive 2013/59/Euratom, thus requiring careful consideration of how the dose limits should be set in future update of the directive.

The changes made to ISO standards and especially the adoption of the spectrometric characterization of radiation beams will improve the harmonisation of calibration beams and their traceability to national references as well as the accuracy of the calibrations. The latter can be drastically improved allowing a more precise and comparable characterisation of the measuring devices. Together with harmonized IEC standards this leads to the revision of the type tests carried out before the devices are put on the market.

This project will assess the consequences on radiation protection measurements and dosimeters caused by the adoption of new operational quantities proposed in the ICRU Report 95 and inform the manufacturers who

will then be able to anticipate the prospected changes, by planning the recalibration, replacement, or adaptation of existing measuring devices. Thus, the transition from the present to the new operational quantities may be carried out in the most harmonious way possible. It is expected that the new operational quantities will be in force with the next update of Council Directive 2013/59/Euratom.

These changes in standards and quantities will require modifications to the dosimeters, either in the data processing algorithms, or in the physical design of the detectors, or both, to remain in compliance with the type test acceptance criteria. Adaptation of these criteria may be necessary in coordination with the improved measurement accuracy and new technologies discussed above.

Outcomes for the metrology and scientific communities

The implementation and harmonization of the spectrometry measurements will ensure reliable validation and calculation of laboratory-specific conversion coefficients. The guidance developed within this project will lead to a better understanding of uncertainties and comparable procedures and thereby increase the confidence in radiation metrology and testing. Spectrometry will provide more accurate and complete data on radiation beams, which is currently available only to a few institutes, and thus will help proliferation of scientific knowledge, techniques and associated research. With expanded spectrometric capabilities, institutes can develop new radiation fields for future applications, needed to metrologically support developments in technology and regulation.

The evaluation of the impact of the new ICRU Report 95 quantities on the photon reference field standards will allow for an informed realization of calibration fields in the metrology institutes and calibration laboratories.

Outcomes for relevant standards

The project will contribute to the implementation and future updates of the ISO 4037 standards series and IEC standards that set requirements for radiation protection dosimeters by providing relevant data, guidance documents and validated limits for the performance of the dosimeters. Moreover, the implementation of the newly proposed operational quantities of ICRU Report 95 will have an impact on some of the limits given by the ISO 4037:2019-1 standard for matched and characterised reference fields and on the radiation doses recorded by the dosimeters. This will affect the personal doses that are monitored nowadays in compliance with Council Directive 2013/59/Euratom and will have an effect on the dose limits and the future update of this Basic Safety Standard and national implementations thereof.

Longer-term economic, social and environmental impacts

Stronger confidence in radiation protection dosimetry, both via the promotion of the implementation of the ISO 4037 standard series, and via the assessment of the impact of the new operational quantities defined in ICRU Report 95 on daily measurements in radiation protection, has the clear potential of making radiation protection dosimetry practices even better than presently; it also enables small laboratories to set up the reference beams according to the standard, thus increasing the availability of harmonised testing and calibration services. This provides an advantage to European-based dosimeter manufacturers on the global market.

Through the objectives of this project, procedures will be brought to maturity so that the implementation of the ISO 4037 standard series both at NMI/DIs and through European national networks of accredited dosimetry calibration laboratories will be facilitated and, therefore, requests of instrument tests and calibrations can be satisfied within Europe.

With the adoption of the new ISO 4037:2019 standard series throughout Europe, and with the related CMCs and services that derive from them, the European citizen would find him/herself in a context of measurement confidence and reliability, the basis on which citizen safety and security can hinge on.

More reliable, accurate, and harmonised tested instrumentation in radiation protection dosimetry, possibly supported by the well-informed technical adoption of the new operational quantities defined in ICRU Report 95, could also lead to a stronger European industry and an increased wealth that this can bring. Moreover, the project will also identify possible pitfalls in implementing the new quantities to avoid excessive costs and to support optimized solutions for the future Basic Safety Standard.

List of publications

1. Towards metrological best practices in radiation protection. M. C. Ferreira, T. Siiskonen, M. Zivanovic, and GuideRadPROS consortium. International Joint Conference on Industrial Engineering and Operations Management. DOI: [10.14488/ijcieom2024_full_0057_37886](https://doi.org/10.14488/ijcieom2024_full_0057_37886).

This list is also available here: <https://www.euramet.org/repository/research-publications-repository-link/>

Project start date and duration:		June 2023, 36 months	
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Internal Beneficiaries:		External Beneficiaries:	Unfunded Beneficiaries:
1. STUK, Finland		14. EEAE, Greece	17. Mirion, Finland
2. CEA, France		15. INM, Republic of Moldova	
3. CIEMAT, Spain		16. VINS, Serbia	
4. CMI, Czechia			
5. ENEA, Italy			
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7. IMBiH, Bosnia and Herzegovina			
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18. QST, Japan			