

Metrology Laboratory of Ionizing Radiation

Carlos Oliveira

The Metrology Laboratory of Ionizing Radiation (LMRI) has been involved in activities related with scientific, technical and legal metrology.

Scientific and technical activities:

LMRI continues to participate in the European project in the framework of the EURAMET organization: JRP06 “Increasing cancer treatment efficacy using 3D brachytherapy” which has finished in July and the new project “Ionizing Radiation Metrology for Metallurgical Industry” initiated in December. These projects arise from the implementation of the “European Metrology Research Programme” (EMRP) and are co-funded by the European Commission.

Two projects for the construction of the two air kerma primary standards have been submitted to FCT: a cavity chamber for ^{60}Co gamma rays and a free air chamber for low and medium X-ray energies (20 keV to 150 keV). Although classified as very good they were not recommended for funding.

The collaboration with the University has pursued, namely with the IST and FCT-UNL. A Ph.D. degree in the field of air kerma primary standard for ^{60}Co gamma rays is ongoing. Three master thesis have been presented and a new thesis has been accepted by the FCT to be performed at the LMRI during the next year.

A collaboration with the ESTeSL – Escola Superior de Tecnologia da Saúde de Lisboa do Instituto Politécnico de Lisboa took place with the realization of two B.Sc. thesis.

A collaboration with the other Institutions, Centro de Instrumentação Científica do LNEC (Laboratório Nacional de Engenharia Civil), Laboratório de Electricidade e Laboratório de Comprimento do IPQ (Instituto Português de Qualidade), Laboratoire National Henri Becquerel, CEA was initiated.

Collaboration with BIPM was agreed in the framework of the construction of a free air chamber, the air kerma primary standard for low and medium X-ray energies (20 keV to 150 keV).

The LMRI has participated in the TLD audit to the absorbed dose to water for ^{60}Co and is participating in the comparison of therapy level ionizing chamber

calibration coefficients, both of them promoted by the IAEA.

The dosimetry of radiation qualities used in diagnostic radiology, including conventional X ray examinations, mammography and computed tomography has been carried out enabling the LMRI to calibrate clinical dosimeters.

A review of the 43 Calibration and Measurement Capabilities (CMC's) was realized according the recommendations of the EURAMET and this includes a revision of technical procedures, uncertainty assessment and inter-comparison reports.

Legal activities:

Taking the opportunity originated by the publications of the revisions of the IEC Standards deep revision of the current law (Portaria n.º. 1106/2009) has been realized. A purpose for this revision was presented to the IPQ for publication.

Concerning the legal metrology, the LMRI, as OVM, has calibrated 15 medical dosimeters and metrological controlled 182 radiation monitors.

Quality System

The LMRI Quality System has been extended to all the UPSR Unit. LMRI has prepared the accreditation process, ready for IPAC audit, for two techniques. The annual report concerning the CMC's has been approved by the Technical Committee of Euramet.

Internal collaborations

The LMRI has participated in the ICARO course and collaborated with the URSN and UFA Units of the Campus. Technical assistance concerning specific equipment of the LMRI has been given by UFA.

International organizations

A member of the Group have been appointed delegate for the Consultive Committee for Ionizing Radiation of International Committee for Weights and Measures (CIPM), is the contact person on the Technical Committee for Ionising Radiation of EURAMET, have participated on the Computational Dosimetry Group of EURADOS and is designated for the Group of Experts of art. 31 (Radiation Protection) of UE.

Research Team

Researcher

C. OLIVEIRA, Princ., (Habil.), Group Leader

Technical Personnel

A. CASTRO (until June)

J. CARDOSO

L. SANTOS, (50%) Quality Manager of the UPSR QS until June

Student

M. CALDEIRA, Ph.D. student, FCT grant

Dosimetry of radiation qualities used in diagnostic radiology.

Mário de Oliveira¹, João Cardoso and C. Oliveira

Objectives

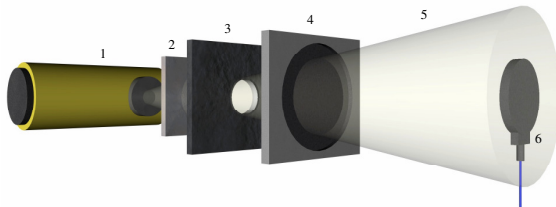
The radiation qualities used in conventional diagnosis are RQR (simulating radiation beam emerging from the target of tungsten), RQA (simulating radiation beam emerging from the patient) and RQT (simulating radiation beam emerging from the tomograph). These radiation qualities are established at the international standard IEC 61267 [1] For mammography, qualities established at the *Bureau International des Poids et Mesures* (BIPM) are the ones used.

Dosimetry procedures necessary to establish appropriated calibration of the dosimeters at the metrology Laboratory of Ionizing Radiation (LMRI) are performed according to the IEC 61267 and the code of practice TRS 457 [2]. The first step of this work was to verify the uniformity and homogeneity of the radiation field. The characterization of radiation qualities namely its dimensions should follow those described on the calibration certified of the ionizing chambers. The additional filtration, in mm of aluminium, was determined, to obtain the values of Half Value Layer (HVL) and homogeneity coefficient described by IEC 61267.

Methods and Results

The experimental arrangement for dosimetry is represented in the Figure 1.

Parameters as distances, dimensions of collimator



aperture, additional filtration and polarizing voltage are different for each set of radiation quality.

The value of air kerma (K_{ar}) was calculated by the equation 1, where N_k is the calibration coefficient, M is the reading of the plane parallel chamber, U is the reading of the monitor chamber, P and T are the air pressure and air temperature during the measurements and C_{PT} is the correction factor for temperature and pressure.

Fig.1 Scheme of dosimetry procedure. 1- X ray tube; 2- Additional filtration; 3- Collimator; 4- Monitor chamber; 5- Radiation beam; 6- Plane parallel chamber.

$$K_{ar} = \frac{M \cdot C_{PT}}{U \cdot C_{PT}} \cdot N_k \quad [mGy/um] \quad (1)$$

The calibration coefficients for RQR, RQA and RQT were determined at AIEA with traceability to the PTB. The calibration coefficients for mammography were realized at BIPM.

Pencil ionization chambers are calibrated in air kerma length. The results of the calibration coefficient of air kerma length versus collimator aperture are represented in Figure 2. For small apertures the sensitive length to scattered radiation is greater, and for full irradiation of the sensitive length, the ends (less sensitive) are irradiated too. Therefore the results suggest that irradiation of the chamber to 50% of its sensitive length, is the best option for carrying out the calibration of such chambers.

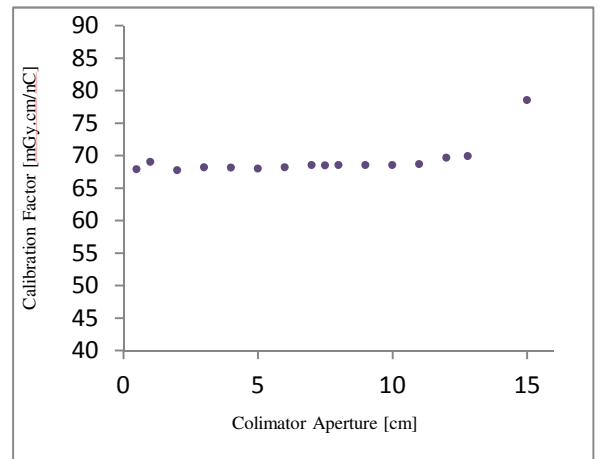


Fig.2 Air kerma length calibration factors versus collimator aperture of the chamber PTW 77336.

The sources of uncertainties were estimated according to the Guide to the expression of Uncertainty Measurement [3]. The calibration coefficient uncertainty is the dominant uncertainty.

¹(FCT-UNL, M.Sc. thesis).

References

- [1] IEC 61267. Medical diagnostic X-ray equipment - Radiation conditions for use in the determination of characteristics. 2005.
- [2] TRS 2007. Technical Reports Series no. 457 - Dosimetry in Diagnostic Radiology: An international Code of Practice. Rapport technique, International Atomic Energy Agency – IAEA. 2007.
- [3] JCGM. Evaluation of measurement data –"Guide to the expression of uncertainty in measurement" JCGM 100:2008.

Full characterisation of the 125I IBt bebig I25.S16 brachytherapy source and sensitivity study of the absorbed dose to water due to the seed dimensional variations

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Low dose rate brachytherapy using ¹²⁵I seeds are a worldwide well established technique to treat prostate or ophthalmic cancers in early stage. The angular emission of photons leaving the source seeds and the dose to water distribution around the sources (calculated using the radial dose function and the anisotropy function) are directly linked to the design and composition of the source seeds. The purpose of this study was to quantify the sensitivity of the absorbed dose to water distribution due to the seed dimensional variations. To measure the geometric seed dimensions, two different methods were used. The external dimensions were measured with a calliper rule and the internal dimensions were obtained with radiographic pictures. The photonic emission was measured with a silicon detector (Si-PIN) of 15 mm² of area and 0.5 mm of thickness. The measurements were carried out for eight sources. Results show that the variations of photonic emission within each source and between sources are lower than $\pm 2-3\%$ in the two considered planes.

In the framework of this study an uncertainty analysis was carried out for radial dose function and 2D anisotropy function. For this analysis, uncertainties associated to geometrical seed variations relatively to the reference geometry were considered. To study the uncertainty components associated with radial dose function due to differences in geometry, three causes for these differences were considered: the length of the gold marker, the thickness of the titanium capsule and the thickness of the radioactive ceramic core. The results obtained reveal an overall uncertainty of 0.2 % and 0.1 % for distances of 0.10 cm and 0.25 cm, respectively. For longer distances the uncertainty is negligible. To study the uncertainty contributions associated with the 2D anisotropy function due to differences in geometry, two causes for these differences were considered: the thickness of the ends of the seed and the length of the gold marker. For each angle, the uncertainty decreases with increasing distance r . Uncertainties ranging from 6.7 % to 1.7 % are found for polar angles θ smaller than 20°. For polar angles $\theta \geq 20^\circ$ the uncertainty decreases significantly.

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Modelling and uncertainty evaluation for the radiation quality parameters used in metrological management of diagnostic radiology dosimeters

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Diagnostic radiology methods require radiation detectors for quality control of X-ray radiation qualities, with the measurement procedure and the parameters to be determined in accordance with International Standard IEC 61267:2005, the first and second Half-Value Layer values (HVL1 and HVL2) and the homogeneity coefficient h (HVL1/HVL2) given in the Standard. A mathematical approach and numerical method are given for obtaining these parameters. The GUM uncertainty framework is used to evaluate the measurement uncertainties associated with the resulting parameter estimates. Because the measurement model used is non-linear and implicitly defined, the results are compared with those from a Monte Carlo method. For all radiation qualities, IEC 61267:2005 gives admissible limits that are not supported by any rationale. For radiation qualities RQR, determinations of uncertainties associated with typical experimental data have been achieved.

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Project, construction and characterization of a cavity chamber for ⁶⁰Co gamma rays

M. Caldeira¹, C. Oliveira

A prototype of a graphite cavity chamber has been constructed at the workshop of ITN. The electrical connections and assemble of the pieces were made at the Laboratory of Electrical Measurements of the Portuguese Institute for Quality (IPQ). After the first tests with radiation developed at ITN, new measurements were made, this time at the facilities of Laboratoire National Henri Becquerel. Tests for stability of measurements of the chamber and working plateau were made at the LMRI. Tests for stability, plateau and polarity effects were performed at LNHB. Also a simulation of the electric field inside the chamber was realized at LNHB. The conclusions taken from these tests should indicate a new methodology in the development of the work, concerning not only the geometrical and electrical aspects of the construction of a cavity chamber, but also those related to the data acquisition and measurement set up.

¹FCT-ITN-IST

Ionizing Radiation Metrology for Metallurgical Industry

C. Oliveira, L. Portugal, I. Paiva, M. Reis, C. Cruz, J. Cardoso, L. Santos, R. Trindade

This new European project, “Ionizing Radiation Metrology for Metallurgical Industry” in the framework of the EURAMET, results from the implementation of the “European Metrology Research Programme” (EMRP) and is co-funded by the European Commission. The project, initiated in December, 2011, has the following scientific and technical objectives: WP1 - The development of reliable, SI traceable methods optimized for the control/measurement of radioactivity at each stage of the smelting process (e.g. scrap loads, metal products, slag and fumes dust), WP2 - The development of reference standards for cast steel (real and composite reference standards), slag and fume dust. Reference standards will be contaminated with potential contaminant radionuclides (e.g. ⁶⁰Co, ¹³⁷Cs, ¹⁹²Ir, ²²⁶Ra) and have different geometries/matrices that correspond to the cast steel probes currently used for on-line measurements and the slag cartridges used for

the calibration of radioactivity detectors, WP3 - The characterisation of the measurement methods recommended in WP1 with the reference standards produced in WP2, using inter-laboratory comparisons and Monte Carlo simulations to cover the large diversity of sample geometries, shapes, densities and elemental compositions, WP4 - The design of an optimised spectrometric device and the production of prototype devices for the measurement of activity in cast steel, fume dust and slag samples using the methods developed in WP1. This work package includes laboratory testing of the prototype devices, WP5 - Evaluation of the prototype spectrometric devices produced in WP4 and the methods developed in WP1, WP4, at end-user facilities (i.e. foundries). Evaluation criteria will be developed based on end-user needs/constraints, WP6 - Demonstration of the prototype spectrometric devices at selected foundries in Europe, development of technical recommendations and input into European and National Standards Committees for the standardisation of radioactivity monitoring (e.g. calibration of measurement systems, on-line monitoring of production and certification of cast steel batches), and worldwide dissemination of project results to end-users, stakeholders and the general society through journal articles, conference presentations and specialised workshops. The project has 14 funded partners and ITN is involved in WP1, WP3, WP5 and WP6 tasks.

Quality System

L. Santos, J. Cardoso, C. Oliveira

The Quality System, essential in the LMRI namely to maintain the CMC's (Calibration and Measurement Capabilities) in order to participate in Mutual recognition Arrangement (MRA) of the International Committee of Weights and Measures (CIPM), under the authority given to it in the Metre Convention has been maintained. According to the recommendations of the EURAMET a revision of the CMC's, namely the revision of procedures, uncertainties assessment, update of inter-laboratorial comparison, have been finished and sent to EURAMET.

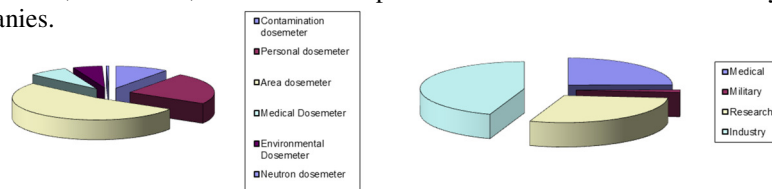
The LMRI submitted for accreditation two techniques in metrological control of radiation protection monitors in terms of the operational quantities, personal dose equivalent, $H_p(10)$, and ambient dose equivalent, $H^*(10)$, according to the standards IEC 61526 and IEC 60846, respectively.

As happened in recent years the LMRI participated in the TLD audit to the absorbed dose to water for ^{60}Co promoted by the AIEA. Besides, LMRI participated in a comparison of therapy level ionizing chamber calibration coefficients also promoted by the AIEA.

Services

L. Santos, J. Cardoso, A. Castro, C. Oliveira

LMRI provides the community, mainly hospitals, industry, universities, armed forces and ITN Units with calibration and metrological control services. This metrological control of instruments is being carried out under a contract with Portuguese Institute of Quality and is the enforcement of Portaria n°. 1106/2009 dated of 24 of September. During 2011 were calibrated and controlled 197 dosimeters. The following figures describe the work done. In 2011, the LMRI, have irradiated personal dosimeters for the reader system calibration of two private companies.



LMRI COLLABORATION WITH ITN UNITS/GROUPS

Unit of Reactors and Nuclear Safety (URSN)

The LMRI performs, every year, the metrological control of installed detectors and associated instrumentation of the RPI radiological protection system. In 2011 have been verified, calibrated or tested 41 monitors/detectors.

Unit of Physics and Accelerators (UFA)

LMRI has carried out three calibrations: one ionizing chamber calibrated in air kerma and the second ionizing chamber calibrated in air kerma and absorbed dose to water for the "Radiation Technologies: Process and Products Group".

The Ion Beam Laboratory Group and the Nuclear Methods and Instrumentation Group gave technical assistance to the specific equipment of the LMRI.

Unit of Radiological Protection and Safety (UPSR)

Dosimetry and Radiobiology Group

In 2011 about 1050 TLD dosimeters have been irradiated. About 700 for $H_p(10)$ and about 350 for $H_p(0.07)$. Cells and blood have been irradiated. The purpose of the work was the establishment of a dose response curve for biological dosimetry, using lymphocytes from human peripheral blood from healthy donors for both gender and different age group. The dose range studied is from 0.25 Gy to 3.0 Gy using a source of ^{60}Co .

Environmental Radioactivity Group

The technical support to Environmental Radioactivity Group database (SIAC) and the data submission for the Radioactivity European Measurement Database (REM) have been made by a LMRI technician (LS).

Radioprotection and Radioactive Waste

LMRI has carried out the metrological control of 15 radiation protection instrumentation.