# Metrology Laboratory of Ionizing Radiation

*João Cardoso and C. Oliveira*

The Metrology Laboratory of Ionising Radiation (LMRI) of Nuclear and Technological Institute (ITN) had actively been involved in activities concerning the legal, applied and scientific metrology as well as other related research topics and services.

The primary standard for air kerma for the gamma radiation of Cs-137 is an ionisation chamber of the type CC01. For the first time this instrument was used to characterize the radiation field, in terms of air kerma, originated by the Shepherd irradiator, model 81, with a Cs-137 source used mainly for radiation protection calibration purposes. Monte Carlo simulation studies in order to characterize this radiation field and to obtain correction factors were also performed. This work was presented, in the Workshop on "Absorbed Dose and Air Kerma Primary Standards", organised by LNHB and BIPM.

In order to know the air kerma value at 50 cm distance from a $^{137}$Cs source positioned inside an irradiator for the reference configuration and to investigate the influence of some parameters on air kerma value and consequently to have an uncertainty budget, calculations were performed considering different values for several parameters. This type of exercises was promoted by Conrad WP4 of EURADOS. This work was presented in the *Workshop on Uncertainty Assessment in Computational Dosimetry: A Comparison of Approaches*, in Bolonha.

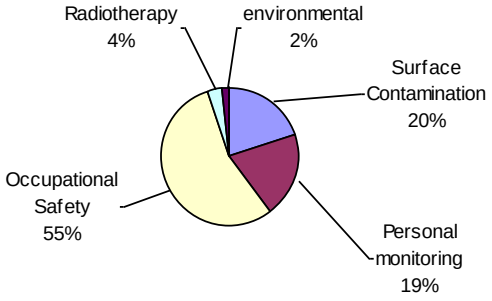
The LMRI has also developed efforts to be involved in the Targeted Program 2 (TP2 (Health)) of EURAMET. These efforts result in the inclusion of LMRI in two Joint Research Projects, the JRP6, Brachytherapy Dosimetry and the JRP7, External Beam Cancer Therapy.

Some lectures activities to universities and in professional courses were made during this year, namely lectures on radiation detection techniques. It is also usual to have visits from university students to have a close contact with the dosimetry reality in order to complement their knowledge and training. A staff member from Health Ministry of Mozambique was trained in dosimetry and calibration of instruments during three months.

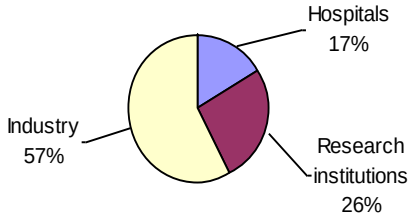
The irradiation facilities of LMRI are often seeked for research teams from ITN or outside ITN. However the calibration services are our more visible activity, providing to the community, mainly for industry, universities, hospitals, armed forces and departments of ITN, services of metrological control. This metrological control of instruments for measurement of ionising radiation is being carried out under a contract with Portuguese Institute of Quality and is the enforcement of *Portaria* nº. 423/98 from 21 of July. Technical support was given to the Portuguese Institute for Quality (IPQ) to write a new *Portaria* for the metrological control of ionising radiation measuring instruments in Portugal. This new law will be published in 2008 and will include new domains of metrological control namely in instruments dedicated to nuclear medicine and diagnostic radiology.

During 2007 were calibrated 135 dosemeters and about 1000 TLD dosimeters were irradiated. The following figures can quantify the work done in this particular area.

**Instruments calibrated by type of use**




**Intruments calibrated by users activity**




## Research Team

### Researchers

C. OLIVEIRA, Princ. (50%) (since July 2007)

### Technical Personnel

J. CARDOSO, graduated technician
L. SANTOS, technician
A. CASTRO, technician ITN consultancy contract

# Air Kerma Primary Standard: Experimental and Simulation Studies on Cs-137

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## Objectives

Determination of the air kerma rate of the gamma radiation of $^{137}$Cs using a graphite-cavity ionization chamber as an air kerma primary standard.

## Results

The gamma radiation from $^{137}$Cs sources is used in the LMRI mainly for calibration and verification of radiation protection dosemeters. Until now the air kerma rate was obtained using a secondary standard, an ionization chamber OFZ LS-01/113 calibrated by PTB. For the first time a graphite-cavity ionization chamber of the type CC01, with serial number 134, schematically presented in figure 1, was used at LMRI as an air kerma primary standard for the gamma radiation of $^{137}$Cs. The CC01 ionization chamber is made of graphite with a density of 1.80 g/cm$^3$. The chamber wall has a thickness of 4 mm and the electrode has a diameter of 2 mm and 9 mm height. The sensitive volume of the ionization chamber is 1.0161 cm$^3$ obtained with an uncertainty of 0.1 % (1 σ). The polarising potential is +250 V and is applied in the wall.

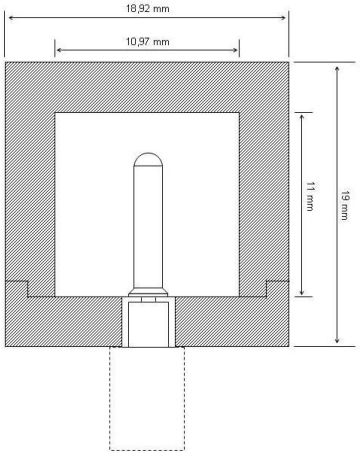


Fig. 1. CC01 ionisation chamber scheme.

The air kerma rate, $\dot{K}$, is obtained from,

$$\dot{K} = \frac{I}{m}\frac{W}{e}\frac{1}{1-\bar{g}}\left(\frac{\mu_{en}}{\rho}\right)_{a,c}\bar{s}_{c,a}\prod k_i$$

where $I$ is the ionization current measured; $m$ is the mass of air in the sensitive volume of the ionization chamber, $W$ is the average energy spent by an electron of charge $e$ to produce an ion pair in dry air, $\bar{g}$ is average fraction of electron energy lost to radiative processes, $(\bar{\mu}_{en}/\rho)_{a,c}$ is the ratio of the mean mass energy absorption coefficients of air and graphite, $\bar{s}_{c,a}$ is the ratio of the mean stopping powers of graphite and air, $\prod k_i$ is the product of correction factors to be applied to the standard. Correction factors as polarization, recombination losses, stem scattering and wall effects were experimentally determined; axial non-uniformity, radial non-uniformity and humidity are obtained from the published data.

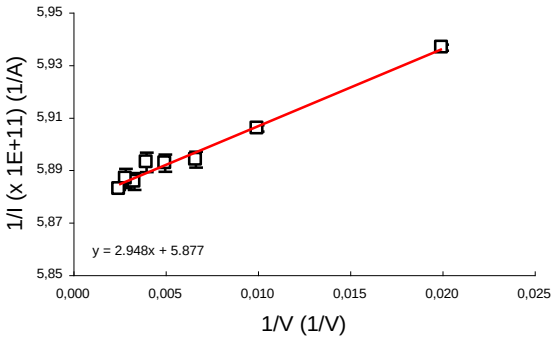


Fig. 2. Results on the calculation of recombination losses.

Additionally, a Monte Carlo simulation study was performed in order to calculate some experimental correction factors used in the determination of air kerma for $^{137}$Cs. In the computational simulation the transport of photons and electrons has been considered (mode p e).
: The value obtained for the air kerma rate at 1m is 6.212 mGy min$^{-1}$ (at 7$^{th}$ Dec. 2006). This value is in agreement with the previous reference air kerma rate, however decreasing the uncertainty from 0.9 % to 0.4% (1 σ). In conclusion, the LMRI air kerma primary standard was used, successfully, to obtain the air kerma rate of a $^{137}$Cs source. The simulations studies allowed a better knowledge of the irradiation conditions and of the ionization chamber itself. Further work is needed, namely in the characterization of the LMRI irradiator in order to obtain the LMRI radiation beam fluence and more accurate correction factors.

## Published work

This work was presented on the Workshop on "Absorbed Dose and Air Kerma Primary Standards, Paris, May 2007 as invited talk and can be seen on site http://www.nucleide.org/ADAKPS_WS/Session%20F%20-%20IC%20Kerma/F3_Or-Cardoso.pdf

**Photon Irradiation Facility**
*J. Cardoso, C. Oliveira*

The aim of the problem concerning the Photon Irradiation Facility is to calculate the air kerma value at 50 cm distance from a $^{137}$Cs source positioned inside an irradiator for the reference configuration. Besides that, and in order to investigate the influence of some parameters on air kerma value and consequently to have an uncertainty budget, calculations were performed considering different values for several parameters.
The shape and dimensions of the irradiator are described in the problem protocol, as well the shape, dimensions and material composition of the source. The variables studied in this problem with potential influence on air kerma value were the positioning of source, the source chamber depth, the dimension of the rings collimator, the tungsten density, the CsCl density and the source diameter. The problem was simulated by Monte Carlo method using the MCNP code, version 5.
All the results presented arise from the averaging of four independent runs which use different control numbers in the card DBCN. The simulations were done in mode P. With this mode on photons were transported and the electrons were not transported. However in this mode electrons can originate bremmstrhalung photons. This simplification saves computer time and the physics of the problem support this decision.
The photon fluence is obtained with a F4 tally, which averages the photon fluence over a cell, in a cylinder of 0.5 cm radius and height. The air kerma at 50 cm from radioactive source is obtained by applying the conversion coefficients, suggested in the protocol, to the photon fluence. However a new calculation was done with different conversion coefficients. These conversion coefficients are described in table A.21 of ICRP publication 74, which are slightly different from the ones that the problem suggests. All the other calculations were obtained with the conversion coefficients suggested. The photon energy considered in the $^{137}$Cs emission is 0.66166 MeV. The number of particles simulated in each run was 1E+8 and each run spent approximately 150 min of computer time. Each run has a standard uncertainty of 4%. For the reference conditions and for each different condition, 4 independent runs were performed. The uncertainties were calculated according to GUM.

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**Ionising Radiation Metrological Control Law**
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The ITN-LMRI belongs, as associated laboratory, to the National Metrology Subsystem which is included in the Portuguese Quality System managed by IPQ. The Subsystem of Metrology is organized according to figure 1.

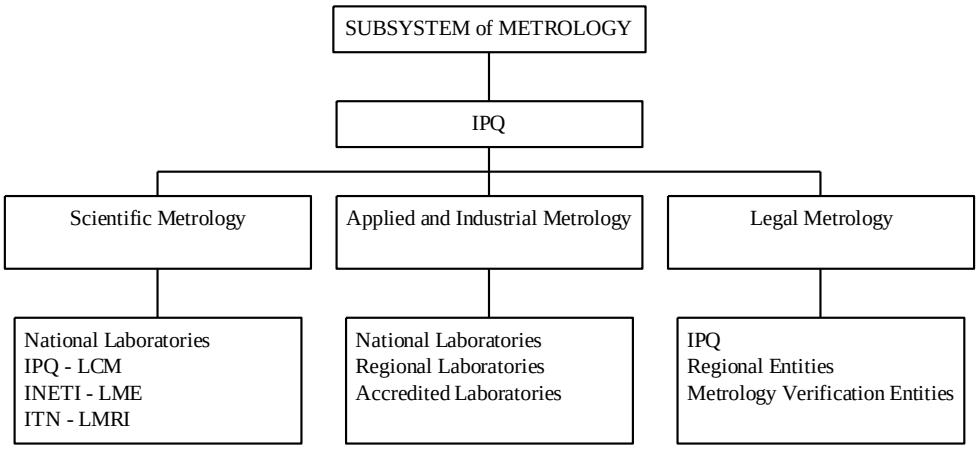


Fig.1. Structure of the National Metrology Subsystem

According to this figure, the National Laboratories for Scientific Metrology are IPQ-LCM, INETI-LME and ITN-LMRI. This link to IPQ is clearly defined by a Protocol between the two institutions and according to this the ITN-LMRI gives scientific and technical support to IPQ in the ionizing radiation field. Recently, technical support was given to the Portuguese Institute for Quality (IPQ) to write a new law for the metrological control of ionising radiation measuring instruments in Portugal. This new law will be published in 2008 and will substitute the old one from 1998, Portaria nº 423/98 and will include new domains of metrological control namely in instruments for measurements in nuclear medicine and diagnostic radiology. For Radiation Protection, new type of instruments, concerning their use, were added.