ЗБОРНИК РАДОВА

XXX СИМПОЗИЈУМ
ДРУШТВА ЗА ЗАШТИТУ ОД ЗРАЧЕЊА
СРБИЈЕ И ЦРНЕ ГОРЕ

2. - 4. октобар 2019. године
Хотел "Дивчибаре", Дивчибаре, Србија

ДРУШТВО ЗА ЗАШТИТУ ОД ЗРАЧЕЊА
СРБИЈЕ И ЦРНЕ ГОРЕ

ЗБОРНИК РАДОВА

XXX СИМПОЗИЈУМ ДЗЗСЦГ
Дивчибаре
2- 4. oktобар 2019. године

Београд
2019. године

RADIATION PROTECTION SOCIETY OF SERBIA AND MONTENEGRO

PROCEEDINGS

XXX SYMPOSIUM RPSSM
Divčibare
2^{nd}- 4^{th} October 2019

Belgrade
2019

ЗБОРНИК РАДОВА

XXX СИМПОЗИЈУМ ДЗЗСЦГ
2-4.10.2019.

Издавачи:
Институт за нуклеарне науке „Винча“
Друштво за заштиту од зрачења Србије и Црне Горе

За извршног издавача:
Проф. др Снежана Пајовић, научни саветник
в.д. директора Института за нуклеарне науке Винча

Уредници:
Др Михајло Јовић
Др Гордана Пантелић

ISBN 978-86-7306-154-2

Техничка обрада:
Михајло Јовић, Гордана Пантелић

Електронско издање:
Институт за нуклеарне науке ”Винча”, Мике Петровића Аласа 12-14, 11351 Винча, Београд, Србија

Тираж:
150 примерака

Година издања:
Септембар 2019.

DETERMINATION OF UNIFORMITY AND FIELD SIZE OF REFERENCE X-RAY BEAMS

Vedrana MAKARIĆ[1], Miloš ŽIVANOVIĆ[2], Nikola KRŽANOVIĆ[2] and Miloš ĐALETIĆ[2]

1) *Institute of Metrology of Bosnia and Herzegovina, Sarajevo, Bosnia i Hercegovina, vedrana.makaric@met.gov.ba*
2) *Vinca Institute of Nuclear Sciences, Department of Radiation and Environmental Protection, University of Belgrade, Belgrade, Serbia, milosz@vinca.rs, krzanovic@vinca.rs, djaletic@vin.bg.ac.rs*

ABSTRACT

The aim of this paper is to study the uniformity and the size of a reference radiation field produced by an x-ray generator. This work uses a technique to map dose distribution and measure dose rates with a small-volume spherical ionization chamber in order to determine the correction factor for non uniformity of the radiation field. Results shown in this paper are profile measurements performed in radiation beam collimated by a 4.2 cm diameter aperture, generated by calibration x-ray equipment of constant voltage and current. The study was conducted in a diagnostic radiology radiation quality, but this procedure is also applicable to the new revised version of ISO 4037 standard from 2019 which specifies protection level reference radiation qualities.

1. Introduction

Reference radiation fields used for calibration of dosimeters should be realized in agreement with their purpose and they conform to the requirements which are defined by the International Organization for Standardization (ISO) and International Electrotechnical Commission (IEC) standards. ISO and IEC standards specify the requirements for reference radiation qualities used for radiation protection and for quality control in diagnostic radiology [1, 2]. International Atomic Energy Agency (IAEA) technical documents can also be used to establish reference radiation qualities [3, 4]. Technical document dealing with protection level radiation qualities, IAEA Safety Report Series 16, is currently based on the old version of the ISO standard and will need to be revised [3].

Taking into account the fact that x-ray beam is continuous in energies, phenomena such as the heel effect (the reduction of the radiation field intensity at the anode side due to the formation of x-rays that undergoes absorption or attenuation in the interior of the anode) and also scattered radiation from the experimental setup inside and outside the collimated beam, it is obvious that there are significant factors that could contribute to beam non uniformity.

According to the new version of ISO 4037, the air kerma rate at each point of test should not vary by more than 5% over the entire cross sectional area of the sensitive volume of the detector under test [1]. The requirements for diagnostic radiology calibrations are stricter – the air kerma rate variation should be less than 2% [4].

Considering the above requirements, this study investigates a technique that could allow precise determination of the field size and its uniformity, since both of these parameters are essential when performing calibration of radiation detectors.
In the previous work, dose profiles were determined in the same dosimetry laboratory for the old X-ray equipment by using a medical class ionization chamber [5].

2. Materials and methods

The study and characterization of the radiation field were realized in the beam generated by a Hopewell Designs x-ray generator model X80-225 with a constant potential (10 kV – 225 kV), in the Secondary Standard Dosimetry Laboratory (SSDL) of Vinca Institute of Nuclear Sciences (VINS). The dosimeter used in order to address the need for profile measurements was a 3.6 cm^3 Exradin A3 spherical ionization chamber.
X-ray dose measurements were conducted using the chamber connected to a PTW UNIDOS Webline electrometer. The chamber's active volume has a radius of 9.7 mm and it is a reference standard for diagnostic radiology calibrations in VINS. During the field profile measurements, the chamber was positioned horizontally with its stem normal to the beam. The ionization chamber was irradiated for 10 minutes before the measurements for stabilization purposes. The tube voltage and current were kept constant and their values were 70 kV and 10 mA, respectively.
Beam profiles along horizontal and vertical axes were determined in RQR 5 radiation quality at 100 cm focus-detector-distance, and the chamber was moved horizontally and vertically covering the distance range from -14 cm to 14 cm in increments of 1 cm.
The correction factor for non uniformity of the radiation field can be calculated using the following equation:

$$k_{nu} = \frac{g(0)\cdot\int_0^R r dr}{\int_0^R g(r) r dr} \tag{1}$$

where:

$2\pi\int_0^R g(r) r dr$ is the dose integral over the sensitive surface of the dosimeter used for the measurements, $2\pi\int_0^R r dr$ is the sensitive surface of the dosimeter – R being the radius of the dosimeter, $g(r)$ is the dose at a distance r from the axis and $g(0)$ is the dose at a point on the axis [6].

In order to apply the above mentioned approach in this study, it was necessary to calculate the mean value of the profile and fit to a 4^{th} degree polynomial to obtain the correction factor.

3. Results and discussion

According to the data provided by the X-ray generator manufacturer, the field diameter at 100 cm with 4.2 cm aperture was calculated to be 13.45 cm. Horizontal and vertical beam profiles measured with the ionization chamber are shown in Figure 1.

Measurements were corrected for influence quantities such as temperature and pressure. For better clarity, data are normalized at the origin of the profile axes.

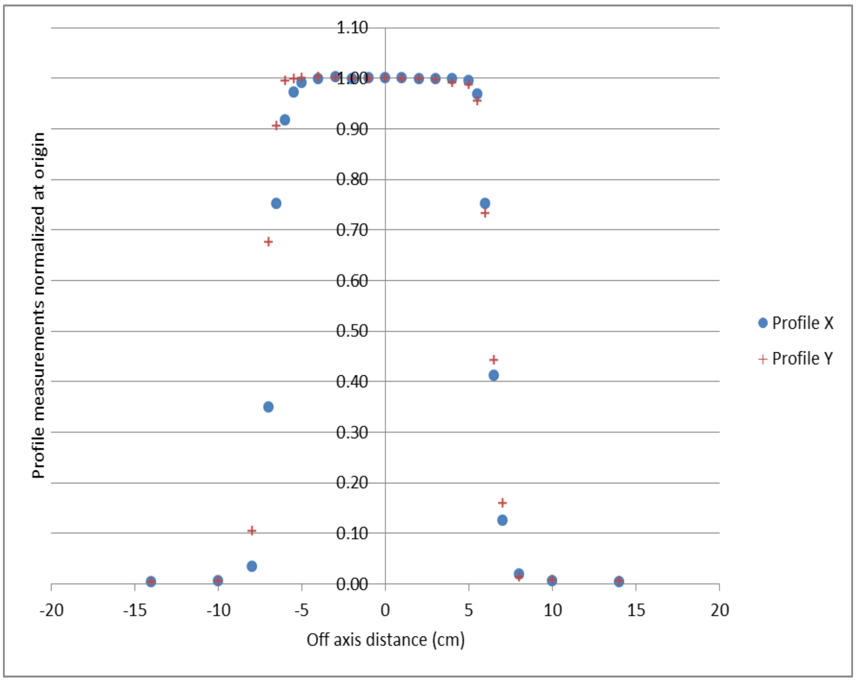

Figure 1. Horizontal and vertical profiles measured with Exradin A3 ionization chamber at 100 cm focus-detector distance.

The field-size was calculated based on the measured horizontal and vertical relative intensity profiles (profile region within 50% intensity). As can be seen in the results in Table 1, data obtained with ionization chamber agree well with the calculated geometrical field size. The homogeneous profile regions (defined as 95% isodose level) were determined also. For applications in diagnostic radiology, homogenous region is often defined more strictly [4]. Using the wider field increases the measurement uncertainty, unless the non uniformity correction is applied.
The values of the deviation of the calculated center of the field compared to the laser main beam axis are also included. The slightly negative values of the field center in x- and y-axes means that the main beam laser should be positioned lower by about 4 mm and in right direction by about 2 mm for perfect alignment. These deviations of the beam axis are calculated from the 50% profiles.
It is important to note that the finite size of the chamber used for measuring beam profiles is influencing the results and introducing measurement uncertainty. Use of smaller chambers would provide better spatial resolution, but the uncertainty due to the repeatability would increase significantly, because of the relatively low dose rate. The problem of low dose rates would be more pronounced for protection level fields compared to the diagnostic radiology fields. A radiation field profile measurement technique which uses radio chromic films could be used to increase the spatial resolution.

Table 1. X ray field size as the result of the ionization chamber measurements.

	x-axis (cm)	y-axis (cm)
Field size	13.18	13.71
Homogeneous region	11.93	11.84
Field center deviation	-0.2	-0.4

In order to determine the correction factor for non uniformity of the reference radiation field, the average value of data obtained by measurements over 2 axes is calculated and the mean profile is presented in Figure 2.

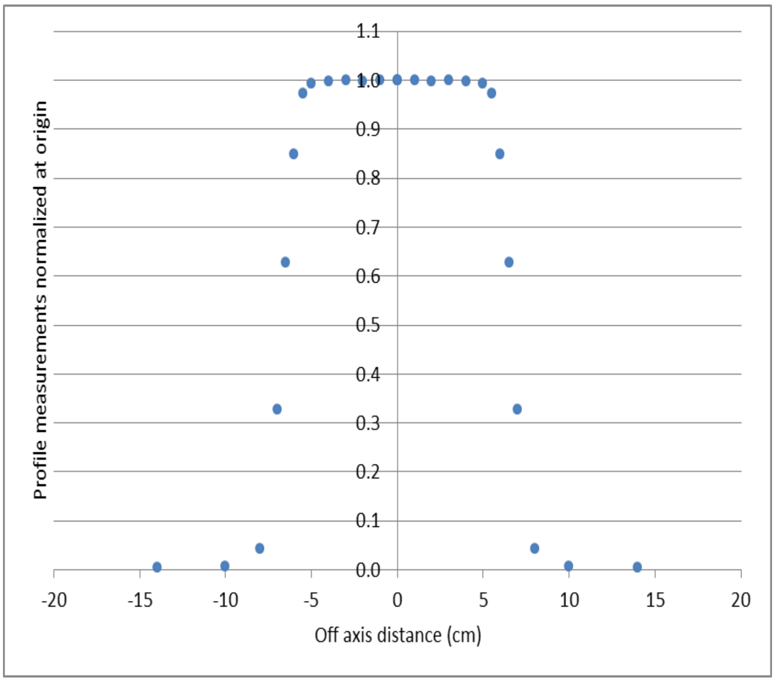

Figure 2. Mean profile calculated from measurements with Exradin A3 ionization chamber at 100 cm focus-detector distance in a 4.2 cm diameter field.

Mean profile was fitted using 4th degree polynomial from the 95% profile region to allow analytical calculation of the correction factor k_{nu}. The correction factor calculated by applying the formula (1) gives value of 1.0005 for Exradin A3 chamber over a sensitive surface of 1.94 cm diameter. This correction is under 0.1%, and the corrections of this magnitude are usually neglected in SSDLs [7].
In this case the correction is small as it was expected. However, the correction factor could significantly increase for larger dosimeters. This is very important for determining maximum allowed detector sizes at certain distances and uncertainties due to field nonuniformity.

4. Conclusion

X-ray beams used in calibration laboratories are well collimated, but some non uniformity is always present. Mapping the dose rate is necessary in order to estimate the measurement uncertainty, to determine the useful area of the beam and to perform corrections for non uniformity. Method with small ionization chamber was successfully used and results are presented in this paper. Results are comparable to the manufacturer specifications. Comparison of this method with radio chromic films would provide better understanding of the beam mapping and would help determine the influence of the finite size of ionization chamber.

5. Acknowledgement

The research was supported by the International Atomic Energy Agency (IAEA) under the IAEA TC BOH9009 project "Sustaining an Integrated Management System and Capabilities in the Regulatory Body and Strengthening Capabilities of the Dosimetry Laboratory".

6. Literature

[1] ISO 4037-1:2019, X and gamma reference radiation fields for calibrating dosemeters and doserate meters and for determining their response as a function of photon energy - Part 1: Radiation characteristics and production methods, ISO, Geneva, 2019.

[2] IEC 61267:2005, Medical diagnostic X-ray equipment – Radiation conditions for use in the determination of characteristics, IEC, 2005.

[3] Safety Report Series No. 16, Calibration of Radiation Protection Monitoring Instruments, IAEA, Vienna, 2000.

[4] Technical Report Series No. 457, Dosimetry in Diagnostic Radiology: An International code of practice, IAEA, Vienna, 2007.

[5] S. Ćeklić, M. Živanović, D. Aranđić, P. Božović, J. Stanković, Đ. Lazarević, Dozni profili referentnih snopova X-zračenja, *XXVIII simpozijum Društva za zaštitu od zračenja Srbije i Crne Gore*, 30. septembar – 2. oktobar 2015, Vršac, 2015, 340 - 343.

[6] S. Dufreneix, A. Ostrowsky, M. Le Roy, L. Sommier, J. Gouriou, F. Delaunay, B. Rapp, J. Daures and J-M. Bordy. Using a dose-area product for absolute measurements in small fields: a feasibility study. *Phys. Med. Biol*. 61(2), 2015, 650-662.

[7] IAEA-TECDOC-1585, Measurement Uncertainty - A practical guide for Secondary Standards Dosimetry Laboratories, IAEA, Vienna, 2008.

ODREĐIVANJE UNIFORMNOSTI I VELIČINE REFERENTNOG POLJA X- ZRAČENJA

Vedrana MAKARIĆ[1], Miloš ŽIVANOVIĆ[2], Nikola KRŽANOVIĆ[2] i Miloš ĐALETIĆ[2]

1) *Institut za mjeriteljstvo Bosne i Hercegovine, Sarajevo, Bosna i Hercegovina, vedrana.makaric@met.gov.ba*

2) *Institut za nuklearne nauke Vinča, Univerzitet u Beogradu, Beograd, Srbija, milosz@vinca.rs, krzanovic@vinca.rs, djaletic@vin.bg.ac.rs*

SADRŽAJ

Cilj ovog rada je da se ispita uniformnost i veličina referentnog polja generisanog pomoću generatora X-zračenja. U tu svrhu je korišćena jonizaciona komora male zapremine tako što su mapirane jačine doze. Na osnovu merenja, određen je korekcioni faktor za neuniformnost polja zračenja. Rezultati prikazani u ovom radu se odnose na polje kolimisano pomoću aperture prečnika 4,2 cm i generisano pomoću generatora X-zračenja konstantnog napona i struje. Ispitivanje je izvršeno u kvalitetu zračenja koji se koristi u dijagnostičkoj radiologiji, ali je ova procedura takođe primenjiva i na kvalitete koji se koriste za etaloniranje uređaja za zaštitu od zračenja definisane u novoj verziji ISO 4037 iz 2019. godine.