ETRAN

Zbornik radova

62. Konferencija ETRAN 2018

&

5th International Conference IcETRAN 2018

Palić, 11-14.06.2018.

Društvo za ETRAN, Beograd & Akademska misao, Beograd

ETRAN Society, Belgrade & Academic Mind, Belgrade

Zbornik radova - 62. Konferencija za elektroniku, telekomunikacije, računarstvo, automatiku i nuklearnu tehniku, ETRAN 2018, Palić, 11 – 14. juna, 2018. godine

Proceedings of Papers – 5th International Conference on Electrical, Electronic and Computing Engineering, IcETRAN 2018, Palić, Serbia, June 11 – 14, 2018

Glavni urednik / Main Editor **Dejan Popović**

Urednici / Editors **Vladimir Katić, Nikola Jorgovanović**

Izdavači / Published by **Društvo za ETRAN, Beograd i Akademska misao, Beograd / ETRAN Society, Belgrade, Academic Mind, Belgrade**

Izrada / Production **Akademska misao, Beograd / Academic Mind, Belgrade**

Mesto i godina izdanja/ Place and year of publication **Beograd, 2018./ Belgrade, 2018**

Tiraž/ Circulation **300 primeraka / 300 copies**

ISBN 978-86-7466-752-1

www.etran.rs

CIP - Каталогизација у публикацији - Народна библиотека Србије, Београд

621.3(082)(0.034.2)
534(082)
004(082)(0.034.2)
681.5(082)(0.034.2)
621.039(082)(0.034.2)
66.017(082)(0.034.2)
57+61(048)(0.034.2)
006.91(082)(0.034.2)

ДРУШТВО за електронику, телекомуникације, рачунарство, аутоматику и нуклеарну технику. Конференција (62 ; 2018 ; Палић) ETRAN [Elektronski izvor] : zbornik radova / 62. Konferencija ETRAN2018, Kladovo, 05-08. juna, 2017. godine & 5th International Conference IcETRAN 2018 Palić, 11-14.07.2018. ; urednici, editors Vladimir Katić, Nikola Jorgovanović]. - Beograd : Društvo za ETRAN : Akademska misao = Belgrade : ETRAN Society : Academic Mind, 2018 (Beograd : Akademska misao). - 1 elektronski optički disk (CD-ROM) ; 12 cm Sistemski zahtevi: Nisu navedeni. - Nasl. sa nasl. ekrana. - Tekst ćir. i lat. - Radovi na srp. i engl. jeziku. - Tiraž 300. - Bibliografija uz svaki rad. - Abstracts.

ISBN 978-86-7466-752-1 (AM)

1. International Conference on Electrical, Electronic and Computing
Engineering (5 ; 2018 ; Palić)

а) Електротехника - Зборници b) Акустика - Зборници c) Рачунарска технологија - Зборници d) Системи аутоматског управљања - Зборници e) Нуклеарна техника - Зборници f) Технички материјали - Зборници g) Биомедицина - Зборници h) Метрологија - Зборници

COBISS.SR-ID 268605452

Proceedings of Papers – 5th International Conference on Electrical, Electronic and Computing Engineering, IcETRAN 2018, Palić, Serbia, June 11 – 14, 2018 ISBN 978-86-7466-752-1

Energy, Angular and Dose-rate Dependence of the GM Survey Meter Response

Nikola Kržanović, Filip Haralambos Apostolakopoulos, Miloš Đaletić,
Miloš Živanović, Koviljka Stanković

***Abstract*—Survey meters represent common radiation protection instruments used for ambient monitoring. They estimate the effective dose of occupationally exposed personnel, by measuring the ambient dose equivalent. A performance testing of a Geiger-Müller tube-based survey meter was realized in this paper. The energy and the dose rate dependence were determined for different thicknesses of lead tube wrappings, in order to achieve the optimal energy compensation. The energy response for higher-energy photons slightly improved by applying these filters, while it significantly worsened for low-energy X-rays. The angular dependence was tested in terms of angular response and its symmetry for different radiation qualities.**

***Index Terms*—ambient dose equivalent; angular response; dose rate dependence; energy compensation; survey meter**

I. INTRODUCTION

The Geiger-Müller (G-M) counter represents one of the oldest ionizing radiation detectors, known for its simplicity, low cost and ease of operation. These gas-filled detectors are based on the principle of gas multiplication, under the influence of high-intensity electric fields, which results in a self-propagating chain of multiple avalanches (i.e. the Geiger discharge) [1]. A G-M tube-based survey meter should exhibit a flat energy and angular dependence if possible. The flattening of the energy response (the energy compensation) is achieved by wrapping the G-M tube in various materials of different thicknesses. The most commonly used materials for this process are lead and tin, or an alloy containing both of these metals. In the experimental part of this paper, a pancake G-M tube detector has been type tested (including the dose rate, energy and angular dependence). In previous research, the performance of various radiation survey meters (ionization chambers, G-M counters and scintillation detectors) has been tested in X- and gamma-ray fields [2, 3].

Survey meters are used to estimate the effective dose by measuring the ambient dose equivalent $H^*(10)$ in the working areas of occupationally exposed personnel. The ambient dose equivalent is a physical quantity used for radiation protection. It is defined as the dose equivalent produced by the corresponding expanded and aligned field in the ICRU sphere at a depth of 10 mm, on the radius, in the opposite direction of the aligned field. The ICRU sphere has a 30 cm diameter, and it represents a tissue equivalent which is consisted of a material of a 1 g cm^{-3} density, and a mass composition of 76.2% oxygen, 11.1% carbon, 10.1% hydrogen and 2.6% nitrogen. The term expanded field approximates fluence, so that its directional and energy distributions are constant throughout the volume of interest as in the actual field at the point of reference. The terms expanded and aligned field approximate the unidirectional fluence [4].

II. MATERIALS AND METHODS

Survey meters represent standard dosimetry equipment for ambient monitoring of ionizing radiation. A DMRZ-M15 survey meter with an S1 probe, developed by Vinča Institute of Nuclear Sciences, was used for the ambient dose equivalent rate measurements [5]. The survey meter probe contains an SI-8B G-M tube, with a polyamide cover of 2 mm on the front side and 8 mm on the lateral sides of the active volume. The tested G-M tube was compared to an ionization chamber, which is a secondary standard for air kerma, in order to determine the energy and angular response. The response R of a measuring instrument is the quotient of the indication M of the instrument and the conventional true value determined by the standard. To obtain the reference values of the ambient dose equivalent, the air kerma to the ambient dose equivalent conversion coefficients (h_k) were used [6].

The dose rate dependence test has been performed in gamma-ray fields of radioisotopes ^{60}Co (S-Co, mean energy 1.25 MeV) and ^{137}Cs (S-Cs, photon energy of 662 keV). The ambient dose equivalent rate ranged from 20 μSv/h to 3 mSv/h for both radiation qualities. This test was performed on a tube with no energy compensation filters and with lead filters of varying thicknesses (90 μm, 120 μm and 160 μm). The thin lead layers were inserted in-between the G-M tube and the polyamide cover.

The energy response was determined for the 33 keV to 1.25 MeV energy range. Apart from the mentioned radiation qualities, narrow-beam X-ray radiation qualities (abbreviated as N-series) have been used, established according to international standards [7]. The list of the used radiation qualities and the corresponding air kerma to the

Nikola Kržanović is with the School of Electrical Engineering, University of Belgrade, 73 Bulevar kralja Aleksandra, 11020 Belgrade, Serbia; Vinča Institute of Nuclear Sciences, Department of Radiation and Environmental Protection, 12-14 Mike Petrovića Alasa, 11351 Vinča, Belgrade, Serbia (e-mail: nikolakrzanovic@yahoo.com).

Filip Haralambos Apostolakopoulos is with the School of Electrical Engineering, University of Belgrade, 73 Bulevar kralja Aleksandra, 11020 Belgrade, Serbia (e-mail: apostolfilip@gmail.com).

Miloš Đaletić is with the Vinča Institute of Nuclear Sciences, Department of Radiation and Environmental Protection, University of Belgrade, 12-14 Mike Petrovića Alasa, 11351 Vinča, Belgrade, Serbia (e-mail: djaletic@vin.bg.ac.rs).

Miloš Živanović is with the Vinča Institute of Nuclear Sciences, Department of Radiation and Environmental Protection, University of Belgrade, 12-14 Mike Petrovića Alasa, 11351 Vinča, Belgrade, Serbia (e-mail: milosz@vin.bg.ac.rs).

Koviljka Stanković is with the School of Electrical Engineering, University of Belgrade, 73 Bulevar kralja Aleksandra, 11020 Belgrade, Serbia (e-mail: kstankovic@etf.bg.ac.rs).

ambient dose equivalent conversion coefficients is presented in Table I. The reference dose rate value was 500 µSv/h for all the radiation qualities. The measured values for each radiation quality were normalized to the S-Cs radiation quality value.

The angular response test was performed for the N-40, N-200 and the S-Cs radiation qualities. The angle range was from 0° to 120°, with an increment of 15°. The reference value of the angular response was measured at the 0° angle of incidence. The symmetry of the angular response was also tested, by measuring the response at the -45°, -90° and the 180° angles of incidence, where the chosen reference value was measured at 0° as well.

TABLE I
THE USED RADIATION QUALITIES, ALONG WITH THEIR MEAN PHOTON ENERGIES AND THE AIR KERMA TO THE AMBIENT DOSE EQUIVALENT CONVERSION FACTORS [3, 4].

Radiation quality	E [keV]	h_k [Sv/Gy]
N-40	33	1.18
N-60	48	1.59
N-80	65	1.73
N-100	83	1.71
N-120	100	1.64
N-200	164	1.46
S-Cs	662	1.20
S-Co	1250	1.16

Fig. 1. The pancake G-M tube-based probe in the S-Co and S-Cs irradiation unit in the Secondary Standard Dosimetry Laboratory (SSDL) in the Vinča Institute of Nuclear Sciences.

III. RESULTS AND DISCUSSION

The results of the type tests of the G-M tube-based survey meter are displayed in Figs. 2-6. The linearity test results are presented in Fig. 2. For the low dose rates, the tube is linear, while for the high dose rates, the influence of the G-M tube dead time is considerable, resulting in a nonlinear dose rate dependence. The deviation of the S-Co count rate from the S-Cs count rate is calculated by using the following equation:

$$\delta[\%] = \frac{M(^{60}\mathrm{Co}) - M(^{137}\mathrm{Cs})}{M(^{137}\mathrm{Cs})}, \qquad (1)$$

where quantity M represents the count rate of the G-M tube.

The δ value results are displayed in Fig. 3. For the higher ambient dose equivalent rates, the δ value is in the range of ±5% for all the lead thicknesses, while it increases as the dose rate decreases, reaching +30.1% when no compensation filter was used, and -16.8% for the 0.12 mm lead filter. The recorded δ values also indicate that adding lead filters reduces the deviation of the instrument for the S-Co radiation quality, compared to the S-Cs radiation quality for lower dose rates, i.e. the energy compensation has been achieved for this high-energy radiation quality. With the increase of the ambient dose equivalent rate, the δ values converge.

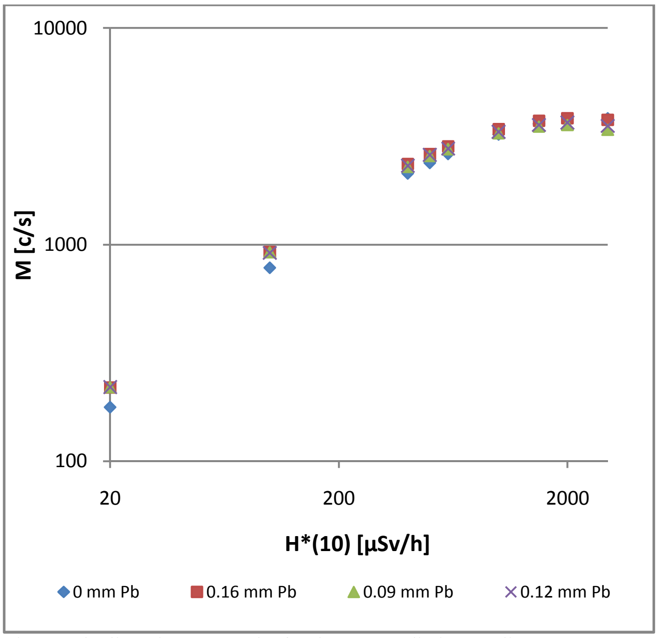

Fig. 2. The linearity test results for the S-Cs radiation quality.

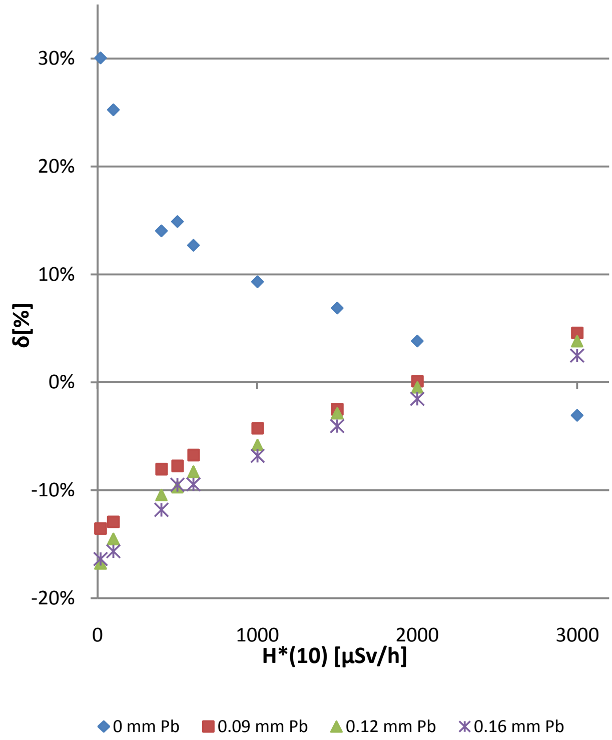

Fig. 3. The δ value of the S-Co to the S-Cs radiation quality

Regarding the energy compensation for the low-energy radiation qualities, the relative energy response $R(E)$ was determined by normalizing the response of all the radiation qualities to the S-Cs response. The energy dependence results of the G-M tube, for the low-energy X-ray radiation qualities, are given in Fig. 4. The G-M probe displayed in Fig. 1, with no lead compensation layers, has exhibited a flat energy response for low energies, ranging from 0.9 to 1.1. The lead compensation layers have resulted in a minor improvement of $R(E)$ for the N-80, N-100, N-120 and the N-200 radiation qualities, while the response for the N-40 and N-60 radiation qualities has significantly declined.

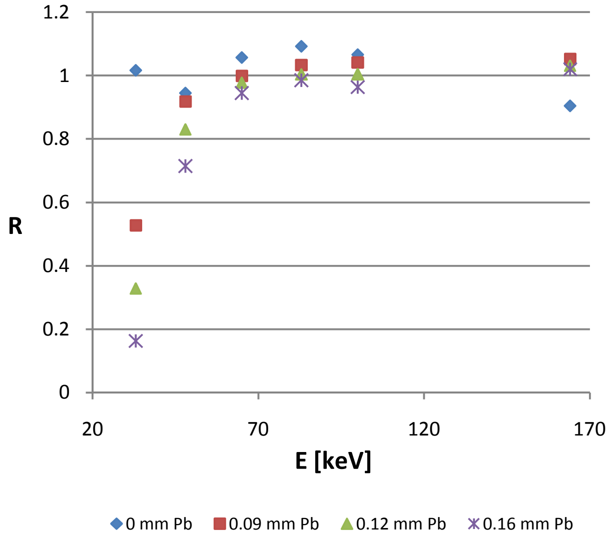

Fig. 4. The relative energy response of the G-M tube, normalized to the S-Cs radiation quality.

The angular dependence test results are presented in terms of the angular response $R(\Omega)$ in Fig. 5. For the high-energy radiation qualities (N-200 and S-Cs), the angular response shows a slow decline with the increase of the angle of incidence, while a steep drop in the angular response is noticeable for the low-energy N-40 radiation quality. For all the radiation qualities, $R(\Omega)$ had a deviation up to ±20% for the angles of incidence up to 75°.

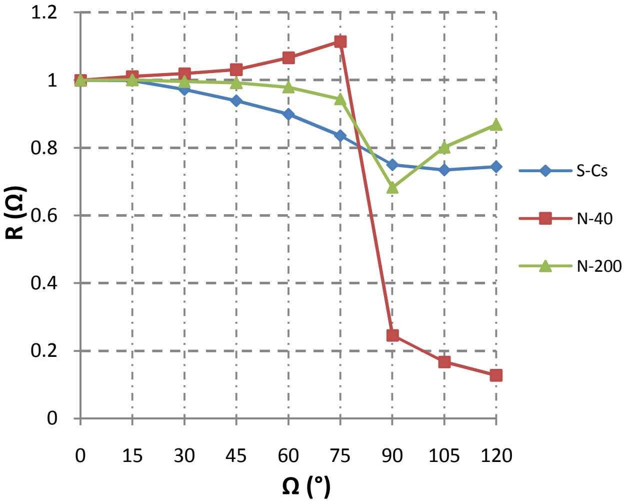

Fig. 5. The relative angular response of the G-M tube, normalized to the 0° angle of incidence for the used radiation qualities, in the angle range from 0° to 120°.

In Fig. 6, the symmetry test results of the angular response are presented. For the angles of ±45° and ±90°, the response differences are negligible (in the range of ±3% for all the used radiation qualities). However, by comparing the angles of 0° and 180°, an under-response of -90%, -8% and -18% has been measured, for the N-40, N-200 and the S-Cs radiation qualities, respectively. The cause of this decline in the angular response is due to the geometry of the pancake detector.

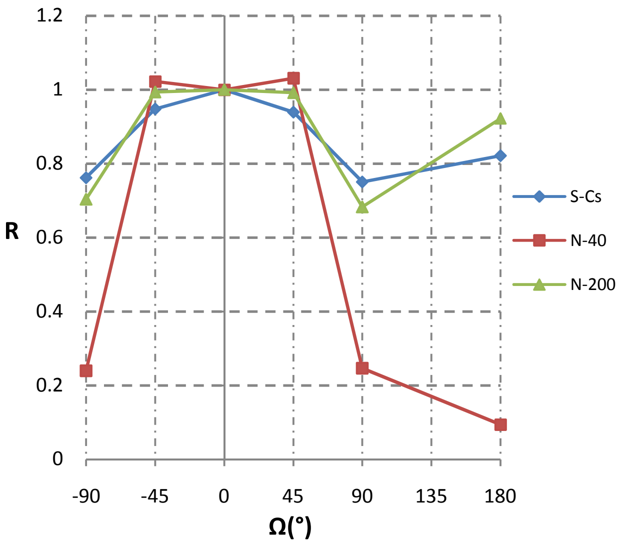

Fig. 6. The relative angular response of the G-M tube, normalized to the 0° angle of incidence for the ±45°, ±90° and the 180° angles of incidence, for the used radiation qualities.

IV. CONCLUSION

G-M tube-based survey meters are a part of basic dosimetry equipment for ambient monitoring. Hence, a pancake G-M detector was type tested in order to check its performance in photon ionizing radiation fields for various dose rates, energies and angles of incidence. The S1 probe (with the SI-8B G-M tube) has a flat energy response, relative to the S-Cs radiation quality, with no energy compensation filters. The addition of different thicknesses of lead filters for energy compensation resulted in a minor improvement for higher photon energies. On the contrary, in the low-energy X-ray range, a major decline in response has been noticed. The dose rate dependence was tested for different energy compensation layers, which also resulted in large deviations at low dose rates. The angular response was symmetric, excluding the major deviation for the angle of 180° in reference to 0°. A similar type testing procedure will be performed for a cylindrical G-M tube-based ambient dosimeter in the future. Apart from the wrapping of the uncompensated tube with lead filters of various thicknesses, slits of different widths in the lead will be incorporated.

ACKNOWLEDGMENT

The paper is supported by the Ministry of Education, Science and Technological Development of Serbia under contracts 171007 and 43009.

REFERENCES

[1] G.F. Knoll, “Miscellaneous Detector Types”, in *Radiation Detection and Measurement,* 3rd ed., John Wiley & Sons Inc., 2010

[2] S. Ceklic, D. Arandjic, M. Zivanovic, O. Ciraj-Bjelac, Dj. Lazarevic, "Performance of Radiation Survey Meters in X- and gamma radiation fields" Radiation Protection Dosimetry Vol. 162, No. 1-2, pp. 139-143; 2014.

[3] M. Djaletic, M. Zivanovic, K. Karadzic, Dj. Lazarevic, "Measurement of Energy Dependence of the Energy Compensated and Uncompensated Geiger Muller Tubes", Proc. XXVIII DZZSCG, Vršac, Serbia, 2015 (M. Đaletić, M. Živanović, K. Karadžić, Đ. Lazarević, "Ispitivanje energetske zavisnosti energetski nekompenzovanih i kompenzovanih Gajger-Milerovih cevi, XXVIII simpozi~~v~~jum Društva za zaštitu od zračenja Srbije i Crne Gore, Vršac, Srbija, 2015).

[4] *Safety Report Series No. 16 Calibration of Radiation Protection Monitoring Instruments*, International Atomic Energy Agency, Vienna, 2000.

[5] M. Djaletic, Dj. Lazarevic, "Digital Radiation Survey Meter DMRZ-M15", Proc. XXVIII DZZSCG, Vršac, Serbia, 2015 (M. Đaletić, Đ. Lazarević, "Digitalni merač radioaktivnog zračenja DMRZ-M15", XXVIII simpozijum Društva za zaštitu od zračenja Srbije i Crne Gore, Vršac, Srbija, 2015).

[6] *X and gamma reference radiation for calibrating dosemeters and doserate meters and for determining their response as a function of photon energy – Part 3: Calibration of area and personal dosimeters and the measurement of their response as a function of energy and angle of incidence*, ISO 4037-3, 1999.

[7] *X and gamma reference radiation for calibrating dosimeters and doserate meters and for determining their response as a function of photon energy - Part 1: Radiation characteristics and production methods,* ISO 4037-1, 1996.