

THE ACTIVITIES OF THE RADIATION PROTECTION MEASUREMENTS LABORATORY

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The Radiation Protection Measurements Laboratory (RPML) of the Institute of Atomic Energy is responsible for handling all the problems concerning radiation protection at the Institute and in the vicinity of Nuclear Centre (NC) Świerk and National Repository of Radioactive Waste (NRRW) at Różan.

The main tasks of RPML are:

- Radiation monitoring of the Świerk and Różan sites.
- Surveillance of radiation safety.
- Radioactive waste control.
- Radiation protection in emergency conditions.
- Improvement of radiation protection measurements and methods.
- Calibration of radiation protection monitoring instruments.
- Personal dosimetry.
- Sewage and drainage water activity measurements.
- Environmental radiation monitoring.

The following laboratories and facilities are available in the Laboratory:

- Mixed radiation fields laboratory (MRF).
- Whole body counter (WBC).
- Counter of thyroid activity (TC).
- Calibration laboratory with standard radiation sources (Calibration Division, CD).
- Environmental measurements laboratory.
- Radiochemical laboratory (RL).

On December 31, 2007 the Laboratory employed 19 graduate staff members and 9 non graduated.

In 2007 RPML continued successfully the activities concerning improvement of measurement procedures in two main domains of Laboratory accredited by the Polish Centre for Accreditation (PCA):

- The determination of internal body contamination (whole body, thyroid and excretions) – accreditation No. AB 567.
- Calibration of dosimetric instruments (gamma, neutron and surface contamination monitors) – accreditation No. AP 070.

The improved versions of Quality Manual as well as all the procedures were completed and some technical and organizational activities undertaken, especially concerning validation, traceability and estimation of uncertainties of the methods used.

Several internal quality audits were performed, opinions collected from experts, and in March 2007 the yearly PCA audit took place for AB 567 and in September 2007 for AP 070, both with positive results.

The research activities of Laboratory are described on the next pages of the Annual Report.

The technical activities of the RPML in 2007:

- Whole body (WBC), thyroid (TC) and “in vitro” (RL) monitoring were carried out for radiation workers from NC Świerk and external customers: 392 WBC, 161 TC and 170 RL measurements were made in 2007 (Tables 1- 3). The collected results of measurements of ¹³⁷Cs internal activity in people, from 1986 and 2007, are presented in Fig. 1.
- Regular monitoring of radiation workers was carried out with TLD dose meters. Values of individual dose equivalents registered are below the annual dose limit.
- The environmental monitoring within or outside the NC and NRRW boundaries included the measurements of direct or stray radiation due to the operation of reactors, accelerators, etc. and the measurement of radioactivity in samples of air, rivers’ and underground water, soil, sediment, mud and vegetation. In 2007 more than 1000 environmental samples were measured (Tables 4-6).

Table 1. Whole body counter measurements.

	Dose	measurements	persons
< 1% E _w		392	282*
> 1% E _w		-	-
Total		392	282

* - 37 persons were contaminated by iodine 131 including 19 persons measured by Thyroid Counter and calculated the committed dose equivalent.

E_w – limit of annual effective dose.

Table 2. Thyroid counter measurements.

	Measurements	Persons	Dose	
			< 1% E _w	> 1% E _w
Total	161	32	24	8

Table 3. Measurements of biological probes.

	Measure- ments	Persons	<1% E _w	>1% E _w
Total α-activity	2	2	2	-
Total β-activity	126	103	103	-
Activity of P-32	9	6	6	-
Activity of S-35	7	5	5	-
Activity of tritium (HTO)	23	19	19	-
Activity of Sr-90	3	3	3	-

The results of performed measurements indicate that there is no contamination of the environment and the human population in the vicinity of the NC and NRRW.

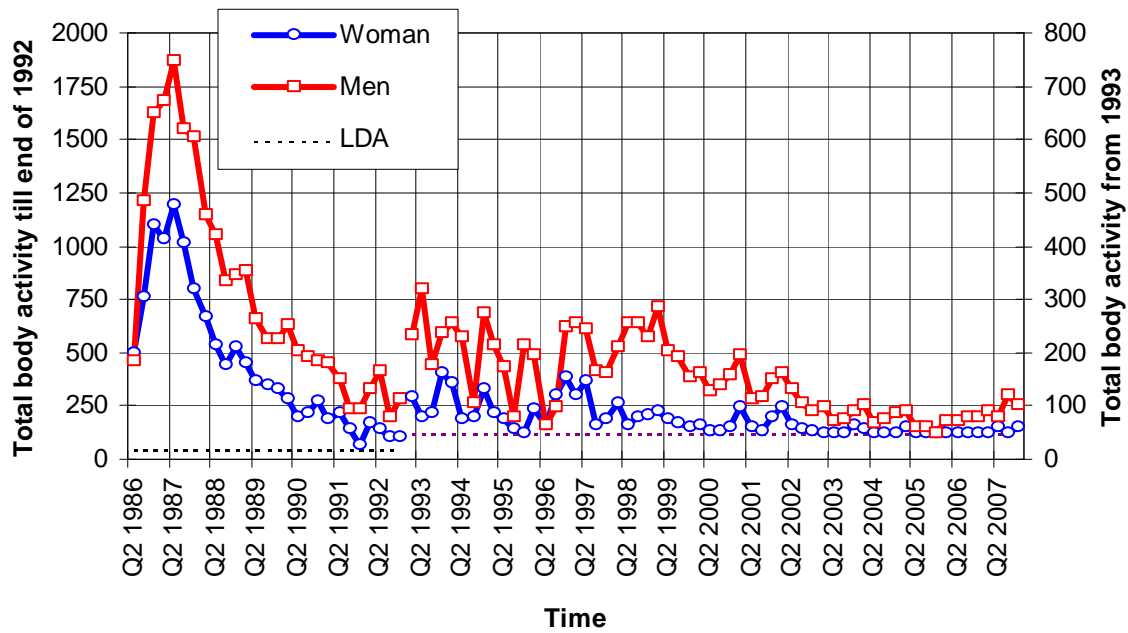


Fig. 1. The activity of ¹³⁷Cs in people after the Chernobyl accident (mean per person).

Table 4. Total activity of β-radiation of water samples from inside and outside of the – NRRW Różan in 2007.

Type of probe and place of collection	Number of probe	Average value 2006	Concentration [Bq/dm ³]		
			min 2007	max 2007	medium 2007
Ground waters	10p	0,09	< 0,08	0,15	0,10
Inside of NRRW Różan	11p	0,16	< 0,08	0,20	0,13
	12p	0,29	< 0,08	0,29	0,18
	17p	0,12	< 0,08	0,34	0,16
	18p	< 0,08	< 0,08	0,10	0,09
	131	0,54	0,60	0,74	0,66
Tap water (inside NRRW)	F-R	0,11	< 0,08	0,13	0,10

Table 5. Activity of tritium (HTO) in water samples from inside and outside of the NRRW Różan in 2007.

Type of probe and place of collection	Number of probe	Average value 2006	Concentration of trytium [Bq/dm ³]			
			I Q 2007	II Q 2007	III Q 2007	IV Q 2007
Ground waters	10p	< 4,0	< 4,0	< 4,0	19	7,0
Inside of NRRW Różan	11p	310	240	250	320	320
	12p	3700	2400	1600	3000	1400
	17p	680	680	580	660	620
	18p	< 4,0	< 4,0	10	15	5,0
	130p	180	220	220	21	240
	131p	16000	16000	14000	16000	18000
	132p	43	< 4,0	8,0	260	380
Ground waters Outside of NRRW RÓŻAN	F-1	24	10	36	42	27
Tap water (inside NRRW)	F-R	< 4,0	< 4,0	< 4,0	26	< 4,0

Table 6. Activity of environmental samples (soil and grass) from inside and outside the NRRW Różan in 2007 [Bq/kg].

Type of probe and place of collection	Place	K-40	Cs-137	Ac-228 (Th-232)	Ra-226 (U-238)
Soil - II quarter					
<i>inside</i>	G 706	350	6,4	11	10
	707	570	450	18	12
<i>outside</i>	701	640	34	22	20
	703	470	58	17	10
Soil - III quarter					
<i>inside</i>	G 706	400	50	17	20
	707	510	400	11	15
<i>outside</i>	701	640	68	21	22
	703	350	3,2	10	15
Grass - II quarter					
<i>inside</i>	R 706	800	10	< 7,0	< 3,0
	R 707	790	5,5	< 7,0	< 3,0
<i>outside</i>	R 701	920	2,0	< 7,0	< 3,0
	R 703	950	< 1,0	< 7,0	< 3,0
Grass - III quarter					
<i>inside</i>	R 706	1200	< 1,0	< 7,0	< 3,0
	R 707	1100	12	< 7,0	< 3,0
<i>outside</i>	R 701	430	3,2	< 7,0	< 3,0
	R 703	920	1,5	< 7,0	< 3,0

The Calibration Laboratory is maintaining and using the standard fields of neutron and gamma radiation. The ^{137}Cs is the main calibration source of gamma radiation. Standard neutron fields, traceable to primary standard laboratory National Physical Laboratory (NPL, Great Britain) were established at the Institute of Atomic Energy (IAE) ten years ago. The fields are formed by calibrated sources of ^{252}Cf and $^{241}\text{Am-Be}$. For routine use, there is also $^{239}\text{Pu-Be}$ neutron source available calibrated against standard source of $^{241}\text{Am-Be}$. Additionally, spherical filters made of iron or paraffin can be applied for modification of the neutron spectrum and gamma component of absorbed dose.

The neutron sources are used mostly for research purposes. However, since they form the only standard neutron fields in Poland, they are employed for calibration of neutron dose meters used in radiation protection. Maintenance of the fields includes periodic assessment of the dosimetric parameters, development of measuring methods and international interlaboratory comparisons. The parameters of neutron fields in the IAE calibration hall have been periodically checked. In 2006 the Laboratory participated in International Neutron Intercomparison EUROMET Project No 608. The preliminary results of the comparison were disclosed in 2007.

In the field of ^{137}Cs gamma source the periodical check measurements were performed applying specially designed and constructed reference instrument. The kerma rate in gamma radiation fields of new gamma irradiator were measured by Central Office of Measures. The complementary tests with Laboratory own reference instrument, have started.

Calibration Laboratory performs calibrations of surface contamination monitors, using reference sources of beta and alpha radiation. In 2007 a new standard source ^{36}Cl for contamination monitors was introduced for routine use.

Total number of monitors calibrated in 2007 was:

- Surface contamination monitors - 107
- Gamma dose and dose rate monitors - 150
- Neutron dose equivalent monitors - 7

In 2007 the staff of CD performed the periodical tests of dosimetric monitoring system of MARIA reactor as well as the calibration of data lines of the system with the detectors.

The calibration of radiation monitors in liquid radioactive waste storage tanks of Radioactive Waste Management Plant was performed as well as the calibration of radiation monitoring personal gate.

DETERMINATION OF INITIAL RECOMBINATION OF IONS CREATED IN QUASI-PULSED RADIATION FIELDS

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There are two main recombination processes influencing the ion collection efficiency in high pressure ionization chambers – initial recombination and volume recombination.

Initial recombination occurs between oppositely charged ions from the same track of a charged particle. It dominates at gas densities of several kg/m³, electrical field strength above 1 kV/m and the absorbed dose rate in the gas below ca. 1 Gy/h.

Volume recombination occurs between ions from different tracks formed by ionizing particles. It depends on the measured current, i , hence on the absorbed dose rate in the gas cavity. It is independent neither of LET, ionization particle energy nor of other parameters describing the radiation quality. This kind of recombination is a dominant process of ion recombination at high dose rates, in ionization chambers with large distance between electrodes and at low gas density. The chambers with smaller distance between electrodes can operate at higher dose rates, or at lower voltages.

Initial recombination occurs in very short time after formation of the charged particle track, until the ions diffuse to the distance of few hundreds nanometers. The volume recombination is present all the time of ion collection in the chamber. The initial and volume recombination are the consecutive processes, i.e. the ions that recombine through volume recombination are those which have avoided the initial recombination.

The ion collection efficiency in an ionization chamber can be expressed as the product:

$$f = f_i \cdot f_v \cdot f_k$$

where f_i and f_v are ion collection efficiencies of local and volume recombination, respectively, f_k is the correction factor for other effects including back diffusion of ions, radiation background, leakage current, and temperature effects.

For steady radiation and given polarizing voltage U , the ion collection efficiency in the volume recombination process, f_{vs} , can be expressed as [2]:

$$f_{vs} = \frac{1}{1 + a_v i / U^2}$$

For pulse radiation, the ion collection efficiency f_{vp} , can be approximated by similar formula:

$$f_{vp} = \frac{1}{1 + b_v i / U}$$

Both coefficients, a_v and b_v , depend on the distance between electrodes in the chamber and the gas parameters. For given ionization chamber, a_v and b_v are constant. The coefficient a_v can be determined from the measurements of ion collection efficiency at different dose rates in a steady radiation field [3]. Similar procedure can be performed in order to determine the constant b_v in a pulse radiation field.

In the case of quasi-pulsed fields when the ion collection time and the pulse repetition time are of the same order of magnitude or when both the steady and the pulse components are present none of the above equations is correct.

In our approach [4], we assume that the ion collection efficiency in the volume recombination process, has the form

$$f_v = \frac{1}{1 + i / F(U)}$$

where $F(U)$ is an unknown function of the voltage U .

Then, the ion collection efficiency $f(U)$ should be determined for two different dose rates of investigated radiation, without changing its time structure. The dose rates should grant the negligible volume recombination at highest voltage applied to the chamber. Combining the first and the last of the above equations, one can get two equations for two values of i , with two parameters – F and f_i to be calculated, for each voltage U . No detailed information is needed about the time structure of radiation.

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- [3] M.A. Gryziński et al., *Nukleonika*, **52**(1) 7 (2007)
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NEUTRON-TO-GAMMA SENSITIVITY RATIO OF THE RECOMBINATION CHAMBER AS A FUNCTION OF NEUTRON ENERGY

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Relative neutron sensitivity of the REM-2 chamber (versus reference gamma radiation) was determined from the measurements of saturation current in almost monoenergetic neutron fields with energies ranging from 75 keV to 19 MeV. The measurements were performed in the low-scatter environment of the Physikalisch Technische Bundesanstalt (PTB, Braunschweig, Germany) accelerator facility [1]. A De Pangher precision long counter and a ^3He detector served as neutron monitors. In addition, the beam charge collected on the target was continuously monitored.

The REM-2 chamber was positioned at a distance of 2.5 m from the target. The reading of the chamber was normalized to the beam charge.

The photon dose fraction of the mixed neutron/photon fields was determined with a Geiger-Müller (GM) counter (type ZP1100). The photon contribution to the absorbed dose was below 2% for all neutron fields with nominal energies greater than 0.6 MeV.

The measurements in high-energy neutron fields were performed at CERF facility in CERN. The beam, of 120 GeV/c positively charged particles (protons and pions extracted from the SPS accelerator) was directed onto a copper target. The target was placed either in the position under a 40 cm thick iron roof shield (called iron position) or under an 80 cm thick concrete roof shield (called concrete position). The beam was shielded from the side by a concrete wall with the thickness of 80 cm for the concrete position and of 160 cm for the iron position. The time characteristic of the field revealed the pulse structure of the beam with the duration time of 2 s and repetition time of 14.4 s. Beam intensity was monitored with a Precision Ionization Chamber (PIC) in the beam line located at the end of the beam pipe upstream of the target positions. The reference values of $H^*(10)$ are based on calculations and evaluated results of the intercomparisons [2].

Measurements were performed also in frame of the EURADOS benchmark experiment at Gesellschaft für Schwerionenforschung (GSI, Darmstadt, Germany). Beam of ^{12}C ions with a specific energy of 400 MeV/u and intensity of $2 \cdot 10^9$ ions per spill was delivered by the heavy-ion synchrotron SIS-18 to the experimental area at Cave A. The measurement position, marked as OC-10 [3], was in forward direction to the target position, behind a 160 cm thick concrete shield. The preliminary $H^*(10)$ values, determined with the Bonner sphere spectrometer NEMUS, by PTB group, were used here as the reference values.

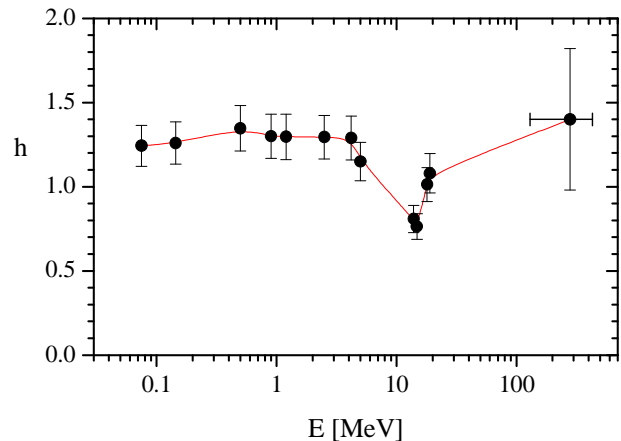


Fig. 1. Dependence of the relative neutron sensitivity to $D^*(10)$ on neutron energy, for REM-2 chamber.

We found [4] that the REM-2 chamber calibrated with the ^{137}Cs source, overestimates the $D^*(10)$ values for neutrons of 0.05-4 MeV and in high energy region (Fig. 1). The effect at lower energies is due to higher content of hydrogen in the gas in the chamber than it is in tissue. The influence of the gas composition becomes less important at higher energies and the overestimation is caused mainly by higher contents of carbon and lower content of oxygen in tissue equivalent material, compared to tissue.

At the energies around 14 MeV, there is a narrow minimum in the relative neutron sensitivity of the chamber. The lowest value of $h = 0.76$ was recorded for 14.8 MeV neutrons but the range of neutron energies where h is considerably below 1 is narrow and the influence of the region on the results of the measurements in high energy radiation fields is usually very small or negligible.

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MONTE CARLO CALCULATION OF NaI DETECTOR FOR IODINE ^{131}I IN THYROID

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The aim of our work was to calculate the iodine ^{131}I radiation spectrum registered by NaI(Tl) detector during measurement of iodine ^{131}I source immersed in the water thyroid phantom.

The calculations were carried out for the thyroid phantom used in Radiation Protection Measurements Laboratory for thyroid counter calibration. The thyroid location inside the phantom can be altered in vertical and horizontal plane [1]. The results of the ^{131}I radiation spectrum simulation can serve as an assessment of the implementation of changes into the testing equipment.

Our calculations were performed with the Monte Carlo "Penelope" code using the appropriate modification of "Penmain" program [2]. The modelled detector consists of cylindrical scintillator plate (40 mm diameter, 25 mm height) contained within 1 mm thick aluminium sheath (46 mm diameter, 32 mm height). The space between the scintillator and the wall is filled with Al_2O_3 powder. Detector is sheltered with the cone shaped lead collimator. The spherical ^{131}I source was placed in cylinder which was modelled as tissue and water. The results of measurements of iodine source in the water thyroid phantom and in the human neck should be comparable.

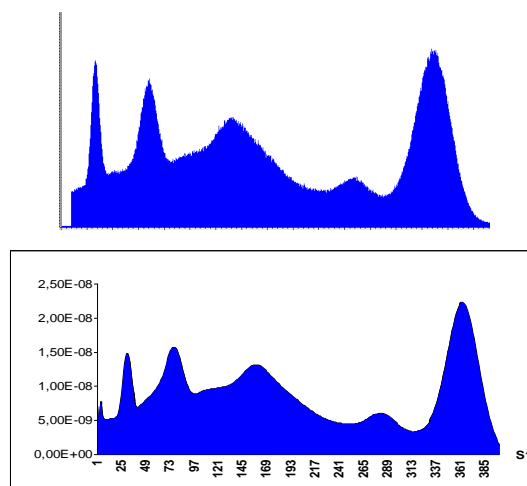


Fig. 1. The iodine ^{131}I spectrum for thyroid depth 23 mm – measured (upper) and calculated (lower).

The calculated and measured radiation spectra for 23 mm thyroid depth are similar except the height of the 30 keV energy peak (Fig. 1). Since this part of spectrum is not used in determination of the iodine activity, the difference is not of practical importance.

The method for calibration of the thyroid counter with ^{131}I used in Radiation Protection Measurements Laboratory takes into account the position of the thyroid inside human neck. The thyroid depth is determined using parameter S defined as the ratio of the 364 keV counts and number of counts in the spectrum region of Compton scattering photons. This region is 100-150 keV (S_1) or 110-140 keV (S_2). The results of the calibration process are two curves: values of the parameter S versus the thyroid depth and values of detection efficiency versus parameter S [1].

The Monte Carlo calculations were carried out for six different values of thyroid depth. The calculated S_1 and S_2 parameters agree to those determined experimentally (Fig. 2).

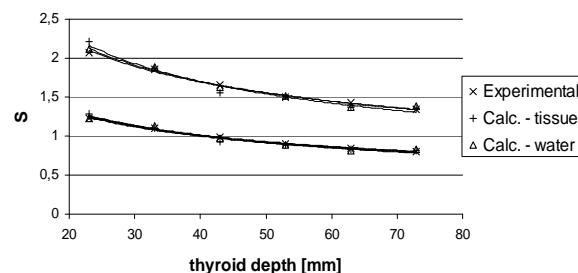


Fig. 2. The values of parameter S_1 (lower curve) and S_2 (upper curve) versus thyroid depth determined from measurements and calculations results.

Our results indicate that the Monte Carlo model can be used for pre-calibration research and the water thyroid phantom is a good model for the gamma ray absorption and scattering in human neck.

References

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RELATIVE NEUTRON SENSITIVITY OF IONIZATION CHAMBER FILLED WITH HYDROCARBON GASES

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Neutron sensitivity of the tissue-equivalent ionization chamber is lower than its sensitivity to gamma radiation. In order to increase the neutron sensitivity, the chamber is filled with a gas mixture containing more hydrogen than the soft tissue. The hydrocarbon gases are suitable for this goal. It is preferable if the ionization chambers, especially the recombination chambers for measurements in mixed radiation fields, have similar sensitivity to gamma and neutron radiation, i.e. the relative neutron sensitivity, h_n , is close to unity. The following definition is used [1]:

$$H_N = A_N / A_C$$

where $A_n = i_n(U_S) / \dot{D}_n$ is the sensitivity of the chamber to neutrons with spectrum considered; $\dot{D} \equiv D^*(10)$ is the ambient absorbed dose rate at the point of measurement; and $A_C = i_C(U_S) / \dot{D}_C$ is the sensitivity to the reference gamma radiation (^{137}Cs source). $i_n(U_S)$ and $i_C(U_S)$ are ionization currents in neutron radiation field and in the reference gamma radiation field measured at the voltage U_S respectively.

The value of relative sensitivity h_n is necessary when the chamber is used for the determination of the dose components in mixed (neutron + gamma) radiation field, using the twin-chambers techniques. The second chamber is usually a hydrogen-free chamber with low relative sensitivity to neutrons. The dependence of h_n on gas density was determined [1] using reference radiation fields of ^{137}Cs and $^{239}\text{Pu-Be}$ sources and subtracting the earlier known contribution of gamma radiation from the Pu-Be source.

The recombination chamber of REM-2 type with tissue equivalent electrodes was used in the studies. The chamber of $\sim 1800 \text{ cm}^3$ volume and the distance $d = 7$ mm between electrodes was employed. The measurements were performed with the chamber filled with methane, ethane, ethylene or propane up to the pressure of 1.8 MPa. The results are presented in the form of the h_n dependence on gas density instead of gas pressure (Fig. 1).

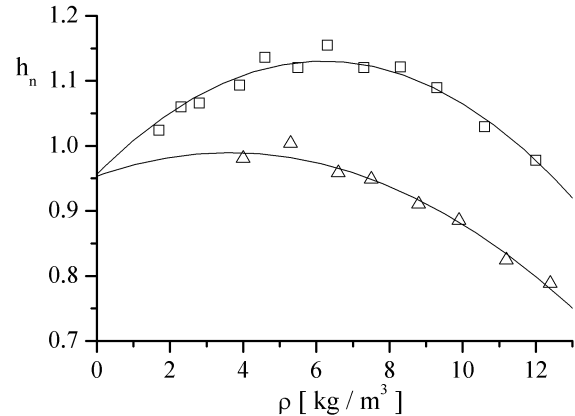


Fig. 1. Dependence of the relative neutron sensitivity (neutrons from $^{238}\text{Pu-Be}$ source) of the REM-2 chamber on filling gas density for methane (the upper curve) and propane (the lower curve).

The gases with high content of hydrogen (CH_4) are most convenient for the high pressure recombination chambers used in mixed radiation fields, because with such gases it is easier to obtain similar sensitivity of the chamber to neutron and gamma radiations. However, it is not possible to have $h_n \approx 1$ for all neutron energies. For the REM-2 chamber filled with methane ($p = 1 \text{ MPa}$, $U_S = 1200 \text{ V}$) the h_n changes from 0.6 up to 1.5 in the neutron energy range from thermal to 200 MeV. However, in the case of the radiation of unknown neutron energy, it is preferable to have h_n less energy dependent, even if the value of h_n considerably differs from unity.

The maximum observed in the dependence of h_n on the gas density (Fig.1) is caused by increasing contribution of directly ionizing particles created in gas to the ionization current, with increasing gas density. The decrease of h_n with increasing density observed at higher gas densities is due to the initial recombination of ions in tracks formed by ionizing particles produced by neutrons.

References

- [1] M.A. Gryziński et al., Nukleonika **52** 7 (2007)

RELATIVE LOCAL IONIZATION DENSITY – CORRELATIONS WITH MICRODOSIMETRIC PARAMETERS

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Local recombination of ions is the recombination which occurs within a column or group of ions created by one charged particle. This type of recombination occurs a short time after the primary ionization events, before the ion column spreads out due to the diffusion and ion drift in the electrical field in the detector. The volume recombination may take place afterwards. Local recombination of ions does not depend on the dose rate but it does depend on local ionization density in the track of the charged particle, thus it depends on LET, it can therefore be used for determination of the radiation quality factor. It was shown [1] that the ion collection efficiency, f , of the ionization chamber with the local recombination, defined as the ratio of the ionization current at a given polarizing voltage to the saturation current, can be described by simplified formula:

$$f = \frac{1}{1 + \mu \cdot \frac{1 - f_{Cs}}{f_{Cs}}}$$

where μ is the relative local ion density of the considered charged particles, defined in such a way that $\mu = 1$ for gamma radiation in a reference radiation field of ^{137}Cs under conditions of initial recombination, while ion collection efficiency in this field is f_{Cs} . The f and f_{Cs} have to be determined at the same polarizing voltage.

Although the parameter μ has not clear physical meaning it is measurable quantity defined as:

$$\mu = \frac{1 - f}{f} \cdot \frac{f_{Cs}}{1 - f_{Cs}}$$

The parameter μ is constant for given radiation for the ionization chamber filled with pressurized gas at a definite range of density. Therefore, it is considered as a physical parameter which characterizes the radiation quality.

In different theories of ionization energy deposition, the value of μ can be used as approximations of the following quantities [2]:

1. Ratio of the linear ionization density v , of the considered ionizing particles to the mean linear ionization density of the standard gamma radiation v_{Cs} :

$$\mu = \frac{v}{v_{Cs}}$$

The equation can be used at $v \geq v_{Cs} \approx 100$ ion pairs/ μm H_2O .

2. Ratio of the mean lineal energies:

$$\mu = \frac{\bar{y}_d}{(\bar{y}_d)_{Cs}}$$

The mean chord of the site, d , is in this case of about 25 nm, what corresponds to a sphere diameter of about 0.15 μm . The dose mean lineal energy for ^{137}Cs gamma radiation is about 5 keV/ μm .

3. Ratio of the effective restricted LET of the considered particles and the reference radiation:

$$\mu = \frac{\bar{L}_\Delta}{(\bar{L}_\Delta)_{Cs}}$$

with the cut-off $\Delta \approx 500$ eV or $\Delta \approx 70$ nm if the cut-off is expressed in units of length. Effective restricted LET means here the mean value of restricted LET weighted by the transferred energy, taking into account the primary particle and delta electrons with energy $E_\delta > \Delta$, which are considered as the separate particles associated with the primary ones.

4. Ratio of unrestricted LET of the considered particles and of the reference radiation:

$$\mu = L / L_0 \quad \text{for} \quad L \geq L_0 \equiv L_{Cs} = 3.5 \text{ keV}/\mu$$

$$\mu = 0.85 + 0.15 L / L_0 \quad \text{for} \quad L < L_0$$

5. Ratio of the numbers of ion pairs generated in a micro-site with the mass of about 1 fg crossed by a particle track in the radiation fields of the considered and reference radiations:

$$\mu = \frac{v}{v_{Cs}}$$

6. Ratio of the proximity function $T(x)$ for the considered and reference radiations.

$$\mu = \frac{T(x)}{T(x)_{Cs}}$$

at $x = 70$ nm.

The equations given above may yield somewhat different values of μ for the same, well defined radiation but within inaccuracy range of about 10%, which is usually acceptable in radiation protection. In radiation fields of unknown composition, μ can be determined experimentally using a recombination chamber.

References

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RADIATION FIELDS OF GAMMA IRRADIATOR IN CALIBRATION ROOM OF RADIATION PROTECTION MEASUREMENTS LABORATORY

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In calibration hall of Radiation Protection Measurements Laboratory (LPD) a new gamma irradiator [1] for calibration of dosimetric instruments has been installed within a PHARE program PL2002/000-632.07.01. The computer operated irradiator contains ^{137}Cs , ^{60}Co and ^{241}Am sources, recommended by International Standard Organisation (ISO) for calibration of dosimetric instruments [2]. The sources are stored inside the heavy shield container and the pneumatic system is used to transport a source into working position in a collimator. Computer program is applied to choose a source and to establish the mode of irradiation.



Fig. 1. Gamma irradiator.

An extensive work has been performed to determine the dosimetric parameters of the gamma fields produced by irradiator [3]. Standard fields of gamma radiation in LPD are traceable to Central Office of Measures, Poland (GUM). The measurements of air kerma have been performed for sources of ^{137}Cs and ^{60}Co at several distances by the GUM officers, using secondary standard ionisation chamber. According to the GUM certificates, the air kerma rate at distance 1 m on 31 December 2007 was equal to $(29.39 \pm 0.28) \text{ mGy h}^{-1}$ for ^{137}Cs and $(2.834 \pm 0.028) \text{ mGy h}^{-1}$ for ^{60}Co . From the results of the GUM measurements, the tables and graphs of air kerma rate and ambient dose equivalent rate dependence on the distance from the source were constructed. The estimated total uncertainty of the air kerma rate is 1% for ^{137}Cs and $1 \div 2\%$ (depending on the distance) for ^{60}Co .

To determine the gamma field of ^{241}Am , emitting 60 keV gamma rays, two chambers of flat energy dependence, Robotron VAJ with air chamber [4], and ionization chamber KG-2, developed in IAE [5], have been applied. The air kerma rate determined with Robotron chamber at 1 m distance is $(20 \pm 1) \mu\text{Gy h}^{-1}$ (Fig.2). To dependence the air kerma rate on the distance from the source was determined with the KG-2 chamber. The full account of the results is given in [3].

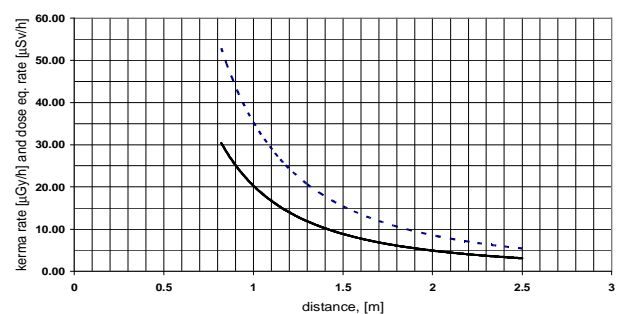


Fig. 2. The dependence of the air kerma rate (solid line) and ambient dose equivalent rate (dotted line) on the distance from ^{241}Am gamma source.

The accuracy of measurements performed with ^{241}Am source is poorer than those with ^{137}Cs and ^{60}Co . The estimated total uncertainty of air kerma rate is 5.2%.

The new gamma irradiator extends the possibility of the gamma calibrations to three energies; with higher dose rates available. The whole set of gamma field sources assembled in the calibration hall of Laboratory, provides an important tool for calibrations of radiation protection instruments and experiments with new devices.

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