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DOSE CHARACTERISTICS OF IHEP REFERENCE NEUTRON FIELDS

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[1] Gosstandart of Russia, NPO "VNIIFTRI".

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Abstract

Alekseev A.G. et al. Dose Characteristics of the IHEP Neutron Reference Fields: IHEP Preprint 93-43. – Protvino, 1993. – p. 15, figs. 3, tables 5, refs.: 13.

The reference radiation fields are used for calibration and obtaining some metrological characteristics of various neutron dosimeters. The dose characteristics investigation of the IHEP reference radiation fields has been carried out using different methods.

The linear energy transfer (LET) spectrometer on the base of tissue-equivalent proportional counter, component remmeter based on ionization chambers with different sensitivity to neutrons and photons, thermoluminescent detectors have been used for the measurements. The calibration of the detectors was fulfilled on the basis of the National primary standard neutron field of dose-equivalent rates.

The measurement data are given for the standard calibration system UKPN-1M, reference calibration fields on the base of $Pu-Be$, ^{252}Cf neutron sources and ^{252}Cf with moderators made of iron and polyethylene.

Аннотация

Алексеев А.Г. и др. Дозовые характеристики нейтронных опорных полей ИФВЭ: Препринт ИФВЭ 93-43. – Протвино, 1993. – 15 с., 3 рис., 5 табл., библиогр.: 13.

Проведено исследование дозовых характеристик нейтронных опорных полей, используемых в ИФВЭ для калибровки, исследования метрологических характеристик различных дозиметров нейтронов.

В измерениях использовались спектрометр линейной передачи энергии на основе тканеэквивалентного пропорционального счетчика; аналоговый компонентный бэрметр на основе набора ионизационных камер, имеющих избирательную чувствительность к фотонам и нейтронам; термолюминесцентные детекторы. Представлены результаты калибровки детекторов на государственном первичном эталоне мощности эквивалентной и поглощенной доз нейтронов. Результаты измерений приведены для опорных полей: стандартизованной установки УКПН-1М, радионуклидных источников $Pu-Be$ и ^{252}Cf и для радионуклидного источника ^{252}Cf, помещенного в стальной и полиэтиленовый замедлители.

INTRODUCTION

The IHEP reference fields (RF) are used for calibration and investigation of a neutron detector energy response. Last time they were used for the intercomparison of personnel neutron dosimeters and area neutron dosimeters.

The experimental investigation of the RF neutron spectra has been carried out by Bonner multisphere spectrometer [1]. This paper describes the dose characteristics of neutron reference fields and their standartization for metrological sertification by National standard of calibration structure (GOST 8.347-79).

1. EXPERIMENTAL PROCEDURE

The nonstandartized detector system of IHEP has been applied to obtain the dose characteristics of the reference fields.

1. The linear energy transfer spectrometer (SLET-03) on the base of low-pressure tissue-equivalent proportional counter (TEPC) [2] is able to determine dose equivalent and absorbed dose of penetrating radiation of any kind. The energy responses have been calculated for neutrons in energy range from 0.01 to 100 MeV [3]. The systematical uncertainty of the neutron dose equivalent measuring may be decreased to 10% by the method of correction.

The charge produced in the cavity and event spectrum are being measured simultaneously. The tissue kerma and dose equivalent are then calculated according to

$$K_T = R_{ph} \cdot q, \tag{1}$$

$$K_n = A \cdot \sum_i N_i \cdot i, \tag{2}$$

$$K_{ph} = K_T - K_n, \tag{3}$$

$$H_n = A \cdot B_n \cdot \sum_i N_i \cdot Q(i), \tag{4}$$

$$H_{ph} = K_{ph} \cdot B_{ph}, \tag{5}$$

$$Q_n = H_n / K_n \cdot B_n, \tag{6}$$

where R_{ph} and A are the calibration factors; q is the charge produced in the cavity; N_i is the total number of events in i-th channel of the pulse-height analyzer.

The $Q(i)$ functions were chosen to simulate the quality factor dependence from linear energy transfer L.

K_{ph} and K_n are the photon and neutron tissue kerma, respectively; K_{ph} and H_n are the photon and neutron dose equivalent, respectively; B_n is the phantom conversion factor from neutron kerma to neutron dose equivalent. B_{ph} is the same value for photons.

The events with pulse height above 6 keV/μm (in units of linear energy y) are included to obtain K_n and H_n values.

The National Norms and Rules of Radiation Protection NPRB-76/87 requires the maximal-in-human-body dose equivalent (MDE) to be used as operational quantity for area monitoring. The International Commission on Radiological Protection (ICRP) introduced new operational quantities such as ambient dose equivalent $H^*(10)$. This operational quantity depends on the form of the phantom simulating the human body. $H^*(10)$ and MED have different energy dependence for neutrons as well as for photons.

The dose equivalent could be obtained by using the phantom factor B_n and kerma. The phantom factor depends on the neutron spectrum and on the type of operational quantity ($H^*(10)$ or MDE). B_n may be in the range from 1.0 to 1.5.

The phantom factor B_n is obtained from the calibration of TEPC in reference field. The values of B_n are different for MDE and $H^*(10)$.

The dependence of B_n on the type of neutron spectrum has not been taken into account in the present measurements.

The factor R_{ph} (in units of tissue kerma, Gy/C) is obtained by calibration with ^{137}Cs photon source. The factor A is derived from the counter sensitive volume size. This factor converts the event pulse height into tissue kerma units. Primarily the factor A can be calculated on the base of geometrical dimensions of the counter and additionally – from the calibration in the neutron reference field. For calibration of the event spectrum in units of linear energy (y) a built-in α-source is used. In the present measurements the conversion phantom factor B_{ph} from kerma to $H^*(10)$ obtained for ^{137}Cs photon radionuclide source is equal to 1.094.

2. The analog component remmeter (ACR) [4] includes three high-pressure (11 torr) ionization chambers (IC) with volume about 1000 cm^3, namely: argon-filled ionization chamber permitting to measure the contribution of photons and charged particles (generally) into the total dose, tissue-equivalent ionization chamber for measurement of photon and neutron kerma, ^3He-filled ionization chamber allowing us to measure the neutron contribution into the total dose equivalent. For minimization of the neutron dose equivalent measurement error the correction method based on additional information about behaviour of the IC neutron response in different neutron spectra is applied.

The following processing is applied after the readings of the chambers q^{Ar}, q^{TE} and q^{He} are measured. The ratios q^{TE}/q^{Ar} and q^{He}/q^{Ar} are calculated. If the ratio q^{He}/q^{Ar} is in the limits:

$$\frac{R_{ph}^{He}}{R_{ph}^{Ar}} < \frac{q^{He}}{q^{Ar}} < \frac{R_n^{He}}{R_n^{Ar}} \tag{7}$$

then photon dose H_{ph}, neutron kerma K_n' and neutron dose K_n' equivalent H_n' could be calculated (K_n', H_n' are original estimations of values) as:

$$H_{ph} = \frac{q^{Ar} - (R_n^{Ar}/R_n^{He}) \cdot q^{He}}{R_{ph}^{Ar}}, \tag{8}$$

$$H_n' = \frac{q^{He} - (R_{ph}^{He}/R_{ph}^{Ar}) \cdot q^{Ar}}{R_h^{He}}, \tag{9}$$

$$K_n' = \frac{q^{TE} \cdot R_{ph}^{Ar} - q^{Ar} \cdot R_{ph}^{TE}}{R_n^{TE} \cdot R_{ph}^{Ar} - R_n^{Ar} \cdot R_{ph}^{TE}}, \tag{10}$$

where R_{ph}^i is the sensitivity of the i-th ionization chamber ($i = TE,\ Ar,\ He$) to photons (C/Sv); R_n^i is the sensitivity of the i-th ionization chamber to neutrons in tissue kerma units (C/Gy); R_h^i is the sensitivity of the i-th ionization chamber to neutrons in dose equivalent units (C/Sv).

If the following relation is true:

$$\frac{q^{TE}}{q^{Ar}} < 1.5 \cdot \frac{R_{ph}^{TE}}{R_{ph}^{Ar}} \tag{11}$$

then correction cannot be applied, i.e.:

$$H_n = H_n'.$$

In case when relation (11) is false, the correction could be introduced as:

$$H_n = H'_n / k(Q'_n),$$

where $Q'_n = H'_n / K'_n$.

The function $k(Q'_n)$ has been calculated using the detector energy responses; the analysis of measurements in various neutron fields has also been involved.

Finally, there are two boundary cases:

1) photon dose is neglected, i.e.:

$$\frac{q^{He}}{q^{Ar}} > R_n^{He} / R_n^{Ar}; \tag{12}$$

2) neutron dose equivalent is neglected, i.e.:

$$\frac{q^{He}}{q^{Ar}} < R_{ph}^{He} / R_{ph}^{Ar}. \tag{13}$$

For the first case we use

$$H_{ph} = 0; \quad H_n = \frac{q^{He}}{R_h^{He}},$$

and for the second case

$$H_{ph} = \frac{q^{Ar}}{R_{ph}^{Ar}}; \quad H_n = 0.$$

3. The linear energy transfer spectrometer of charged particles (SLETCP) is able to determine the absorbed dose of photons and charged particles at high level of neutron radiation. SLETCP detector is a spherical aluminium (2 mm wall thickness) proportional counter. It is filled by argon at pressure of 0.7 torr. The sensitive volume diameter is 10.8 cm. The measurement procedure for SLETCP is analogous to SLET-03.

The total kerma is obtained as:

$$K_T = R_{ph} \cdot q, \tag{14}$$

the photon kerma is given by

$$K_{ph} = K_T - K_n, \tag{15}$$

where K_n is the neutron kerma for argon:

$$K_n = A \cdot \int_{E_o} E \cdot N(E) dE,$$

where $N(E)$ is event distribution; E is the energy absorbed in the detector volume; A is the conversion factor from the pulse height to tissue kerma (Gy/MeV); E_o is the level for separation of the photon events. As for SLET-03, the event pulse height scale is calibrated in energy units by using the α-source.

4. The aluminium-phosphorus glass IKS [5,6] has been used to obtain the photon doses. The IKS-C reader used for IKS-detector readings treatment has metrological certification given by VNIIM.

2. DETECTOR CALIBRATION

The detector calibration in terms of the photon kerma was carried out on the basis of a standard calibration system using ^{137}Cs source with certified uncertainty 4%.

The calibration of the detectors in terms of neutron kerma and in terms of neutron dose equivalent was carried out in the National primary standard neutron field of dose equivalent rate on the base of VNIIFTRI [7].

This standard field is used for the absorbed dose measurements in neutron energy from 0.05 to 14 MeV, and the dose equivalent measurements in neutron energy range from 0.01 to 14 MeV. The National primary standard neutron field consists of the standard calibration system UKPN-1M with the set of ionization chambers, the system on the base of a cylindrical polyethylene proportional counter and the system on the base of Rossi-type spherical tissue-equivalent proportional counter. The set of tissue equivalent phantoms is used for obtained phantom factor B_n. Two types of neutron source were considered: $^{238}Pu-Be$ and ^{252}Cf. The neutron absorbed dose is obtained with 5% systematic uncertainty and with relative standard deviation range 2%. The neutron dose equivalent is measured with 8% uncertainty when using the instruments of the National Standard field.

The calibration factors (R_{ph} and A for TEPC and calibration factors R for ACR) have been obtained in the field. Table 1 shows the results of measuring dosimetric characteristics of the National Standard field by the IHEP systems. The phantom factor B_n for TEPC is equal to 1.20 for $Pu-Be$ and 1.14 for ^{252}Cf. The phantom factor for MED in a plane tissue-equivalent phantom according to the measurements of [7] is equal to 1.17, i.e. coincides with the average one for TEPC.

Table 1. Results of neutron and photon dose equivalent and kerma measurements by TEPC and ACR in the national primary standard neutron fields. The results are normalized by VNIIFTRI data.

	TEPC		ACR	
	$^{238}Pu-Be$	^{252}Cf	$^{238}Pu-Be$	^{252}Cf
K_n, relative units	0.96	1.03	1.	0.80
MED, relative units	0.99	1.02	0.93	0.75
K_{ph}, relative units	0.92	1.03	0.94	1.07

The photon energy responses of TEPC and ACR detectors in energy range from 29 to 114 keV have been investigated on the National secondary standard field of absorbed dose rate (VET 38-4-85, VNIIFTRI). The measurements were fulfilled in wide beam of x-ray radiation. The standartized Robotron 27012 dosimeter was used as a monitor. Table 2 contains the experimental values of photon dose.

Table 2. Results of exposure dose X, field dose or kerma K and ambient dose equivalent measurements by TEPC and ACR. The results are normalized by the monitor readings.

Effective photon energy, keV	TEPC			ACR					
				TE-chamber			Ar-chamber		
	X	K	$H^*(10)$	X	K	$H^*(10)$	X	K	$H^*(10)$
114	1.12	1.12	0.84	0.90	0.91	0.68	3.1	3.1	2.3
64	1.34	1.42	0.92	0.61	0.65	0.42	6.3	6.7	4.3
29	0.93	1.19	1.02	0.21	0.27	0.23	5.6	7.2	6.1

The experimental data in comparison with photon energy responses calculation are represented in fig.1 (in kerma units). The detector composition, detector wall thickness and size of sensitive volume are taken into account in the calculation. The dose overestimation by ACR detectors in photon range from 30 to 100 keV is "payment" for its high absolute sensibility. One can see from fig.1 that the detectors have different energy responses at the photon energy below 200 keV. The detectors with different energy response allow one to estimate the mean energy of photon spectrum.

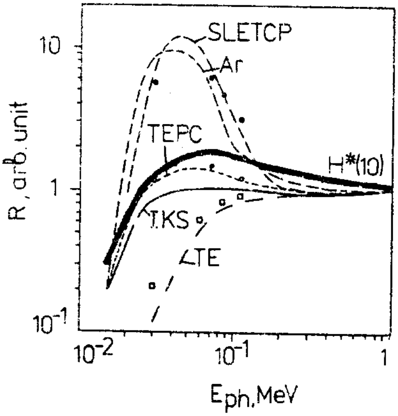

Figure 1. Calculated (curves) and experimental (symbols) data of normalized photon energy responce for TEPC (o), SLETCP, IKS, Ar (•) and TE (□) ionization chambers. For comparison, tissue kerma-to-ambient dose equivalent conversion factors $H^*(10)/K$ are given (thick line).

The experimental data in Table 2 are given by

$$X = \frac{R_{ph,X} \cdot q}{X_o}, \tag{16}$$

$$K = \frac{R_{ph,k} \cdot q}{X_o \cdot C_k}, \tag{17}$$

$$H^*(10) = \frac{R_{ph,h} \cdot q}{X_o \cdot C_h}, \tag{18}$$

where q is the detector reading value (C/s); $R_{ph,X}$ is the dosimeter calibration factor in terms of exposure dose for ^{137}Cs source; $R_{ph,k}$ is the dosimeter calibration factor in terms of tissue kerma for ^{137}Cs source; $R_{ph,h}$ is the dosimeter calibration factor in terms of ambient dose equivalent for ^{137}Cs source; X_o is the exposure dose measured by the monitor; C_k is the conversion factor from the exposure to tissue kerma for effective photon energy; C_h is the conversion factor from the exposure to ambient dose equivalent for effective photon energy.

The energy dependence of $H^*(10)$/K ratio is also given in fig.1. It is clear that TEPC could measure $H^*(10)$ after the corresponding calibration.

3. CALIBRATION RESULTS

Using the calibration coefficients obtained as described above, the dose characteristics have been measured for the following IHEP reference neutron fields:

1. The standard calibration system UKPN-1M. The commercial system UKPN-1M designed by VNIIM has a container with polyethylene collimator with 3% of ^{10}B [8]. The ^{252}Cf and $^{239}Pu-Be$ sources are involved in measurements.

2. Reference fields:
- $^{239}Pu-Be$ (RF 1),
- ^{252}Cf (RF 2),
- ^{252}Cf into 30 cm diameter spherical polyethylene moderator (RF 3),
- ^{252}Cf into 30 cm diameter spherical iron moderator (RF 4).

The irradiation geometry in the field is the same as it was described in papers [1,9].

Tables 3,4 and figures 2,3 reflect the measurement results obtained by various methods. For comparison the VNIIFTRI dose data and the doses obtained from spectra [1] have been included. In Tables 3,4 and in Figures 2,3 the values are normalized by mean data from Table 5. The expert estimations of doses are given in Table 5.

The values in Table 5 are normalized by factor $\varphi = \frac{1}{4\pi R^2} \cdot Y_n$, where R is the distance between the source and detector (cm); Y_n is neutron source flux, 1/s. This normalization allows one to compare the measured doses for various sources with different contribution of secondary radiation.

For TEPC the errors of the neutron measurements are estimated to be less than 8% (for kerma) and less than 9% (for dose equivalent). The photon kerma was obtained with 9% error (except the case of $^{252}Cf + Fe$ field, where it is 60%). For other IHEP systems (ACR, IKS, SLETCP) the uncertainties of photon kerma measured are in the limits of 6-10%.

The value of the source flux with sertified uncertainty of 5% was given by VNIIM. For TEPC the value of 1.17 for the phantom factor B_n was taken. The measurements have been carried out for different types of sources and different sources fluxes. The influence of these source parameters on dose characteristics is considered.

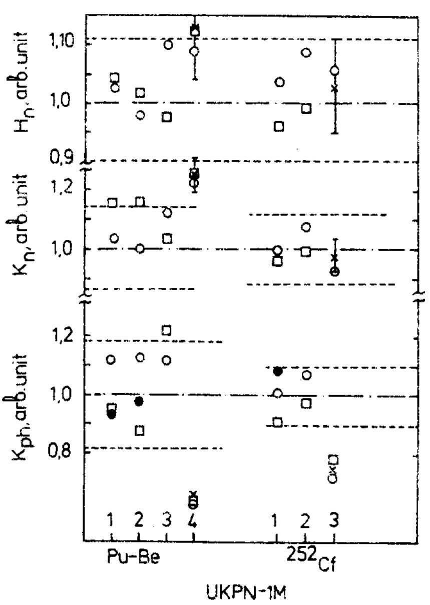

Figure 2. Normalized results of measurement for UKPN with $Pu-Be$ and ^{252}Cf source. H_n (neutron dose equivalent), K_n (neutron tissue kerma), K_{ph} (photon tissue kerma). Key: (o) experimental data of TEPC; (□) experimental data of ACR; (•) experimental data of IKS; (x) data from [7]; (- - -) errors of expert data; (1,2,3,4) number of source.

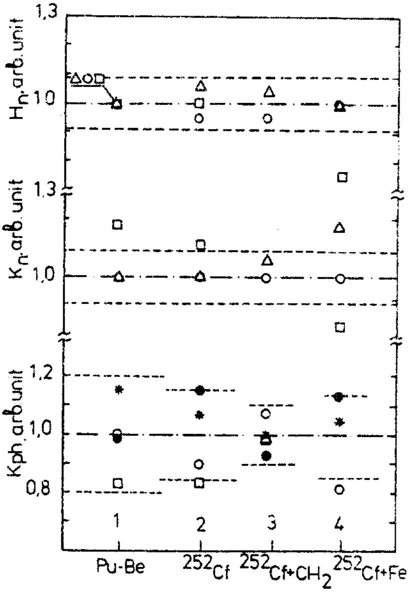

Figure 3. Normalized results of measurement for IHEP reference neutron fields. Key: (o) TEPC data; (□) ACR data; (Δ) values from [1]; (*) SLETCP data; (•) data of IKS; (- - -) errors of expert data.

Table 3. Dose characteristics of some source applied in the UKPN-1M system measured by various methods. Values are normalized by the expert data from Table 5.

Source, detector	Neutron dose equivalent H_n, relative unit	Neutron qual. factor Q_n	Neutron tissue kerma, K_n relative unit	Photon kerma, $\dot{K}_{ph}$, relative unit	Source flux, Y_n , 10^6 n/s
$^{239}Pu - Be$					
TEPC	1.03	7.9	1.04	1.12	53.7
ACR	1.04	-	1.17	0.95	
IKS	-	-	-	0.94	
$^{239}Pu - Be$					
TEPC	0.98	7.9	1.00	1.13	
ACR	1.02	-	1.17	0.88	53.3
IKS	-		-	0.98	
$^{239}Pu - Be$					
TEPC	1.11	7.8	1.14	1.12	2.25
ACR	0.98	-	1.04	1.22	
$^{238}Pu - Be$ (VNIIFTRI)	1.23	7.3	1.37	0.65	48.2
^{252}Cf					
TEPC	1.04	8.5	1.00	1.01	49.2
ACR	0.96	-	0.96	0.91	
IKS	-	-	-	1.09	
^{252}Cf					
TEPC	1.09	8.2	1.08	1.07	1.57
ACR	0.99	-	0.99	0.97	
^{252}Cf (VNIIFTRI)	1.03	8.7	0.98	0.75	4.73

Table 4. Dose characteristics of the IHEP reference fields. Normalization is the same as in Table 3.

Source, detector	Neutron dose equivalent, H_n, relative unit	Neutron quality factor, Q_n, relative unit	Neutron kerma, K_n, relative unit	Photon kerma, K_{ph} relative unit	Source flux, Y_n, 10^6 n/s
RF 1 $^{239}Pu - Be$					
TEPC	1.00	8.2	1.00	1.01	53.3
ACR	1.00	-	1.18	0.83	
[1]	0.99	8.8	0.99	-	
SLETCP	-	-	-	1.17	
IKS	-	-	-	0.98	
RF 2 ^{252}Cf					
TEPC	0.95	8.6	1.00	0.90	49.2
ACR	0.99	-	1.11	0.85	
[1]	1.06	9.7	1.01	-	
SLETCP	-	-	-	1.08	
IKS	-	-	-	1.15	
RF 3 $^{252}Cf + CH_2$					
TEPC	0.95	9.1	1.00	1.07	49.2
ACR	1.63	-	0.51	0.99	
[1]	1.04	8.9	1.06	-	
SLETCP	-	-	-	0.99	
IKS	-	-	-	0.93	
RF 4 $^{252}Cf + Fe$					
TEPC	1.00	9.7	1.00	0.80	49.2
ACR	0.75	-	0.83	0.00	
[1]	0.99	11.0	1.18	-	
SLETCP	-	-		1.05	
IKS	-	-	-	1.15	

Table 5. The dose characteristics of the reference fields (expert estimation).

Source	H_n 10^{-10} Sv · cm^2	Q_n	K_n 10^{-11} Gy · cm^2	K_{ph} 10^{-11} Gy · cm^2
$^{239}Pu - Be$ (UKPN-1M)	3.61± 10% (±11%)	7.9 ± 2% (±2%)	3.84± 9% (± 14%)	1.64±14% (± 18%)
$^{239}Pu - Be$ (RF-1)	3.45± 9%	8.2± 2%	3.6 ± 9%	1.29 ± 20%
^{252}Cf (UKPN-1M)	3.25±9% (±11%)	8.5 ± 2% (±3%)	3.4 ±9% (±12%)	2.11±10% (± 32%)
^{252}Cf (RF-2)	3.16 ± 12%	8.6 ± 2%	3.0 ± 9%	1.56 ± 15%
$^{252}Cf + CH_2$ (RF-3)	0.46 ± 9%	9.1 ± 2%	0.41 ±9%	1.77 ± 10%
$^{252}Cf + Fe$ (RF-4)	2.39 ± 9%	9.7 ± 2%	2.11 ± 9%	0.16 ± 15%

The ambient dose equivalent $H^*(10)$ and MDE are calculated using the neutron spectra data [1] and the fluence-to-dose equivalent conversion factor given by [10,11]. The values of $MDE/H^*(10)$ are equal to 1.007 ($Pu - Be$), 0.99 (^{252}Cf), 0.98 ($^{252}Cf + CH_2$), 0.91 ($^{252}Cf + Fe$). The neutron kerma data for soft tissue was taken from [12].

The calibration of TEPC and ACR has been carried out by using $Pu - Be$ and ^{252}Cf neutron sources. The value $MDE/H^*(10)$ is equal to 1 for these source, therefore, detectors have been calibrated in terms of $H^*(10)$ and MDE, simultaneously.

The TEPC results show that there are no significant (maximum 11%) deviation from values calculated in [1]. Taking into account that the contribution of intermediate neutrons into neutron dose equivalent is about 10% for $^{252}Cf + Fe$ and $^{252}Cf + CH_2$ fields and the fact that TEPC has low sensitivity to neutrons with energy below 50 keV, we can explain why TEPC results are smaller values than those of [1]. An additional source of errors arises from using the same factor B_n for all reference fields.

Comparing the neutron doses measured by ACR in the $^{252}Cf + CH_2$ field with those measured by TEPC one can see that ACR doses are greater (about 30%). Because of great contribution of photons in the total dose the ACR correction method couldn't be applied in this field (see ref.11). On the contrary, the reference field $^{252}Cf + Fe$ has low contribution of photons in total dose and the errors of measurement by TEPC and ACR are not satisfied. The IKS detectors and SLETCP have lower neutron sensitivity, therefore, their results have been preferred to obtain photon doses.

All detectors (TEPC, ACR, SLETCP and IKS) have strongly different photon energy responses in energy range below 0.5 MeV, nevertheless, the deviations of the results from photon dose are within 20%. The doses measured by

TEPC are in a good agreement (within 15%) with ACR experimental values for UKPN fields. It may be explained by the fact that the main contribution to photon dose is produced by photons with energy above 200 keV. The deviations of the values H_n, K_n, K_{ph} measured in UKPN fields from the ones measured in RF-1 and RF-2 are explained by difference of low energy scattering components in the rooms. The low energy scattering component of neutron fluence for UKPN has been measured by cylindrical multienergy counter. This component is equal to 38% for UKPN and 16-18% for the reference fields [1].

The expert estimations of the dose characteristics from Table 5 have been calculated as average value between TEPC, ACR and [1] data. When estimating expert neutron data the ACR results are not included for $^{252}Cf + Fe$ and $^{252}Cf + CH_2$ fields. The TEPC data are preferable in case of neutron kerma. The photon kerma expert data are calculated as average from TEPC, ACR, IKS, SLETCP, but the photon ACR and TEPC results are not included for $^{252}Cf + Fe$ field expert estimations.

Traditionally, the fluence-to-dose equivalent conversion factors are the same for sources of the same type. The errors in brackets given in Table 5 for UKPN correspond to the case when average conversion factor is used for different sources. The calculations of these errors took into accout the difference between VNIIFTRI and IHEP data for UKPN. Maximal error arises when the same conversion factor ”fluence-to-photon kerma” was used for different sources (30%). The difference of the other individual conversion factors for all sources is smaller than 11% (for conversion factor ”fluence-to-neutron dose equivalent” and smaller than 14% – for conversion factor ”fluence-to-neutron kerma”.

As it is seen from Table 3 the $^{238}Pu - Be$ data for H_n and K_n are larger than $^{239}Pu - Be$ data. It may be explained by the difference in the masses of neutron sources rather than neutron spectra, because according to data [14] the neutron spectra of these sources are negligibly different.

The results show that ACR may be used as a standard dosimeter for UKPN and ^{252}Cf, $Pu - Be$ fields only.

4. SUMMARY

The calibration of TEPC and ACR by the National primary standard neutron field in terms of neutron dose equivalent has allowed us to organize metrological certification of IHEP reference neutron field.

The standartization of IHEP reference neutron fields was carried out according to the National standard of calibration structure. The analysis of the results shows that systematic errors of H_n, K_n are smaller than 15% for all reference fields. These errors are admitted for detector calibration for the radiation measurements.

The certified reference neutron fields form the basis for standartization of radiation measurements for IHEP accelerator radiation control purposes.

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References

[1] Britvich G.I., Volkov V.S., Kolevatov Yu.I. et al. – IHEP Preprint 90-48, Protvino, 1990.

[2] Abrosimov A.I., Alekseev A.G., Antipov A.V. et al. – IHEP Preprint 86-70, Serpukhov, 1986.

[3] Abrosimov A.I., Alekseev A.G., Golovachik V.T. – Kernenergy 34, 1991, 108-111.

[4] Abrosimov A.I., Alekseev A.G., Bystrov Yu.V. et al. – Kernenergy 31, 1988, 5 214-222.

[5] Baranenkov N.N., Golovachik V.T., Kustarev V.N. et al. – IHEP Preprint 89-122, Serpukhov, 1989.

[6] Bochvar N.A., Gimadova T.I., Keirim-Markus et al. – Method of IKS Dosimetry – Atomizdat, 1977.

[7] Silin Yu.S., Poprunko L.A., Fominych V.I. et al. – Izmeritelnaya Technika, 1979, N9, 66-67.

[8] Golovachik V.T., Kaskanov G.Ya., Komochkov N.M. et al. – Radiation Prot. Dosim. 1991, Vol. 38, N4, pp. 281-299.

[9] ICRP. Recommendation of the International Commission on Radiological Protection. Publication 51. Oxford: Pergamon Press, 1987.

[10] ICRP. Recommendations of the International Commission on Radiological Protection. Publication 21. Oxford: Pergamon Press, 1972.

[11] Alekseev A.G., Golovachik V.T., Savinsky A.K. - Rad. Prot. Dos. 1986, Vol.14, pp.289.

[12] Norms and Rules of Radiation Protection NRB-76/87, M: Energoizdat, 1988.

[13] Goryachev I.G., Kolevatov Y.I., Semenov V.P., Trykov L.A. - Integral Experiment in the Problem of Radiation Transport. M.: Energoatomizdat, 1985.

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