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CHARACTERISTICS OF POLYETHYLENE-MODERATED ^{252}Cf NEUTRON SOURCES

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1. Introduction

It is widely recognised that neutron dosemeters do not exhibit a constant response factor (per unit dose equivalent) as neutron energies and spectral distributions are varied from one working environment to another. In addition, most dosemeters cannot distinguish one neutron spectrum from another. Algorithms based on the response of a dosemeter cannot, therefore, be developed to determine the appropriate response factor to be applied to a neutron dosemeter irradiated by an unknown neutron spectrum. Thus, it is necessary to determine a response factor for each type of neutron spectrum in which each type of neutron dosemeter will be used.

An alternative (and somewhat more practical) approach is to design a set of reference neutron fields (RF) that simulate the neutron spectra to which a generic group of radiation personnel might be exposed. This set of RF should cover, in practice, the entire interval of neutron energies generated by nuclear installations.

To this end, a set of RF has been created in the Joint Institute for Nuclear Research (JINR) that would produce spectra similar to the neutron spectra observed in the workplaces around high energy accelerators and nuclear reactors. The set comprises reference fields based on a ^{252}Cf source at the centre of polyethylene moderators 12.7 and 29.2 cm in diameter as well as two reference fields based on a 600 MeV phasotron[1].

The paper reports the calculated neutron spectra and dosimetric characteristics of the RF based on polyethylene - moderated ^{252}Cf neutron sources.

2. Reference fields

Reference fields were created using a ^{252}Cf source placed at the centre of polyethylene spheres with diameters 12.7 and 29.2 cm. The fields are produced inside a room 5.2 x 10.8 x 3.5 m^3 and take into account the scattered neutrons. The moderators with the source are placed on a calibration stand and the fields are established at a distance of 100 cm from the source centre. In this case it is not necessary to provide special monitoring. There is a need only to maintain good background conditions in the room and to take into account the source decay.

3. Neutron spectra and conversion coefficients

Neutron spectra were calculated by Monte Carlo method[2] and compared with experimental data [1]. The calculated spectra of the fields free in air and in the calibration room from ^{252}Cf source (with yield 1 $n{\cdot}s^{-1}$) placed at the centre of polyethylene spheres with diameters 12.7cm and 29.2 cm as well as unfolded spectra[1] from count rates of Bonner sphere detectors are shown in figures 1 and 2. Conversion coefficients for monoenergetic neutrons that relate neutron fluence to the operational quantities ambient dose equivalent and personal dose equivalent have been summarized in ICRU Report 57[3]. The fluence-to-dose equivalent coefficient, h^*_Φ, for a neutron spectrum can be evaluated using the following formula:

Tables 1.

Ambient and personal dose equivalent per unit neutron fluence, averaged over neutron spectra of CH_2-moderated ^{252}Cf (diameter of moderator is 12.7 cm).

Neutron source position	$h^*_\Phi(10)$	$h_{p,\Phi}(10,\alpha)$ $\alpha = 0^0$	$h_{p,\Phi}(10,\alpha)$ $\alpha = 15^0$	$h_{p,\Phi}(10,\alpha)$ $\alpha = 30^0$	$h_{p,\Phi}(10,\alpha)$ $\alpha = 45^0$	$h_{p,\Phi}(10,\alpha)$ $\alpha = 60^0$	$h_{p,\Phi}(10,\alpha)$ $\alpha = 75^0$
Free in air	176	188	186	192	179	158	105
In calibration room	120	128	126	130	120	104	68

Tables 2.

Ambient and personal dose equivalent per unit neutron fluence, averaged over neutron spectra of CH_2-moderated ^{252}Cf (diameter of moderator is 29.2 cm).

Neutron source position	$h^*_\Phi(10)$	$h_{p,\Phi}(10,\alpha)$ $\alpha = 0^0$	$h_{p,\Phi}(10,\alpha)$ $\alpha = 15^0$	$h_{p,\Phi}(10,\alpha)$ $\alpha = 30^0$	$h_{p,\Phi}(10,\alpha)$ $\alpha = 45^0$	$h_{p,\Phi}(10,\alpha)$ $\alpha = 60^0$	$h_{p,\Phi}(10,\alpha)$ $\alpha = 75^0$
Free in air	127	135	134	138	129	115	79
In calibration room	90	96	95	97	90	78	52

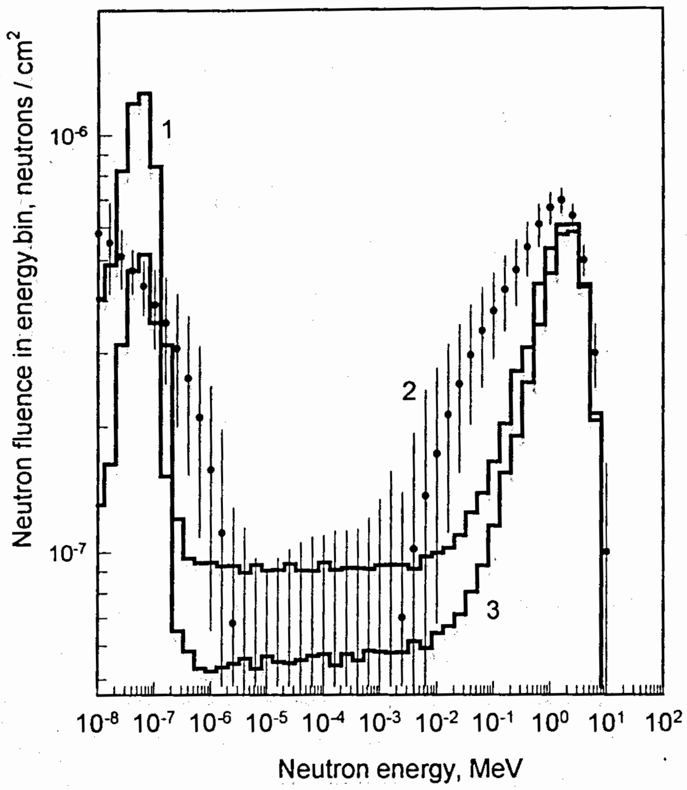

Fig 1. The neutron spectra of the fields free in air and in the calibration room from ^{252}Cf source (with yield 1 n·s^{-1}) placed at the centre of polyethylene spheres with diameter 12.7 cm.

1 - calculated spectrum in the calibration room; 2 - unfolded spectrum in the calibration room;

3 - calculated spectrum free in air.

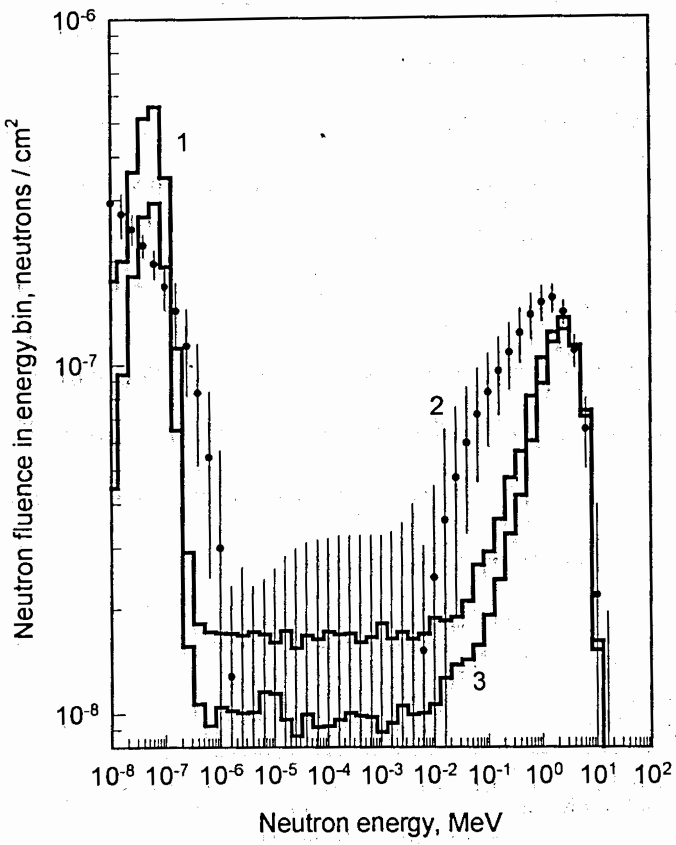

Fig 2. The neutron spectra of the fields free in air and in the calibration room from ^{252}Cf source (with yield 1 n·s^{-1}) placed at the centre of polyethylene spheres with diameter 29.2 cm.

1 - calculated spectrum in the calibration room; 2 - unfolded spectrum in the calibration room;

3 - calculated spectrum free in air.

$$h^*_\Phi = \frac{\int h(E)\Phi(E)dE}{\int \Phi(E)dE} \quad , \qquad (1)$$

where h(E) is conversion coefficients for monoenergetic neutrons, $pSv \cdot cm^2$; Φ(E) is neutron spectrum and E is neutron energy.

Table 1 and 2 show ambient and personal dose equivalent per unit neutron fluence, $h^*_\Phi(10) = H^*(10)/\Phi$ and $h_{p,\Phi}(10,\alpha) = H_{p,slab}(10,\alpha)/\Phi$ ($pSv \cdot cm^2$), averaged over the neutron spectra.

4. Concluding remarks

The neutron reference fields produce neutron spectra that are similar to the spectra observed in the workplace of a major category of workers. When used properly, these fields provide a convenient method to calibrate neutron dosemeters and to conduct neutron dosimetry intercomparision studies.

References

[1] V.E. Aleinikov et al., Radiat. Prot. Dosim. 54 (1994) 57.

[2] MCNP - A General Monte Carlo N-Particle Transport Code, La-12625-M, Version 4B, (1997).

[3] ICRU Report 57, International Commission on Radiation Units and Measurements, Bethesda, Maryland, (1998).

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