Construction of the Calibration Neutron Fields and Spectrum Weighted Response of Several Detectors

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1. Introduction

The types and the forms of radioactive source term are getting a variety due to expansion of the radiation industry such as medical radiation treatments and research. of materials. For neutron sources, it is necessary to account for the neutron energy distribution to evaluate exactly the dose equivalent, because the energy range of the neutron from thermal neutrons (0.025 eV) to a few GeV. The neutron dose equivalent depends heavily on the energy of the neutrons. [1]

The neutron field spectra from a DT neutron generator at Korea Atomic Energy research Institute (KAERI) and the proton accelerators at Korea Institute of Radiological and Medical Science (KIRAMS) were measured by using the Bonner sphere measurement system (BS system) and several neutron detectors. The spectrum weighted response was obtained by using the response function of the neutron detectors as given in the IAEA Technical Report Series 403 (TRS). [2]

2. Methods and Results

2.1 Construction of Neutron Calibration Fields

Three kinds of calibration neutron fields at KAERI were constructed by using a DT neutron generator (14 MeV mono-energetic neutron source). The generator was positioned in the center of the calibration. A 14 MeV neutrons were generated by using deuteron-tritium reaction. The reference positions were 50, 75, and 100 cm from the target of the DT neutron generator. The total neutron emission rate was 8×10^7 s^{-1} at 80 kV acceleration voltage and 50 μA applied current.

Eight kinds of the neutron fields at KIRAMS were produced by addition of two kinds of the beam stopper (Pb and Cu), and two types of moderator on the fixed Be target of the proton accelerator (MC50). The thickness of the Be target was 15 mm and the thickness of the Pb and Cu stoppers was 61 mm. A cylindrical polyethylene moderator of 10 cm thickness covered with 0.5 mm thick Cd sheet, and a D_2O sphere moderator of 32 cm diameter covered with 1 mm thick Cd sheet and 1 mm thick stainless steel were used. The accelerated protons generate neutrons by bombarding on a 1 mm thick Be target. The setup position (the reference position) of the BS systems measuring the neutron spectra was 90 cm away from the Be target of the beam port.

The neutron spectra were measured by using six kinds of the Bonner sphere incoporated with the LiI(Eu) scintillator and ^{3}He proportional counter. The BS data (event rate) were fed to unfold the program UMF3.3. [3] The dosimetric properties of the produced neutron spectra are summarized in Table 1. The quantities $h^*(10)$ and $h_p(10)$ were calculated by using dose equivalent conversion factor of ICRP-74[1].

Table 1 Summary of the dosimetric properties of spectra.

Field's name	E_{ave} (MeV)	$h^*(10)$ [a] ($pSv.cm^2$)	$h_P(10)$ [b] ($pSv.cm^2$)	$H^*(10)$ rate ($mSv.h^{-1}$)
NG50	11.6	445	469	2.82
NG75	10.8	419	442	1.48
NG50	10.5	401	423	1.01
Be15	10.5	383	408	16.5
Pb61	9.31	372	395	7.74
Cu61	6.44	340	359	8.68
Be15_PE	16.9	414	447	4.82
Pb61_PE	10.2	295	317	1.35
Cu61_PE	12.6	344	370	1.17
Pb61_D2O	5.58	201	214	0.99
Cu61_D2O	3.80	171	182	1.08

E_{ave}. : fluenced mean energy
[a] $h^*(10)$: fluence to ambient dose equivalent conversion coefficient
[b] $h_P(10)$: fluence to personal dose equivalent conversion coefficient

2.2 Calculation of the Spectrum Weighted Response

The spectra data of IAEA TRS403 have 61 energy intervals from 1 meV to 630 MeV. But, the neutron spectra obtained through the unfolding process had 281 energy intervals from 1 meV to 100 GeV. In order to compare with two data sets, the energy intervals of these spectra were matched. For this purpose, the source spectra and the response function of detector with 281 energy interval was recalculated to correspond with TRS403's intervals through the K-SWR program. The K-SWR program consists of four parts; the data input part, the transform part of the input data, the calculation part for the spectrum weighted response, and the output part.

Fig.1 and Fig. 2 show the neutron spectra produced by using the DT neutron generator and the MC50 of KIRAMS, respectively. The spectrum, "^{252}Cf" in Fig. 1 was measured at 1 meter from the ^{252}Cf source in order to compare with the other spectra. These spectra were unfolded from the BS and the extended BS system.

The K-SWR program also can calculate the spectrum weighted response (SWR) of several detectors. The SWR of the neutron spectra arrived at this study are summarized in Table 1.

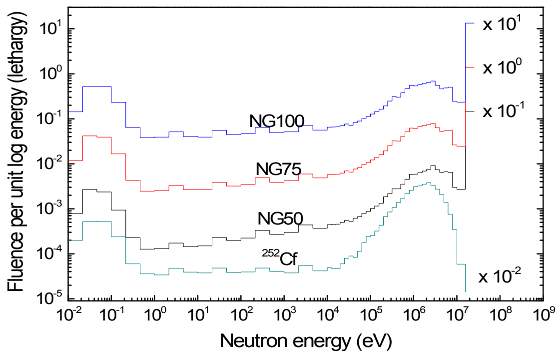

Fig. 1 Neutron spectra produced by the DT neutron generator. The Numeric value in the notations of the spectrum name, "NG50", "NG75", and "NG100" means the distance between the generator and the reference position. The "^{252}Cf" spectrum was measured at 1 m from ^{252}Cf source.

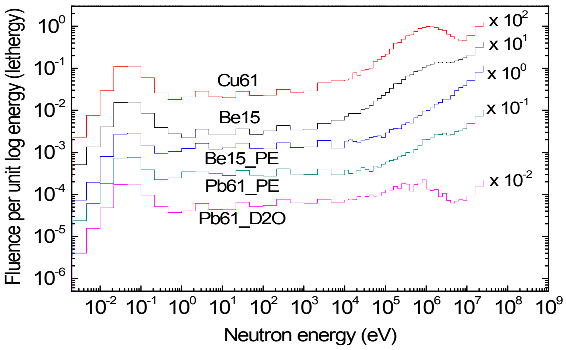

Fig. 2 Neutron spectra produced by the Be target and the beam stoppers, Pb and Cu at KIRAMS. The Numeric value in the notations of the field name, "Cu61", Be15", etc. means the thickness of the targets and the beam stopper. In this study, proton beam energy is 45 MeV.

2.3 Results of Measurement

Various neutron fields were constructed by with changing the beam stopper and the moderator of the MC50, and the reference position from the DT neutron generator. As shown in Table 1,The mean energy of the neutron spectra ranges from 3.80 MeV to 16.9 MeV, while the quantities of $h^*(10)$ and $h_p(10)$ varied from around 170 pSv/cm^2 to 470 pSv/cm^2. Most of the spectra have various spectrum shapes in over than 1 keV energy as shown in Fig. 1 and Fig. 2.

3. Conclusions

The neutron calibration fields were constructed by using MC50 proton accelerator and DT neutron generator. The dosimetric properties and neutron spectra of these neutron fields were measured by using the BS system. From those results, it could be concluded that the constructed neutron calibration fields are suitable for a high energy neutron measurement.

The spectrum weighted response of the various neutron detectors were calculated through the K-SWR program developed in this study. The K-SWR program can be easily and usefully used to obtain the response of the neutron detectors.

Acknowledgement

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REFERENCES

[1] ICRP, Conversion Coefficients for Use in Radiological Protection Against External Radiation, ICRP Publication No. 74, 1997.
[2] IAEA Technical Reports Series 403, Compendium of Neutron Spectra and Detector Responses for Radiation Protection Purposes (2001)
[3] Reginato, M., Golhagen, P., MAXED, a computer code for the deconvolution of multi-shphere neutron spectrometer data using the maximum entropy method. US DOE Report EML-595. 1998.

Table 1. Spectrum weighted response of several BS systems and the neutron detectors to KAERI's and KIRAMS' neutron fields, SWR (cm^2)

Detector	Spectrum weighted Response (cm^2)									
	NG50	NG100	Be15	Pb61	Cu61	Be15_PE	Pb61_PE	Cu61_PE	Pb61_D2O	Cu61_D2O
BS LiI 3″	1.39×10^{-2}	4.14×10^{-2}	4.05×10^{-2}	7.73×10^{-2}	6.93×10^{-2}	4.00×10^{-2}	5.18×10^{-2}	6.54×10^{-2}	1.36×10^{-2}	1.25×10^{-2}
BS LiI 8″	1.09×10^{-1}	9.97×10^{-2}	1.41×10^{-1}	1.73×10^{-1}	1.61×10^{-1}	1.13×10^{-1}	1.14×10^{-1}	1.20×10^{-1}	9.78×10^{-1}	9.64×10^{-1}
BS LiI 12″	9.25×10^{-2}	8.18×10^{-2}	9.20×10^{-2}	7.61×10^{-2}	7.81×10^{-2}	9.09×10^{-2}	8.45×10^{-2}	7.96×10^{-2}	3.39×10^{-2}	4.00×10^{-2}
LiI 358	1.57×10^{-1}	1.48×10^{-1}	1.75×10^{-1}	1.92×10^{-1}	1.88×10^{-1}	1.61×10^{-1}	1.60×10^{-1}	1.60×10^{-1}	1.41×10^{-1}	1.42×10^{-1}
BS He 3″	2.10×10^{-1}	3.55×10^{-1}	3.04×10^{-1}	5.33×10^{-1}	4.72×10^{-1}	3.06×10^{-1}	4.12×10^{-1}	5.31×10^{-1}	1.18×10^{-1}	1.09×10^{-1}
BS He 8″	1.05×10^{0}	9.77×10^{-1}	1.40×10^{0}	1.78×10^{0}	1.65×10^{0}	1.01×10^{0}	1.12×10^{0}	1.20×10^{0}	1.08×10^{0}	1.05×10^{0}
BS He 12″	1.11×10^{0}	9.86×10^{-1}	1.15×10^{0}	1.03×10^{0}	1.03×10^{0}	1.09×10^{0}	1.02×10^{-1}	9.83×10^{-1}	4.64×10^{-1}	5.26×10^{-1}
A-B-2	1.76×10^{-1}	1.59×10^{-1}	3.75×10^{-1}	5.13×10^{-1}	4.57×10^{-1}	2.60×10^{-1}	2.67×10^{-1}	3.02×10^{-1}	2.49×10^{-1}	2.37×10^{-1}
NRD	3.77×10^{-1}	3.40×10^{-1}	4.67×10^{-1}	5.47×10^{-1}	5.11×10^{-1}	3.83×10^{-1}	3.78×10^{-1}	3.90×10^{-1}	2.71×10^{-1}	2.74×10^{-1}
2202D	8.60×10^{-2}	7.33×10^{-2}	1.79×10^{-1}	2.38×10^{-1}	2.13×10^{-1}	1.21×10^{-1}	1.22×10^{-1}	1.38×10^{-1}	9.99×10^{-2}	9.58×10^{-2}
LB6411	2.73×10^{-1}	2.34×10^{-1}	6.06×10^{-1}	7.67×10^{-1}	6.93×10^{-1}	4.39×10^{-1}	4.36×10^{-1}	4.79×10^{-1}	3.24×10^{-1}	3.17×10^{-1}
LiF + Cd	1.90×10^{-2}	2.80×10^{-2}	2.91×10^{-2}	4.69×10^{-2}	4.20×10^{-2}	2.87×10^{-2}	3.64×10^{-2}	4.53×10^{-2}	8.91×10^{-2}	8.26×10^{-2}
leake	1.48×10^{-1}	1.34×10^{-1}	1.55×10^{-1}	1.93×10^{-1}	1.78×10^{-1}	1.19×10^{-1}	1.20×10^{-1}	1.27×10^{-1}	9.67×10^{-2}	9.50×10^{-2}