Application of Neutron Fields With Fractional Changes of Fast and Thermal Neutron To Test Neutron Measuring Devices

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Abstract

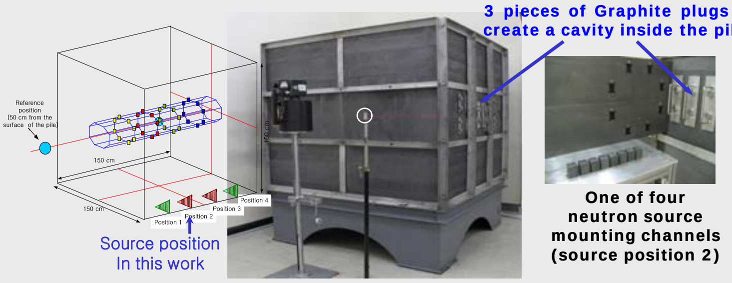
Reference neutron calibration fields such as those recommended in the ISO-8529 are always not enough to test neutron detectors used for workplace monitoring because neutron fluence spectra in a working environment are different from those reference fields and finally neutron measuring devices over or under respond to them. Simulated neutron calibration fields (SNCFs) were constructed using a thermal neutron field and a 14 MeV neutron source produced from a DT neutron generator at the Korea Atomic Energy Research Institute (KAERI), and six kinds of commercial neutron survey meters were tested under the fractional changes of thermal and fast neutron fluence. Thermal neutron calibration fields were constructed using eight AmBe sources installed inside a graphite pile with a dimensions of 1.5 x 1.5 x 1.5 m^3. The ratio of the fast neutron portion to the total neutron fluence was provided by changing the distance of the position of an additional AmBe source or the DT generator from the reference position. Ten kinds of neutron fields were used for the test including a pure thermal neutron and a 14 MeV neutron. All dosimetric quantities of SNCFs were determined using a KAERI's Bonner Sphere system. The responses of the neutron detectors, calibrated using a ^{252}Cf source before the test, were ranged from 0.12 to 3.43.

Materials and Methods

Construction of Neutron Fields

➢ Thermal Neutron Field

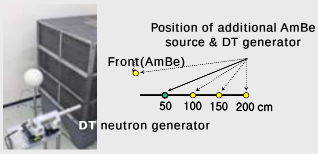
- **Graphite Pile : 1.5 x 1.5 x 1.5 m^3 (old and new one of density of 1.75 $g.cm^{-3}$)**
- **Eight AmBe sources mounted in a plane inside the pile : 1.82 x 10^7 s^{-1}**
- **Steel base which is 50 cm above the floor for stacking the graphite blocks**



Graphite pile and Neutron Survey meter, NP-2, with an additional AmBe source of 111 GBq (50 cm from the reference position, inside a circle)

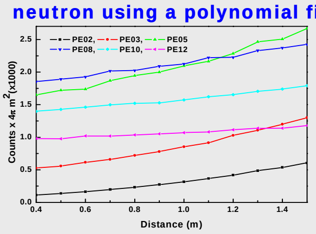
➢ Fast Neutron Fields

- ***Adding another AmBe source of 111 GBq or an operating DT generator to increase the amounts of fast neutrons with distances, 50 ~ 200 cm from the reference position***



Neutron Spectrometry Using the KAERI's Bonner Sphere

➢ **Calibration of BS using a ^{252}Cf source : Response (ε) to a scatter-free neutron using a polynomial fitting method (ISO 8529-2)[2]**



Conventional BS 2, 3, 5, 8, 10, 12 in.(D) PE moderators and a LiI(Eu) scintillator

$$\frac{M(d)\cdot 4\pi d^2}{F_G(d)} = B\cdot F(\theta)\cdot \varepsilon \cdot (1+Ad+Rd^2)$$

Preparation of Priori Information for unfolding

Calculation of Neutron Fluence Spectra for An Initial Guess

➡ Use of the MCNPX Code (ver. 2.4.0)

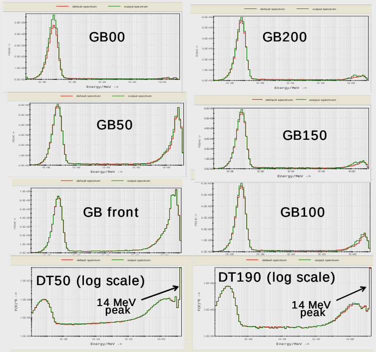
- **Neutron transport of from AmBe sources and DT neuron generator to the reference position in the RCL of KAERI**
- **using a surface crossing tally (F2) with a radius of 17.5 cm at the reference position of 50 cm from the surface of the graphite pile.(106.5 cm from position 2)**
- **sampling histories : 1.0 x 10^8**
- **computing time (with a CPU of 2.1 GHz) : ~ 1 154 min.**
- **energy binning : 10 points/decade (9 x 10^{-10} to 14 MeV), using a spectrum of ISO 8529-1[2] for AmBe source**

Results and Discussion

Spectral Measurement and Unfolding

➢ **Statistical uncertainty in measurements : < 1.0 %**

➢ **Unfolding program[3] : MXD_FC31, response matrix reconstructed**



Source ID or SDD[1)]	Ambient Dose Equivalent, H*(10)		
	h*(10)[2)] (pSv.cm²)	H*(10) Rate (μSv.h⁻¹)	E_{ADE}[3)] (MeV)
GB00	23.5	26.1	1.54
GB200	48.9	62.7	2.76
GB150	63.3	84.3	3.18
GB100	94.2	143	3.91
GB50	184	417	4.55
GB front	201	620	4.05
^{252}Cf(100 cm)	316	268	2.49
DT 190 cm	216	657	11.5
DT 150 cm	261	996	12.3
DT 100 cm	330	2 090	12.8
DT 50 cm	419	7 290	13.6

Fluence Spetra with fractional changes of Thermal and fast neutrons using an additional AmBe & DT generator as a 14 MeV neutron source(measured by BS : Left), and dosimetric quantities of neutron fields used in this measurement : right ([1)]SDD : source to detector distance in cm, [2)] h*(10) : Fluence to dose Equivalent conversion coefficient was derived using the values presented in the ICRU57 , and [3)] E_{ADE} : Ambient dose equivalent mean energy**)**

➢ **Ten kinds of neutron fields were used to check the response of several neutron survey meters considering that the amount of presence of thermal neutron would give a difference in their reading a conventional dose equivalent rate.**

➡ **Spectral Information of Neutron Fields of in this measurement**

SSD[1)] (AmBe or DT)	Total Fluence Rate ($cm^{-2}h^{-1}$)	Percentile to the Total Fluence Rate (%)				Fluence Averaged Mean energy (MeV)
		< 0.5 eV	0.5 eV ~ 10 keV	10 k eV ~ 10 MeV	> 10 MeV	
No[2)]	1.11 x 10^6	94.3	2.2	3.5	0	0.09
200 cm	1.28 x 10^6	86.0	3.6	10.3	0.1	0.33
150 cm	1.33 x 10^6	82.5	3.3	14	0.2	0.49
100 cm	1.52 x 10^6	74.1	3.6	21.8	0.5	0.90
50 cm	2.27 x 10^6	50.4	3.6	44.8	1.2	2.02
Front	3.08 x 10^6	40.0	6.4	52.5	1.1	1.98
^{252}Cf (100 cm)	8.48 x 10^5	11.8	4.0	8.39	0.3	1.93
190 cm	3.04 x 10^6	45.7	6.9	19.5	27.9	4.86
150 cm	3.81 x 10^6	37.5	6.3	19.6	36.6	6.26
100 cm	6.31 x 10^6	24.6	5.1	21.8	48.5	8.21
50 cm	1.74 x 10^7	10.5	2.9	20.1	66.5	11.0

[1)]SDD : source to detector distance in cm

[2)] No means a condition without an additional AmBe source and a pure thermal neutron field

➡ **Ratio of several neutron monitors' reading[1)] to the reference dose equivalent rate determined by BS measurement**

Commercial Neutron Survey Meters used in this measurement ➩

Source ID	SDD[1)] (cm)	Eavg. (MeV)	H*(10) rate (μSv.h⁻¹)	LB6411	WENDI2	Ludlum	NP2	Dineutron	REM500
GB00	No	0.09	26.1	0.69	0.85	3.43	0.86	3.03	0.48
GB200	200	0.33	62.7	0.82	0.83	2.11	0.88	0.89	0.67
GB150	150	0.49	84.3	0.79	0.82	1.82	0.77	0.68	0.80
GB100	100	0.90	143	0.82	0.84	1.37	0.87	0.41	0.90
GB50	50	2.02	417	0.85	0.86	1.04	0.98	0.19	0.91
GB front	50	1.98	620	0.95	0.92	1.08	1.01	0.13	0.91
DT 190	190	4.80	656	0.60	0.69	–	–	0.12	1.34
DT 150	150	6.16	990	0.55	0.66	–	–	0.14	0.92
DT 100	100	8.14	2 080	0.53	0.63	–	–	0.21	1.09
DT 50	50	7.29	7 290	0.53	0.62	–	–	0.13	1.12

[1)]SDD : source to detector distance in cm

[2)]All neutron survey meters were calibrated by a ^{252}Cf source using a polynomial fitting method of ISO8529-2.

➡ **This measurement is a series of the consecutive extension of the previous work[4] for response data preparation of commercial neutron survey meters.**

Conclusion

➢ **Even neutron survey meters having good response in the neutron fields of energy below 10 MeV were found to have a low response to 14 MeV neutron dominant fields : Radiological calibration fields should be same or similar to workplace as possible to minimize the response difference or work fields quantified using a field spectrometry technique.**

➢ **A TEPC type neutron monitor was preferable to measure high energy neutron compared to PE moderated survey meters.**

REFERENCES

1. B.H. Kim et. al, *Measurement of the neutron fluence and dose spectra using an extended BS and a TEPC*, *Radiat. Prot. Dosim.* 110(1-4), 717 (2004)
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