Calibration of Neutron Measuring Instruments by ^{252}Cf Neutron Source

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1. Introduction

Calibration laboratory in the Korea Atomic Energy Research Institute(KAERI) provides calibration service of neutron measuring instruments by ^{252}Cf neutron source. Since the amount of room scattering neutron is considerable, calculation of room scattering fraction is important in the calibration of neutron instrument. Semi-empirical method is used in this laboratory for the determination of room scattering fraction. Neutron calibration laboratory, neutron source, semi-empirical method and calibration procedures are presented in this paper.

2. Method and results

Neutron calibration laboratory is located in underground of radiation research building of KAERI.

Size of the room is 8m(L)×6m(W)×6m(H) and the room is enclosed with concrete wall, floor and ceiling.

Distance positioning system, source storage and pneumatically transporting system, video camera, D_2O moderating sphere and laser pointing the source position are installed for the calibration. Figure 1 shows a calibration view of neutron instrument. Two kinds of neutron field, bare ^{252}Cf and D_2O moderated ^{252}Cf neutron field, are being used for the calibration.

Figure 1. Calibration view of neutron instrument by D_2O moderated ^{252}Cf source

D_2O moderating sphere with diameter of 32.3 cm is filled with D_2O and covered with 0.53 mm thick cadmium. Emission rate of ^{252}Cf source is 2.03×10^9 n/sec (1992.2.16) and is calibrated by NIST, USA.

^{241}AmBe source with emission rate of 7.01×10^6 n/sec (1997.7.15) is also being used for the calibration.

Anisotropy factor due to cylindrical encapsulation of the source is 1.057 for the bare ^{252}Cf source, 1.036 for the ^{241}AmBe source and is negligible for D_2O moderated source. Air inscattering is approximately two times air outscattering, so that the net effect is always increase the fluence at the detector.[3] Air scattering is increase approximately linearly with distance. Inscattered neutron spectrum is, however, shifted to lower energy due to elastic scattering in nitrogen and oxygen. This laboratory uses ISO(10647) recommended air scattering correction value. (1.2%/m for bare ^{252}Cf, and 2.6%/m for D_2O moderated ^{252}Cf source.) Air scatter is very small compared with room scatter. In an enclosed calibration room, neutrons are scattered off the walls, floor, ceiling and structures in a complex way. Since the amount of scattered neutron is considerable comparing with direct neutrons, scattered neutron should be calculated and corrected. Room scattering fraction is determined by semi-empirical method in this laboratory. Semi-empirical method is preferable for cubical or almost cubical shape of room and when neutron source is at the geometrical center of the room, and neutron emission is isotropic or nearly isotropic. Room scattered fraction by semi-empirical method can be calculated as follows.[3]

$$H = H_0 / d^2 + Hs, \quad H * d^2 = H_0(1+S\ d^2), \quad S = Hs / H_0$$

Where, H : detector response (corrected for air scatter and geometrical effect between source and detector)

H_0 : calculated detector response due to direct neutron only

Hs : response to room scattered neutron

d : source to detector distance

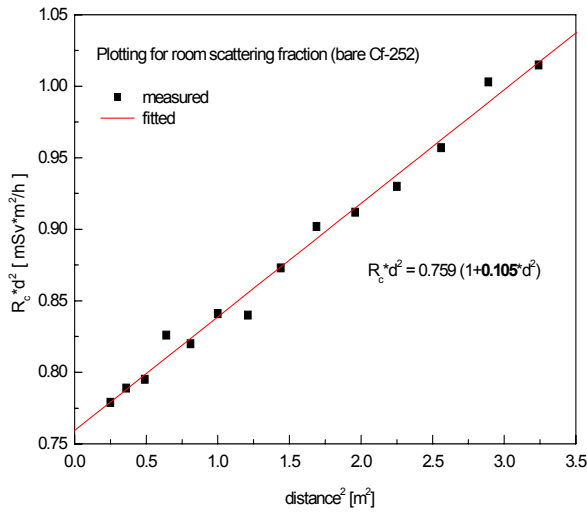S : fractional room scatter contribution at unit source – detector distance

Figure 2. Plotting for room scattering fraction

End user should multiply calibtation factor to the instrument reading to obtain a corrected value. Table 1 shows data processing for calibration factor..

3. Conclusion

Semi-empirical method is used in this laboratory for room scattering fraction and is adequate in small calibration room. The room scattered neutrons are uniformly distributed throughout the room. For all scatter contributions(air inscatter and room scatter) the spectral distribution changes compared with the original source spectrum. The scatter contribution to the instrument reading at the same local position varies from instrument to instrument depending upon the instrument response.

Plotting $H * d^2$ vs. d^2 should result in a straight line with intercept of H_0 and slope of H_0S. Thus, the room scatter correction coefficient S can be determined. Once the value of S is obtained, it can be used to correct readings of other instruments of the same type, without doing the fitting procedure. Sample plotting of $H * d^2$ vs. d^2 for bare ^{252}Cf source is shown in Figure 2. Calibration factor is the ratio of FFDE(Free Field Dose Equivalent) to air, room scattering corrected instrument reading value. FFDE is dose equivalent , air, room scattering free, only from the source and can be calculated as following for the bare ^{252}Cf source.

$$FFDE = B*F_I(\theta)*h(10)*3600*10^{-6} / 4\pi d^2 \text{ [uSv/h]}$$

B : neutron emission rate (n/sec)
F_I : anisotropic factor, 1.057 for bare ^{252}Cf source
h(10) : dose conversion coefficient, 385 pSv cm^2 / n
d : source to detector distance (cm)

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$R_c=R/Fg/AS/RS$

Distance (m)	FFDE (uSv/h)	Reading (uSv/h)	Reading uncertainty(%)	Fg $1+\delta$ (a/2d)^2	AS(%/m) 1.2	RS (%/m^2) 10.5	Reading corrected	Calibration factor
0.5	2875	3154	0.75	1.007	1.004	1.026	3039.94	0.95
0.8	1123	1305	0.53	1.003	1.008	1.067	1210.01	0.93
1.0	719	852	0.84	1.002	1.010	1.105	761.84	0.94
1.3	425	542	0.68	1.001	1.014	1.177	453.51	0.94
1.5	319	421	0.83	1.001	1.016	1.236	334.80	0.95
1.8	222	320	0.73	1.001	1.020	1.340	233.97	0.95
Uncertainty (%)		u(Reading)	u(Fg)	u(AS)	u(RS)	CF$_{ave.}$	0.94	
		0.84	0.10	0.29	2.54	u(CF)	0.39	

Table 1. Data processing for calibration factor   Source used : bare ^{252}Cf   emission rate : 6.1656E+07