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■ 論 文 ■

Comparison Study of Experimental Neutron Room Scattering Corrections with Theoretical Corrections in RCL's Calibration Facility at KAERI

Suk-Chul Yoon, Si-Young Chang, Jong-Soo Kim,
Jang-Lyul Kim, Bong-Hwan Kim
Korea Atomic Energy Research Institute

한국원자력연구소 중성자교정실에 대한 중성자산란보정인자 결정연구

윤석철 · 장시영 · 김종수 · 김장렬 · 김봉환
한국원자력연구소

Abstract—Neutron room scattering corrections that should be made when neutron detectors are calibrated with a D_2O moderated ^{252}Cf neutron source in the center of a calibration room are considered. Such room scattering corrections are dependent on specific neutron source type, detector type, calibration distance, and calibration room configuration. Room scattering corrections for the responses of a thermoluminescence dosimeter and two different types of spherical detectors to neutron source in the Radiation Calibration Laboratory(RCL) neutron calibration facility at the Korea Atomic Energy Research Institute(KAERI) were experimentally determined and are presented. The measured room scattering results are then compared with theoretical results calculated by predicting room scattering effects in terms of parameters related to the specific configuration. Agreement between measured and calculated scattering correction is generally about 10% for three kinds of detectors in the calibration facility.

Key words : room scattering correction, D_2O moderated ^{252}Cf neutron source, RCL

요약—중성자교정실내에서 D_2O 감속 ^{252}Cf중성자선원을 사용하여 계측기를 교정할 때는 그 계측기에 대한 교정실산란보정인자를 미리 결정하여야 한다. 이러한 교정실산란보정인자는 계측기의 종류, 교정거리, 교정실형태에 따라 다르게 결정된다. 본 연구에서는 한국원자력연구소에서 운영하는 2차 표준중성자교정실에서 한가지의 열형광선량계와 2가지의 구형검출기에 대한 교정실산란보정인자를 실험적으로 결정하였고 본소의 2차 표준중성자교정실조건에 의하여 이론적으로 예측한 값과 비교하였다. 비교한 결과 실험하여 얻어진 상기의 3가지 계측기에 대한 교정실산란보정인자가 이론적으로 예측한 결과와 최대 약 10% 이내에서 일치하였다.

중심어 : 교정실산란보정인자, D_2O 감속 ^{252}Cf 중성자선원, RCL

INTRODUCTION

In this paper we consider neutron room scattering corrections that should be made when neutron dosimeters and measuring devices are calibrated with a D_2O moderated ^{252}Cf neutron sources in the center of a calibration room. Such room scattering corrections are dependent on specific neutron source type, detector type, calibration distance, and calibration room configuration. Unfortunately, these effects are sometimes ignored, giving rise to faulty calibrations [1]. When neutron room scattering is considered, data of a complete neutron spectral measurement as a function of distance in the calibration room would be used to evaluate the effect of the neutrons reflected from the surfaces of a calibration room. However, this kind of approach is not always feasible due to time or instrumentation constraints. Monte Carlo calculations based on various simplifying assumptions are more commonly used to determine the neutron scattering corrections[2, 3]

The Radiation Calibration Laboratory(RCL) has being operated for almost two decades at the Korea Atomic Energy Research Institute(KAERI) as one of the secondary standard dosimetry calibration laboratories, and the old RCL has moved and finished expanding the RCL recently. The neutron calibration room which we consider in this paper is a new RCL neutron calibration facility, which is located in the basement of a newly-constructed radiation application building at KAERI. The calibration room is 8m long, 6m wide and 6m high. The source and detector are placed at a height of 2.9m near the center of the room. And the room is entirely enclosed with concrete.

Room scattering corrections for the responses of a thermoluminescence dosimeter(TLD) and two different types of spherical detectors with the neutron source in the RCL neutron calibration facility at KAERI were experimentally determined and are presented. The measured room scattering results are then compared with theoretical results calculated by predicting room scattering effects in terms of parameters related to the specific configuration[2, 4]

THEORETICAL CONSIDERATIONS

Scattering from the room walls, ceiling, and floor, or "room scattering", is not a new problem and has been investigated at many laboratories in the past. Room scattering in the case of a completely enclosed concrete room is a much more serious problem. When we consider the reflected fluence of neutrons in the ideal case of a neutron source at the center of a spherical cavity, the singly reflected neutron fluence in the cavity is everywhere constant and isotropic, as shown by Savinskii and Filyushkin[5].

The relative response of a detector to reflected and source neutrons, M_s/M_o, depends on the two spectra, as well as on the relative fluence. Therefore, the relative response can be expressed as

$$M_s/M_o = 4.5g(R^s_\Phi/R^o_\Phi)(r/r_c)^2 \quad (1)$$

where R^s_Φ and R^o_Φ are the spectrum-averaged responses for the reflected and source neutrons, respectively. The predicted room scattering correction S divided by r^2 from equation (1) is given by :

$$S = 4.5g(R^s_\Phi/R^o_\Phi)(r/r_c)^2 \quad (2)$$

These calculations were made for a spherical cavity. In applying them to a real room which is formed like the rectangular parallelepiped, we need to find the radius of a spherical room which has the same surface area as the real room. This suggests that the effective radius r_c of an equivalent spherical room can be obtained from

$$4\pi r_c^2 = \Sigma A_i \qquad (3)$$

where A_i is the area of the ith surface of the room. Finally, the room scattering correction S from the rectangular parallelepiped shape room can be calculated using equation (2) after finding the effective radius r_c of an equivalent spherical room equation (3).

EXPERIMENTAL RESULTS

Measurements have been made for three kinds of neutron detectors as a function of distance from a D_2O moderated ^{252}Cf neutron source at KAERI. The neutron detectors included an Eberline 9−inch dia. spherical rem−meter(9″ sphere), an Eberline 3−inch cadmium−covered detector(3″ sphere), and a Albedo TLD(Teledyne TLD : PB−3 Badge). These instruments were chosen because the 9″ spherical rem−meters and the TLD are commonly used in nuclear power plant and industry and because the ratio of the response of the 9″ and 3″ spherical detectors can sometimes be used as an index to derive dose calibration factors for an albedo TLD in various neutron fields[6]. Griffith et al.[7] found that the dose calibration factor for albedo neutron dosimeters in various neutron spectra could be related to the ratio of responses of the 9″ and 3″ spherical detectors.

Measurements of the TLD were carried out on a phantom. Measurements of the response D of the 9″ and 3″ spheres and the TLD were first corrected for air scatter by subtracting a contribution of 2.3% and 4.5% per meter for 9″ and 3″ spheres and 3.0% per meter for the TLD, respectively. These recommended air scatter corrections were derived from McCall's air scatter calculations[8] and Hankins measurements of detector response functions[9]. These corrected responses, multiplied by the square of the source−detector distance r in meters, are plotted against r^2 in Figs. 1 and 2. These points lie approximately on a straight line which can be expressed as

$$Mr^2 = M_0(1 + Sr^2) \qquad (4)$$

The linear equations from least squares fit are shown in the Figures. The intercept of such a plot at r=0 gives the response M_0 at 1m from neutron source and the slope S gives information on the relative response from reflected neutrons, namely, room scattering corrections. In Fig. 1 the measured response ratio of 9″ and 3″ spheres at 1m, which includes room−reflected neutrons, is 4.46 and the slopes are $S=0.17m^{-2}$ and $S=0.33m^{-2}$, respectively for the 9″ and the 3″ spheres. Thus the relative effect of reflected neutrons for the 3″ sphere is about 2 times greater than for the 9″ sphere. In the case of the TLD, the slope is determined to be $S=0.115m^{-2}$ as shown in Fig. 2.

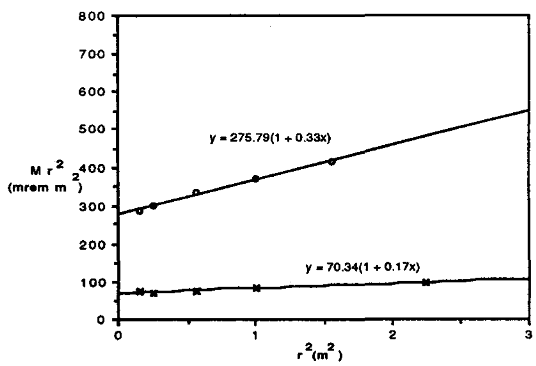

Fig. 1. Response D of the Eberline 9″(x) and 3″(o) spheres as a function of distance from a D_2O moderated ^{252}Cf neutron source in the RCL calibration facility.

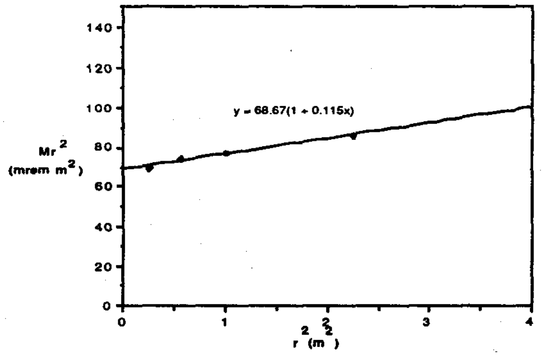

Fig. 2. Response D of the TLD as a function of distance from a D_2O moderated ^{252}Cf neutron source in the RCL calibration facility.

COMPARISION OF THEORETICAL AND EXPERIMENTAL RESULTS

Theoretical room scattering correction can be estimated by calculation using equation(2). A comparison of the measured and the calculated room scattering correction is shown in Table 1. The calculated $g(R^s_\Phi/R^o_\Phi)$ values for D_2O moderated ^{252}Cf neutron source were 0.86, 1.4 and 0.58 for 9″ sphere, 3″ sphere and albedo TLD, respectively[10]. The effective radius of the RCL's calibration room calculated from equation (3) was 4.58m. Agreement between measured and calculated scattering correction is generally about 10% for three kinds of detectors in the calibration room. The fact that both measured corrections for 9″ and 3″ spheres in the RCL calibration room are slightly different from calculated corrections suggests that perhaps prediction for the calibration room is complicated because it does not have perfect concrete enclosed six walls, but with 12cm thick concrete slab structure(3.5m long×6m high) in front of door which intends to prevent neutrons from leaking out of the door. In addition, there is some concern that the 3′ sphere used for measuring scattering correction in the calibration room was almost 10 years old. However, any problems have not been shown so far.

CONCLUSIONS

Because of the fact that the agreement in Table 1 is good for 9″ sphere, 3″ sphere and albedo TLD and the measured points have good least squares fits(Figs. 1 and 2), it can be concluded that the formulae(Equation 2) is reliable for the calculation of the room scattering corrections for detector calibration at RCL′ neutron calibration facility. Further scattering correction measurements will be performed for 9″ cylindrical remmeter and Bonner spheres at the RCL calibration facility. These measurements and their interpretation will be the subject of a further paper.

Table 1. Comparison of the measured and the calculated neutron room scattering corrections of detectors responses for the D_2O moderated ^{252}Cf neutron source at KAERI.

Detector	Measured $S(m^{-2})$	Calculated $S(m^{-2})$	Meas./Calc. S (% at 1m)
9″sphere	0.17	0.185	91.9
3″sphere	0.33	0.30	110.0
TLD	0.115	0.124	92.7

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