Neutron Response Matrix for Unfolding NE-213 Scintillator Measurements in 6 < En < 34 MeV

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In shielding study of neutrons, the measurement of the energy spectrum of the fast neutrons is widely carried out with NE-213 organic scintillators. The neutron unfolding spectrum is represented as a linear integral equation;

$$M(E) = \int_0^\infty R(E,E')\cdot T(E')\cdot dE'$$

where T(E') is the true spectrum, M(E) is the measured pulse-height distribution from the detector, and R(E,E') is the detector response function. The response function is approximated by a matrix, and the integral equation is written by the matrix equation

$$M_i = \sum_j R_{ij} T_j \ .$$

The accuracy of the result depends on the determination of the neutron response, and also on the numerical technique. The difficulty appears oftenly in unfolded spectra, such as the appearance of negative parts of the spectrum, extraneous oscillations, or simply an unreasonable shape.

Although the response matrix based on the measured response functions by Verbinski et al.[1] has been widely used[2], this is restricted, however, to the detector dimension of 4.65-cmϕ × 4.60-cm and the energy range below 22 MeV. Some Monte Carlo calculations are also used to generate the response functions for different sizes of the detectors. It is not adequate to use the calculated responses for response matrix because of the lack of cross-section data for ^{12}C in the high energy region.

It is the purpose of this report to describe the measured neutron response functions of the NE-213 organic scintillator, and the response matrix for unfolding measured pulse-height distributions in the higher energy region up to 34 MeV.

The neutron responses have been measured for a 5-inchϕ × 2-inch NE-213 scintillator in the energy range of 4.4 to 34 MeV[3] at T-O-F facility of Tohoku University Cyclotron R. I. Center. The experimental equipment and the procedure for the measurements are described by Nishihara et al.[4] in detail. Interpolation and extrapolation scheme were used for construction of a 117-energy column matrix from the response data. Additional response data in the energy range 1 to 15 MeV, which were measured at Fast Neutron Laboratory, Department of Nuclear Engineering, were also used. The typical result is shown in Fig. 1. The normalization to the absolute differential efficiency was made by utilizing the proton-recoil plateau calculated with Monte Carlo code 05S[5]; equating the area of the experimental curve that lies above the lowest point on the proton-recoil plateau to the area of the calculation above the same pulse-height. The neutron cross-sections of carbon in the energy region above 15 MeV evaluated by the present authors were used. The FERDOR code[6] was adopted to unfold the pulse-height distributions. The unfolded results shown in Fig. 2 were obtained using pulse-height distributions corresponding to each energy. In these calculations the window function in FERCOR code was taken to 20 % at the neutron energy of 15 MeV. It is found that the unfolding results are fairly good, except for small negative part appeared at the energy over 30 MeV.

The obtained response matrix from the present measurements will be applied to analyse the results of shielding benchmark experiments which is in progress by the present authors for the neutron energy range up to 34 MeV.

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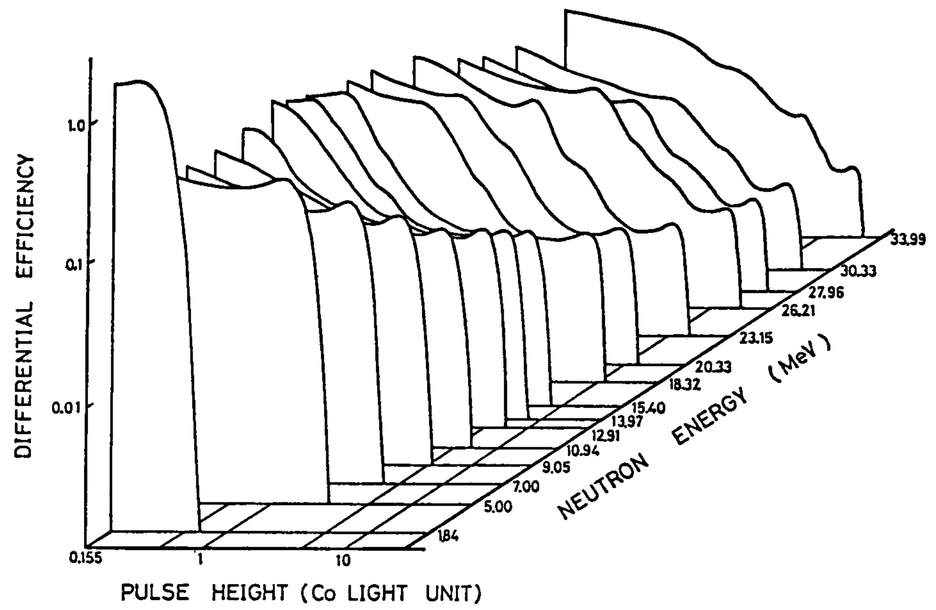

Fig. 1. Measured response functions.

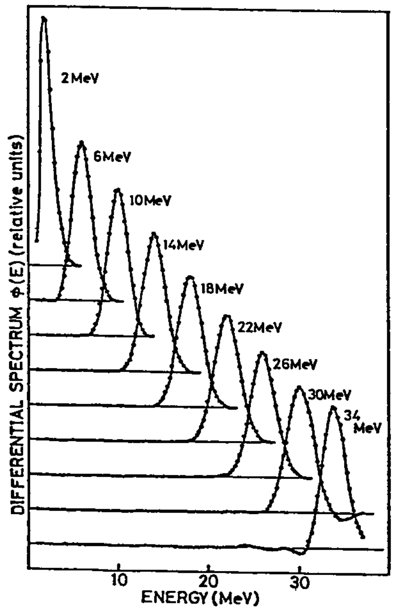

Fig. 2. Unfolded spectra obtained with pulse-height distributions of monoenergetic neutrons.