TRANSMISSION EXPERIMENT OF HIGH ENERGY NEUTRONS

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Abstract

The energy spectra of transmitted neutrons through shield systems of iron, lead, graphite and concrete were obtained by unfolding the pulse height distributions measured behind the shields with an NE-213 scintillator. These measured spectra were compared with calculated spectra by using MORSE code with two sets of cross-section data, DLC-87 Hilo and those released from LANL. These data sets were benchmarked by this comparison.

Introduction

The shield design of medium-energy accelerators up to a few hundreds MeV is being made[1,2] based on the DLC-87 Hilo[3] multigroup cross section data. Since neutron transmission experiments which can be utilized to benchmark the cross section data are very rare above 15 MeV, the accuracy of the shielding design made with the above cross sections is not well known.

In our earlier works,[4,5] the transmitted neutron spectra through several materials were measured in the energy range up to 30 MeV and the DLC-87 data were found to give good agreement with the measured data. In the present work, measurements were made for iron, lead, graphite and concrete shields. White neutrons generated by bombardment of 65 MeV protons on a thick copper target are utilized this time for the neutron source, and the cross section data of DLC-87 Hilo and those released by Little are benchmarked.[6]

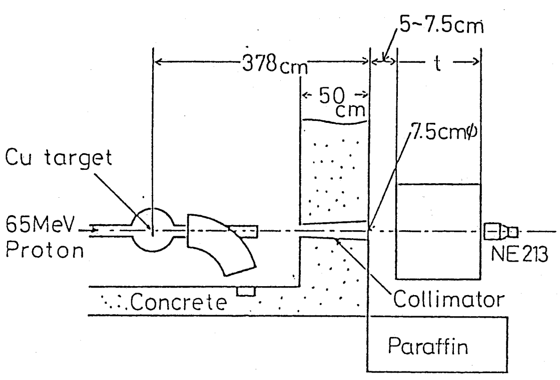

Fig. 1 Experimental arrangement.

Experimental Method

The experiment was carried out at the monoenergy neutron course in the AVF cyclotron facility of Osaka University. A 1-cm thick (i.e. proton stopping range) copper target was irradiated by 65 MeV protons and generated neutrons in the forward direction were pulled out to an experimental room through a 7.5-cm diameter iron-lined concrete collimator of 50-cm thickness. The experimental setup is depicted in Fig.1. The iron, lead, graphite and concrete shields were used in the experiment. Table 1 lists the dimensions of the shields.

Transmitted neutrons were measured just behind the shield system by a 3-inch(7.6-cm) diameter by 3-inch height NE-213 scintillator with an aid of a pulse-shape discrimination circuit. The background data were obtained in the same experimental condition except the collimator was closed by an iron plug. Obtained pulse-height spectra were unfolded to neutron energy spectra by FERDO method[7] with measured response data[8].

Table 1 Dimensions of shield systems

Material	Width (cm)	Height (cm)	Thickness (cm)
Iron	40	40	20,40,50,60
Lead	40	40	10,20,30
Graphite	50	40	30,60,90
Concrete	40	40	10,50,100

Calculational Method

The neutron transport in the shield system was calculated by the MORSE code with the DLC-87 Hilo and the data developed at LANL[6], in a geometrical model which closely simulated the experimental setup.

The DLC-87 uses P_5 Legendre expansion at energies above 15 MeV and P_3 Legendre expansion at energies below 15 MeV. The data are based on the intra-nuclear-cascade-evapolation model for nonelastic scattering and the optical model for elastic scattering. The LANL data use P_3 Legendre expansion at all energies. The data were calculated with the GNASH code based on the pre-equilibrium model.

The source spectrum measured without the shield system was utilized in the calculation.

Results and Discussion

Fig.2 shows comparison of measured and calculated iron transmitted neutron spectra. The measured spectra are well reproduced by the DLC-87 data except for about a factor of five overestimation by the calculation in the energy range from 15 MeV to 25 MeV. Fluctuations seen in both of the measured and calculated data are due to poor statistics and errors in response data.

It was revealed by tests on cross-section data that nonelastic cross sections used in the DLC-87 were in a good agreement with experimental values. But for total cross sections, the data in the DLC-87 at 15-25 MeV were several percent smaller than experimental values. This is the reason for the above overestimation of the transmitted spectra.

The MORSE/LANL gives large overprediction to the measured data as the shield becomes thicker. This is probably caused by the transport approximation adopted by the LANL data library in processing the pointwise cross sections to the multigroup form.

To check this point, the LANL data set was applied to the analysis of a scattering experiment of ^{252}Cf fission neutrons. The MORSE/LANL calculation gave good agreement with measured data at angles other than 0°. But at 0°, it overestimated experimental values. The similar calculation with MORSE/DLC-87 gave good agreement with the measured ones at the entire directions. The both DLC-87 and LANL data sets were based on the same pointwise cross sections from the ENDF/B-IV in the energy range below 15 MeV. The disagreement between the two calculations should be due to the different model used by the two libraries in the multigroup processing.

Fig.3 shows corresponding results for the lead shield. There is no LANL cross section data for lead. The comparison is made only with the MORSE/DLC-87

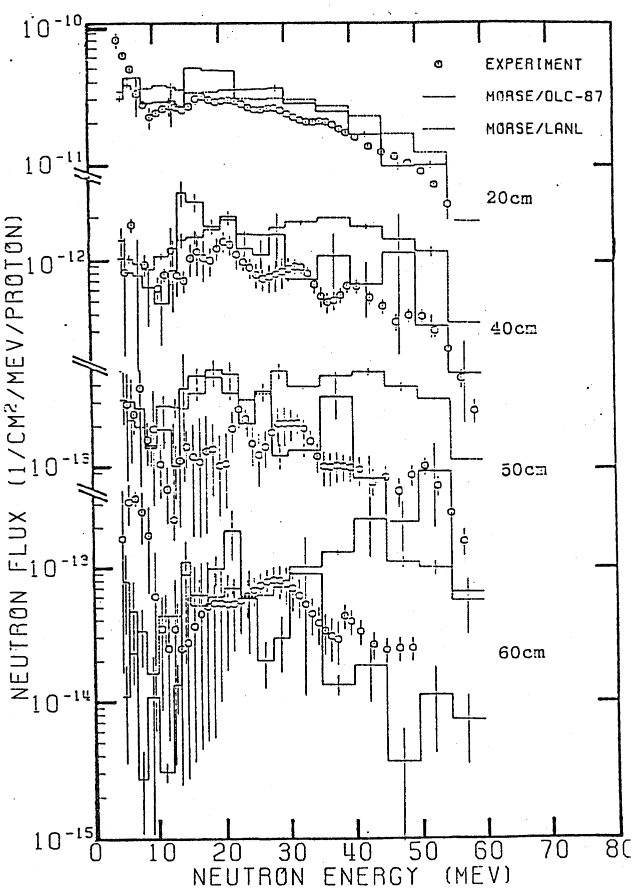

Fig. 2 Transmitted neutron spectra through the iron shields.

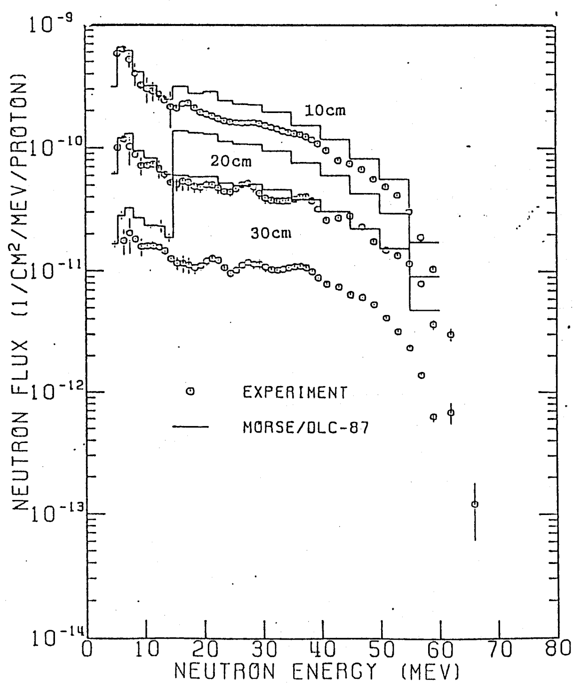

Fig. 3 Transmitted neutron spectra through the lead shields.

calculation. The disagreement between the experiment and the calculation is very large at energies above 15 MeV.

In making up the DLC-87 lead cross section data set, they omitted the elastic scattering at energies above 15 MeV. Since the angular distribution of elastic scattering is very forward peaked, they assumed that the elastic scattering did not contribute to neutron attenuation and could be omitted. However this is not true in particular when the neutron transmission to the forward direction is considered. The cross sections of elastic scattering occupy almost about the half of the total cross sections. More over, nonelastic cross sections of lead above 15 MeV are several-percent underestimated. The overestimation of the lead transmitted spectra by the MORSE/DLC-87 calculation was caused by these reasons.

Fig.4 shows results of the comparison between the experiment and the MORSE/DLC-87 calculation for the graphite shield. The agreement between the two sets of data is quite well except the calculation gives slight lower values below 10 MeV.

The comparison of the concrete transmitted neutron spectra is shown in Fig.5. The MORSE/DLC-87 calculation fairly well reproduces the measured data. Again the MORSE/LANL calculation gives overestimation to the measured data for the thicker shields.

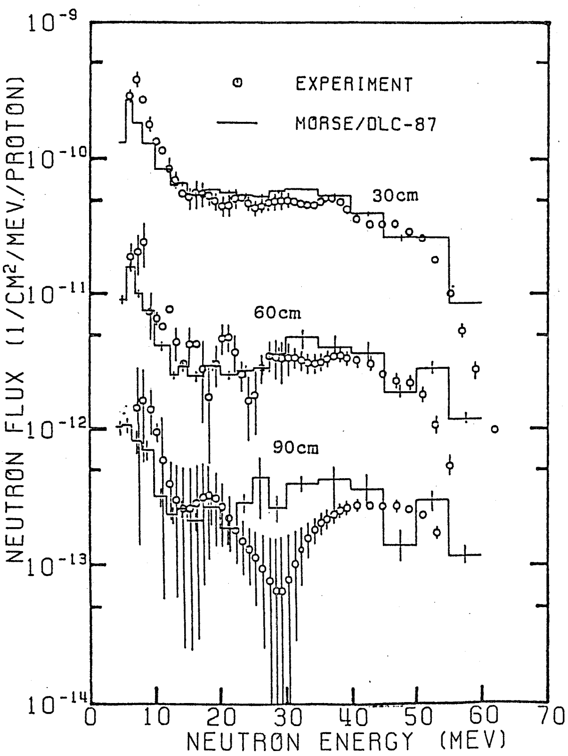

Fig. 4 Transmitted neutron spectra through the graphite shields.

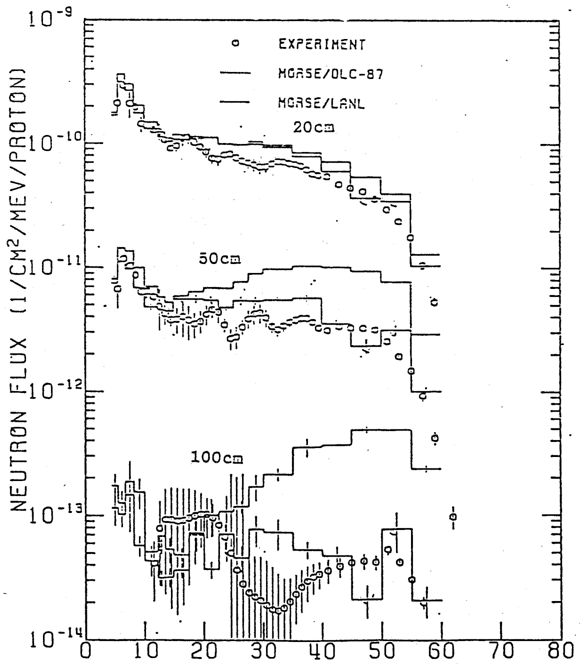

Fig. 5 Transmitted neutron spectra through the concrete shields.

Conclusion

The benchmark test made based on the measured transmission spectra revealed that the calculation by the DLC-87 cross section data gave well agreement with the experiment for the graphite and concrete shields, but partly gave overestimation at energies 15-25 MeV for the iron shield, and gave very large overestimation above 15 MeV for the lead shield.

As for the LANL multigroup data, the transport approximation is not adequate. The calculation resulted in the large overprediction to the measured spectra at the thicker shields.

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