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THE MEASUREMENT OF LEAKAGE NEUTRON SPECTRA FROM VARIOUS SPHERE PILES WITH 14 MeV NEUTRONS

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Abstract: In order to check the existing nuclear data files such as ENDF/B-IV, JENDL-3 etc., neutron leakage spectra from various kinds of sphere piles have been measured using the intense pulsed neutron source at OKTAVIAN and time-of-flight techniques. Measured samples include LiF, TEFLON:$(CF_2)n$, Si, Cr, Mn, Co, Cu, Nb, Mo and W. The thicknesses of the piles were 0.4 to 4.7 mean free paths for 14MeV neutrons. The obtained data were compared with the theoretical calculations using three kinds of transport codes, ANISN, NITRAN or MCNP and the evaluated nuclear data files, ENDF/B-IV, JENDL-3T and ENDL-73. ENDF/B-IV and ENDL-73 data contain several problems resulting considerably large disagreement in the spectra for LiF, TEFLON, Cr, Mn, Co, Cu, Nb, Mo and W, while JENDL-3T data gave preferable calculated spectra to the other data. Judging from the intercomparison between the measured and the predicted with JENDL-3T, it can be seen (1)satisfactory for Cu in whole energy range, (2)good for Si and Cr above 1 MeV and (3)good for Mn below 5 MeV but considerably large underprediction above this energy.

(integral experiment, leakage spectrum, time-of-flight measurement, 14 MeV neutrons, liquid scintillator, transport calculation, ANISN, MCNP, NITRAN, evaluated nuclear date file, ENDF/B-IV, JENDL-3T, ENDL)

Introduction

An integral experiment is useful for the evaluation of the existing data file and calculational method. We have measured the angular flux in the fission reactor candidate materials using time-of-flight techniques and photo-neutrons from the electron linac at Kyoto University, Research Reactor Institute. The results were analyzed using one-dimensional Sn codes, mainly ANISN and multi-group constants mainly derived from JENDL-2 or ENDF/B-IV nuclear data /1-6/. The design study of fusion reactors or fusion -fission hybrid reactors needs the evaluation of the data at higher energy region.

The new data file JENDL-3 is expected to correspond these requirements, and the temporary version of this file, JENDL-3T was provided prior to the publication. In the present work, the leakage neutron spectra from several candidate materials for fusion or fusion-fission hybrid reactors were measured and compared with the theoretical prediction using JENDL-3T data(Si, Cr, Mn and Cu), ENDF/B-IV data(LiF, TEFLON, Si, Cr, Mn, Co, Cu and Nb), ENDL(Mo,W).

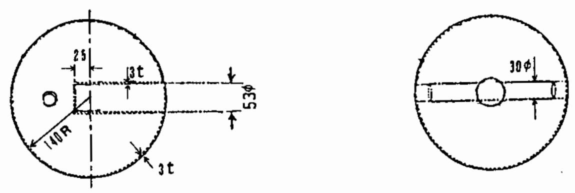
Experiment

Sample Piles

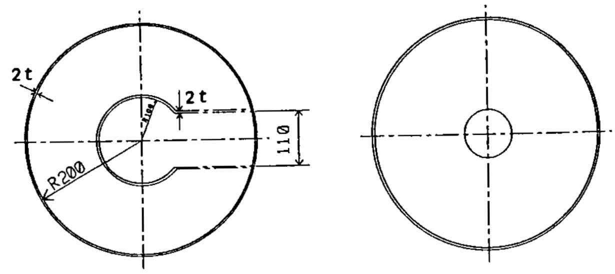
Sample piles were formed as spherical so as to place the tritium target at their centers. The samples include lithium fluoride, TEFLON:$(CF_2)_n$, silicon, chromium, manganese, cobalt, copper, niobium, molybdenum and tungsten. Those samples were packed into spherical shells made of stainless steel or normal steel. Table-1 shows the list of the measured sample piles, where pile diameter and sample thickness (in unit of cm and in mean free paths for 14MeV neutrons) of each pile are given. The geometries of the piles are shown in Fig.1.

Fig.1 The geometries of the sample piles.

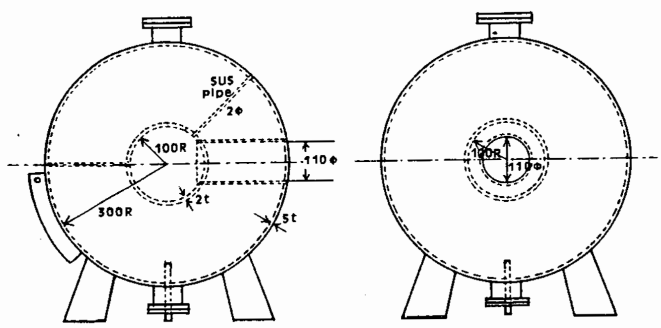
(a) 28 cm diameter sphere for use with Nb pile.



(b) 40 cm diameter sphere for use with TEFLON, Cr, Co and W pile.



(c) 60 cm diameter sphere for use with Si pile.



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Experimental Arrangement

The experiment has been performed by the time-of-flight(TOF) technique using the intense 14MeV neutron source facility OKTAVIAN/7/ of Osaka University. The experimental arrangement in the OKTAVIAN facility is shown in Fig.2. A tritium target is placed at the center of each pile. The energy of the incident deuterons was about 250keV. A cylindrical liquid scintillator NE-213 (5in-diam. x 2in-long) was used as a neutron detector. The detector was located at the angle of 55 with respect to the incident deuteron beam. Neutron flight path was about 10.75 m from the center of the tritium target to the surface of the detector. A pre-collimator system made of polyethylene-iron multi-layers was set between the pile and the detector to reduce the neutron background. The aperture size of this collimator was determined so that the whole surface of the piles facing to the detector could be viewed.

Data Processing

The detector efficiency was determined by combining the O5S calculation and the relative efficiency derived from the TOF measurements of ^{252}Cf spontaneous fission spectrum and the leakage spectrum from a graphite sphere 30 cm Sphere.

The activation foils (aluminum, niobium and zirconium) were irradiated to monitor the source neutron strength during the measurements. By using these monitor values and measured source neutron spectra, the neutron leakage current spectra from the sample surface were determined by the method stated elsewhere/8/.

Calculations

Group constant from JENDL-3T and ENDF/B-IV

A 125-group library(P5S16), FSX125G/J3-T /9/ was used for the ANISN/10/ calculation. This library was processed from JENDL-3T data using PROF.GROUCH-G/B code. A 135-group library(P5S16), GICXFNS processed from ENDF/B-IV was also used for the ANISN calculation. By using both libraries, leakage neutron spectra were calculated for the piles of silicon, chromium, manganese and copper.

DDX library for the NITRAN calculation

A double-differential cross section library with 135-group energy bins and 19 angular bins was prepared for the NITRAN/11/ calculation of the cobalt pile.

MCNP calculations

For the calculations for the lithium fluoride, TEFLON, niobium, molybdenum and tungsten piles, a point Monte Carlo transport code MCNP/12/ was used. The standard continuous energy cross section file BMCCS1(mostly from END/B-IV) was used for this code. The surface current tally from the outer surface of the piles was employed for this calculation.

(d) 60 cm diameter sphere for use with LiF, Mn, Cu and Mo pile.

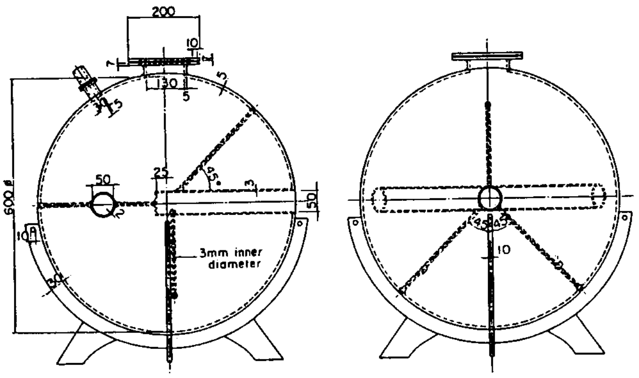
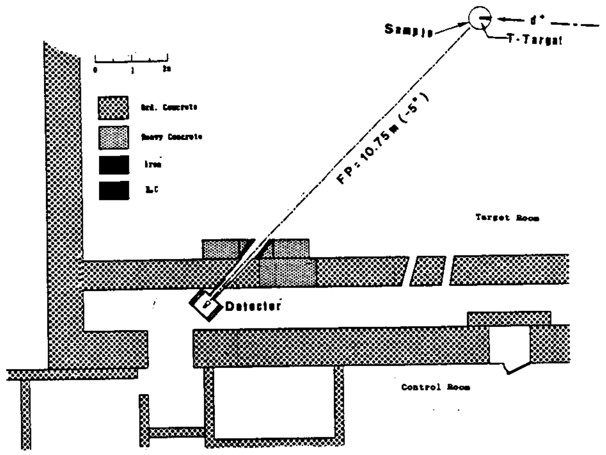


Fig.2 Experimental arrangement



Results

The measured and predicted spectra are shown in Figs. 3-a through 3-j together with the ratio of the calculated and measured values(C/E). In table-1, listed are the calculation methods and the cross section libraries used.

Lithium fluoride and TEFLON

The predicted spectra for both LiF and TEFLON show considerable underestimation in the range 2 MeV<E_n<10 MeV(Fig.3-a,3-b), which suggests too small value in the inelastic level scattering cross sections.

Table-1 Characteristic parameters of the piles, calculation codes and nuclear data files used

Pile	Dia. (cm)	Sample (cm)	Thickness (MFPs)	Calc. Code	Cross-section Libraries
LiF	61.0	27.5	3.5	MCNP	BMCCS1 ^{6}Li:LASL(101) ^{7}Li:ENDF/B-IV(1272) F:ENDF/B-IV(1277)
TEFLON	40.4	10.0	0.7	MCNP	BMCCS1 C:LASL(102) F:ENDF/B-IV(1277)
Si	61.0	20.0	0.4	ANISN	FSX125/J3T-1 and GICXFNS
Cr	40.4	10.0	0.7	ANISN	FSX125/J3T-1 and GICXFNS
Mn	61.0	27.5	3.4	ANISN	FSX125/J3T-1 and GICXFNS
Co	40.4	10.0	0.5	NITRAN	DDX Library from ENDF/B-IV
Cu	61.0	27.5	4.7	ANISN	FSX125/J3T-1 and GICXFNS
Nb	28.6	11.2	1.1	MCNP	BMCCS1 ENDF/B-IV(1191)
Mo	61.0	27.5	1.5	MCNP	BMCCS1 ENDL-73(533)
W	40.4	10.0	0.8	MCNP	BMCCS1 ENDL-73(540)

FSX125/J3T-1: 125-group library processed from JENDL-3T with PROF.GRAUCH/G-B
GICXFNS: 135-group library processed from ENDF/B-IV with NJOY

Silicon

Fig.3-c shows the experimental and calculated leakage spectrum from the silicon pile. Both calculations show similar spectra and good agreement between calculation and experiment is seen in general. Slightly better prediction is obtained by JENDL-3T. However, there still exist some amount of discrepancies in the energy region 0.2 MeV<En<2 MeV. This implies both nuclear data have problems in the cross section data, possibly inelastic continuum-level scattering.

Chromium

Quite different result from the experiment was obtained by the calculation using ENDF/B-IV data (Fig.3-d). It seems that the inelastic level scattering cross section in ENDF/B-IV is too large for chromium. JENDL-3T data give much better prediction as to this problem. However, for the energy region 0.2 MeV<En<2 MeV, both data file give a little overestimation similar to the silicon result.

Manganese

The ENDF/B-IV prediction gives quite erroneous spectrum for the energy region 1 MeV<En<14 MeV (Fig.3-e). The JENDL-3T data are much improved, but there still exists a little discrepancy above 5 MeV probably due to the inelastic continuum-level scattering and/or (n,2n) cross sections.

Cobalt

The calculated spectrum shows large underestimation to the experiment almost uniformly (Fig.3-f). The cause of this underestimation is not clear from the present analysis.

Copper

The ENDF/B-IV calculation considerably underestimates the spectrum around 10 MeV (Fig.3-g). However, other part of the calculation seems good. The calculation using JENDL-3T data predicts the experiment very well. It can be concluded that JENDL-3T data are satisfactory for copper.

Niobium

Though the calculation using ENDF/B-IV data predicts the elastic scattering peak well, the shape of the spectrum under 10 MeV differs from the experiment (Fig.3-h). There might be a problem about the (n,2n) and inelastic continuum level scattering cross section, which are dominant reactions at this energy range.

Molybdenum

From this rather old evaluation data (ENDL-73), considerable underestimation below elastic scattering peak is observed probably caused by the underestimation of the inelastic level scattering cross sections (Fig 3-i). There also exists the overestimation in the energy range 0.7 MeV<En<4 MeV, which implies the problem as to the inelastic continuum level scattering cross sections.

Tungsten

The prediction using the data from ENDL-73 gives a quite different spectrum from the experiment(Fig.3-j). As the discrepancy is observed over almost all energy region, complete re-evaluation of the tungsten data should be required.

Acknowledgment

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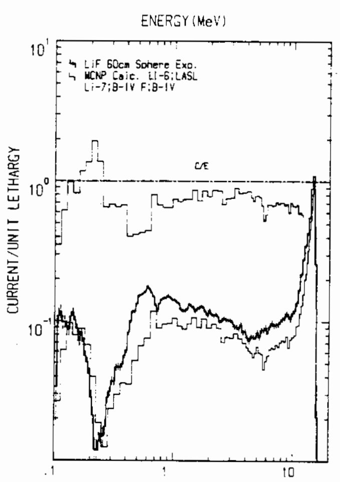
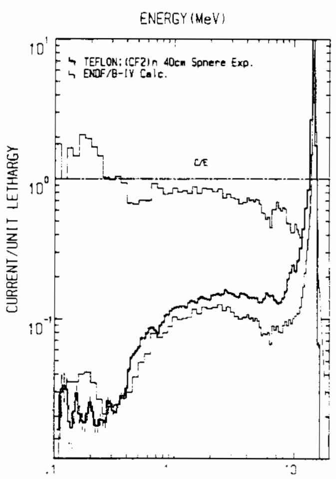
Fig.3 Experimental and calculated spectra

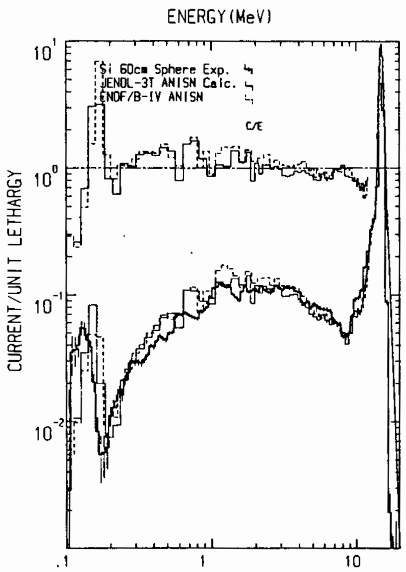
(a) Lithium Fluoride 60 cm Sphere



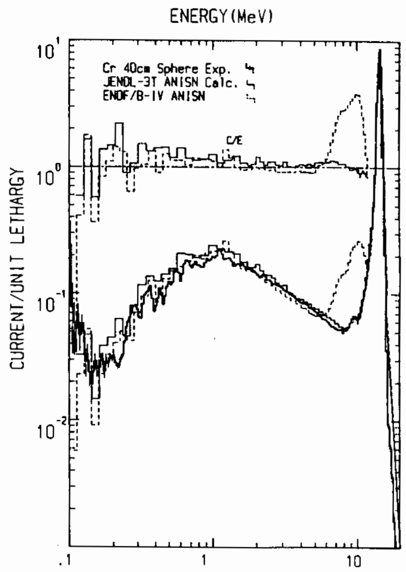
(b) TEFLON:$(CF_2)_n$ 40 cm Sphere



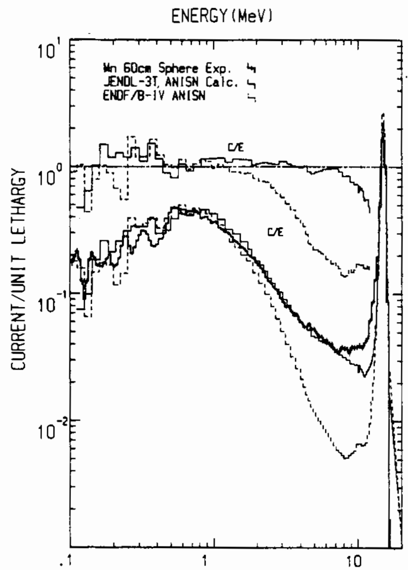
(c) Silicon 60 cm Sphere



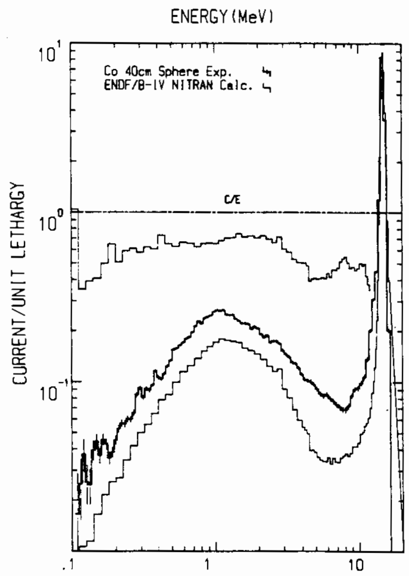
(d) Chromium 40 cm Sphere



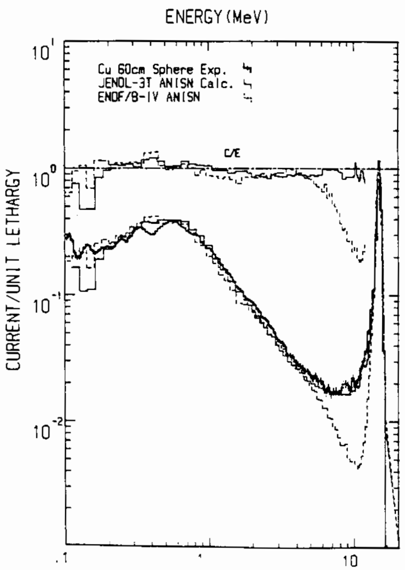
(e) Manganese 60 cm SPhere



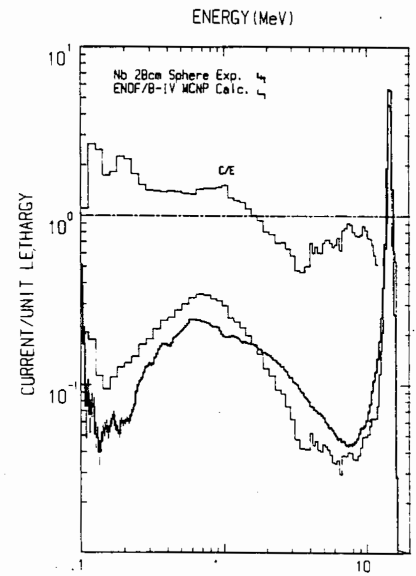
(f) Cobalt 40 cm Sphere



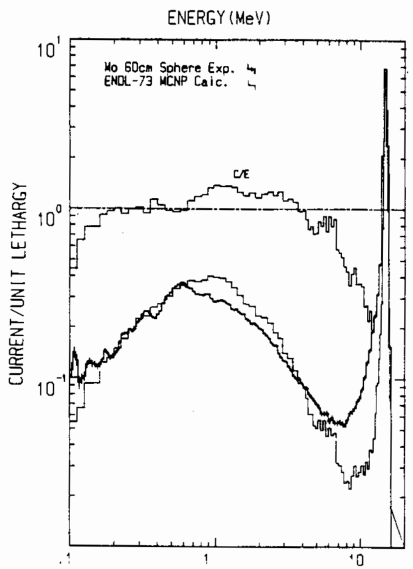
(g) Copper 60 cm Sphere



(h) Niobium 28 cm Sphere



(i) Molybdenum 60 cm Sphere



(j) Tungsten 40 cm Sphere