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^{238}U PULSED SPHERE MEASUREMENTS AND CTR FUSION-FISSION BLANKET CALCULATIONS*

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The neutron emission spectra from ^{238}U spheres pulsed with 14-MeV neutrons have been measured from the source energy down to 10 keV and have been compared with calculations employing ENDF/B-IV and ENDL cross sections. The low energy spectra (10 keV to 1 MeV) are best described using ENDF/B-IV cross sections while the high energy spectra (2 MeV to 15 MeV) are best described using ENDL cross sections. It is concluded that use of ENDL cross sections should yield the best estimate of tritium breeding and ENDF/B-IV that of Pu breeding in a CTR fusion-fission blanket.

[^{238}U Pulsed Sphere Measurements; spectra from 10 keV to 15 MeV compared with calculations; implications for fusion-fission blanket calculations.]

Introduction

A recent study[1] has shown that the breeding of tritium and Pu in a CTR fusion-fission blanket is quite sensitive to the emission spectra from 14-MeV neutrons on ^{238}U and other structural materials in the reactor. To have confidence in the breeding calculations, it is essential that the cross sections used in the calculations describe reasonably well the neutron emission spectra from 14-MeV neutrons incident on ^{238}U. The neutron emission spectra from 0.8 and 2.8 mean-free-paths (m.f.p.) ^{238}U spheres pulsed with 14-MeV neutrons have been measured from the source energy down to 10 keV. From a comparison of these measurements with calculations, it is concluded that use of ENDL cross sections[2] should yield the best estimate of tritium breeding and ENDF/B-IV that of Pu breeding in a CTR fusion-fission blanket.

Experimental Method

Figure 1 shows the 0.8 and 2.8 m.f.p. ^{238}U spheres. A conical insert was machined into the spheres in order to accomodate the low mass target assembly. A tritium loaded titanium target was located at the center of the spherical targets. A solid state silicon detector at 174° with respect to the D^+ beam line monitored the neutron production by counting the associated ^4He particle from the $T(d,n)^4He$ reaction. For measurements between 2 and 15 MeV, 5.1 cm diameter by 5.1 cm long NE 213 and Pilot B scintillators were used at 120° and 30° respectively. The flight paths were 765 cm at 30° and 977 cm at 120°. The repetition rate for the high energy measurements was 2.5 MHz and the burst width was 4 ns.

For measurements between 10 keV and 1 MeV, a 5.1 cm diameter by 1.9 cm long ^6Li glass scintillator was used at 26° with respect to the deuteron beam line at a flight path of 801 cm. The burst widths were 10 and 100 ns while the repetition rate was 10 KHz. A detailed description of the neutron detector packages and the collimations employed is given in ref. 3.

Standard time-of-flight electronics were used in measuring the emitted spectra. The stop pulses into the time-to-amplitude converter were generated from a capacitive beam pick-off unit. Time calibration of the system and the conversion from counts (cts)/channel to cts/ns (high energy) and cts/μs (low energy) are described in detail in ref. 3. The high energy data are presented as time-of-flight spectra while the low energy data have been converted into energy spectra.

Experimental Results and Calculations

Figures 2 and 3 show the measured and calculated high energy time-of-flight spectra. The various spectra are identified by the ^{238}U sphere size, angle of observation and cross section library used. Figures 4, 5 and 6 show the similarly identified low energy spectra.

The high energy spectra are presented as cts (sphere in) per ns per total 14 MeV cts (sphere out). The high energy spectra calculations therefore require that the Pilot B and NE 213 detector efficiencies be folded into the Monte Carlo calculations.

The low energy spectra measurements are presented as neutron/keV/source neutron. The conversion from cts to neutrons requires a knowledge of the ^6Li glass detection efficiency. The detection efficiencies for the ^6Li glass and Pilot B, NE 213 scintillators can be found in ref. 3. The absolute source strength was required for the low energy measurement and it was obtained by calibrating the alpha counter against the 14-MeV flux as measured with the NE 213 and Pilot B scintillators. Reference 4 describes in detail the measurement and data processing of the low energy spectra. In particular, it describes the determination of the time independent background by inserting in good geometry a thick paraffin absorber between the ^6Li detector and ^{238}U sphere.

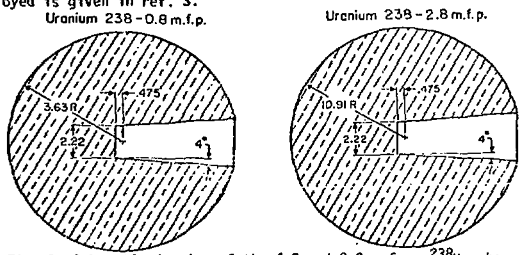


Fig. 1 Schematic drawing of the 0.8 and 2.8 m.f.p. ^{238}U spheres (Dimensions are in centimeters)

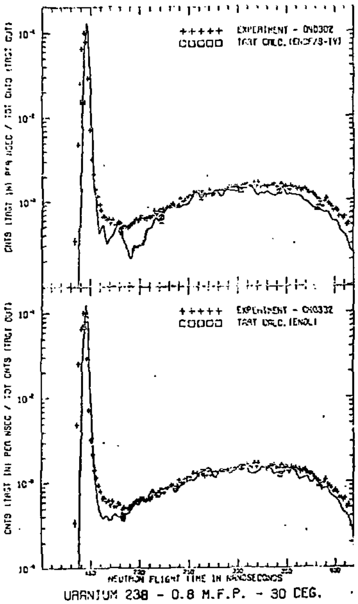


Fig. 2 Comparison between the high energy measurements and calculations for the 0.8 m.f.p. ^{238}U sphere at 30°.

Comparison With Calculations

Table 1 presents a comparison of the measured and calculated integrals for the high energy time-of-flight spectra shown in figs. 2 and 3. The integral above 12 MeV (<164 ns) is a measure of the non-elastic cross section while the integral from 2 to 12 MeV (400 to 164 ns) is a measure of the high energy neutron emission cross section from $\sigma(n,n')$, $\sigma(n,2n)$, and $\bar{\nu}\sigma_f$. Table 1 shows that the ENDF/B-IV non-elastic cross section is correct while that of ENDL appears to be slightly high. In the 2-12 MeV region ENDL gives better agreement with measurements than ENDF/B-IV. The ENDF/B-IV discrepancy for the 2-12 MeV region increases from -16% to -20% in going from 0.8 to 2.8 m.f.p.

Table 1 Comparison of measured[a] and calculated integrals for the 30° high energy emission spectra shown in figs. 2 and 3. 2 and 12 MeV correspond to flight times of 400 and 164 ns, respectively. See figs. 2 and 3 for units on the integrals.

	Measured		ENDF/B-IV		ENDL	
m.f.p.	2-12	>12	2-12	>12	2-12	>12
				(b)		
0.8	0.263	0.644	0.224	0.643	0.243	0.630
2.8	0.324	0.233	0.260	0.232	0.286	0.216

a. The absolute error on the measured integrals is ±5%. The error on the ratio of two integrals is ± 3%.

b. These calculations agree with previous calculations by Powerton.[5]

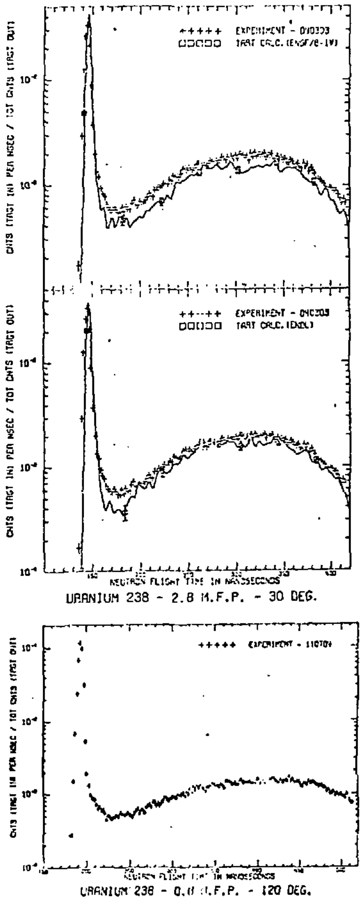


Fig. 3 Comparison between the high energy measurements and calculations for the 2.8 m.f.p. sphere at 30°. The 0.8 m.f.p. data at 120° are presented without calculations.

Table 2 presents the integrals of the 100 ns low energy spectra of figs. 4 and 5 between 10 and 934 keV. Table 2 and figs. 4 and 5 show that the best overall agreement is achieved using ENDF/B-IV cross sections. This agreement is further illustrated by comparison of ENDF/B-IV calculations with the higher resolution 10 ns measurements shown in fig. 6. At 2.8 m.f.p. ENDL yields the correct integral by overestimating the higher energy and underestimating the lower energy neutrons.

Table 2 Comparison of measured[a] and calculated integrals for the emission spectra shown in figs. 4 and 5 between 10 and 934 keV. See figs. 4 and 5 for units.

	0.8 m.f.p. ($x10^{-7}$)	2.8 m.f.p. ($x10^{-6}$)
Measured	9.40	3.70
ENDF/B-IV	10.0	3.75
ENDL	8.57	3.65

a. The absolute error on the measured integrals is ±10% and arises from the uncertainty in the ^6Li glass efficiency. The error on the ratio of the two measured integrals is ±5%.

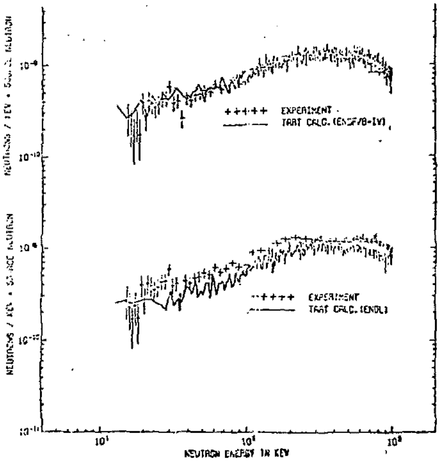


Fig. 4 Comparison between the low energy 100 ns measurements and calculations for the 0.8 m.f.p. sphere.

Conclusions

Neither library yields satisfactory agreement with both low and high energy spectra. However, ENDL should yield the most reliable estimate of tritium breeding and total fissions in a CTR blanket since it yields the best agreement for the 2.8 m.f.p. high energy spectra and gives the correct number of low energy neutrons for the 2.8 m.f.p. sphere. Agreement with the 2.8 m.f.p. measurements is emphasized since the blanket is fueled with a thick layer of ^{238}U. Also, because of multiple collisions, the total number of low energy neutrons is more important than exact spectral shape. On the other hand, the breeding of Pu comes mainly from neutron capture below 1 MeV. Since ENDF/B-IV yields the correct number and spectral shape for neutrons between 10 and 934 keV it should yield the most reliable estimate of Pu breeding.

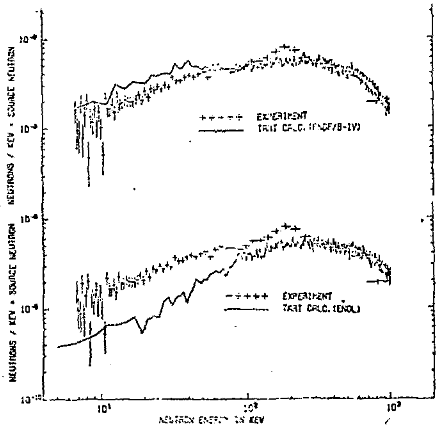
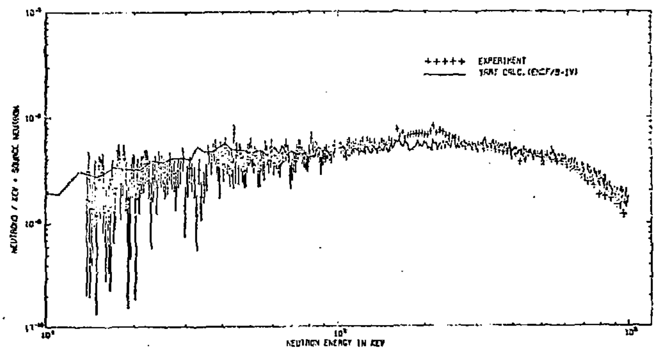


Fig. 5 Comparison between the low energy 100 ns measurements and calculations for the 2.8 m.f.p. sphere.

An earlier calculation[1] of the tritium breeding using ENDL cross sections yielded 1.26 tritons per 14-MeV neutron into the blanket. Since then, ENDL has been revised[6] by decreasing the fission cross section and increasing the (n,3n) cross section in order to preserve the non-elastic cross section. The predictions shown in figs. 2-5 and tables 1 and 2 were calculated with this latest revised ENDL library. As expected, this revised library yielded a lower tritium breeding ratio of 1.11. The corresponding total fissions using revised ENDL is 0.864, and the Pu breeding using ENDF/B-IV is 2.23.

The present measurements do not cover the energy range between 1 and 2 MeV. Since the various libraries predict percentages from 15 to 25% for neutrons between 1-2 MeV in the sphere calculations, it is clear that these neutrons contribute significantly to total fissions and tritium breeding, and measurements in this energy range would provide additional checks on the various libraries.



URANIUM 238 - 2.8 M.F.P. - LOW ENERGY

Fig. 6 Comparison between the low energy 10 ns measurements and calculations for the 2.8 m.f.p. sphere.

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