JAERI-M
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NEACRP-A-244

PRELIMINARY RESULTS OF INTEGRAL EXPERIMENT ON FUSION-FISSION HYBRID BLANKET ASSEMBLIES

March 1976

Hiroshi MAEKAWA and Yasushi SEKI

日本原子力研究所
Japan Atomic Energy Research Institute

Preliminary Results of Integral Experiment on Fusion-Fission Hybrid Blanket Assemblies

Hiroshi MAEKAWA and Yasushi SEKI
Division of Reactor Engineering, Tokai, JAERI

(Received February 20, 1976)

To study neutronics in the fusion-fission hybrid reactor blanket, two types of spherical hybrid assembly, i.e. with and without a graphite reflector, were prepared by piling up lithium, natural uranium and graphite blocks. Effective outer radii of the central cavity, natural uranium, lithium metal and graphite regions are 3.3, 10.0, 34.1 and 55.3 cm, respectively.

In the assembly without a graphite reflector, the forms of measured fission rate distribution are in good agreement with those by calculation; however, there is large difference between the measured and the calculated fission ratios ($^{238}U/^{235}U$). In the assembly with it, the measured fission ratio is in good agreement with the calculated one, except in the graphite region.

The measured neutron multiplication factor due to the natural uranium is about 2.5, in agreement with the calculated one.

核融合・核分裂結合型ブランケット体系における積分実験の予備結果

日本原子力研究所東海研究所原子炉工学部
前川　洋・関　泰

（1976年2月20日受理）

核融合・核分裂結合型炉における中性子の挙動を研究するために，黒鉛反射体がある場合とない場合の2つのハイブリッド球体系をリチウム，天然ウラン，黒鉛の各ブロックで組立てた。各領域の外半径は，中心ボイド3.3 cm，天然ウラン領域10.0 cm，リチウム領域34.1 cm，黒鉛領域55.3 cmであった。

裸のハイブリッド体系における核分裂率分布の形は計算結果とかなり良い一致を示したが，^{238}U／^{235}Uの核分裂比分布の実験値と計算値の間に大きな差があった。黒鉛反射体付ハイブリッド体系では，黒鉛領域を除き，核分裂比の実験値と計算値はかなり良く一致した。

天然ウランによる中性子の増倍の測定値は約2.5倍で，計算値と良く一致した。

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I. Introduction

To design the blanket of a controlled thermonuclear reactor (CTR), it is necessary to know the behavior of neutron in the blanket. The results of analysis on the behavior of neutrons should be evaluated by comparing with those of the blanket neutronics experiment.

Valious kinds of reaction rate distributions and ^{238}U/^{235}U fission ratio distributions in spherical lithium metal assemblies with and without a graphite reflector were measured by micro fission chambers and a ^{6}LiI scintillation detector [1],[2]. The fission ratios measured in the lithium metal assembly without a graphite reflector agreed well with the analytical results. In the assembly with a graphite reflector, however, there was a large discrepancy between the experiment and calculation[3].

In this paper we investigate the spatial distributions of fission rate and ^{238}U/^{235}U fission ratio in two assemblies of fusion-fission hybrid reactor blanket system.

Most of the neutrons in a fusion blanket have the energy high enough to cause the fast fission of ^{238}U or ^{232}Th. Natural uranium, depleted uranium and thorium can be used in hybrid blanket. One of the feature of hybrid blanket in contrast to normal blanket is the neutron multiplication. Another is that there is considerable contribution of fission neutrons in the neutron energy spectrum of hybrid blankets.

II. Preliminary Analysis for the Experiments

The hybrid assemblies are constructed by loading natural uranium between the neutron source and lithium region. Effective thickness of natural uranium region is 6.7 cm. In the previous experiments, this region was a void region. The model used in the calculation is shown in Fig. 1.

The 42 energy group neutron cross sections[1] were prepared from ENDF/B-III data file by SUPERTOG code using 1/E as the weighting function. The neutron flux distribution in the spherical hybrid assemblies was calculated by the one-dimensional transport code ANISN with P_5-S_8 approximation.

The calculated results of tritium breeding ratio in the hybrid and lithium metal assemblies are summalized in Table 1. Symbols T_6 and T_7 mean tritium breeding ratio through $^6Li(n,\alpha)T$ and $^7Li(n,n'\alpha)T$ reaction, respectively. The effect of the graphite reflector upon T_7 is very small. The tritium breeding ratios due to ^7Li in the hybrid assemblies are almost half of the non-hybrid lithium assemblies. The source neutrons having 14 MeV of energy are generally slowed down by the inelastic scattering of uranium nuclei and enter in the lithium region. The threshold energy of $^7Li(n,n'\alpha)T$ is about 5 MeV. Most of the fission neutrons have the energy under the threshold. The calculated number of neutrons that enter the lithium region are about 2.5 times larger than that of source neutrons. The tritium breeding ratios due to ^6Li are larger in hybrid assemblies than in lithium assemblies. The total tritium breeding ratio is close to unity in the hybrid assembly with graphite reflector which has a lithium region only 24 cm thick.

Typical calculated neutron energy spectra in these assemblies are shown in Fig. 2. They are the neutron spectra at 20 cm from the center where the neutrons are generated. The neutron flux of the hybrid assemblies below 1 MeV is a few times larger than that of the lithium assemblies.

III. Experimental Assembly and Procedures

The spherical hybrid assemblies with and without a graphite reflector are prepared by piling up lithium, natural uranium and graphite blocks in the same manner as in the previous experiments.[(1),(2)] A vertical cross section of the spherical hybrid assembly is shown in Fig. 3. Effective outer radii of the central cavity, natural uranium, lithium metal and graphite regions are 3.3, 10.0, 34.1 and 55.3 cm, respectively. The extension tube leading D^+ beam to the target is placed in the central matrix. The experimental hole of 2 cm in diameter is placed in the direction 90 degrees to the incident D^+ beam.

Source neutrons are generated at the center of the assembly by D-T reaction using a 300 KeV Cockcroft-Walton type accelerator.

The measurements of the fission rates traverse were carried out by micro fission chambers of ^{232}Th, ^{235}U, ^{237}Np and ^{238}U. The chambers of ^{232}Th, ^{235}U and ^{238}U are coated with about 4 mg of the fissile oxide. And the chamber of ^{237}Np is coated with about 1.6 mg of neptunium oxide. The fission chambers used are Type FC4A of 20th Century Electronics Ltd.

All traverse measurements were performed along the experimental hole. The fission rates of ^{235}U and ^{238}U, and those of ^{237}Np and ^{232}Th were measured at the same time, respectively. The effective atom numbers of ^{235}U and ^{238}U micro fission chambers were calibrated as $(7.14 \pm 0.33) \times 10^{18}$ and $(7.37 \pm 0.36) \times 10^{18}$, respectively.

IV. Results and Discussion

The experimental results of fission ratio distribution in the hybrid assemblies with and without a graphite reflector are shown in Fig. 4 with the calculated curves. The error in measured fission ratio is about 6 %. This error consists of the accuracy of the effective atom numbers of fissile materials coated in the fission chambers, the extrapolation error of total counts, the error due to the sway of deuteron ion beam, the error due to the configuration of detectors and the statistical error. The error in the position of detectors is about ± 2 mm. The measured fission rate distributions in the assemblies are shown in Figs. 5 and 6, together with the calculated ones. They are nomalized at 15.6 cm from the center.

In the assembly without a graphite reflector, the shapes of measured fission rate distribution are in fairly good agreement with those of calculation, however, there is a large difference between the measured fission ratio and calculated one. In the assembly with a graphite reflector, the measured fission ratio agrees fairly well with the calculated one except in the graphite region. These results are considerably different from the results of the previous experiments[(2)]. This discrepancy may be caused by the change of neutron spectrum due to the fast fission. Further analysis is being carried out.

The neutron multiplication factor due to the natural uranium was measured by a long counter and a radiation monitor.

The measured multiplication factor, that is, the ratio of the counting rate in case of the assembly with a natural uranium region to that of the assembly without a natural uranium, was about 2.5. This agrees well with the calculation.

Acknowledgment

The authors wish to express their thanks to Dr. J. Hirota, Dr. H. Kuroi and Dr. T. Hiraoka for their supports of this work and discussions. They thank very much Mr. J. Kusano and Mr. H. Watanabe for their operation of neutron generator.

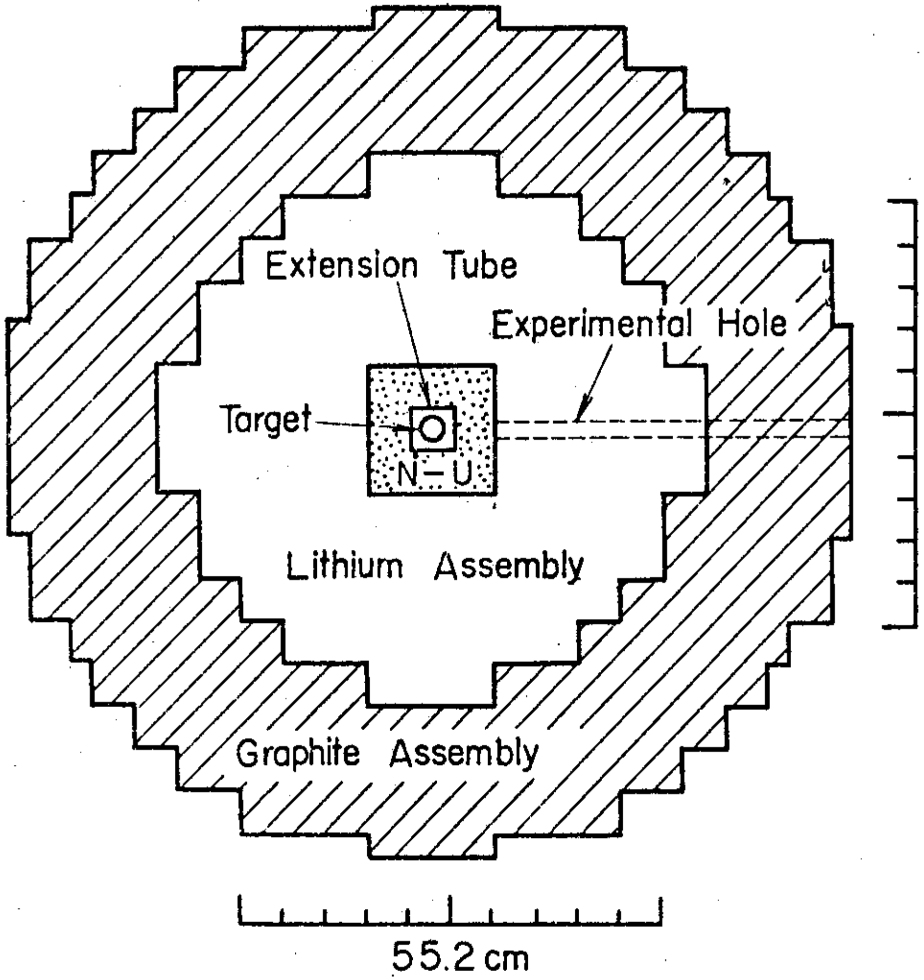

Fig. 3 Vertical Cross Section of the Spherical Hybrid Assembly

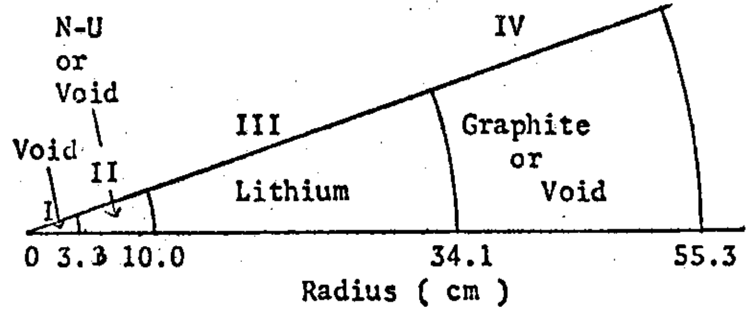

Fig. 1. Model of the Spherical Hybrid Blanket Assembly

Table 1. Tritium Breeding Ratio

Region			T_6	T_7	T_6+T_7
II	III	IV			
N-U	Li	Void	0.289	0.112	0.401
N-U	Li	C	0.835	0.115	0.950
Void	Li	Void	0.076	0.207	0.283
Void	Li	C	0.306	0.213	0.519

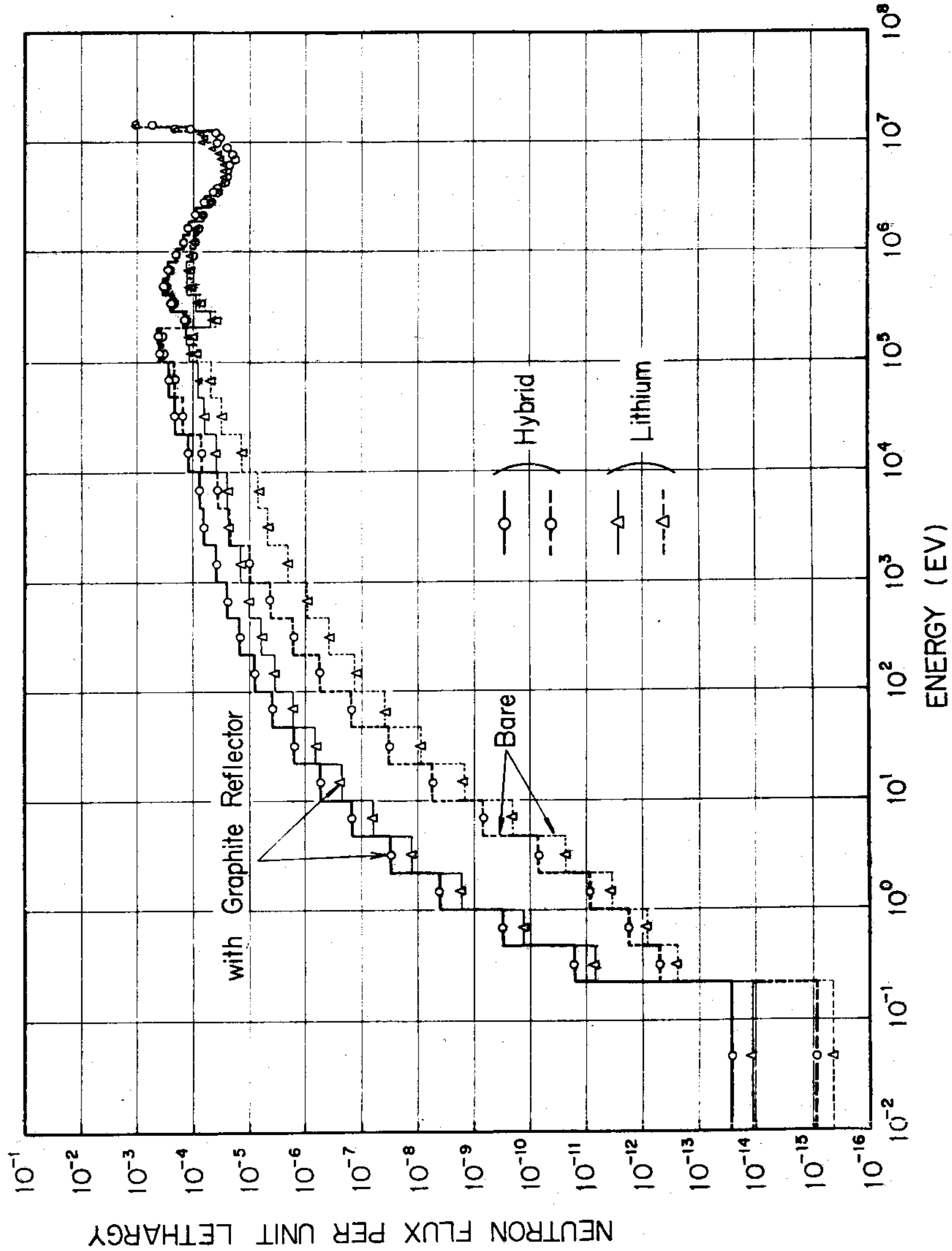

Fig. 2 Neutron Energy Spectra in the Experimental Assemblies at 20 cm from the Center

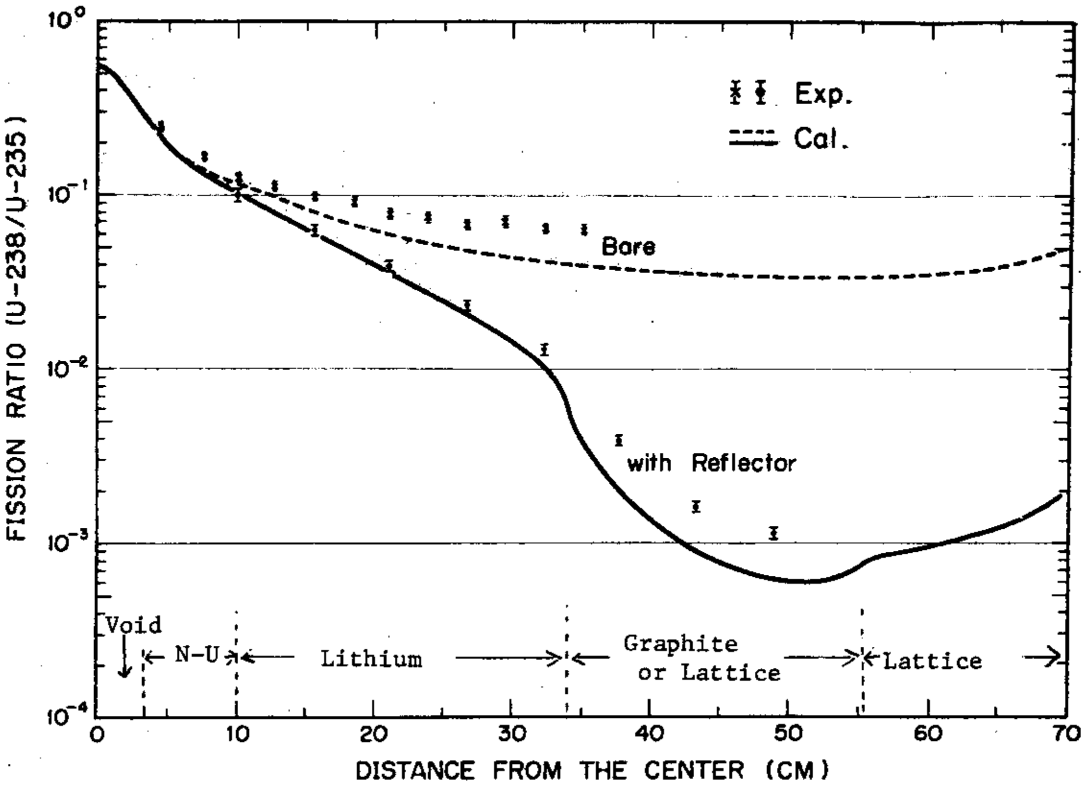

Fig. 4 Fission Ratio Distribution in the Hybrid Assemblies

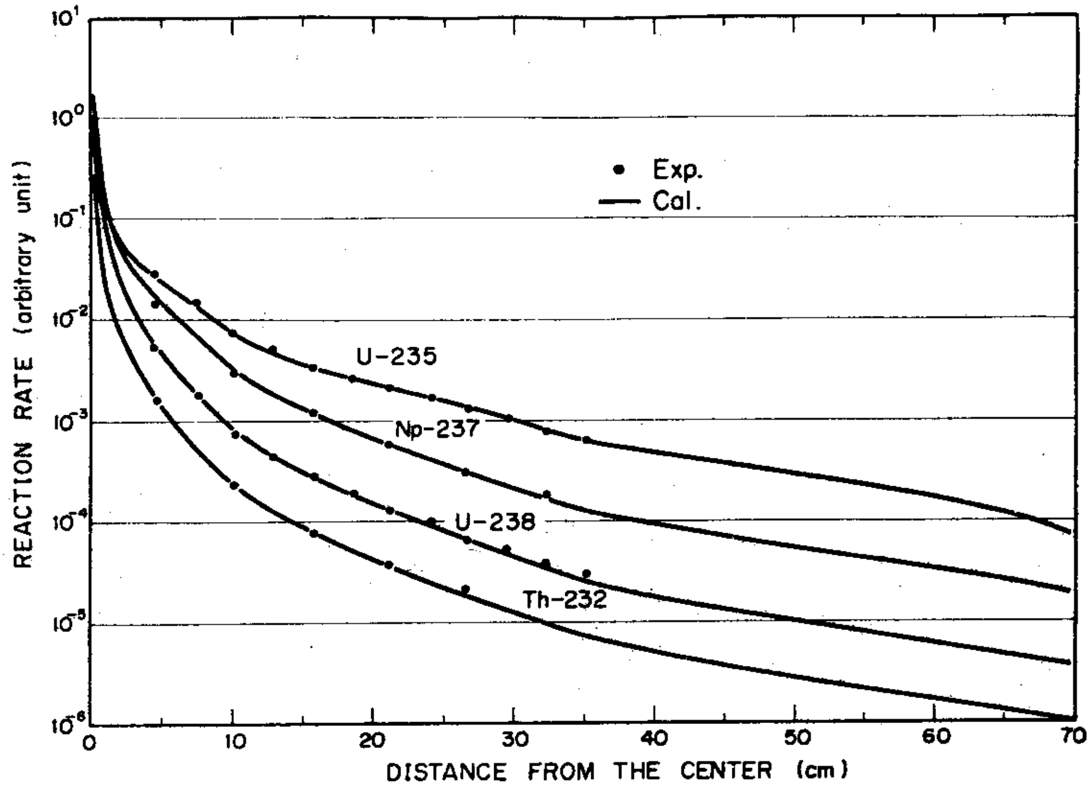

Fig. 5 Fission Rate Distribution in the Hybrid Assembly Without a Graphite Reflector

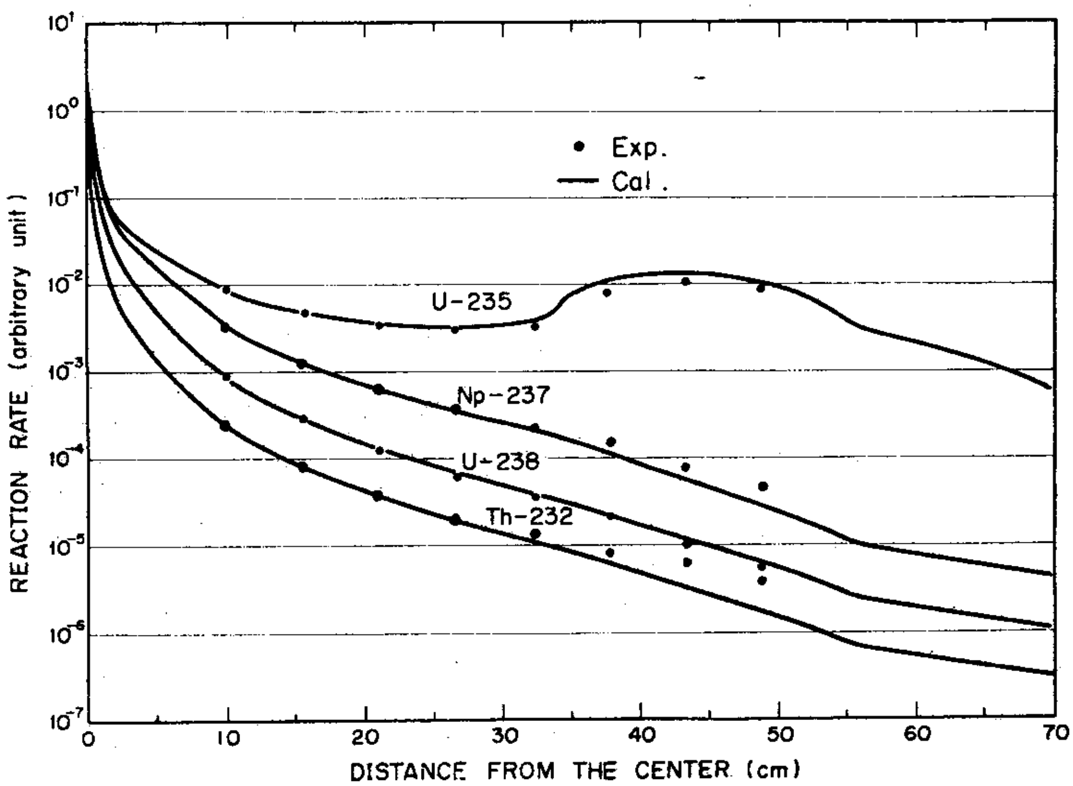

Fig. 6 Fission Rate Distribution in the Hybrid Assembly With a Graphite Reflector

References

(1) HIRAOKA, T. et al., Integral Experiments on a Spherical Lithium Metal Blanket System, Nucl. Fusion Special Suppl. 1974, Proc. Symp. Fusion Reactor Design Problems, p. 363, International Atomic Energy Agency (1974).

(2) MAEKAWA, H. et al., Nucl. Sci. and Eng. 57, 335-340 (1975).

(3) SEKI, Y. et al., Analysis of Fission Ratio Distribution in Spherical Lithium Metal Assembly with a Graphite Reflector, JAERI-M 6220 (NEACRP-L-136) (1975).