G. Phillips

N 941 75—29

Paper Presented
at ANS 21st Annual Meeting
In New Orleans , 1975

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HEAVY-WATER CRITICAL EXPERIMENT FOR FUGEN (II) CELL FLUX DISTRIBUTIONS IN PLUTONIUM LATTICE

June 1975

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Heavy-Water Critical Experiment for FUGEN (II)

Cell Flux Distributions in Plutonium Lattice

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A b s t r a c t

Intra-cell thermal neutron flux distributions were measured by means of dysprosium foil activation method for coolant void fractions of 0%, 30%, 70% and 100% in 0.54 w/o PuO_2-UO_2 fueled lattices and of 0% and 100% in 0.87 w/o PuO_2-UO_2 ones.

With use of new foil setting technique applicable on the inside surfaces of long calandria tube or pressure tube, neutron behavior around the boundary between the fuel and the moderator region was made clear.

On the base of this accurate measurement around the boundary, thermal neutron flux distributions became to be comparable in detail in each region with calculated results for METHUSELAH II code.

In the previous experiment on UO_2 fuel lattice of the same geometry, calculational discrepancies were always seen or were always larger at the lattice condition of 100% void fraction. However, the present data on PuO_2-UO_2 fuel lattices shows that the discrepancy depends on plutonium fuel enrichment: the calculational discrepancy was larger at 100% void in the lower enrichment of 0.54 w/o PuO_2-UO_2, and was larger at 0% void in the higher enrichment of 0.87 w/o PuO_2-UO_2.

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Contents

1. Introduction

The advanced thermal reactor in Japan "FUGEN" is a heavy-water moderated, light-water cooled, cluster-type, thermal reactor. In the FUGEN, plutonium fuel is partially loaded from the initial core to lessen coolant void reactivity and to use nuclear fuel effectively.

Therefore, accuracies of calculation codes which have been used for the core design must be also investigated on the plutonium fueled lattices from various physical points of view in a similar way made on the uranium ones.(1) A fine distribution of thermal neutron flux in a unit cell is a very important and fundamental quantity among those on neutron behaviors.

In the present experiments, intra-cell thermal neutron flux distributions were measured by means of dysprosium foil activation method in the Deuterum Critical Assembly of PNC. Coolant void fractions used in the experiment were 0%, 30%, 70% and 100% for the plutonium fuel lattices of 0.54 weight-percent enrichment. And 0% and 100% coolant void fractions were used in 0.87 weight-percent enriched plutonium fuel.

2. Experimental Facility and Procedure

Plane view of the core configuration of our Deuterium Critical Assembly is shown in Fig. 1. It has 121 fuel channels of 22.5 cm square lattice pitch. In this experiment, 25 assemblies of plutonium fuel are loaded in the central region of this core. The intra-cell thermal neutron flux distributions were measured in the central unit cell of the plutonium fuel region.

Measurement positions of dysprosium-aluminum alloy foils are shown in Fig. 2. They are: in the plutonium fuel pins, in the coolant, on both inside and outside surfaces of calandria tube and pressure tube, and in the D_2O moderator.

For measurement in the fuel pins, four foils 14.8 mm in diameter were set in anti-symmetrical positions F-1, F-2, F-3-1 and F-3-2.

In the coolant region, 0.1 mm thick sector foil was used, which was shown by hatching in the slide. On the calandria tube and pressure tube, the foils 7 mm in diameter were set at the two identical positions around each surfaces.

In the D_2O moderator region, foils with the same diameter were arranged along two directions 0 degree and 45 degrees. Foil arrangements in plutonium fuel pin are shown in Fig. 3. Dysprosium foils 0.1 mm in thickness, which is also shown in the figure as a foil pack,[2] were enveloped with 0.02 mm thick aliminum foils which prevent the foils from contamination by plutonium oxide powder and fission products. The cadmium covered foil was also used for measurement of cadmium-ratio in fuel.

After irradiation, the fuel pins with dysprosium foils were bagged into the glove box in the Plutonium Handling Room in Deuterium Critical Assembly of the PNC, as shown in Fig. 4, where the cladding tubes were cut with silicon-carbide cutter at the plenum position of the fuel pins. Dysprosium foils were taken out from the cladding tubes, and the contaminated aluminum envelope foils were peeled off in the next glove box. To remove any possible contaminations, the foils were further decontaminated there by means of an ultra-sonic cleaner.[3]

After the decontaminations, the β-rays from dysprosium hundred sixty-five decay (it has 139.9 minute half life) were counted with the CaF_2(Eu) scintillation counter.

A sector foil for measurement in the coolant region is shown in Fig. 5 (a). This sector foil was sandwiched with acrylic resin holders as shown underneath. After irradiation, we divided the sector foil into seven pieces as shown, and made counting for each pieces in consideration of difference in counting efficiency.

For measurement in the D_2O moderator, dysprosium foils were arranged into line on a thin aluminum holder as shown in Fig. 6, which is suspended with a fine nylon thread starting from the upper grid plate about 2 m above. By the two wings which protrude from both ends of the holder, accurate and stable positioning of the holder was obtained between two calandria tubes.

Tools for foil setting and their handling procedure are shown for the measurement on both inside surfaces of calandria tube and pressure tube in Fig. 7. Through the detailed explanation is skipped here, it is very difficult to set a foil on the correct positions of inner surface of a long tube.

Reaction rate distribution was obtained from each foil's counting rate by correcting deference in foil weights, activity decays and so far. Besides the necessary corrections, the Dy reaction rate distribution in the unit cell was corrected for gross distribution of thermal neutron flux, which was measured with Dy foil placed at intervals of 2.25 cm on an aluminium holder across the core diameter shown in Fig. 8.

The gross distribution of thermal neutron flux is shown as an example for coolant void fraction of 0% in 0.54 w/o PuO_2-UO_2 fueled lattice in Fig. 9. Six curves, A, B, C, D, E and F, were obtained by the method of least squares using reaction rate on periodically identical and symmetric positions across the unit cells of plutonium fuel region. These curves were normalized into one curve, and this resultant gross distribution was eliminated from the experimental intra-cell thermal neutron flux distribution.

3. Results and Discussion

In Fig. 10, results measured on 0.87 weight-percent enriched fuel and 0% and 100% voided lattices are shown together with the results calculated by METHUSELAH-II code.[4]

If one wants to compare the experimental intra-cell distribution with theoretical one in detail in each region, normalization between their values should be made at the boundary between the fuel and the moderator region. For the purpose, it is necessary to obtain detailed thermal neutron flux distribution at the pressure and the calandria tube. In the present experiment, accurate measurement could be performed by new technique. Besides the problem of normalization, neutron behavior around the boundary was made clear as shown in Fig. 10.

In the result for coolant void fraction of 0%, calculated values lie midway between experimental values along the direction of 0 degree and 45 degrees in the D_2O moderator. This fact means a good agreement between theory and experiment, because the calculation is made using cylindrical cell model. In the fuel region, in spite of good agreement in both third and second layer, considerable discrepancy is seen in the first layer.

As the reasons for this, it is considered that estimation of self-shielding effect by water coolant is small, and also considered that absorption reaction rate by plutonium fuel is estimated smaller because the similar tendency is also seen in the results for 100% voided lattice of the same plutonium fuel enrichment. On the whole, agreement with experiment in this case of 0.87 weight-percent enriched fuel are better in 0% void fraction than 100%.

In Fig. 11, results for coolant void fraction 0% and 100% in 0.54 weight-percent enriched plutonium lattice are shown. As you can see in this slide, the experimental result for coolant void fraction of 100% agrees with the calculated result better than the result for 0%.

Also, for the results of 30% and 70% coolant void fraction, their plots come between 0% and 100% void fractions in both fuel and D_2O moderator region, as shown in Fig. 12 and 13 respectively. And the discrepancies between experiment and theory are also in between.

4. Concluding Remarks

On the basis of these comparisons, it is concluded that discrepancy between the calculation and the experiments in the plutonium fueled lattices is not systematic in contrast to the case of uranium fueled lattices.

Therefore, for the confirmation of calculational accuracy of the nuclear design code for plutonium fuel, it is indispensable to accumulate a large amount of lattice data with emphasis on plutonium fuel enrichment.

On the other hand, from the view point of utilizing a much more accurate calculation code for plutonium lattices, we are now preparing a new detailed calculation code. In the estimation of the code, those data in the present experiment are also playing an important role.

The authors are much indebted to Mr. K. Iijima, Mr. N. Fukumura, Mr. A. Nishi and the operating staff of DCA for their help with experiments and discussions. We would like to thank managers Mr. Miyawaki and Mr. H. Sakata (former) for their support in this series of experiments.

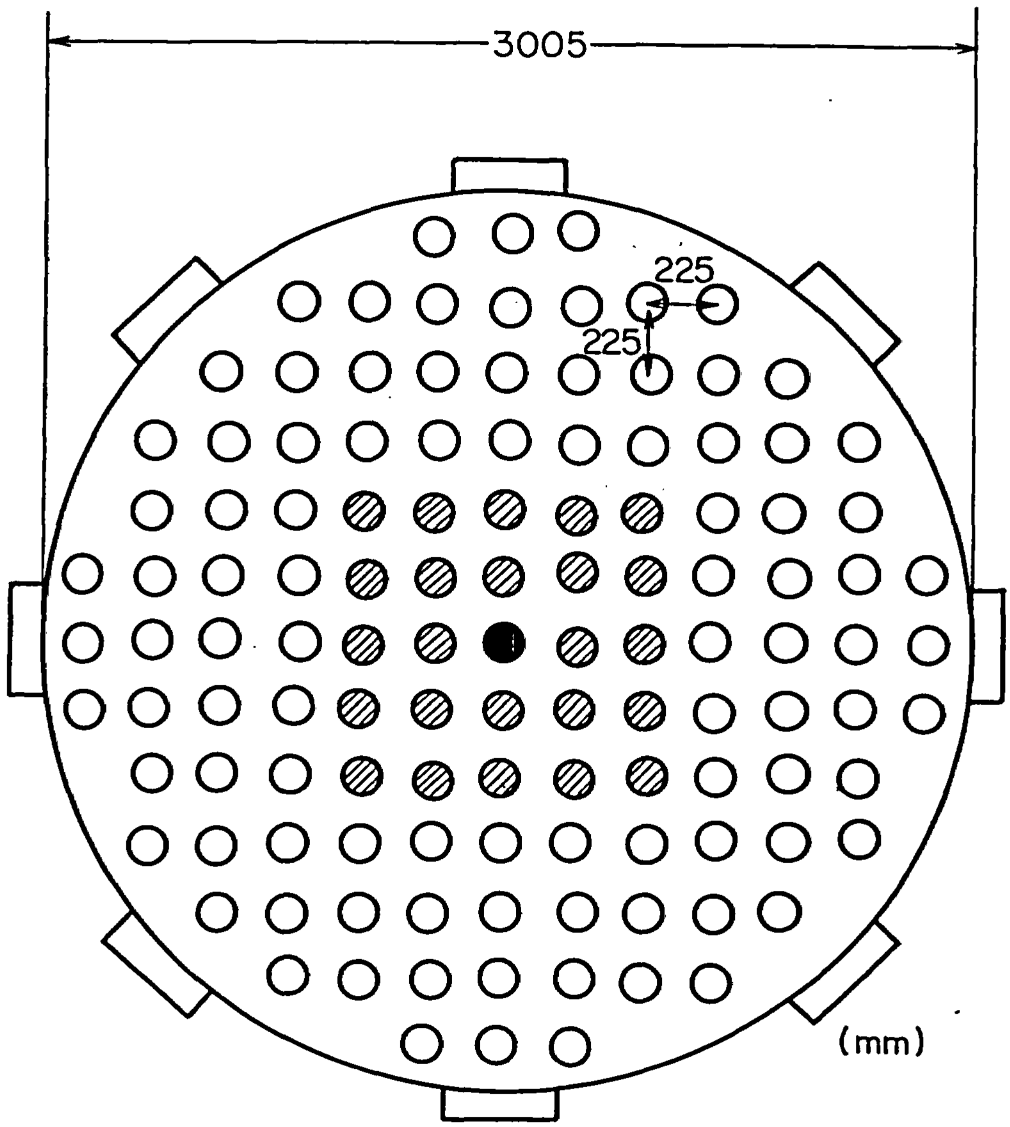
R e f e r e n c e

1. H. SAKATA et al., "Critical Experiments on Cluster-Type Fuel Lattices of ATR in Japan" Trans. A. N. S., 267 (1973).

2. Y. HACHIYA et al., "Neutron Behavior in Cluster-Type Fuel Lattices, (1)," J. Nucl. Sci. Technol., 9, 629 (1972).

3. Y. NAKAMURA et al., "Foil Handling Technique for the Measurement of Lattice Parameters in PuO_2-UO_2 Fuel Rods," J. Nucl. Sci. Technol., 9, 277 (1972).

4. M.J. BRINKWORTH et al., "METHUSELAH II A Fortran Programme and Nuclear Data Library for the Physics Assessment of Liquid Moderated Reactor," AEEW-R480 (1966).



●	PuO_2-UO_2 Fuel	(Position for foil irradiation in a cluster)
◍	PuO_2-UO_2 Fuel	
○	UO_2 Fuel	

Fig. 1 DCA core configuration

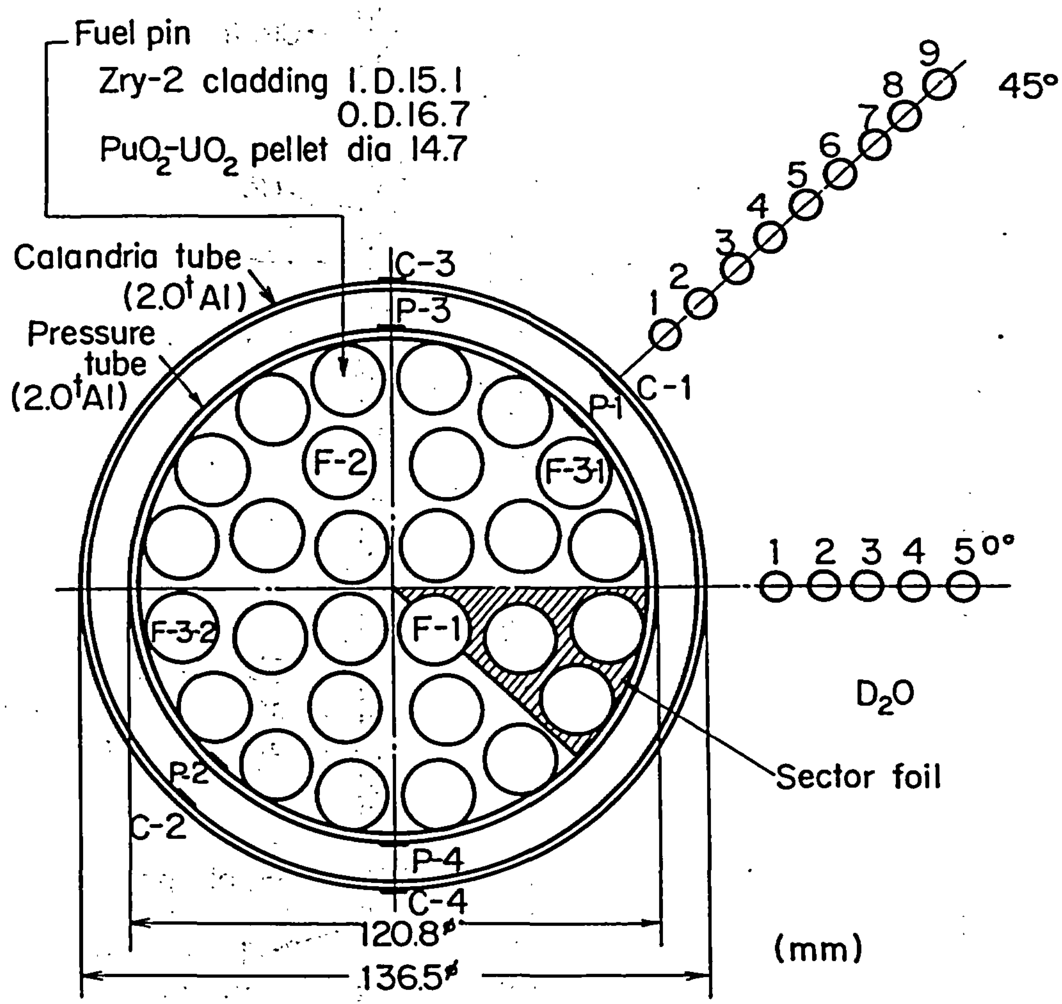


Fig. 2 Foil arrangement in unit cell

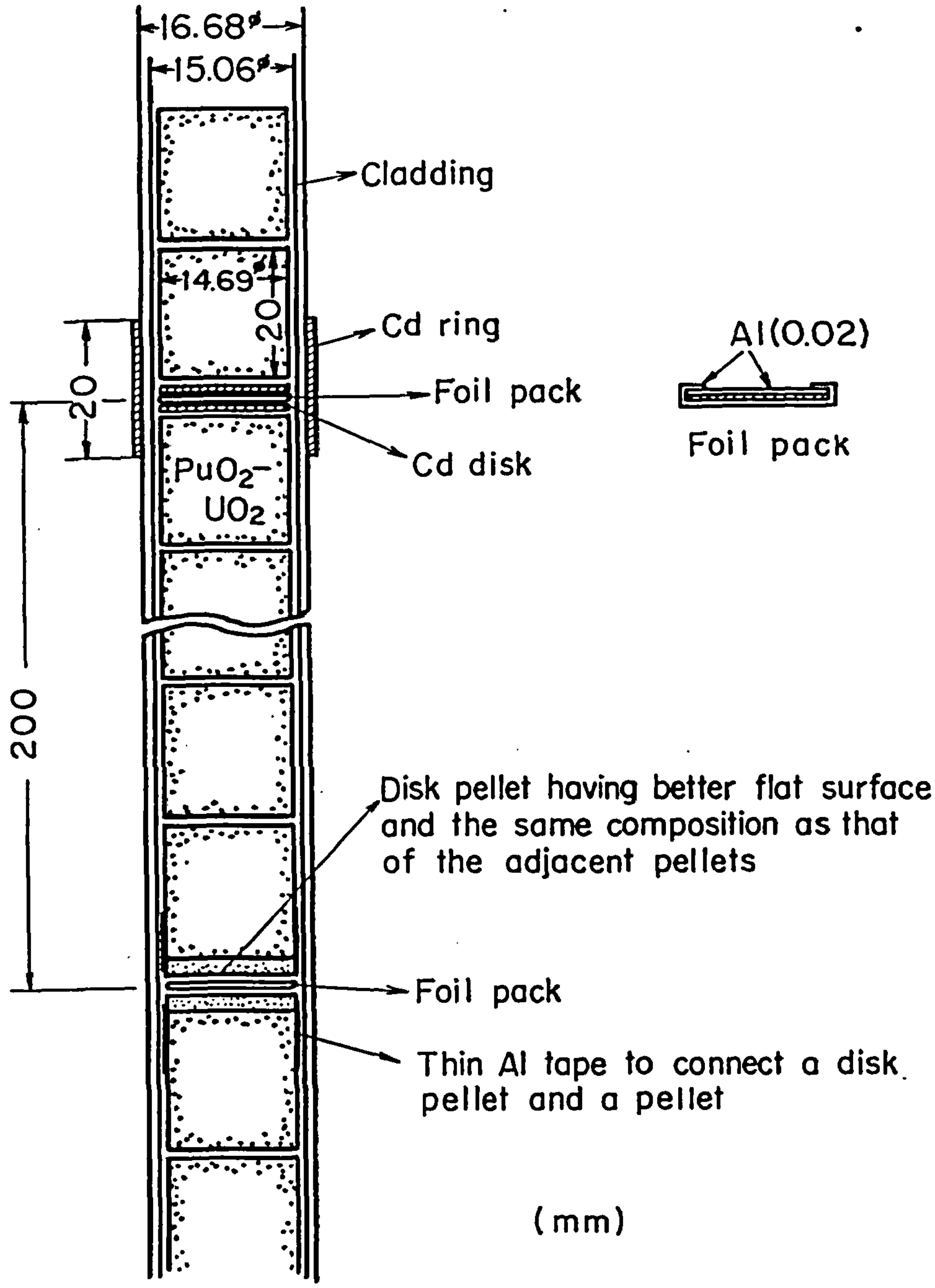
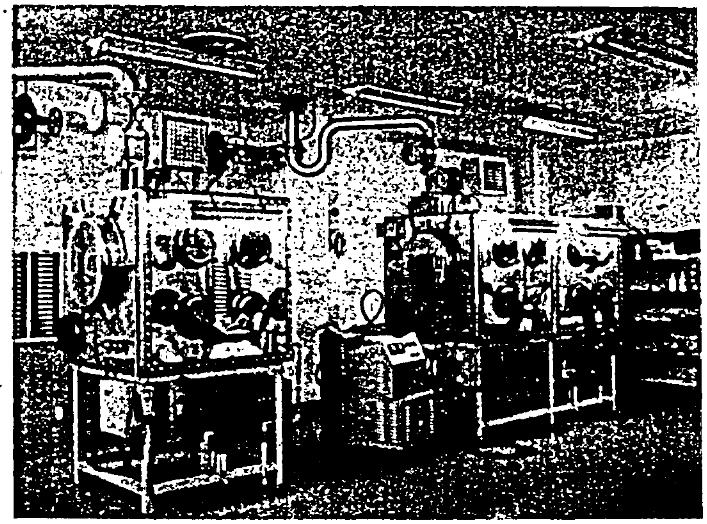


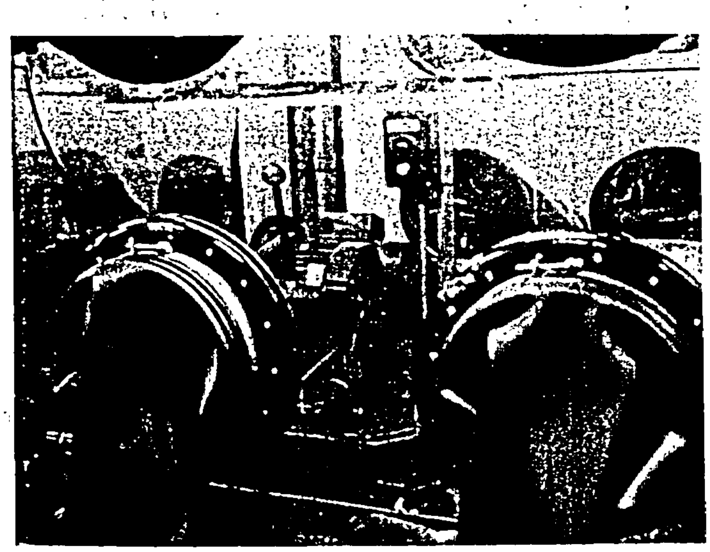
Fig.3 Foil arrangement in PuO_2-UO_2 fuel

Cleaning glove box



Cutting glove box

Plutonium handling room of PNC



Silicon-carbide cutter

Fig. 4 Photographs of Plutonium handling room of PNC

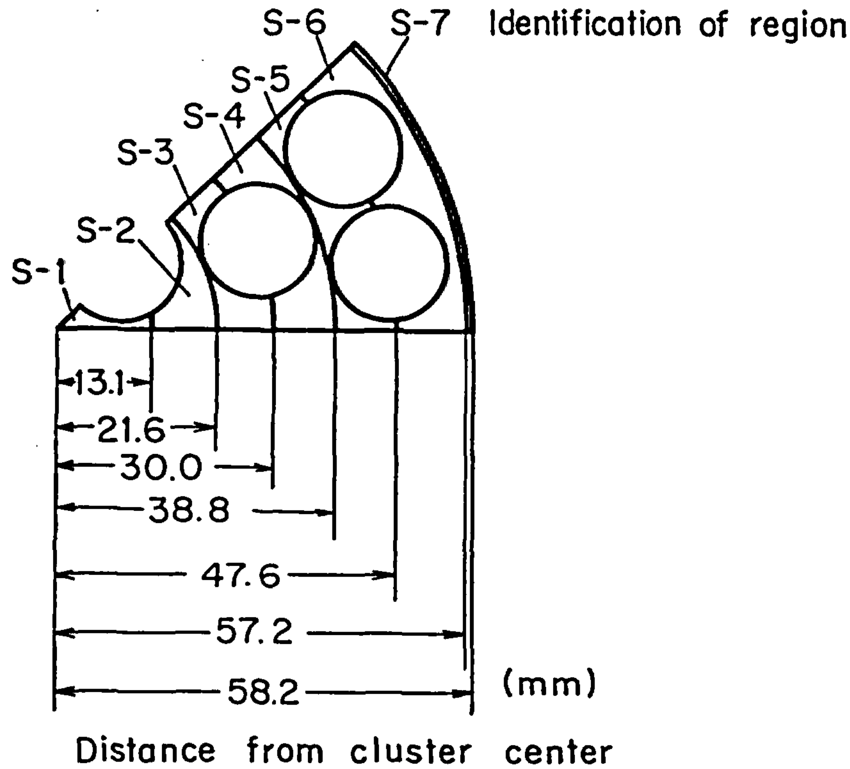


Fig. 5 (a) Sector foil for measurement of Dy reaction rate in coolant region

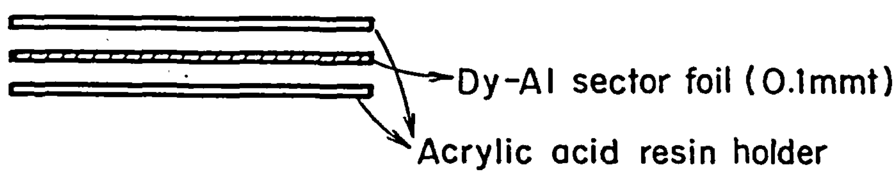


Fig. 5 (b) Sector foil and its holder arrangement in coolant region

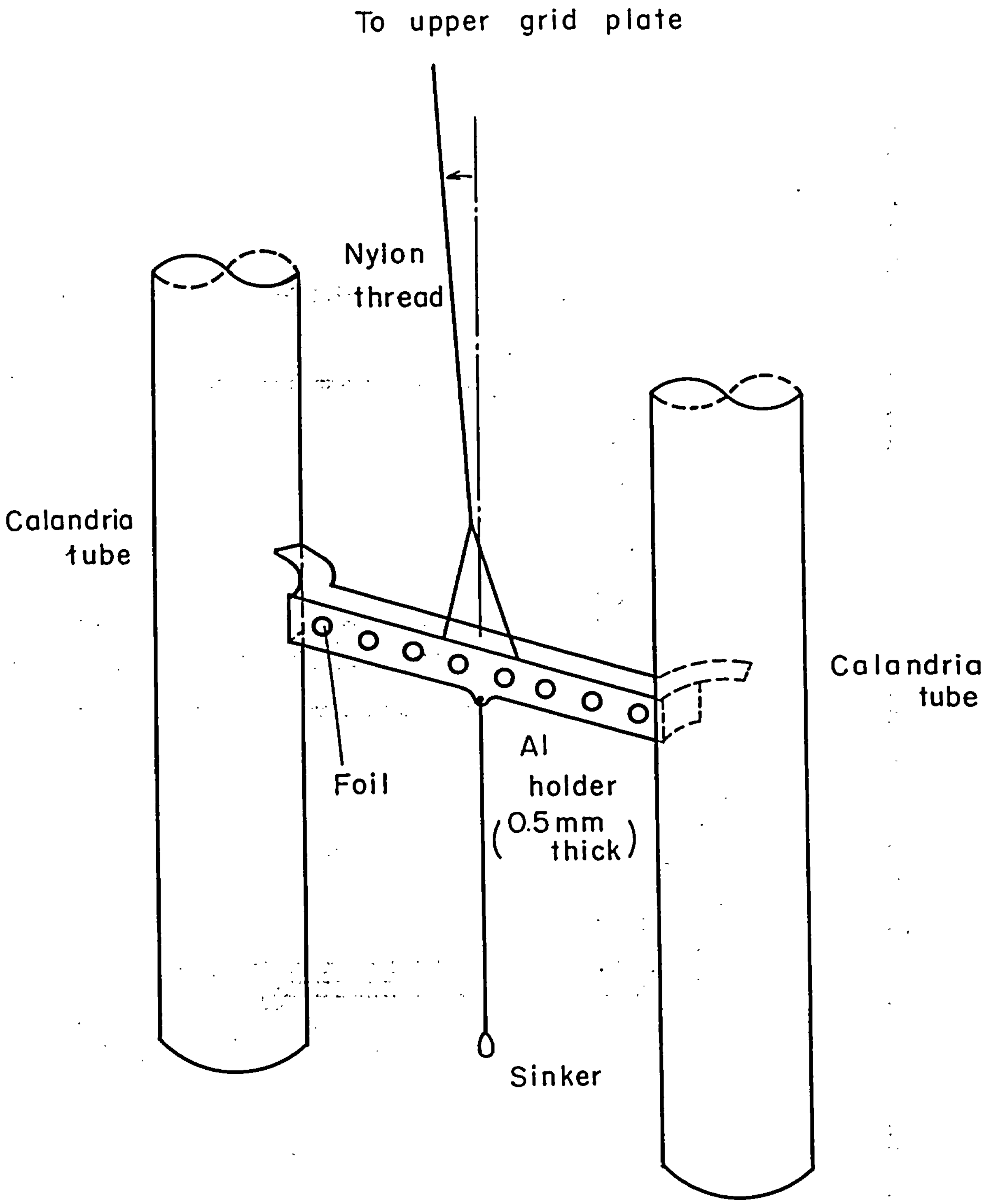


Fig. 6 **Holder arrangement for measurement in the D_2O moderator**

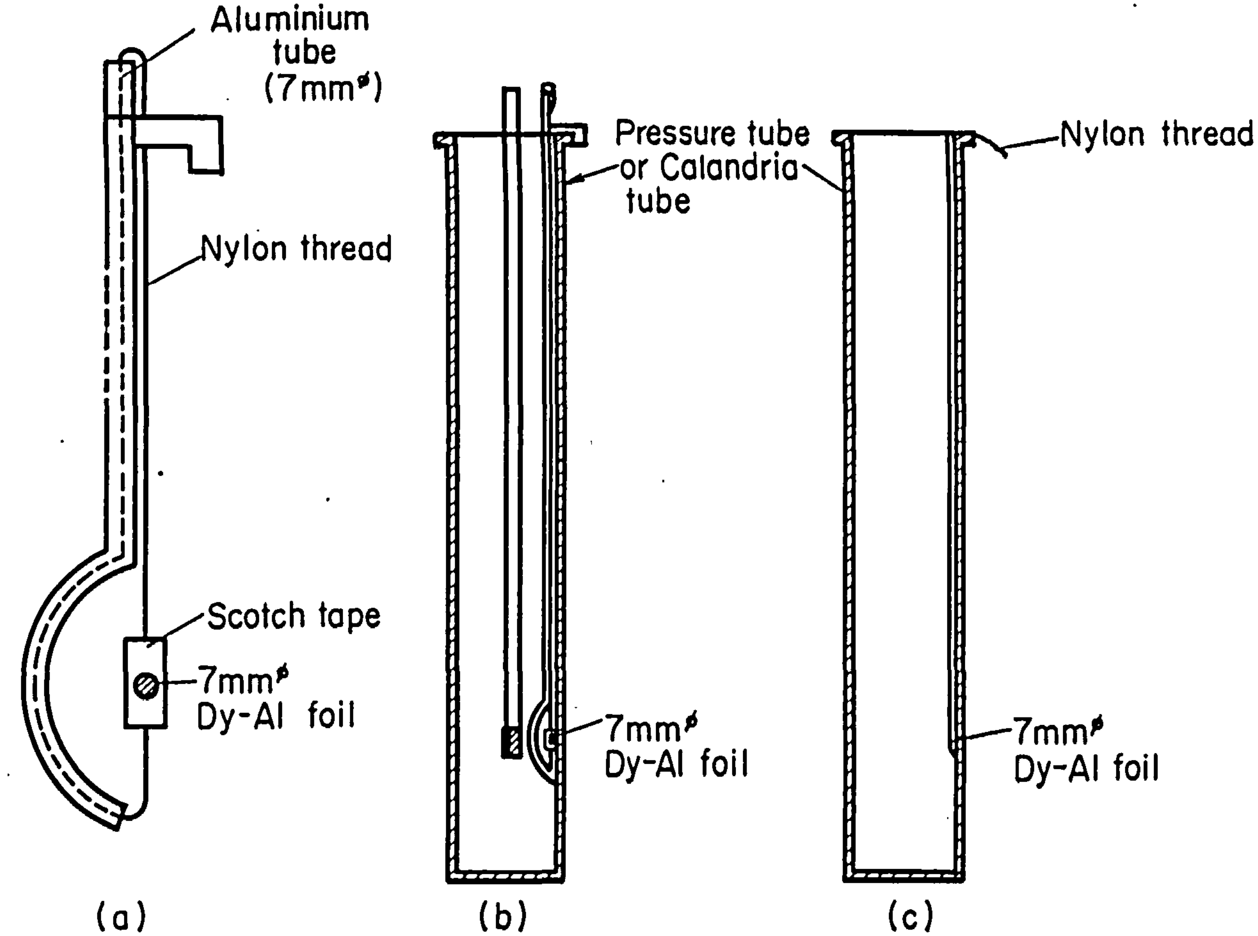


Fig. 7 Experimental technique for measurement on the inside of pressure and calandria tube

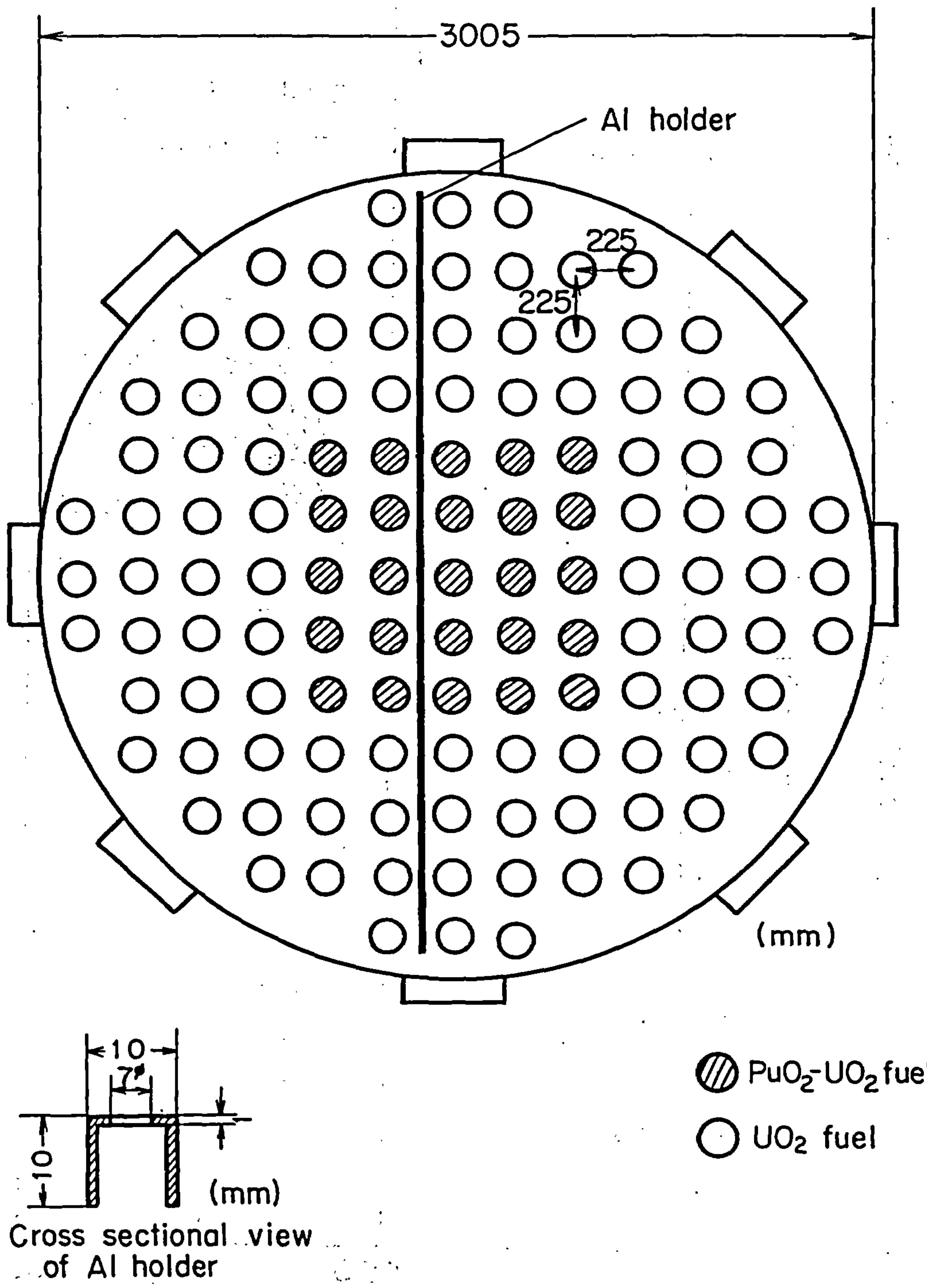


Fig. 8 Al holder arrangement for measurement of gross distribution

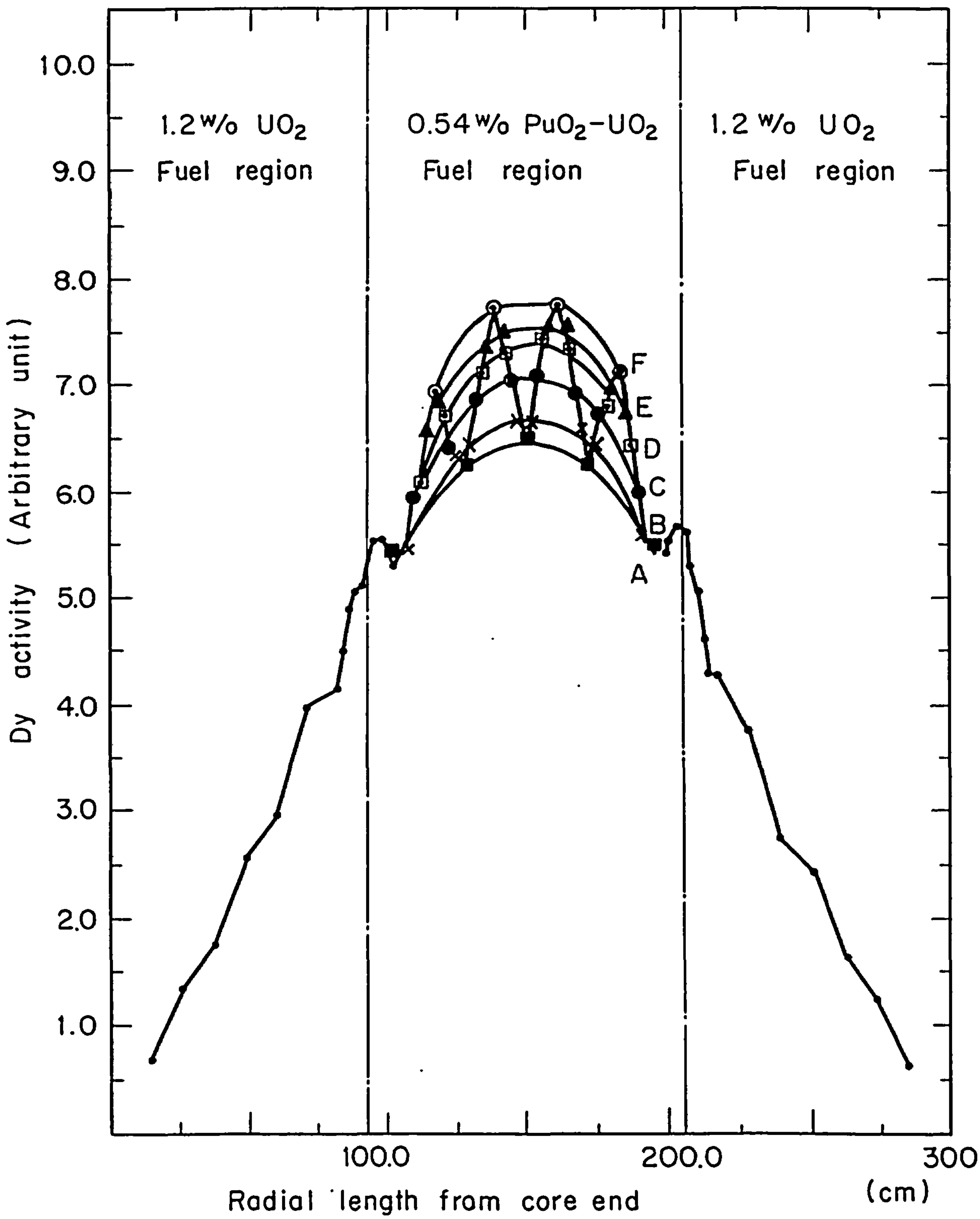


Fig. 9 Radial flux distribution
($0.54^{w}/_{o}$ PuO_2-UO_2, 0 % void)

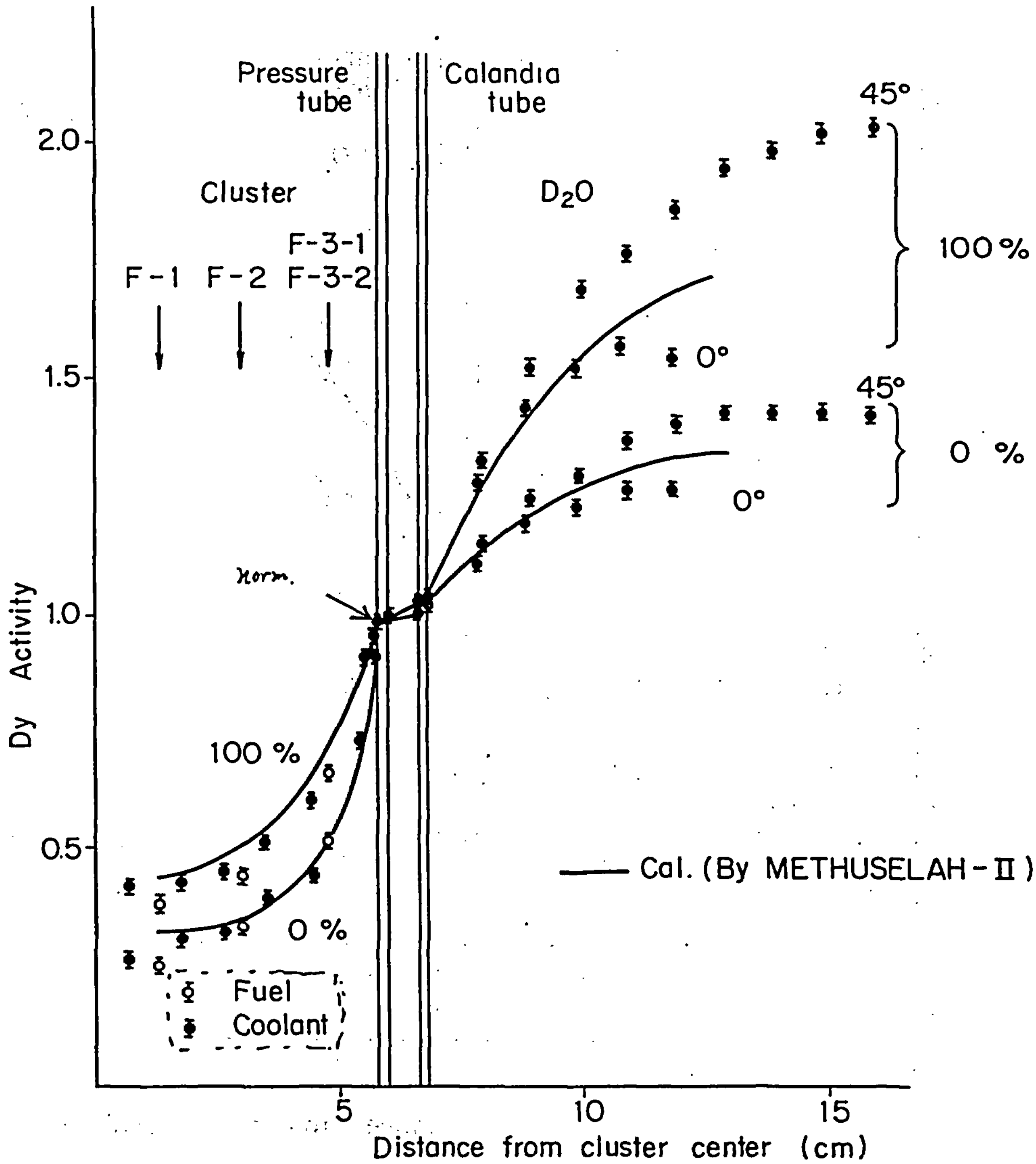


Fig. 10 Intra-cell thermal neutron flux distributions
(0.87 w/o PuO_2 - UO_2 , 0% and 100% void)

Standard
Grade

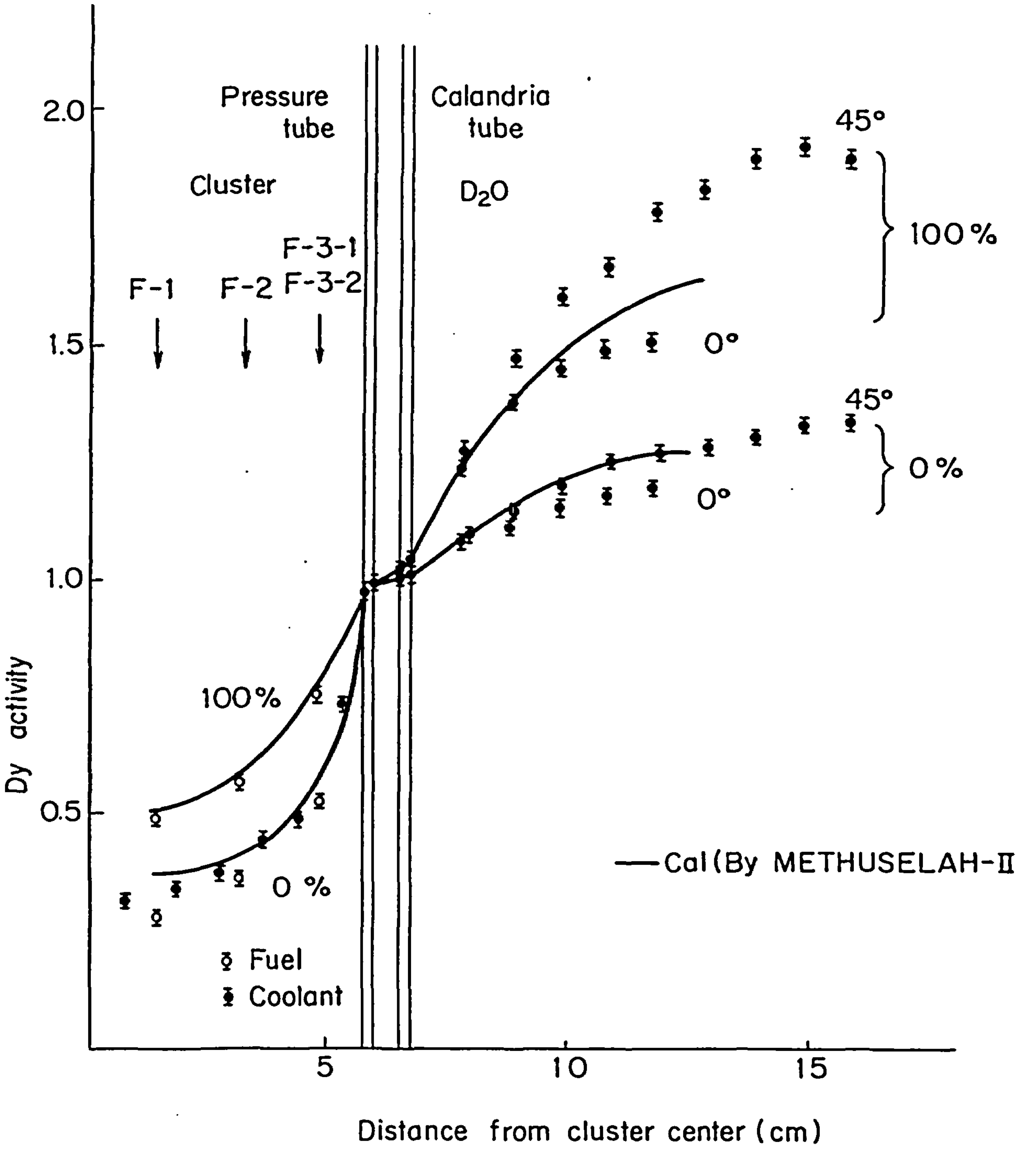


Fig. 11 **Intra-cell thermal neutron flux distributions (0.54 w/o PuO_2-UO_2, 0% and 100% void)**

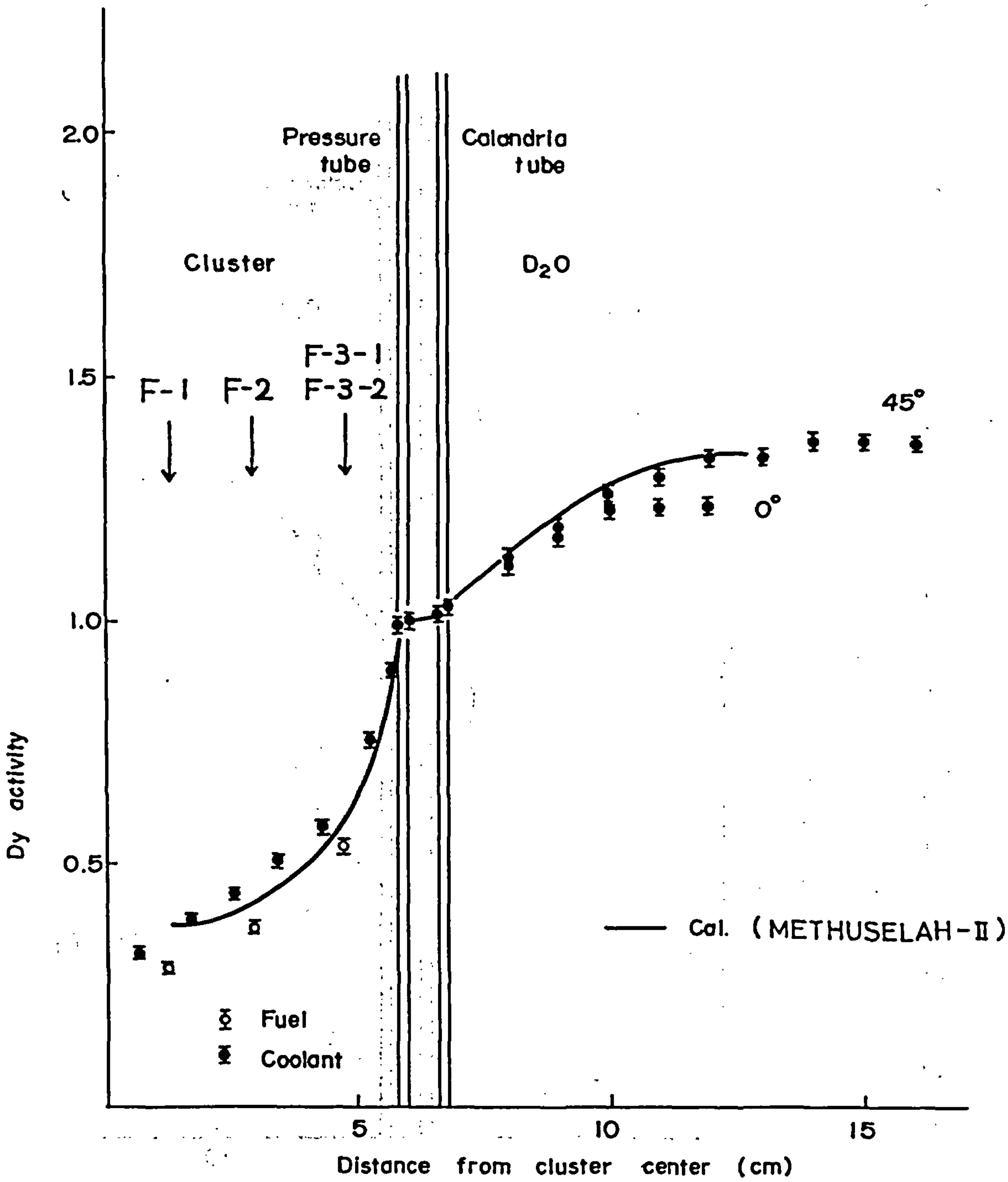


Fig. 12 Intra-cell thermal neutron flux distributions
(0.54 w/o PuO_2-UO_2., 30% Void)

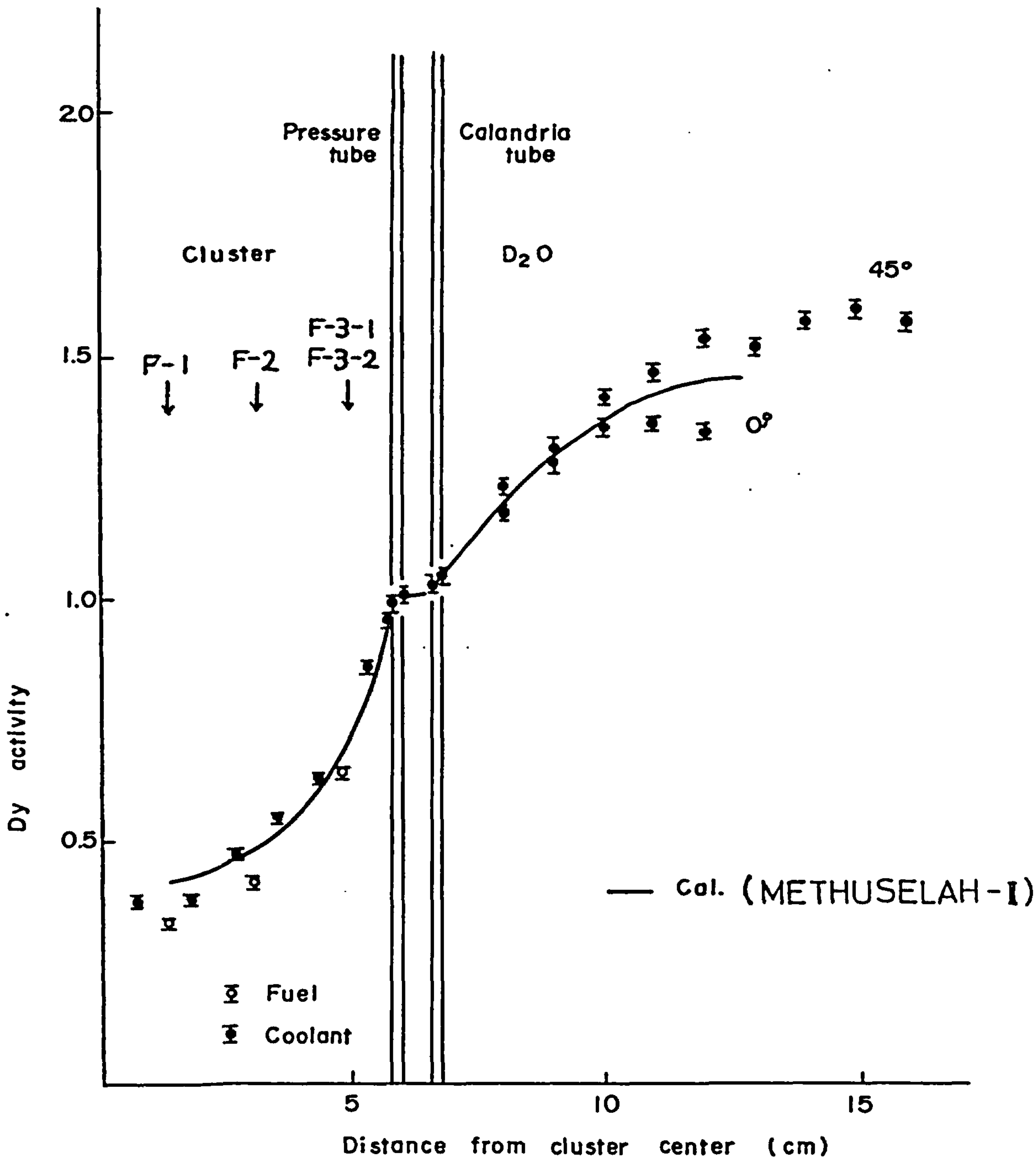


Fig. 13 Intra-cell thermal neutron flux distributions
(0.54 w/o PuO_2-UO_2 , 70 % Void)