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INTRACELL FLUX DISTRIBUTIONS FOR AN EXTENSIVE SERIES OF HEAVY WATER, URANIUM ROD LATTICES

ATOMICS INTERNATIONAL

A DIVISION OF NORTH AMERICAN AVIATION, INC.

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INTRACELL FLUX DISTRIBUTIONS FOR AN EXTENSIVE SERIES OF HEAVY WATER, URANIUM ROD LATTICES

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ABSTRACT

Intracell flux data are presented for an extensive series of heavy water, uranium rod lattices. Three enrichments of uranium fuel were used: depleted, natural and slightly enriched, that is, 0.49, 0.71 and 0.90 weight per cent U^{235}, respectively. The fuel rod diameters ranged from 3/4 to 2 inches and the lattice spacings from 3 to 12 inches. The data of four special lead-cadmium alloy lattices and three single rod "lattices" are also presented.

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I. INTRODUCTION

In the course of the extensive exponential experiment program at North American Aviation, Inc. the intracell flux distributions of over 30 heavy water, uranium lattices were carefully measured. These data had been previously calculated to determine fuel and moderator disadvantage factors for each lattice. These disadvantage factors have already been published.[1,2] Apart from the disadvantage factors, the data have intrinsic interest of their own. These data represent one of the most extensive series of intracell measurements to date and should serve as a useful guide for any computational scheme designed to obtain detailed flux information for simple heterogeneous lattices.

In assembling the data, the intent was not to include everything measured, but rather to collect enough of the material to give a comprehensive view of the main features of the intracell flux patterns. For example, where a given set of lattices were measured utilizing a number of different foil materials, usually only the data of the foil material giving the best coverage are presented. Again, where measurements exist for two nearly similar lattices, e. g. one having 4.5 and the other 4.9 inch lattice spacings, the data for only one lattice may be presented.

II. MEASUREMENTS AND ANALYSIS

The experimental arrangement and the techniques of making the measurements have been described a number of times before.[3,4] Briefly, the lattices were assembled in a 5-foot diameter, 6-foot high, aluminum tank which was covered with cadmium sheet and filled with D_2O. The fuel elements consisted of unclad, uranium slugs in 5-foot long aluminum tubes arranged vertically in the tank. Spacing of the fuel rods in a square lattice array was maintained by special grid plates. In general, the intracell measurements were confined to the lattice cells nearest the axis of the tank. They were made using various metal foils, usually gold or a lead-indium alloy, 2 millimeters wide and 1 centimeter long. In the D_2O, the foils were supported by light aluminum straps and in the uranium, they were placed in specially milled slots. Usually three or more distinct foil-exposure runs were made; both bare and cadmium-covered foils being used. The activity of the foils was measured using at least three different Geiger counter sets and the counting rates were related to saturated activities. Averages of the saturation exposure activities were obtained for the bare foil and for cadmium-covered foil. The cadmium covered foil activity was multiplied by a suitable constant to correct for the absorption by the cadmium of the higher energy neutrons[5] and the product was subtracted from the bare foil activity in order to obtain the thermal neutron activation.

It was customary to normalize the thermal activity at the center of the fuel rod to unity. The greater accuracy of data from the moderator would perhaps make normalization at the moderator center preferable. However, this report preserves the rod center normalization, partially because it facilitated presentation of the data.

III. PRESENTATION OF THE DATA

The essential consideration was how to present the large accumulation of data in a reasonably complete manner, and at the same time avoid a voluminous, hard-to-survey report. In keeping with previous reports, it appeared reasonable to group the data according to the type of fuel element, that is, by fuel diameter and enrichment. Most of the data are presented using this arrangement (see Fig. 1 to 8). The curves represent the relative variation of the flux along a diagonal through the cell and contain corrections for the overall J_o dependence. To reduce the overlapping and crossing of curves the distances have been plotted from the center of the moderator. The end of each curve corresponds to the rod center, while the short vertical line intersecting each curve near the end represents the surface of the fuel rod. The predominant curves in the upper part of each graph represent the relative thermal neutron flux and have in all cases been corrected for the epicadmium activity. The relative epithermal activities after correction for the epithermal neutron absorption by the cadmium are plotted below the thermal curves. The correction factor used depended on the foil material involved being 1.00 for the gold foils and 1.07 for the lead-indium foils. A different symbol is used for each lattice spacing. In general, the standard deviation for each datum point is of the magnitude of one or two per cent. The scatter of the data about the smooth curves drawn is indicative of the reliability of the data.

As a rule, the various foil materials gave the same shape of thermal and epithermal flux distribution. The cadmium ratios varied quite consistently from one foil material to another. The europium foils, however, gave somewhat differently shaped curves. This is because of the significantly different variation of the europium activation cross section with neutron energy changes. Figure 9 presents data obtained for a single lattice using gold, lead-indium, dysprosium, manganese and eurpoium foils. In Fig. 9, one of the curves of thermal neutron activation represents the europium foil data, the other curve represents all of the data obtained with other types of foils. The correction factor for the absorption of epithermal neutrons by the cadmium foil covers was 1.4 for europium, and 1.00 for all other foil materials used except indium. A cadmium thickness of 0.020 inch was used in all experiments. The use of europium foils as neutron temperature indicators is discussed in a previous report.[6]

Fig. 10 presents the intracell data obtained on four lattices containing one inch diameter slugs of lead-cadmium alloy instead of uranium. The composition of these slugs is discussed more fully in a previous report,[7] in which the effective absorption and transport cross sections were determined to be 0.267 cm^{-1} and 0.627 cm^{-1}, respectively. Epithermal activities are not particularly significant for non-multiplying lattices and are therefore not given. In these experiments the cadmium ratios were well above 100 even at the bottom of the lattice.

The last curve, Fig. 11, presents some special data obtained with single fuel elements at the axis of the tank. These data have been normalized to the center of the fuel rod which in this case also represents the axis of the tank. The usual J_o correction has not b een applied to these curves. In a sense these curves represent an extension of other curves for 1-inch rods. Some analysis of these curves has been given previously.[8]

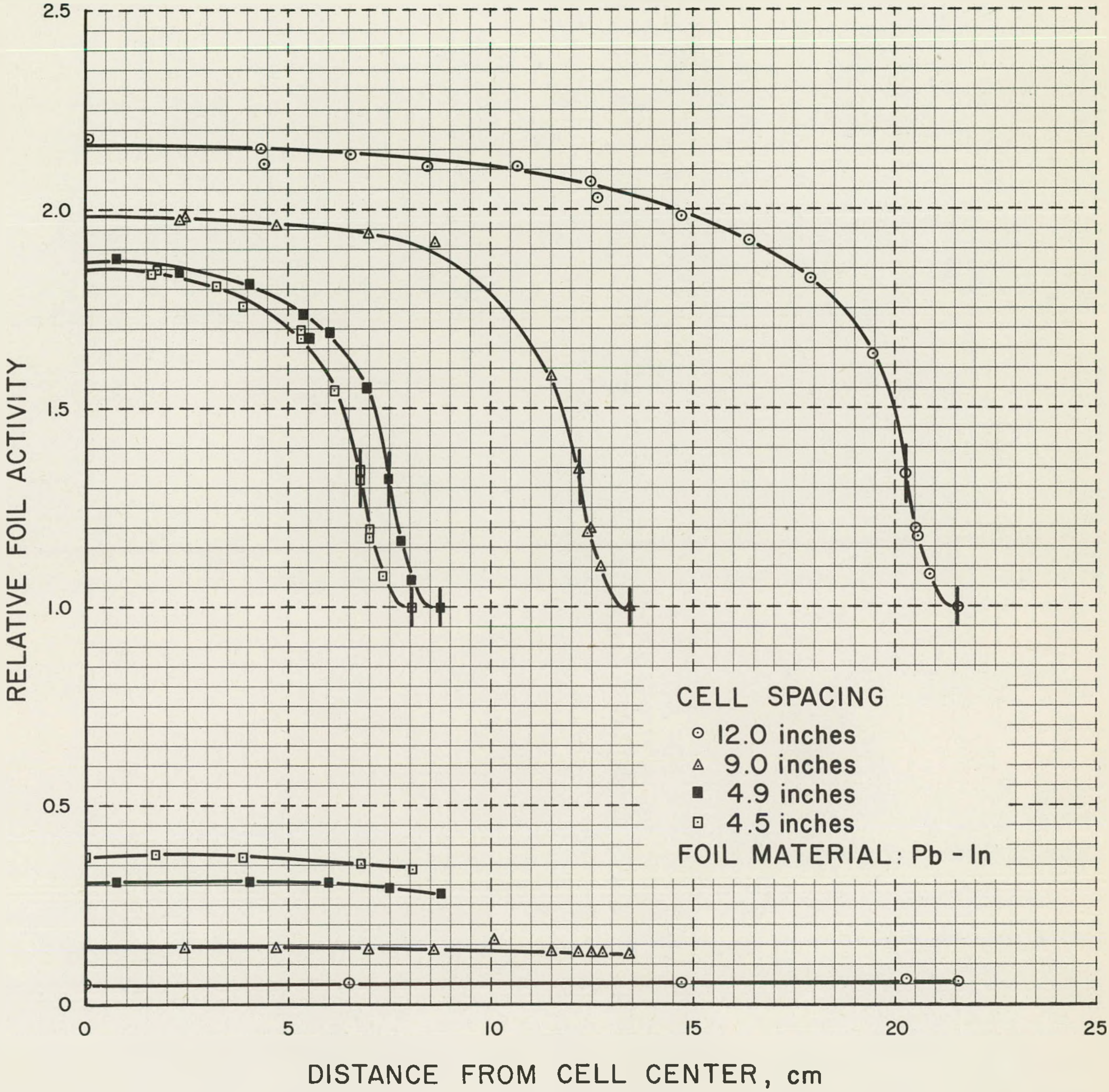

Fig. 1. Relative foil activity for the 1.00 inch diameter, depleted uranium (0.49 per cent U^{235}) rods in D_2O. The upper curves represent the thermal activity, the lower the epithermal activity.

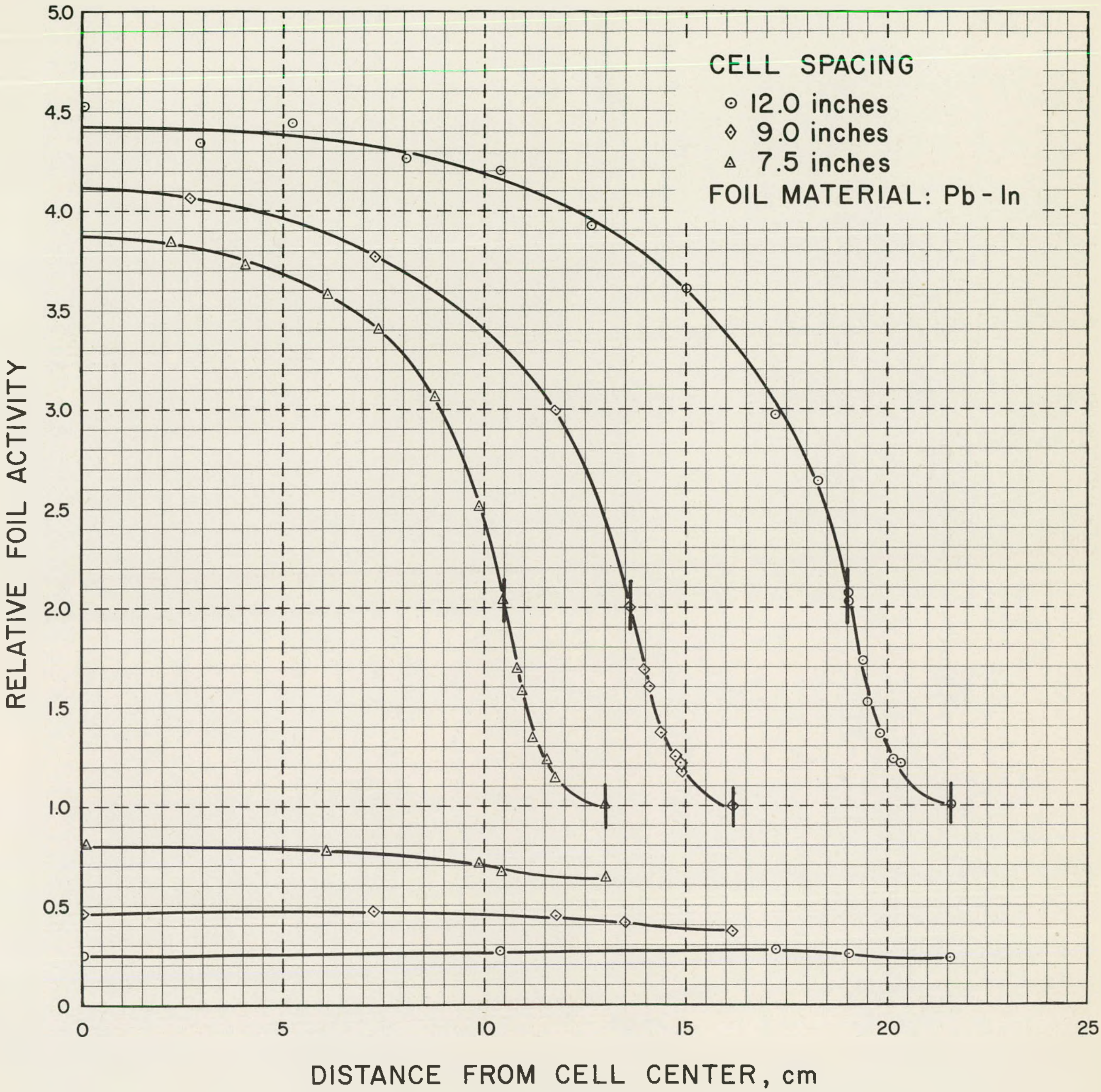

Fig. 2. Relative foil activity for the 2.00 inch diameter, depleted uranium (0.49 per cent U^{235}) rods in D_2O. The upper curves represent the thermal activity, the lower the epithermal activity.

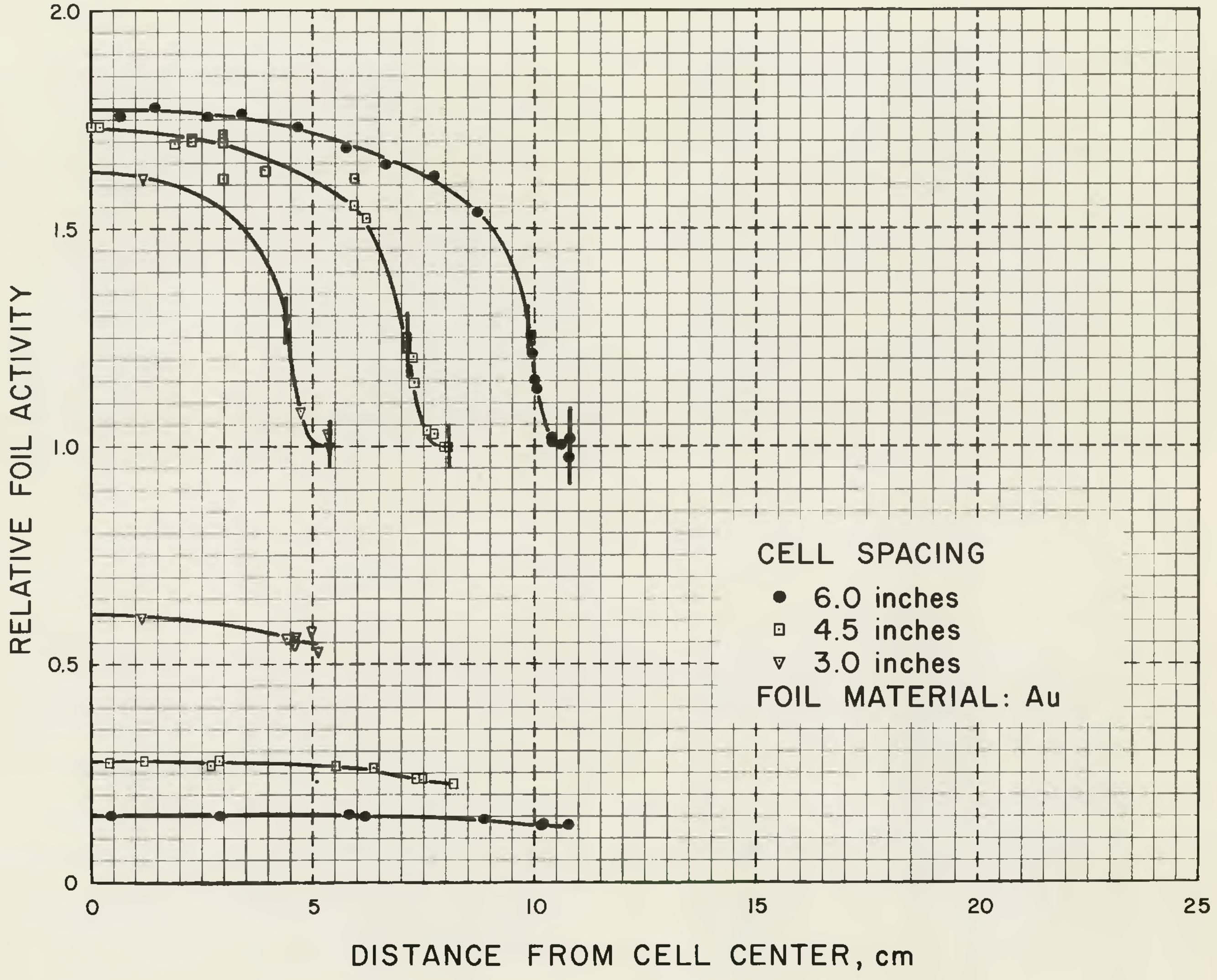

Fig. 3. Relative foil activity for the 0.75 inch diameter, natural uranium (0.71 per cent U^{235}) rods in D_2O. The upper curves represent the thermal activity, the lower the epithermal activity.

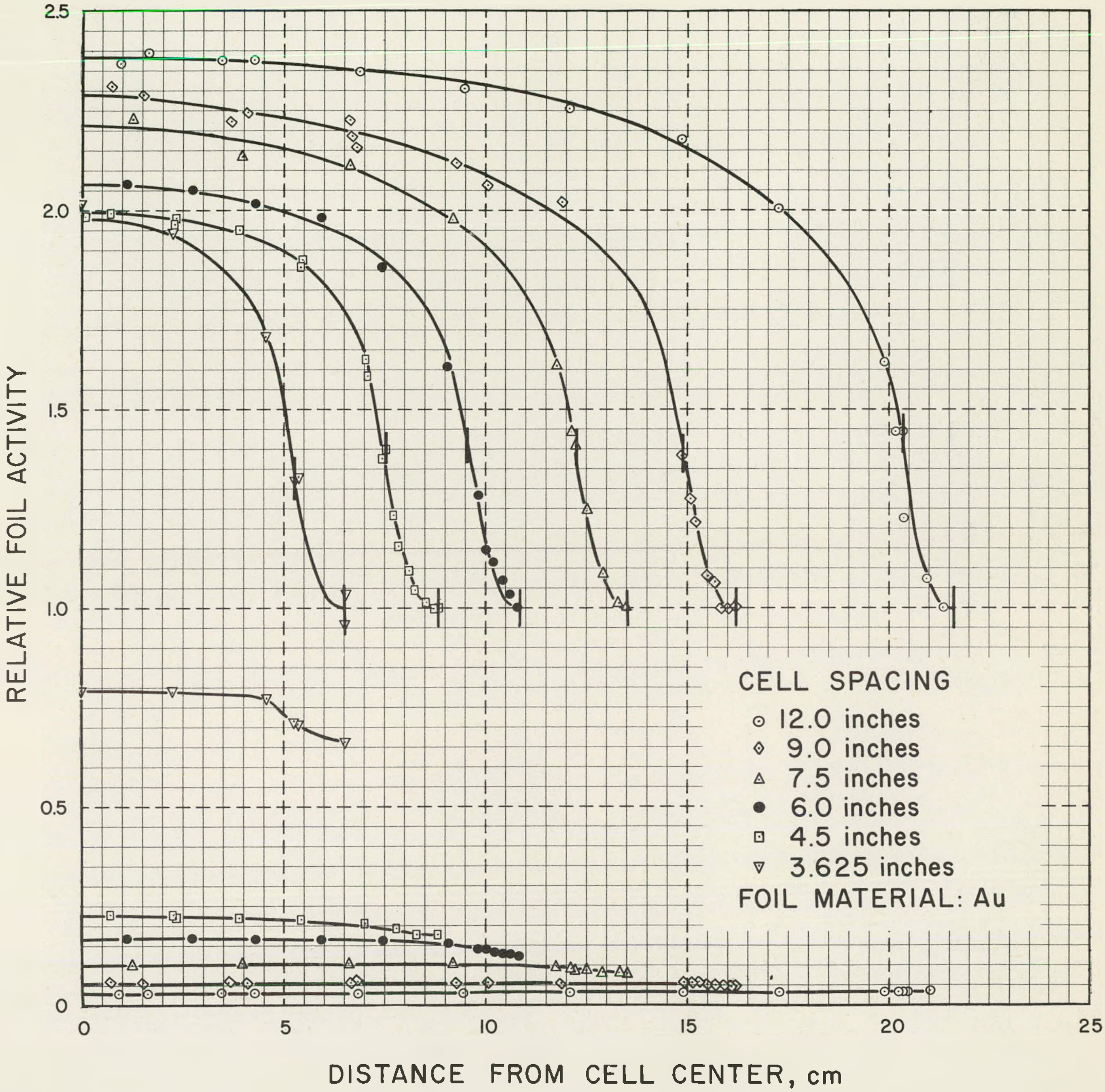

Fig. 4. Relative foil activity for the 1.00 inch diameter, natural uranium (0.71 per cent U^{235}) rods in D_2O. The upper curves represent the thermal activity, the lower the epithermal activity.

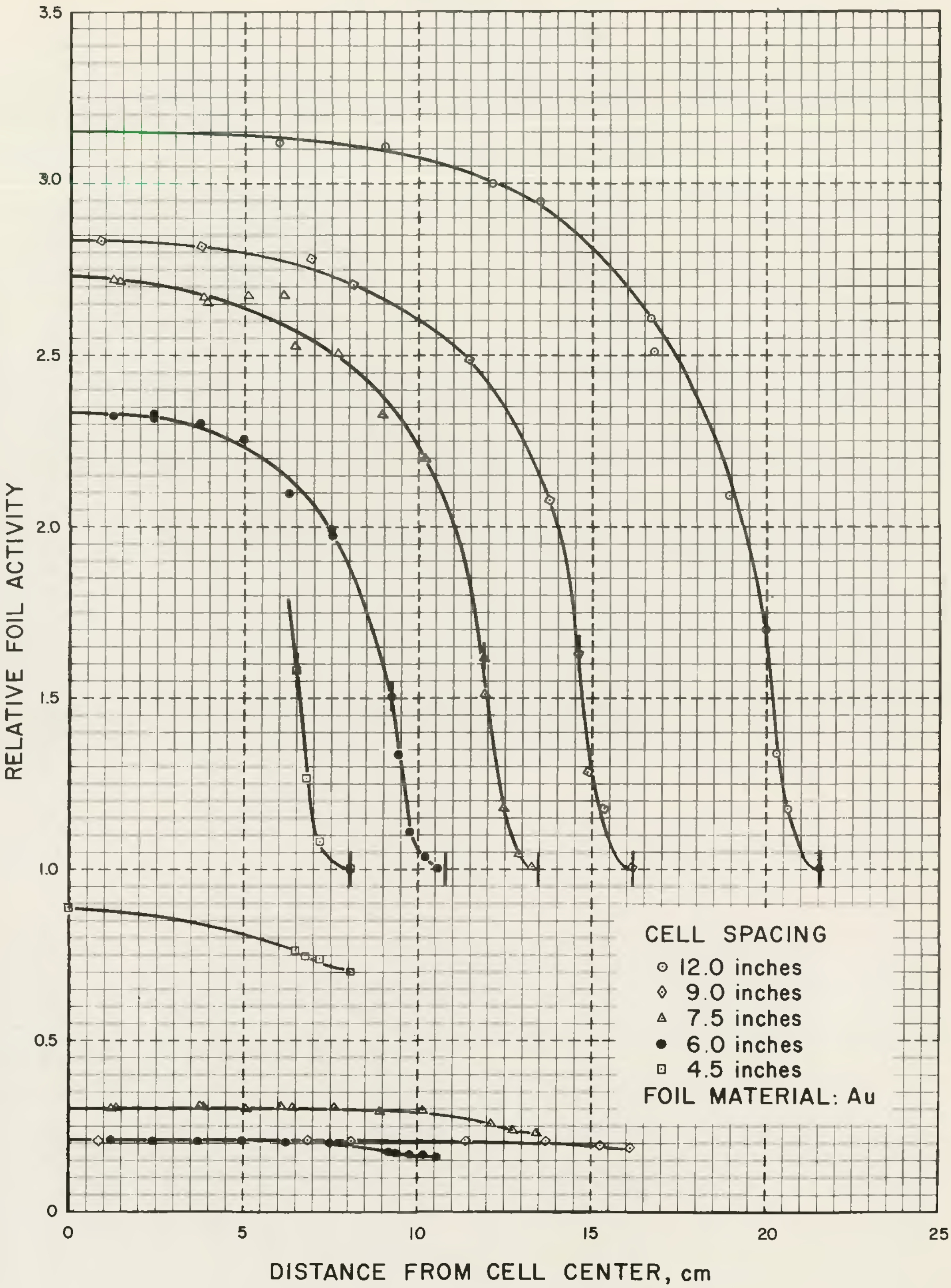

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Fig. 5. Relative foil activity for the 1.25 inch diameter, natural uranium (0.71 per cent U^{235}) rods in D_2O. The upper curves represent the thermal activity, the lower the epithermal activity.

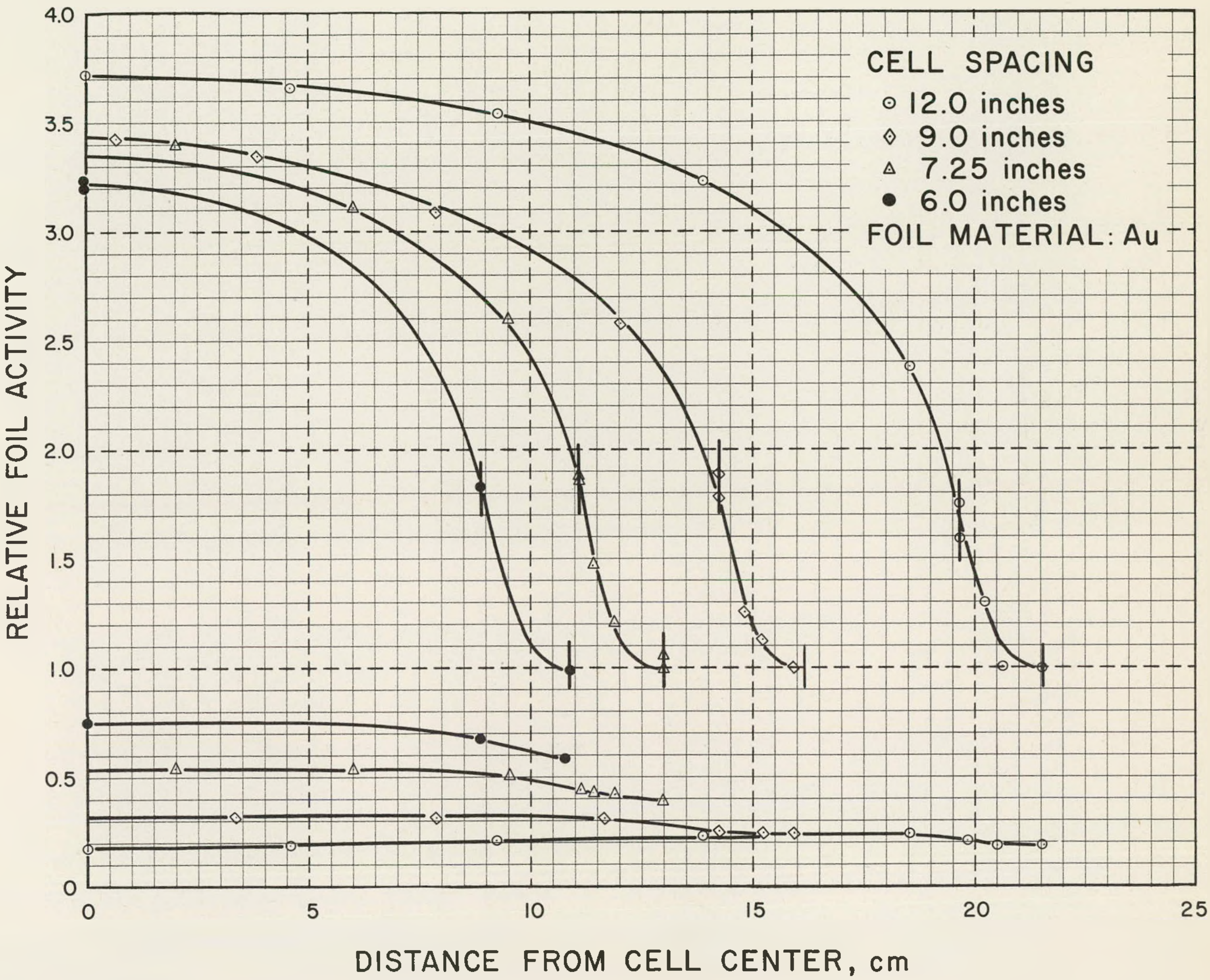
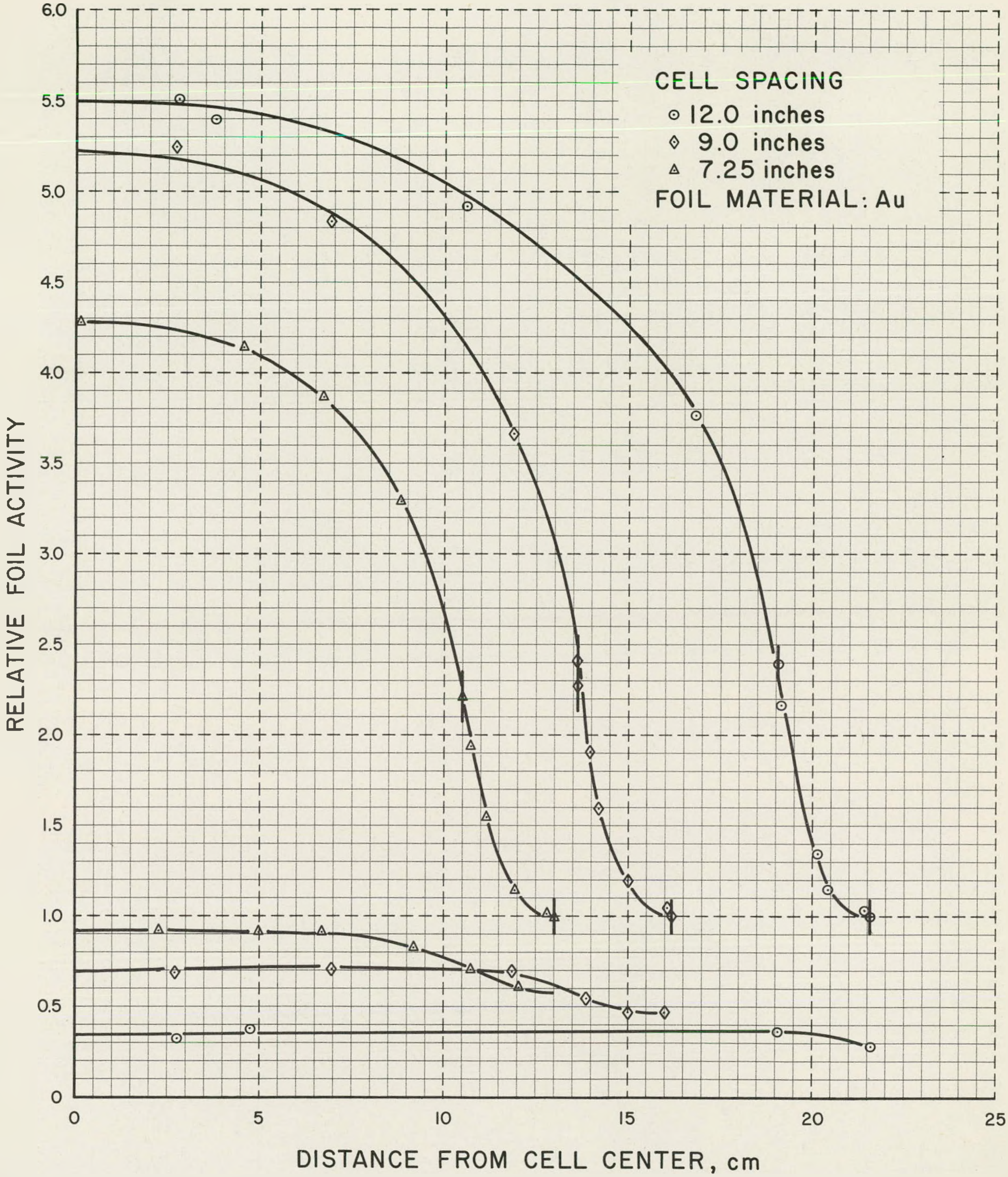
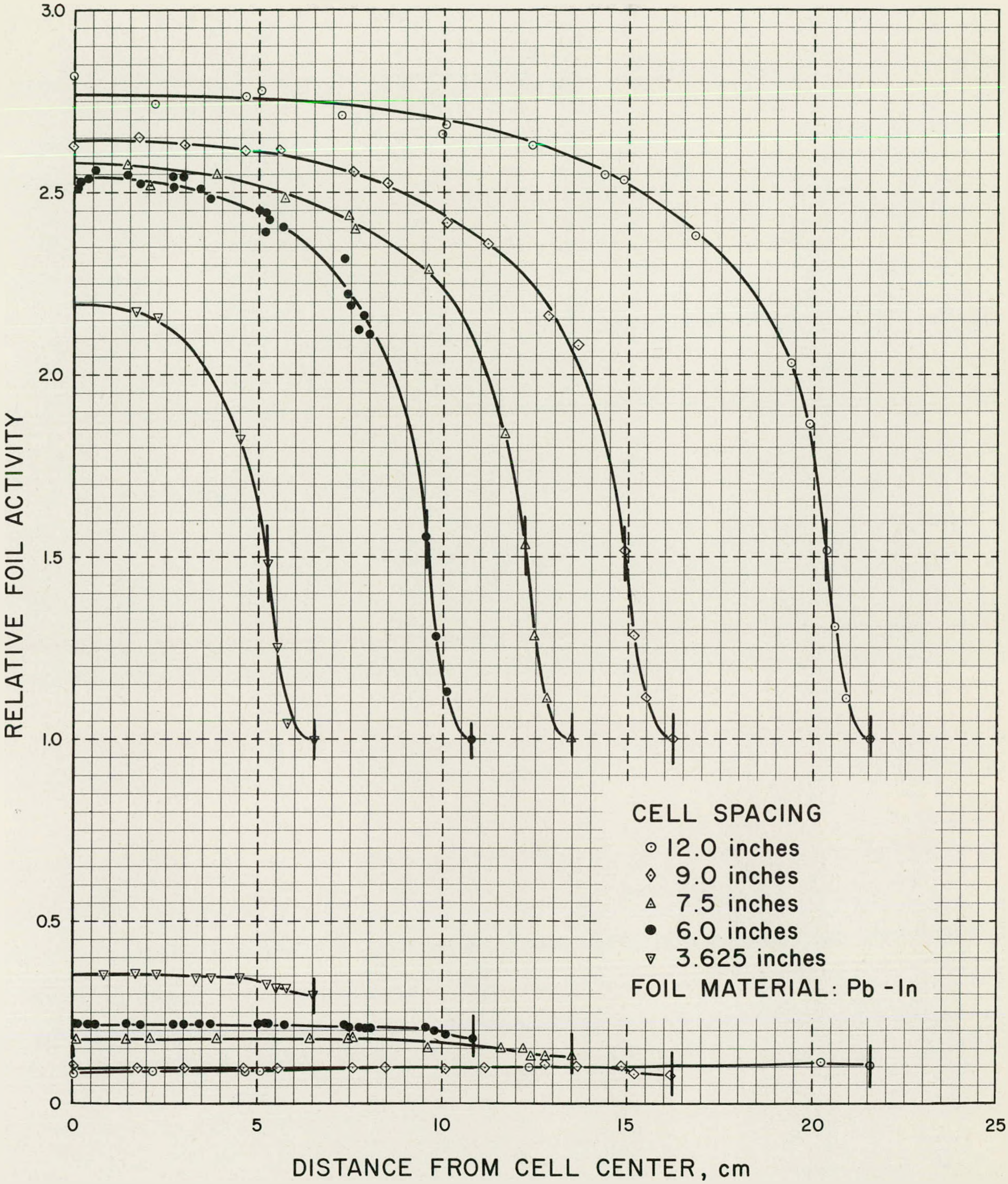


Fig. 6. Relative foil activity for the 1.50 inch diameter, natural uranium (0.71 per cent U^{235}) rods in D_2O. The upper curves represent the thermal activity, the lower the epithermal activity.



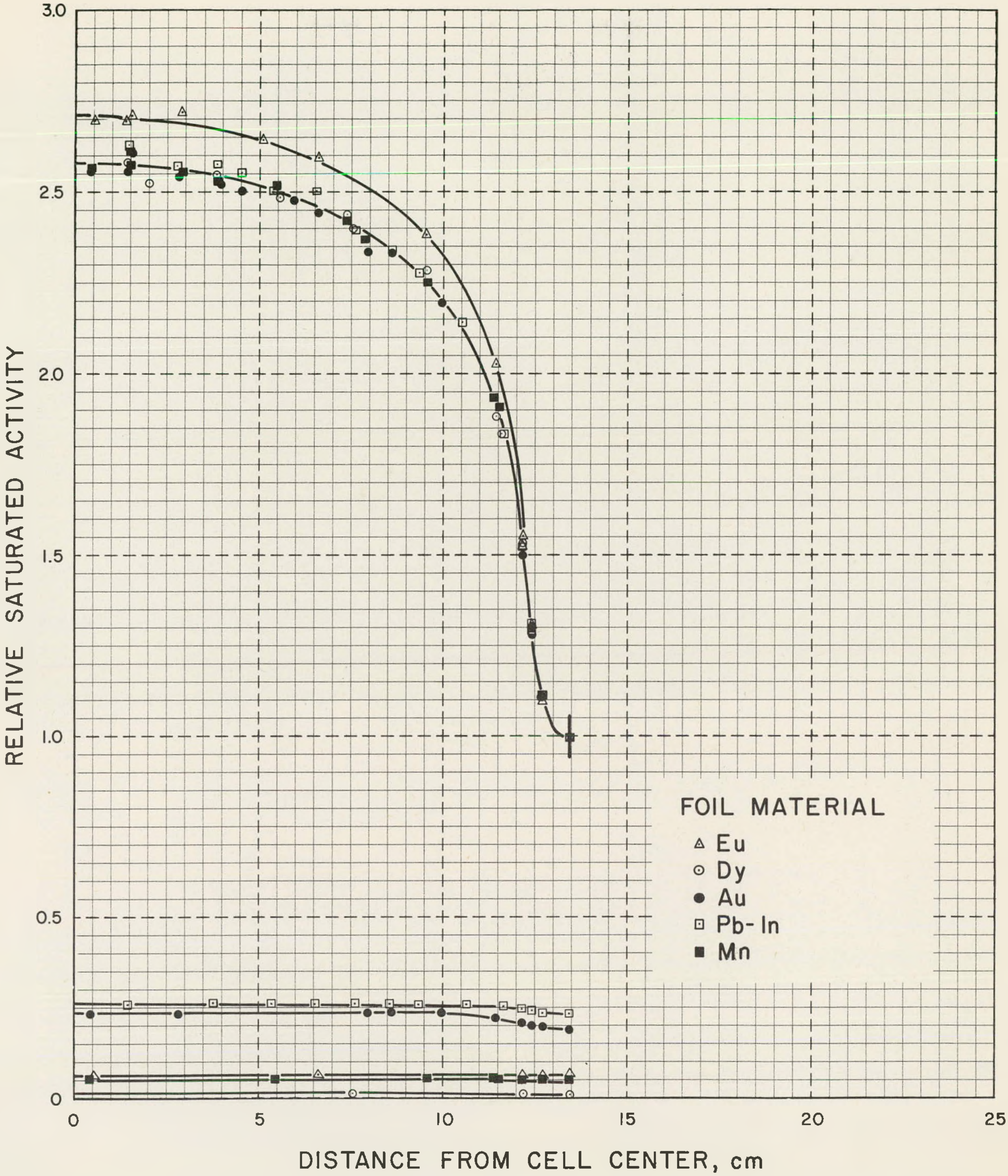
9601-4674

Fig. 7. Relative foil activity for the 2.00 inch diameter, natural uranium (0.71 per cent U^{235}) rods in D_2O. The upper curves represent the thermal activity, the lower the epithermal activity.



9601-4675

Fig. 8. Relative foil activity for the 1.00 inch diameter, slightly enriched uranium (0.90 per cent U^{235}) rods in D_2O. The upper curves represent the thermal activity, the lower the epithermal activity.



9601-4676

Fig. 9. Comparison of europium foil activations with that of other foil materials. Lattice: 1.00 inch slightly enriched uranium (0.90 per cent U^{235}) rods at a 7.5 inch spacing in D_2O. The upper curves represent the thermal activity, the lower the epithermal activity.

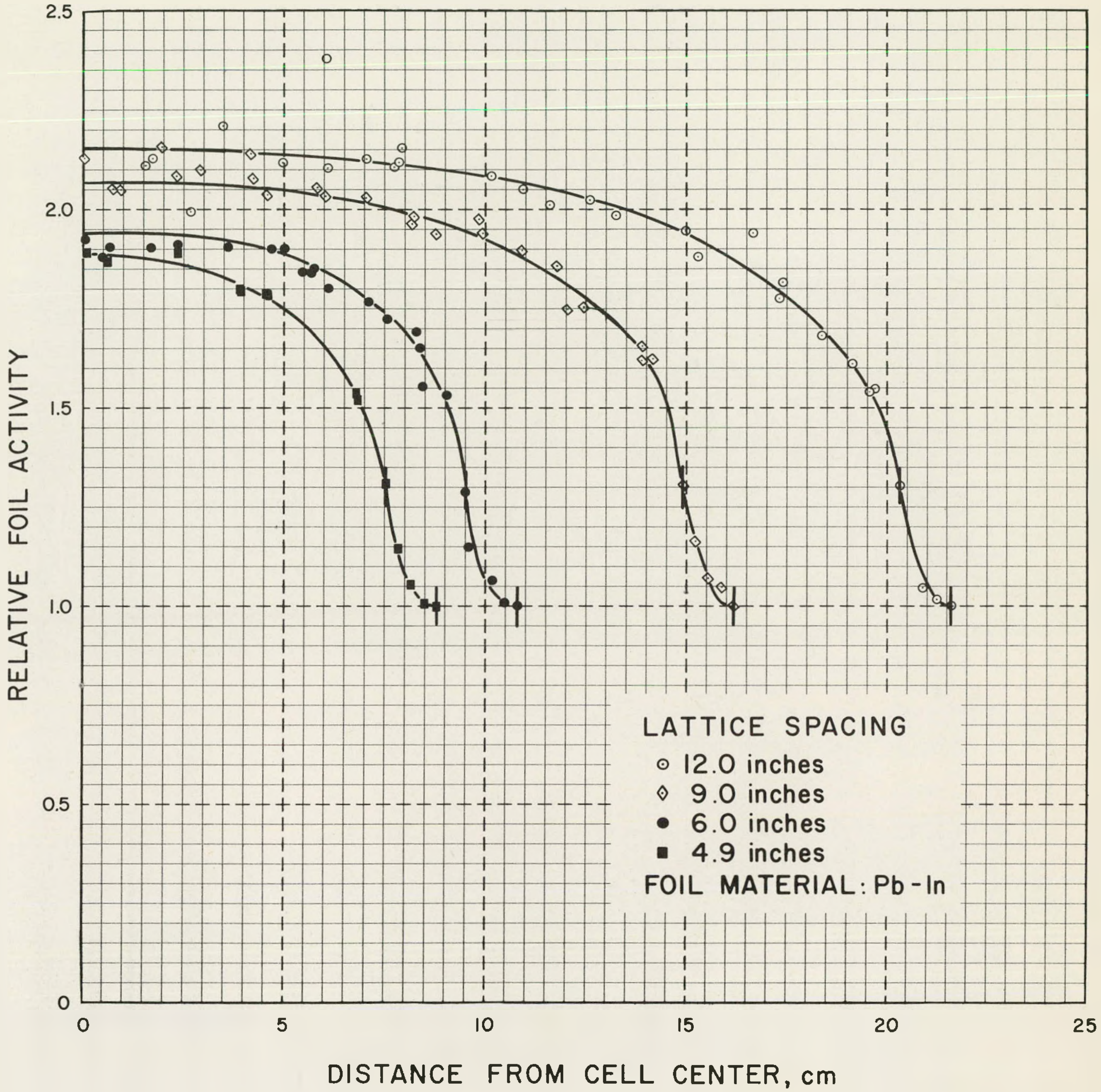


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Fig. 10. Relative foil activity for 1.00 inch diameter lead-cadmium-alloy rods in D_2O. The curves represent the thermal activity.

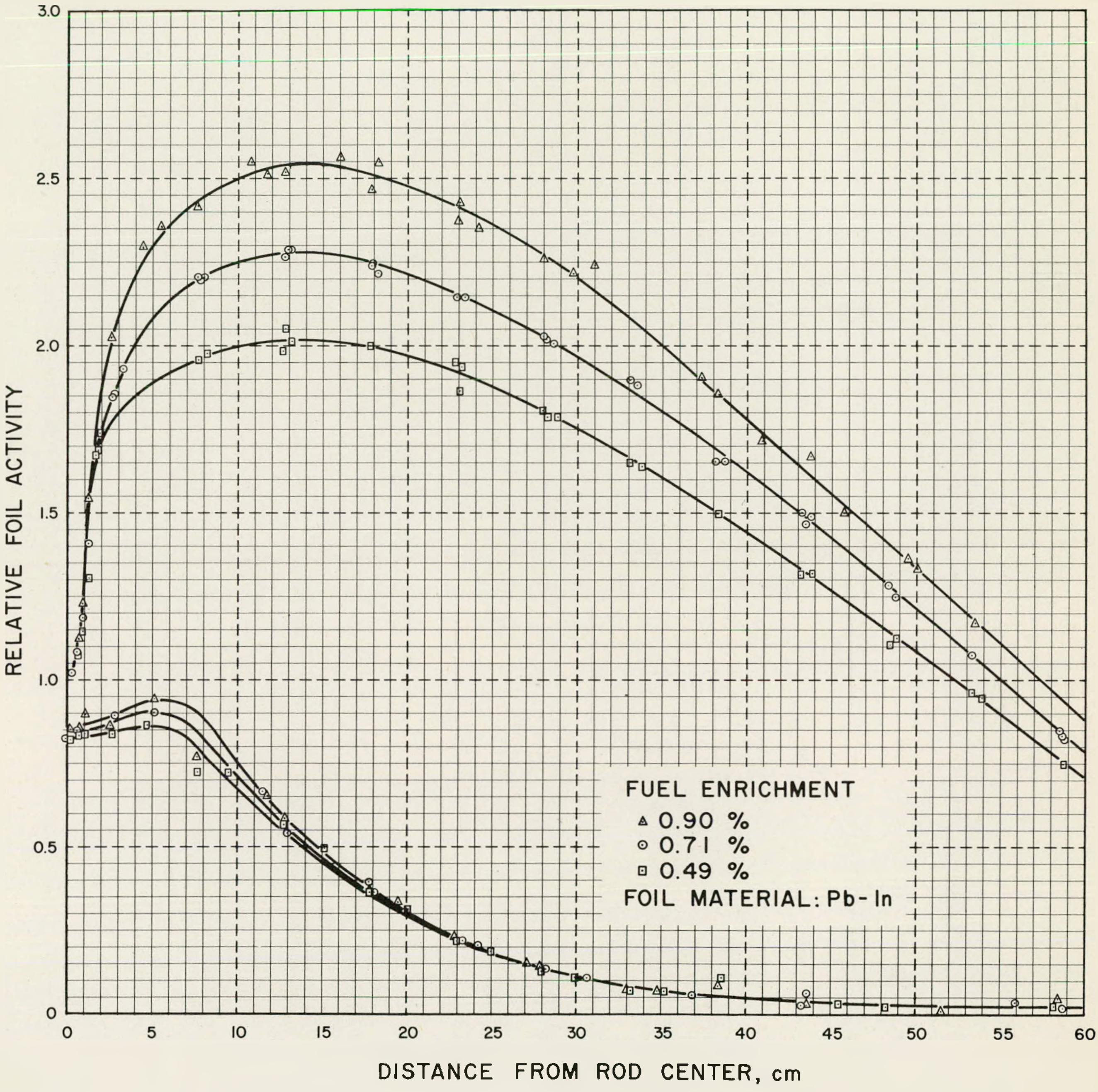

Fig. 11. Relative foil activity for a single 1.00 inch diameter uranium rod at the center of the tank. The upper curves represent the thermal activity and the lower curves the epithermal activity.

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