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UCC
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SUBJECT: Poison Rod Requirements for a Solid-Fuel Leacher Tank

TO: Distribution

FROM: B. E. Prince

(See next page for Summary)

NOTICE

DISCLAIMER

SUMMARY

Estimates were made of the amount of neutron poisoning, in the form of boron rods, required to maintain subcriticality in a tank used for dissolution of solid fuel elements. The tank under consideration was a cylinder 19.5 inches in diameter and 6 ft in height. Maximum concentrations of fuel and fertile material resulting from dissolution of various type fuel elements are given in Table 1.

Table 1. Composition of Solutions in Dissolver Tank

Fuel Element	Composition	Enrichment Ratio	Max. Conc. of Fertile Material (g/liter)
Con. Edison Outer Region	7% UO_2 (93% Enrichment) 93% ThO_2	0.070 g U^{235}/g Th	250
Yankee Atomic	UO_2	0.0267 g U^{235}/g U^{238}	952*
NS Savannah	UO_2	0.0434 g U^{235}/g U^{238}	912*

Below the maximum concentrations listed, it was found that the limiting poisoning requirements are associated with dissolution of the NS Savannah elements. About five 1-inch diameter rods appear necessary: a centrally located rod and four rods in a square array each about 5 inches from the central rod.

* Estimated for double-batch conditions

RESULTS AND DISCUSSION

It was convenient to use the following approximate method of calculation:

(1) Determine the potential multiplication factor for an infinite square array of rods inserted in the fuel solution.

(2) Correct the infinite multiplication constant for the neutron leakage from the tank.

For each type of fuel element listed in Table 1, the poisoning effect was calculated for a range of solution concentrations. The poison rods were assumed to have the neutron absorption characteristics of natural-enrichment boron. The results are given in Figs. 1, 2, and 3, where the neutron multiplication is plotted as a function of concentration of fertile material. In each figure the rod diameter and the mass ratio of fuel to fertile material are constant. The rod pitch is the center-to-center distance of the rods. The neutron multiplication is given in terms of the product of the thermal utilization (f) and the resonance escape probability (p) in the fuel solution-poison rod cell. The basis of the calculation of fp is discussed in reference (1). Using the modified one-group criticality formula:

$$\eta_{25}\, fp = 1 + M^2 B^2$$

the critical upper limit of fp will be given by $(1 + M^2 B^2)/\eta_{25}$. With $M^2 \simeq 32\ cm^2$, $\eta_{25} = 2.08$, and B^2 equal to the geometric buckling of a cylinder,[2] the limits obtained are shown in the figures as dotted horizontal lines. In calculating B^2, 6 inches were added to the height and diameter of the cylinder to account for the reflectivity of the tank enclosure. It may be noted that the infinite medium limit would be a close approximation to the limit for a large tank.

The calculations indicate that the limiting cases are the NS Savannah fuel elements, for which the tank would require about five 1-in. rods, one centrally located and four in a square array about the center. These rods should be spaced about 5 inches from the central rod.

Comparison of the calculations with information obtained from critical experiments are necessary for determining a criticality safe design for the tank. In lieu of experimental data, the above calculations should be used only to indicate the feasibility of poisoning the tank by internal rods.

REFERENCES

1. B. E. Prince, Dump Tank Criticality and Poisons for Slurry Reactors, (ORNL report to be issued).
2. S. Glasstone and M. C. Edlund, The Elements of Nuclear Reactor Theory, Chapter VII, D. Van Nostrand Company, Inc., New York, (1952).

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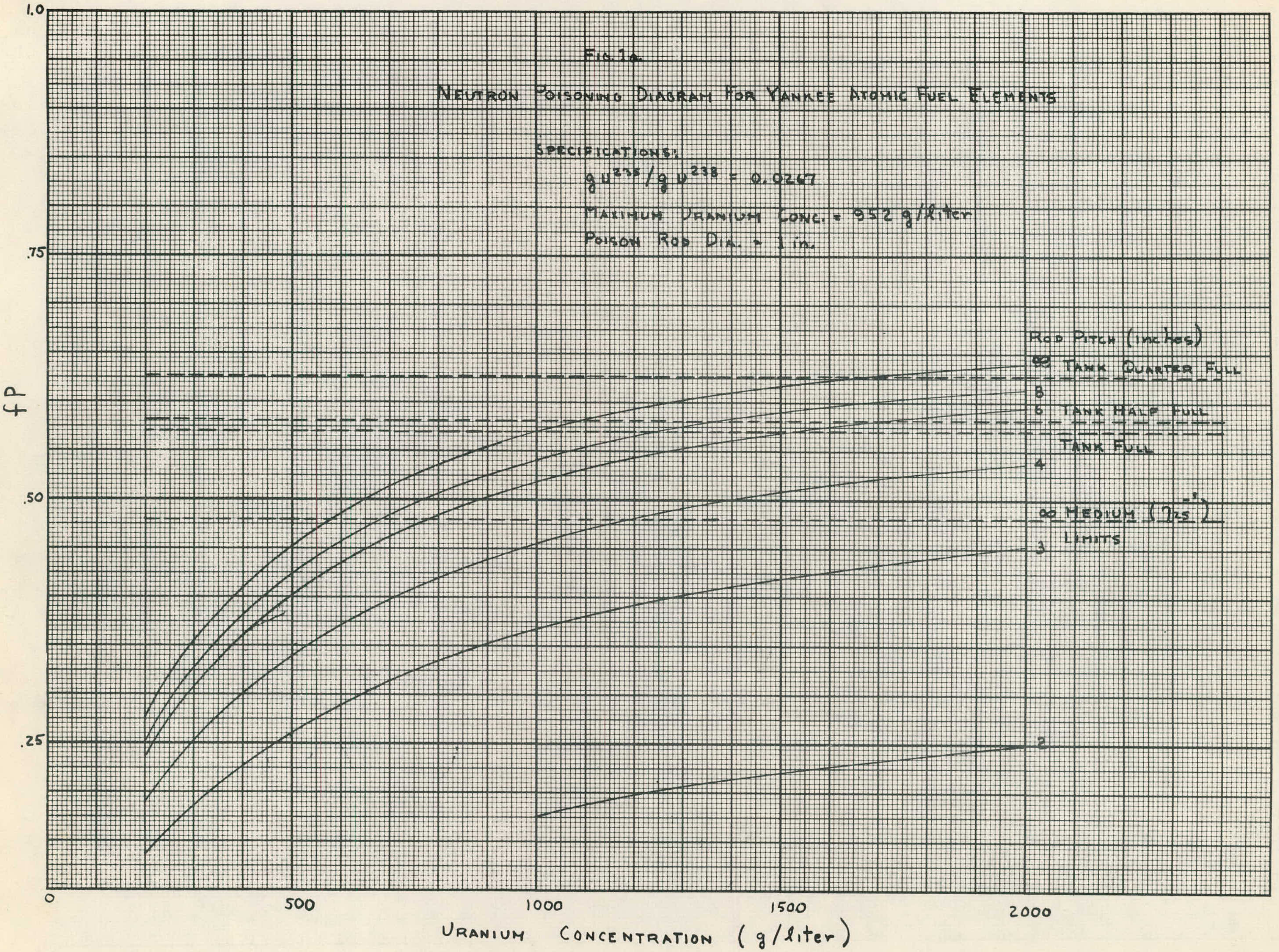

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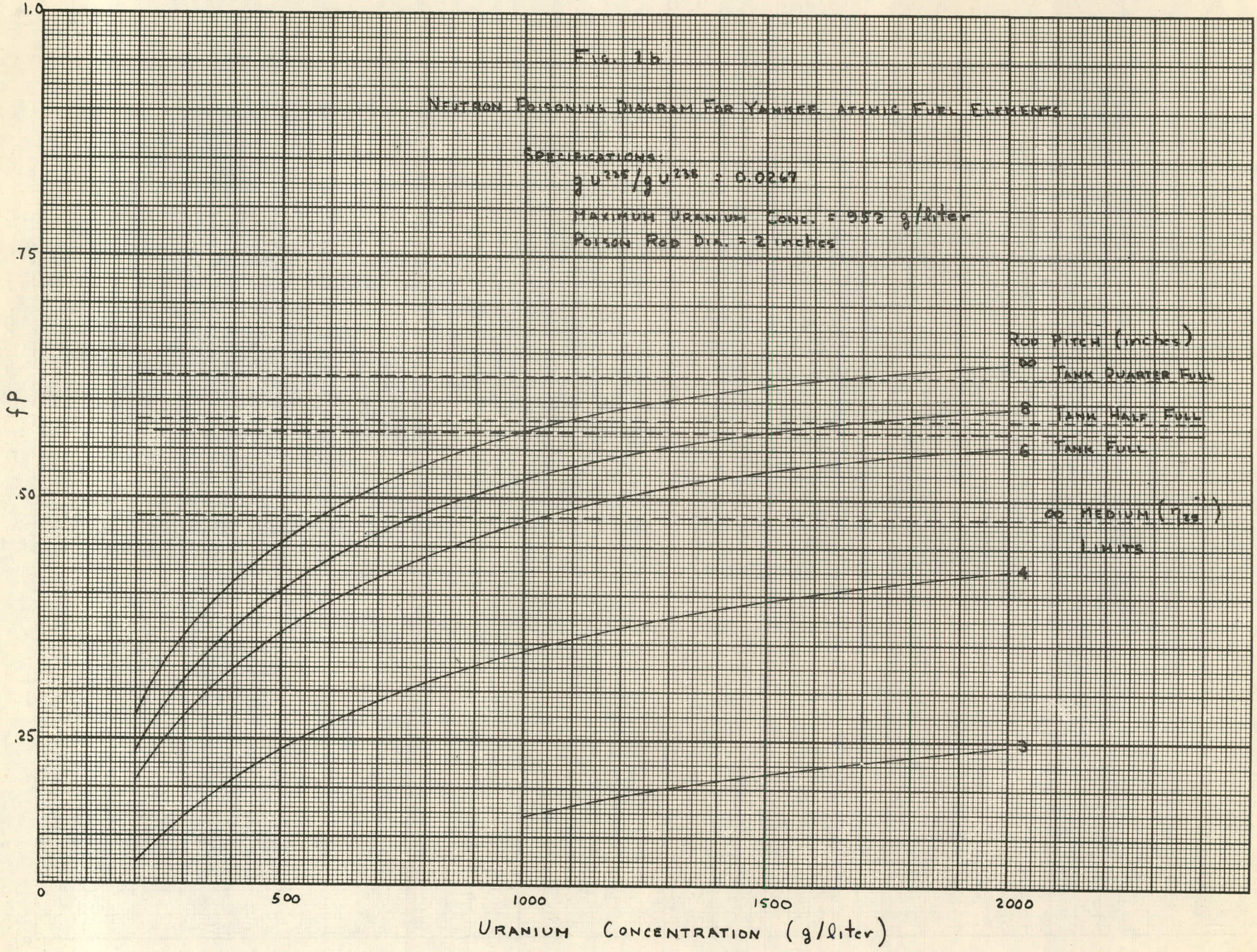

Fig. 1b

Neutron Poisoning Diagram for Yankee Atomic Fuel Elements

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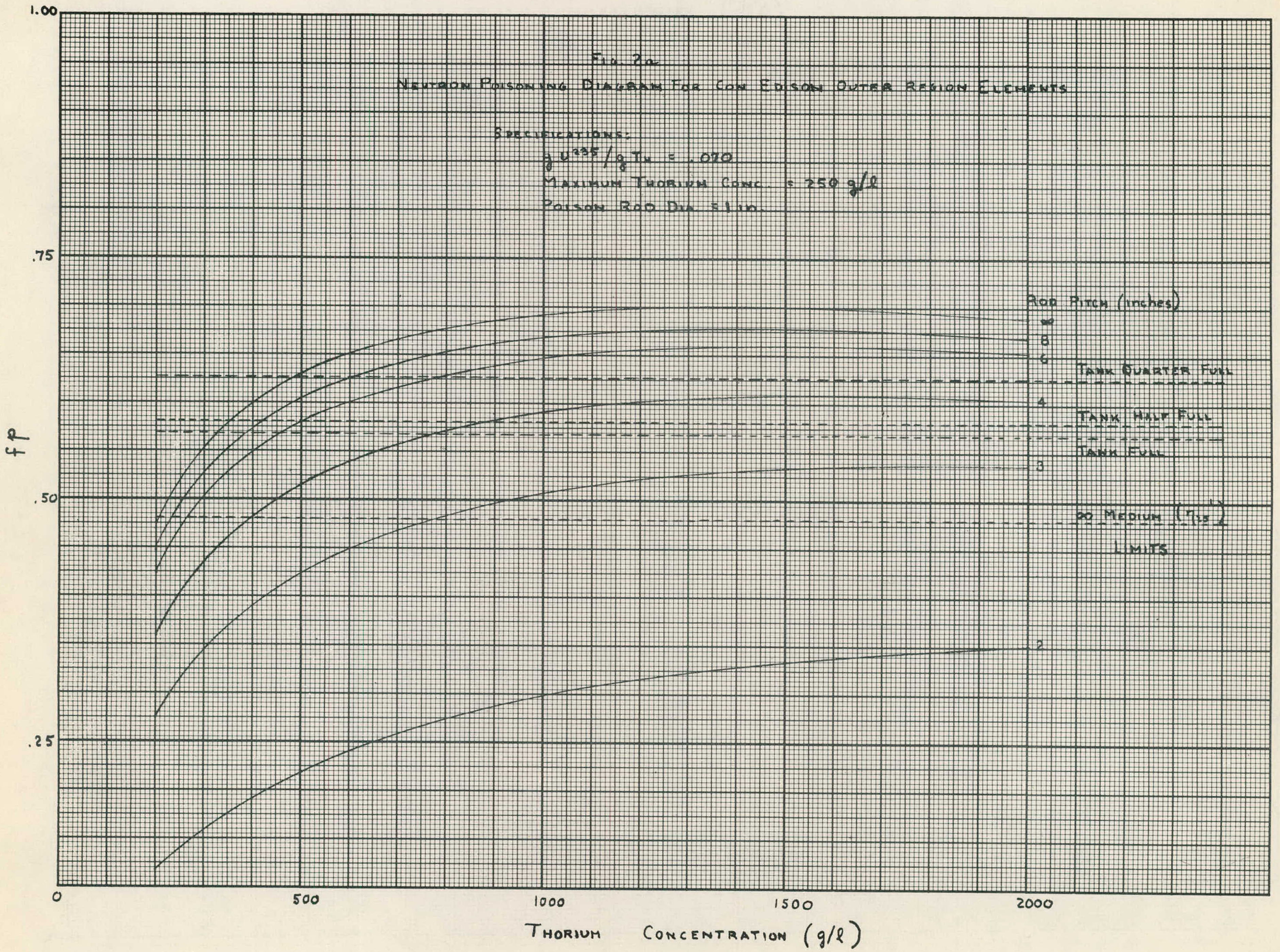

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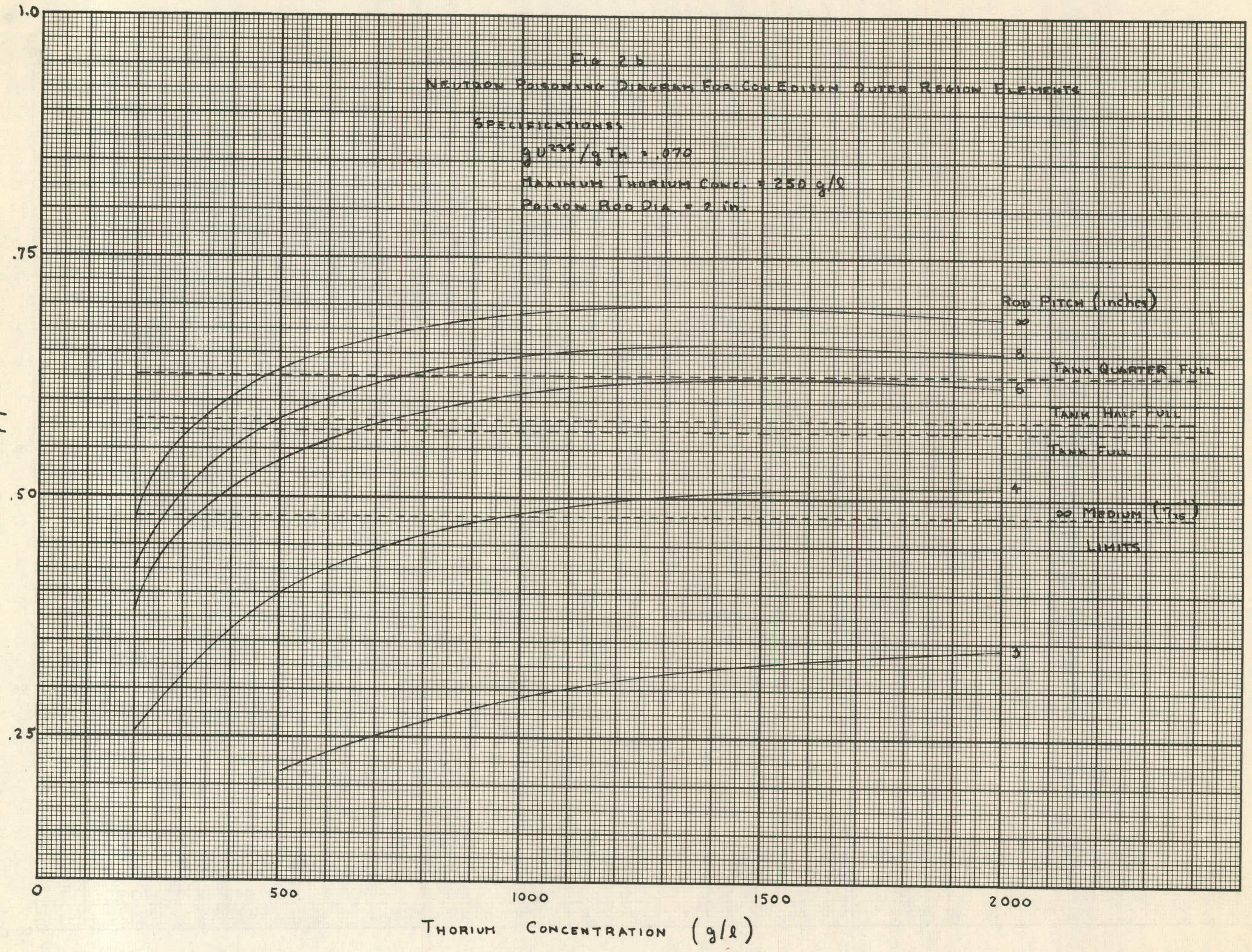

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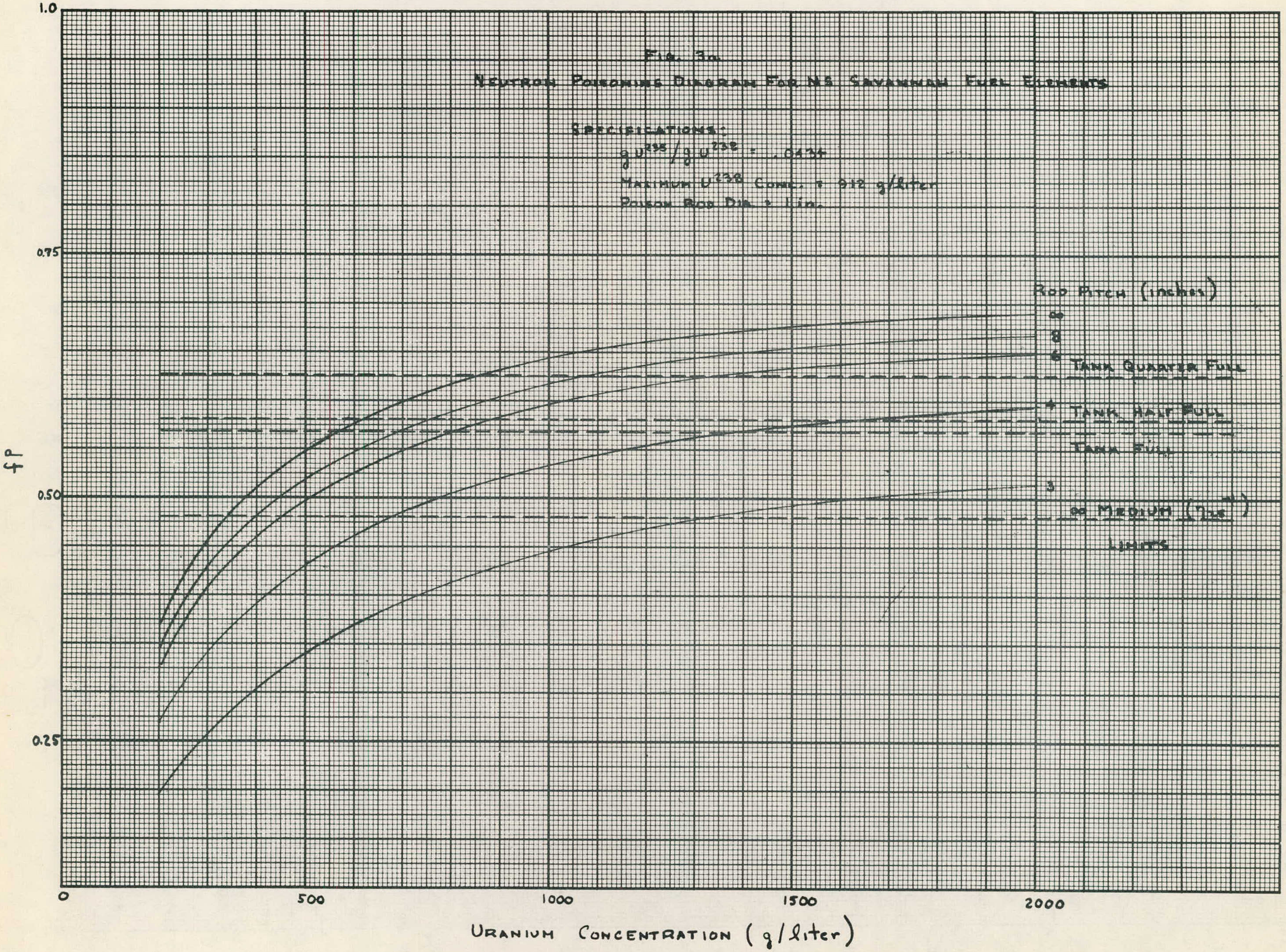

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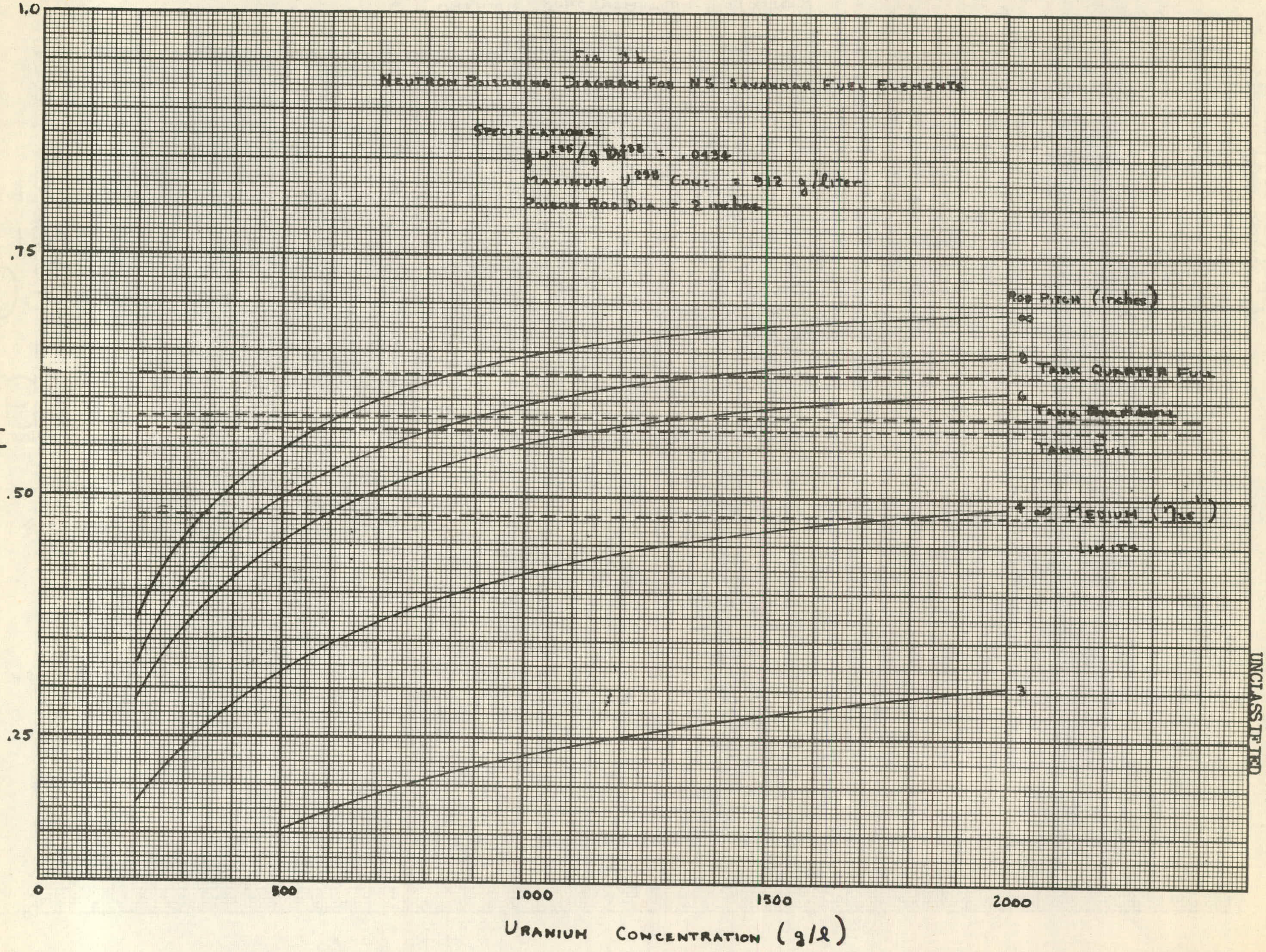

Fig. 3b
Neutron Poisoning Diagram for NS Savannah Fuel Elements

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