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SUBJECT: Survey of the Static Nuclear Characteristics of Small One-Region Slurry Reactors: Part II

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FROM: B. E. Prince

SUMMARY

The critical U^{235}-to-thorium ratios in single-region slurry reactors were calculated for various ratios of H_2O to D_2O in the moderator. Reactors studied had diameters between 3-1/2 and 5-1/2 ft, (bare sphere diameters), temperatures of 280°C, and slurry concentrations between 50 and 900 g thorium/liter.

It was found that the addition of small amounts of H_2O to D_2O (< about 20%) causes the critical mass ratio to become smaller and the minimum ratio for a given reactor size to occur at higher thorium concentrations. For example, in a 4-1/2-ft reactor the minimum ratio was 0.13 g U^{235}/g Th at the conditions of 150 g thorium/liter and 99.8% D_2O in the moderator. If the moderator was 20% H_2O, the minimum ratio was 0.04 g U^{235}/g Th at the concentration of 500 g thorium/liter.

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RESULTS

Parametric studies of the critical uranium-to-thorium ratios in single-region slurry reactors were extended to include moderator mixtures of D_2O and H_2O. Previous results have been reported in reference (1). Neutron ages in the mixtures were obtained from the experiments of Wade.[2] The reactors considered were fueled with U^{235}, and the operating temperature was 280°C. Sizes (in terms of bare sphere diameters) ranged from 3-1/2 to 5-1/2 ft, and the D_2O-H_2O mixture was varied between zero and 99.8 mol per cent D_2O.

In Figs. 1a, b, c, the critical ratios are plotted vs thorium concentration for 4-1/2, 5, and 5-1/2 ft diameter spheres, respectively. Each curve is for a fixed ratio of D_2O to H_2O in the moderator.

DISCUSSION

The principal effect associated with the addition of small amounts of H_2O to D_2O is a reduction in the fast neutron leakage; thus, for a fixed reactor size, the critical ratio decreases with H_2O addition. Also, due to the additional moderating power of H_2O, the neutron losses from resonance capture in thorium become relatively less important at higher thorium concentrations. Thus, in Fig. 1, the minima in the critical mass ratio curves tends to occur at larger thorium concentrations.

At large percentages of H_2O, the neutron losses due to thermal absorption in the moderator become significant, and the critical mass ratio tends to increase in magnitude.

The decrease in fast neutron leakage associated with H_2O addition to D_2O can be counterbalanced by a reduction in the reactor diameter. In this case,

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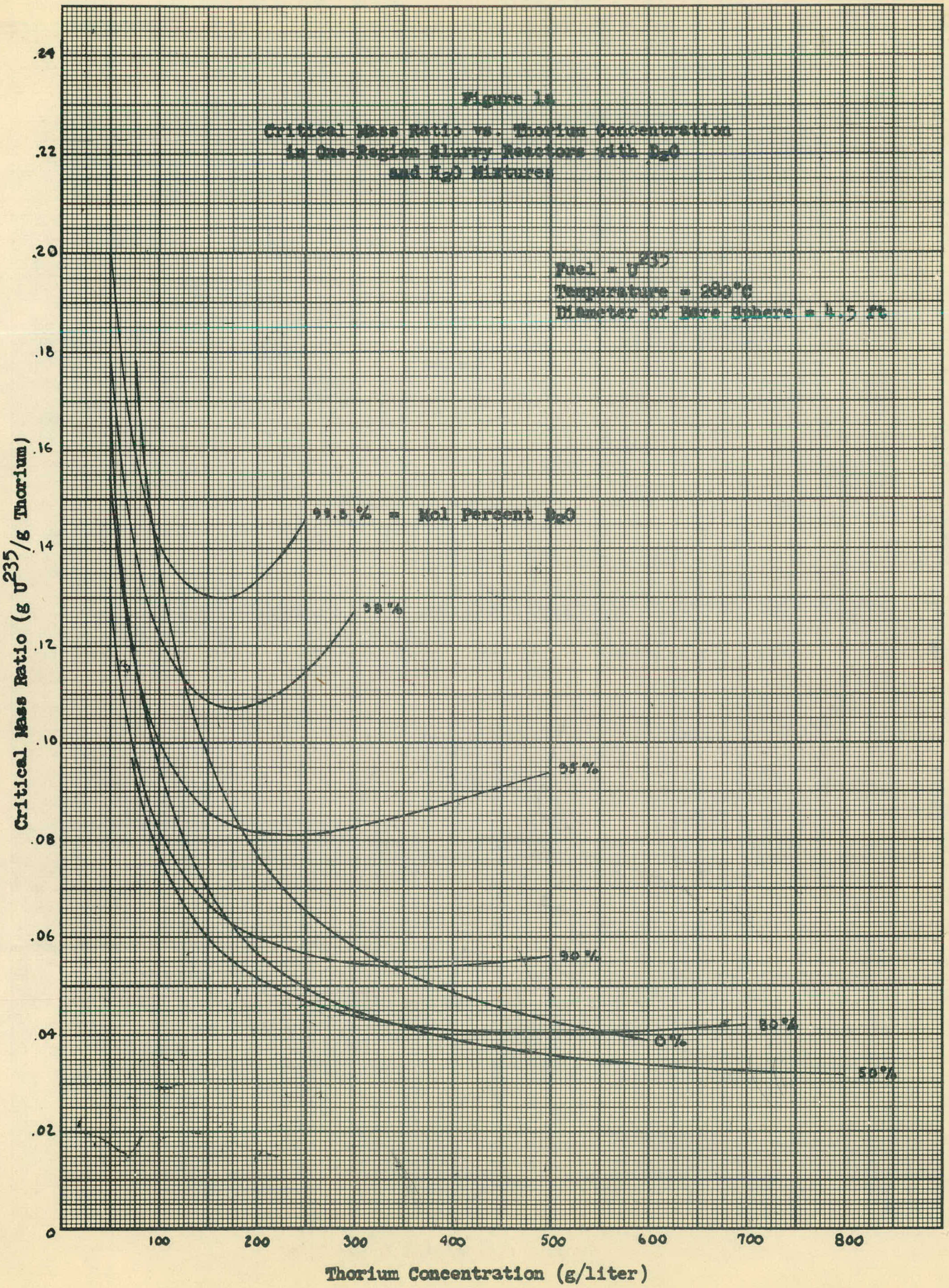

Figure 1a
Critical Mass Ratio vs. Thorium Concentration in One-Region Slurry Reactors with D_2O and H_2O Mixtures

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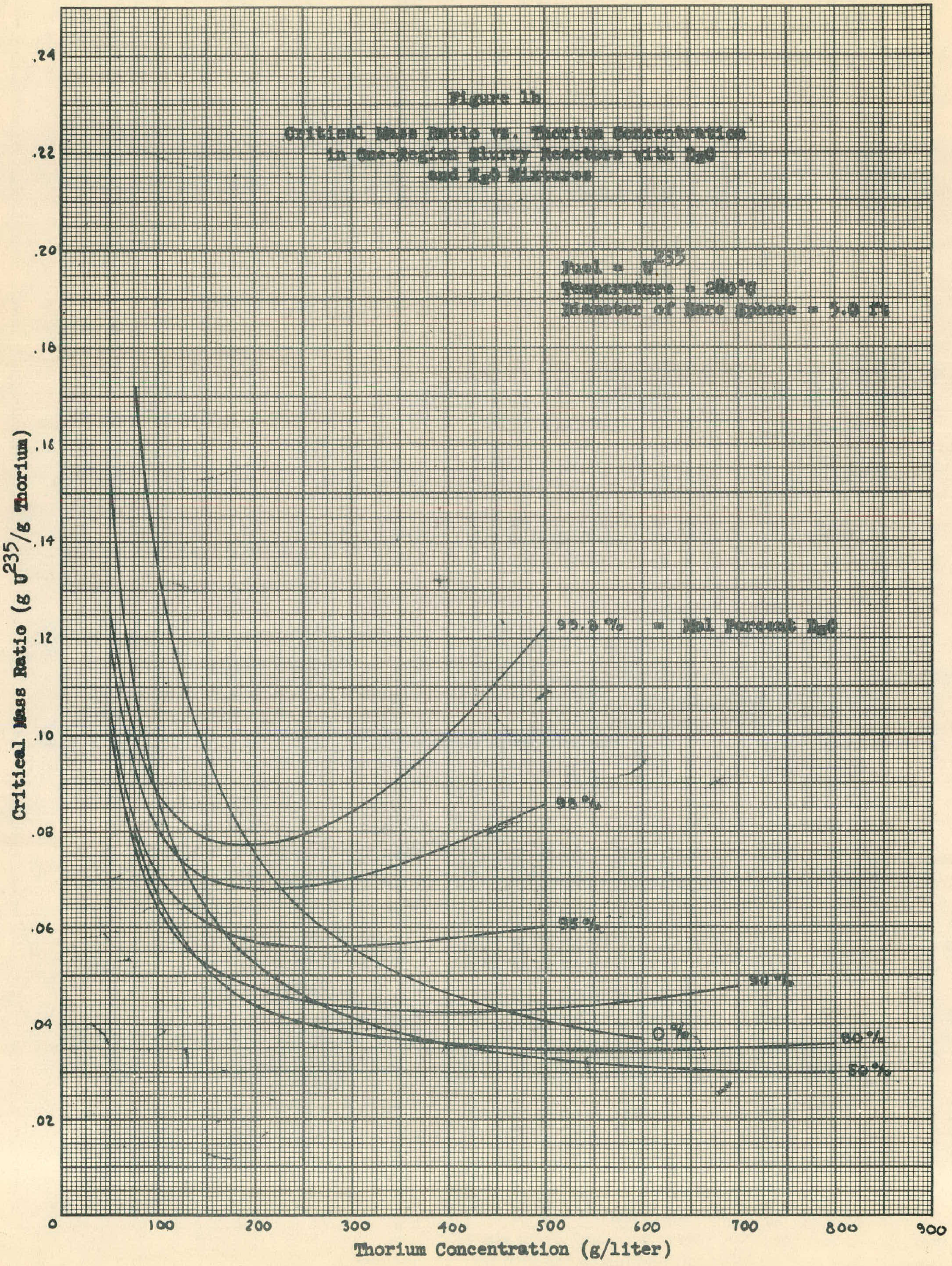

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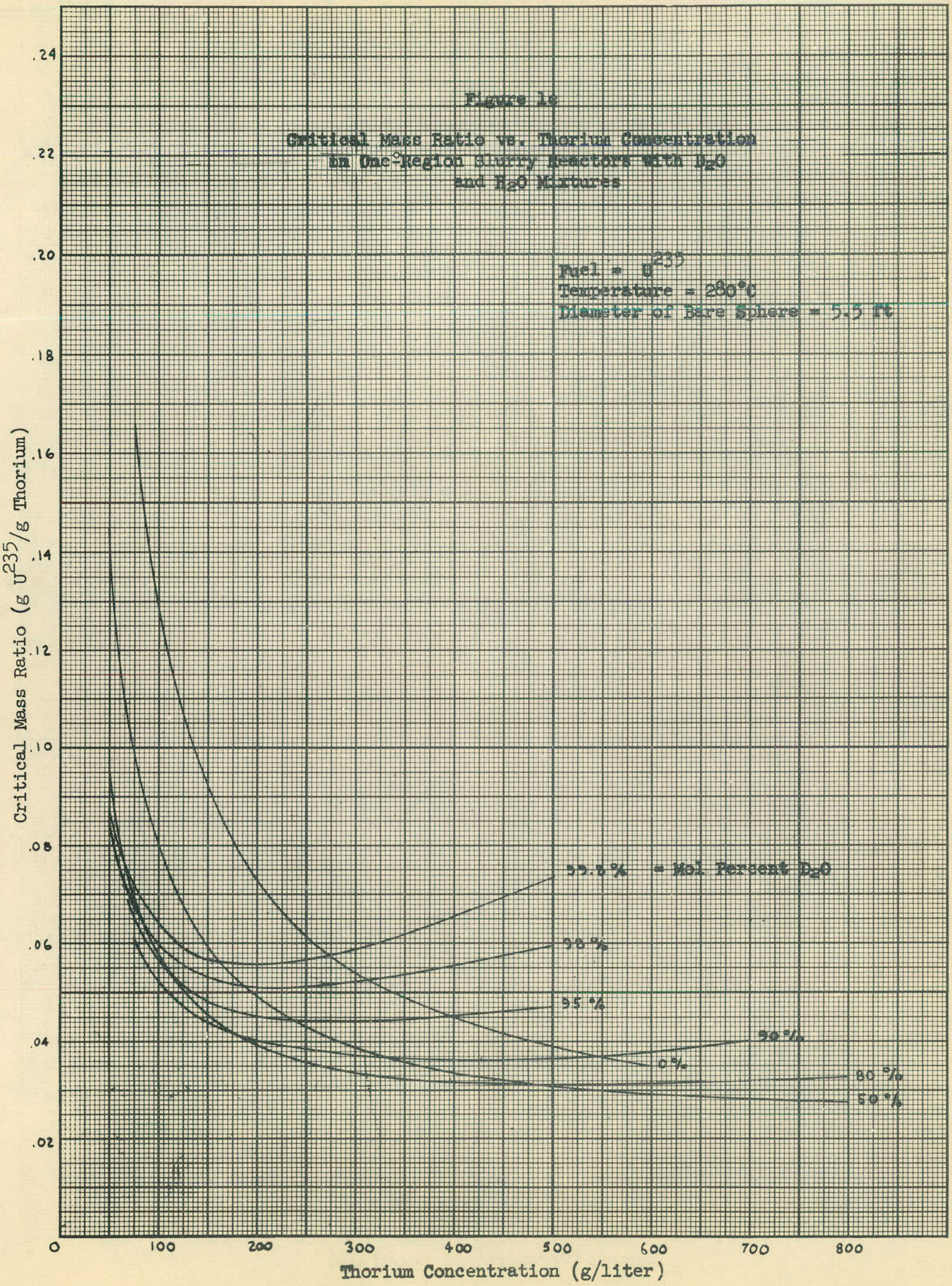


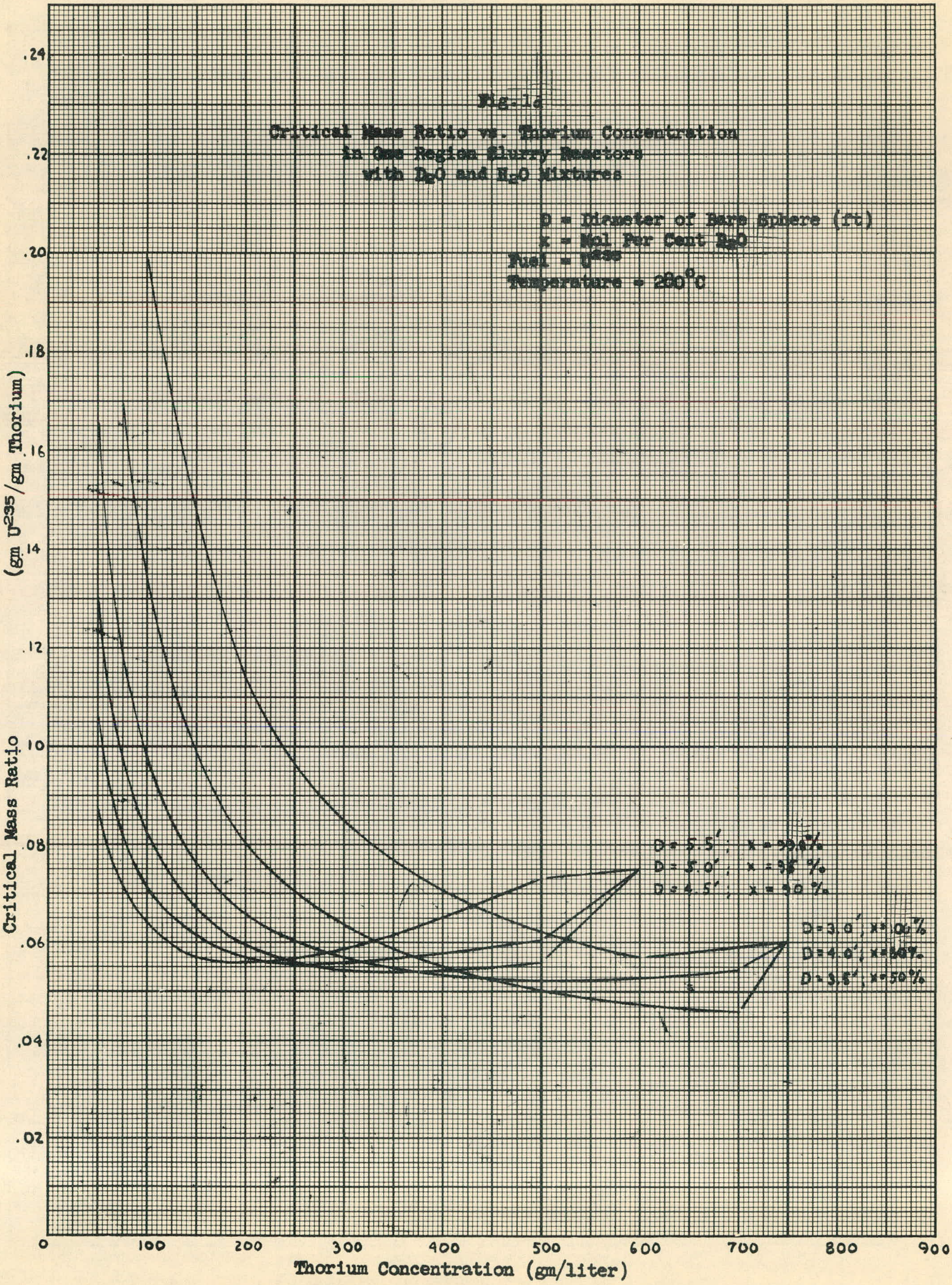
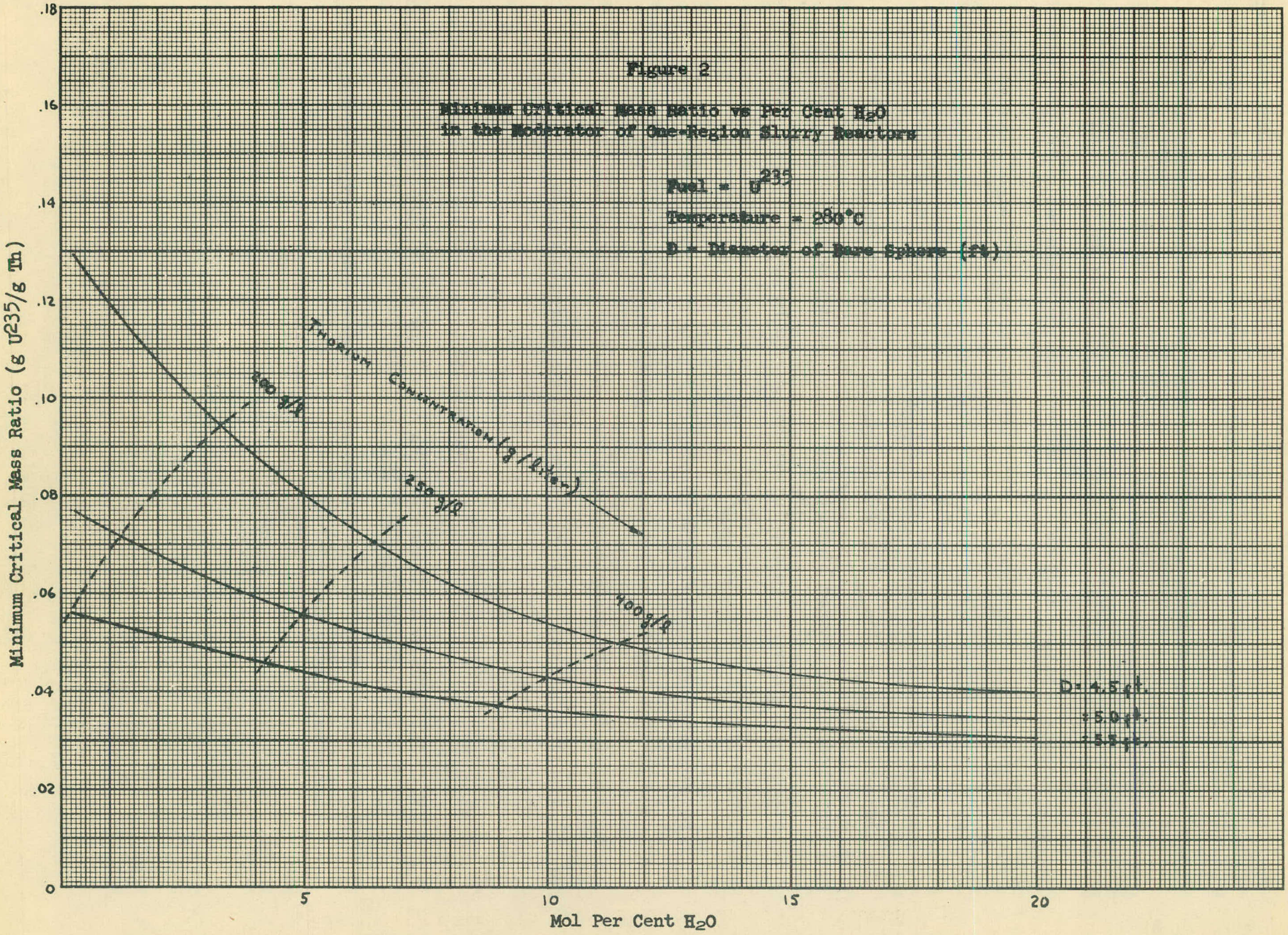


Fig. 1a

Critical Mass Ratio vs. Thorium Concentration
in One Region Slurry Reactors
with D_2O and H_2O Mixtures



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the fast neutron leakage remains approximately constant. The family of curves shown in Fig. 1d is an illustration of this effect. Starting with a bare sphere diameter of 5-1/2 ft, the diameter was reduced in increments of 6 inches between each curve. Simultaneously, H_2O is added to D_2O (initially 99.8% pure) in various amounts. It may be seen that the minimum critical ratio for each reactor remains approximately constant in magnitude, but occurs at larger thorium concentrations.

Figure 2 is a cross plot of the minimum critical ratio as a function of the moderator composition. The thorium concentrations at the minimum ratio are indicated by the dashed lines (lines of constant concentration). These are obtained by graphical interpolation and should be used only as a qualitative description.

An increment of 6 inches may be used as a conservative estimate of the reflector savings due to the presence of a pressure vessel; i.e., 6 inches may be subtracted from the diameter of the bare sphere to obtain the inside diameter of the vessel which would have the same nuclear characteristics.

REFERENCES

1. B. E. Prince and M. W. Rosenthal, Survey of the Static Nuclear Characteristics of Small One-Region Slurry Reactors, ORNL CF-58-7-76, July 28, 1958.

2. James W. Wade, "Neutron Age in Mixtures of D_2O and H_2O," Nuclear Science and Engineering, 4, 12-24 (1958).

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