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Abstract

The possibility of a criticality accident in transferring irradiated fuel solution from the HRT has been investigated. The vessel (a cylinder 19-1/4" in diameter, 30-1/2" high, and shielded with 9" of lead) will be loaded with 100 liters of solution containing 8 kg of enriched uranium and 250 gm of gadolinium.

The infinite multiplication constant (k_{∞}) obtained in the solution is less than unity when the uranium is uniformly distributed. However, if the uranium were to settle, k_{∞} exceeds unity when the concentration is 180 gm U/l. Although there is a corresponding increase in the effective multiplication constant initially, a maximum value of 0.86 is achieved when the uranium concentration reaches 400 gm/l.

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INTRODUCTION

One hundred liters of irradiated fuel solution is to be transferred from the 7500 Area in a large, shielded vessel. The solution contains 8 kg of enriched uranium (83.4% U^{235}) in an aqueous solution (25% D_2O -75% H_2O); 250 grams of gadolinium is also present for neutron-poisoning purposes. The vessel is a right circular cylinder with dished heads, an inside diameter of 19-1/4 inches and a height of 30-1/2 inches. This cavity is completely surrounded by a 3/8-inch stainless-steel liner, 9-1/8 inches of lead shielding, and a 3/8-inch stainless steel skin. The quantity of solution is sufficient to fill the vessel to a height of 21 inches.¹

Since the dimensions of the vessel are large and the shielding acts as a reflector, there is some concern over the possibility of the solution becoming critical if the fuel were to precipitate and become more concentrated. A second problem is the effect on criticality of increasing the D_2O concentration. In all cases it is postulated that the gadolinium will remain uniformly dispersed in the solution.

RESULTS

A uniform dispersion of 8 kg of enriched uranium and 250 grams of gadolinium in 100 liters of water has an infinite multiplication constant of 0.59. However, if the uranium settles uniformly while the gadolinium remains dispersed, the infinite multiplication constant will exceed unity when the uranium concentration is approximately 180 gm/l. On the other hand, since the neutron leakage increases as the uranium settles, the effective multiplication constant will exhibit a maximum value.

To determine whether the solution will achieve criticality as the uranium settles, two-group, two-dimensional calculations were performed using the EQUIPOISE² program on the IBM-704 computer. The configuration and dimensions of the vessel are shown in Figure 1. Effective fast group constants for the fuel bearing region and the water reflector above it were determined using the GNU³ 34-group program.

The effective multiplication constant as a function of the height of the fuel-bearing region is shown in Figure 2. As the concentration of uranium increases and approaches 400 gm/l, the effective multiplication constant increases to a maximum value of 0.86. When the uranium settles further, the increased leakage causes the multiplication constant to decrease.

The effect of increasing the D₂O concentration is also shown in Fig. 2. Again the maximum multiplication constant occurs at approximately 400 gm U/l. Further, in the vicinity of the maximum, an increase in D₂O concentration is accompanied by a decrease in effective multiplication constant.

DISCUSSION OF RESULTS

The results shown in Fig. 2 indicate that the shipping cask, as shown in Fig. 1, may be used to transport the 8 kg of enriched uranium with no possibility of becoming critical if the gadolinium remains in solution. In the performance of these calculations the following conservative approximations have been made:

1. U²³⁵ was allowed to absorb resonance neutrons and undergo resonance fission while the resonance absorptions in U²³⁸ and gadolinium were neglected. To illustrate the importance of resonance absorptions, at 400 gm U/l one third of the neutron absorptions occur at resonance energies.

Fig. 1. Schematic of transfer vessel

Fig. 2. Effect of uranium settling
on multiplication constant.

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2. The presence of thermal poisons other than water and gadolinium were neglected.
3. The Fermi age of neutrons in lead is not well known but was estimated as 770 cm^2 from some data on mixtures of lead and water.⁴ To determine the sensitivity of the results to this estimate, some of the calculations were repeated using an age of 300 cm^2 . The difference in the results was negligible.
4. If the uranium does settle, it would not do so in a uniform manner. The concentration would probably be large near the bottom and decrease with height. Since this configuration places more fuel closer to the vessel boundaries, the leakage would be increased and the multiplication constant decreased. Verification of this theory was obtained by calculating the multiplication constant of the vessel when the uranium was distributed in a non-uniform manner. The upper 87-1/2% of the solution contained 34 gm U/l while the lower 12-1/2% contained 400 gm U/l. The effective multiplication constant in this nonuniform configuration was 0.73 which is well below the multiplication constant associated with a uniform concentration of 400 gm U/l.

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