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EFFECT OF EXPOSURE ON CRITICALITY IN
WATER LATTICES - NPR AND I&E FUEL ELEMENTS

R. E. Tiller and D. L. Johnson

INTRODUCTION

In order to set safe (non-critical) limits for the handling and storage of irradiated uranium it is necessary to know the reactivity of the exposed fuel.

The effect of exposure on the KIVN, KIVE and NPR fuel elements has been studied and results are presented which will allow safe specifications to be written.

SUMMARY

Figure 1 shows the effective enrichment versus exposure for the fuel elements studied. The effective enrichment is defined as the U^{235} enrichment of the unexposed fuel which would give the same maximum reactivity in water lattices as does the exposed fuel element. In all cases the exposures shown are an average for the assembled fuel element.

To ensure that the results are conservative from a criticality standpoint the following assumptions were made.

- 1) There are no fission products present in the irradiated fuel.
- 2) The calculated amount of plutonium present in the NPR element is increased by six per cent.

FIGURE 1
EFFECTIVE ENRICHMENT VERSUS EXPOSURE

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DISCUSSION

The work covered in this report applies to fuel elements irradiated in the Hanford reactors and then stored in a water lattice at room temperature. The results for the KIV slug geometry are based on U^{235} burnout and plutonium buildup values taken from Reference 1. The buildup and burnout values for the NPR fuel elements were obtained from the FLEX II program². Since there is as yet no experimental verification for the calculated values for the NPR, the calculated amount of Plutonium present was increased by six per cent. (See Figure 2). In addition, it was assumed that there were no fission products present in any of the elements studied, this will also tend to make the results conservative.

For the present reactors, only the KIV slug was studied. Since the K piles have a higher conversion ratio than the old piles, the effective enrichment after exposure of the KIV elements will be higher than the effective enrichments for I&E elements (excluding fuel elements for overbore) irradiated in the older piles.

To find the effective enrichment of a fuel element after irradiation, a curve of k_{∞} versus U^{235} enrichment was determined. The IBM-7090 IDIOT code³ was used to calculate k_{∞} for all of the cases studied. Figures 3 and 4 show the ratio of $(k_{\infty})/(k_{\infty})_0$ versus the change in enrichment for the fuel elements studied. Curves were then determined for $(k_{\infty})/(k_{\infty})_0$ as a function of exposure. (See Figures 5, 6, 7, and 8) With these results available, it was possible to determine the effective enrichment as a function of exposure as shown in Figure I. In all cases, k_{∞} and $(k_{\infty})_0$ were taken at the water-to-uranium ratio which gave the highest value.

Figures 6, 7, and 8 also show the results obtained with the calculated values of Plutonium concentration. This illustrates the magnitude of the conservatism introduced by increasing the plutonium concentration by six per cent.

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1. HW-50300-B, "IPD Plutonium Conversion Tables," D. W. Hoba, June, 1961, (Secret).
2. Personal Communication with R. J. Shields.
3. HW-63411, "IDIOT - A Lattice Parameter Code for the IBM-709," C. R. Richey, January, 1960.

FIGURE 2
BUILDUP AND BURNOUT VERSUS EXPOSURE

FIGURE 3
 $(k_{\infty})/(k_{\infty})_0$ VERSUS ENRICHMENT INCREASE - KIV GEOMETRY

FIGURE 4
 $(k_{\infty})/(k_{\infty})_0$ VERSUS ENRICHMENT INCREASE

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FIGURE 5
 $(k_{\infty})/(k_{\infty})_0$ VERSUS EXPOSURE - KIV GEOMETRY

FIGURE 6
 $(k_{\infty})/(k_{\infty})_0$ VERSUS EXPOSURE - NPR TUBE-IN-TUBE ELEMENT

FIGURE 7

$(k_{\infty})/(k_{\infty})_0$ VERSUS EXPOSURE - NPR OUTER TUBE

FIGURE 8

$(k_{\infty})/(k_{\infty})_0$ VERSUS EXPOSURE - NPR INNER TUBE