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		Fuel Element Development	PAGE 1 OF 4

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SUBJECT: **Reactivity in SRE of the Bettis Alloys**

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I STATEMENT OF PROBLEM

Compare the reactivities of the Bettis alloys with the 2.8% enriched uranium fuel.

II. SUMMARY OF RESULTS

The three alloys studied were:

U-15Nb-15Zr
U-12Nb- 6Zr
U- 6Nb-12Zr

where the numbers preceding the niobium and zirconium indicate weight percent in the alloy.

The enrichments ($\frac{N_{25}}{N_{25} + N_{28}}$) required for the uranium in these alloys to give the same reactivity as the 2.8% enriched fuel are:

U-15Nb-15Zr	6.7%
U-12Nb- 6Zr	5.2%
U- 6Nb-12Zr	3.8%

Table I gives the reactivity (compared to 2.8% enriched U) of these alloys with the uranium enrichments of 3, 7, and 11 percent.

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III. METHODS USED

The calculations were made for an SRE wet lattice cell with only the uranium in the fuel being replaced by the alloys. Thus, it is not too far wrong to neglect the changes in age and thermal migration area. The comparison then reduces to a calculation of the infinite multiplication constant for each alloy. The comparisons were made with the SRE wet critical calculation¹.

The infinite multiplication constant is given by

$$k_{\infty} = \eta \epsilon p f$$

Since ϵ depends primarily (although not totally) on the geometry of the fuel element, and since this has not changed, it is not untoward to take ϵ the same as in the 2.8% enriched uranium fuel. ($\epsilon = 1.045$)

Thermal Cross Sections (Maxwell averaged at 180°C)

Uranium

$$\bar{\sigma}_a (25) = 469.8 \text{ barns}$$

$$\bar{\sigma}_f (25) = 396.8$$

$$\bar{\sigma}_a (28) = 1.96$$

Zirconium

$$\bar{\sigma}_a = .128 \text{ barns}$$

Niobium

$$\bar{\sigma}_a = .784 \text{ barns}$$

K_{eff}

K_{eff} is given by

$$\eta_{\text{alloy}} = \frac{\nu \bar{\sigma}_f (25) \epsilon \frac{w_u}{A_u}}{[\epsilon \bar{\sigma}_a (25) + \bar{\sigma}_a (28)] \frac{w_u}{A_u} + \bar{\sigma}_a \frac{w_{Nb}}{A_{Nb}} + \bar{\sigma}_a \frac{w_{Zr}}{A_{Zr}}}$$

where

$$\nu = 2.47$$

$$\epsilon = \frac{N_{25}}{N_{28}}$$

TECHNICAL DATA RECORD

PROGRAM SGR

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w's = weight percent of the element in the alloy.

A's = atomic number of the element in the alloy.

$\bar{\sigma}$'s = Maxwell averaged thermal cross sections.

The values of Eta for the three alloys with enrichments of 3, 7, and 11% are given in Table 2.

Resonance Escape Probability

The SGR lattice code was used to calculate the resonance escape probability. The infinitely dilute resonance integrals, excluding $1/v$ capture for Nb and Zr are 3.43 barns and 3.0 barns respectively². The resonance integral put into the code then was

$$N_{\text{alloy}} (\sigma_{\text{res}})_{\text{eff}} = N_u (\sigma_u)_{\text{eff}} + N_{\text{Nb}} \sigma_{\text{Nb}} + N_{\text{Zr}} \sigma_{\text{Zr}}$$

Thermal Utilization

The thermal utilization is given by

$$f = \frac{\sum_u \Sigma_u \bar{\phi}_u V_u}{\sum_i \Sigma_i V_i \bar{\phi}_i}$$

where the top sum is just over the fuel and the sum in the denominator is for the whole cell.

The cross sections are easily calculated, and the volume fractions are the same as SRE. Thus, the only difficulty is in assigning the fluxes. The fluxes were taken as linear extrapolations of the SRE fluxes.

Recommendations

If these alloys are to be seriously considered, it is recommended that a much more careful study of the cell constants be made, especially for the thermal flux and the resonance integrals of Niobium and Zirconium.

Table 1

$\Delta k/k$ for Bettis Alloys Compared with SRE Wet Calculations

Enrichment (%)	U-15Nb-15Zr	U-12Nb-6Zr	U-6Nb-12Zr
3	- 16.8	- 9.4	- 2.5
7	+ .94	+ 5.2	+ 9.0
11	+ 9.3	+ 10.5	+ 13.5

Table 2

Eta for the Bettis Alloys

Enrichment (%)	U-15Nb-15Zr	U-12Nb-6Zr	U-6Nb-12Zr
3	1.470	1.621	1.728
7	1.730	1.813	1.868
11	1.865	1.920	1.957

IV. REFERENCES

1. Fillmore, F. L., "Two Group Neutron Physics Calculations for the Sodium Reactor Experiment"
2. Macklin, R. L., and Pomerance, H.S., "Resonance Capture Integrals", Progress in Nuclear Energy, Physics and Mathematics, Vol. 1, Charpie, et. al. (editors), McGraw-Hill, New York, 1956.