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TRITIUM PRODUCTION USING HIGHLY ENRICHED FUEL

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TRITIUM PRODUCTION USING HIGHLY ENRICHED FUELS

INTRODUCTION

Preliminary studies utilizing the MOFDA code have been made for tritium production at the K reactors using 33 and 35 grams per foot oralloy (93.5% U-235) in aluminum in conjunction with standard K5N and K5E fuel elements, respectively. For this report, it was assumed that all tritium would be produced in discrete charges of LiAl target elements. It is intended that the study will be extended at some later time to include LiAl splines. The analysis includes the effect of coolant loss on reactivity for hot-or-cold and green-or-exposed conditions for several oralloy loading fractions.

SUMMARY

With a full reactor loading of 35 g/ft oralloy and LiAl targets, it would be possible to produce 13.14 kg of tritium per year at one K reactor. With 25 percent of the process tubes loaded with oralloy fuel (the remaining 75 percent of the columns would contain 95 metal and lithium) the annual production at one K reactor would be about 5.85 kg of tritium and 750 kg of weapons grade plutonium. With the same number of oralloy columns, but with 72 metal, about 3.4 kg of tritium and 950 kg of Pu-239 would be produced annually.

The average burnout of the U-235 in the oralloy-aluminum was assumed to be about 28 percent. This corresponds to a residence time in reactor of about 120 full-power days. The maximum water-loss reactivity gain ($\sim 7.2\% \Delta k/k$) is for the cold exposed full reactor loading of 33 g/ft oralloy with LiAl targets. For fully oralloy fueled loads, a higher uranium concentration would be necessary to reduce the reactivity gain on coolant voiding to a controllable level. With the mixed fuel loadings, the reactivity gain on coolant voiding should be acceptable for up to 50 percent of the process tubes containing oralloy.

DISCUSSION

Basis and Assumptions

In the oralloy-K5E cases, the oralloy is 35 g/ft uranium (93.5% U-235) alloyed in aluminum. In the oralloy-K5N cases, the oralloy is 33 g/ft uranium (93.5% U-235) alloyed in aluminum.

To define the highly enriched uranium concentration in an oralloy-K5E (or K5N) fueled system with an enriched lithium target loading, several rather broad assumptions were made. First, the oralloy concentration was found such that the power generations of the oralloy would be compatible to the K5E (or K5N) power generation. Since the relative oralloy power generation decreases with exposure, limits of 115% to 85% were imposed on the ratio of oralloy power to K5E (or K5N) power at the start and end, respectively, of the irradiation period. The power split between the K5E (or K5N) and oralloy is only slightly dependent on the fraction of each type driver in the reactor; i.e., there is negligible interaction between the K5E (or K5N) and the oralloy.

In order to reduce the problems of "overheating" the graphite due to removal of heavy nuclei from the system, a limit of the number of oralloy fuel columns would necessarily be imposed in any actual loadings. However, for the purpose of this report, it is assumed that the oralloy could be loaded in any amount up to a full reactor load of oralloy-LiAl.

The power match for the oralloy and K5E was found with MOFDA by varying the amount of oralloy content in aluminum. The oralloy elements were I & E type with about 35 grams uranium per foot in the K5E case and about 33 grams uranium per foot in the K5N case. As mentioned above, the power ratio of the oralloy to K5E (or K5N) was allowed to range from 1.15 in the green condition to 0.85 in the exposed condition. This gives an average exposure of about 20,000 Mwd/ton* for the oralloy in the oralloy-K5E system and about 15,000 Mwd/ton for the oralloy in the oralloy-K5N system.

Calculations of Production

The production splits were computed by supercell studies with MOFDA. The supercell was composed of either the oralloy-aluminum and lithium-aluminum or the K5E and lithium-aluminum. Since the number of lithium-aluminum columns allowed is a function of the exposure of both the oralloy and the third component (K5E or K5N), it was necessary to adjust the loading with irradiation time. Figure 1 shows the change in driver to target ratio as a function of average oralloy exposure. The driver to target ratio for the K5E case follows inversely as the long term gains with exposure; the ratio varies from 17.5 in the green case to about 19.2 at the "samarium dip" and drops to about 18.6 at goal exposure (6% Pu-240). In the practical case, of course, splines would be used to control the transient during operation and loading changes would be effected during outages. Figure 2 shows the production splits as the ratio of oralloy and K5E drivers changes. Figure 3 shows the production splits in the natural uranium oralloy case.

A total input production of 1400 kWd/yr was assumed for all cases.

Calculation - Safety Analysis

The safety analysis has been limited to calculation with MOFDA of reactivity change with coolant loss with hot or cold and green or exposed fuel conditions. Tables I and II show the percent $\Delta k/k$ for water loss with the specified condition. As with the production calculations, it is assumed that there is negligible interaction between the oralloy and the K5E (or K5N) fuels. Calculations further assume that water voids from targets as well as the drivers.

*Ton of oralloy-aluminum. For equivalence, 20,000 Mwd/ton equals about 24.2 kg of U-235 burned out per ton of alloy charged.

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TABLE I

WATER LOSS ANALYSIS, ORALLOY - K5E - LiAl

<u>Fraction</u> <u>Oralloy-LiAl</u>	<u>Fraction</u> <u>K5E-LiAl</u>	<u>Conditions</u> <u>Oralloy</u>	<u>Conditions</u> <u>K5E</u>	<u>%Δk/k</u> <u>Water Loss</u>
-	1.	-	cold, green hot, green cold, exposed hot, exposed	2.36 - .32 2.26 .85
.25	.75	cold, green hot, green cold, exposed cold, exposed hot, exposed hot, exposed	cold, green hot, green cold, exposed cold, green hot, exposed hot, green	3.10 - .69 3.31 3.38 0.18 - .69
.50	.50	cold, green hot, green cold, exposed cold, exposed hot, exposed hot, exposed	cold, green hot, green cold, exposed cold, green hot, exposed hot, green	3.84 -1.06 4.36 4.41 - .48 -1.06
.75	.25	cold, green hot, green cold, exposed cold, exposed hot, exposed hot, exposed	cold, green hot, green cold, exposed cold, green hot, exposed hot, green	4.57 -1.43 5.41 5.44 -1.14 -1.43
1.0	-	cold, green hot, green cold, exposed hot, exposed	-	5.32 -1.79 6.46 -1.80

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TABLE II

WATER LOSS ANALYSIS, ORALLOY - K5N - LiAl

<u>Fraction Oralloy-LiAl</u>	<u>Fraction K5N</u>	<u>Conditions Oralloy</u>	<u>Conditions K5N</u>	<u>%Δk/k Water Loss</u>
.25	.75	cold, green	cold, green	3.13
		hot, green	hot, green	0.09
		cold, exposed	cold, exposed	3.31
		cold, exposed	cold, green	3.38
		hot, exposed	hot, exposed	0.96
		hot, exposed	hot, green	0.07
.50	.50	cold, green	cold, green	4.18
		hot, green	hot, green	-0.34
		cold, exposed	cold, exposed	4.62
		cold, exposed	cold, green	4.66
		hot, exposed	hot, exposed	0.20
		hot, exposed	hot, green	-0.39
.75	.25	cold, green	cold, green	5.22
		hot, green	hot, green	-0.78
		cold, exposed	cold, exposed	5.92
		cold, exposed	cold, green	5.94
		hot, exposed	hot, exposed	-0.56
		hot, exposed	hot, green	-0.85
1.0	-	cold, green	-	6.26
		hot, green	-	-1.22
		cold, exposed	-	7.23
		hot, exposed	-	-1.31

Future Studies

In order to better estimate the oralloy-uranium fuel loading, the lattice will be examined with a more sophisticated model such as a HAMMER-EXTERMINATOR-2 combination. Further, the production of tritium from lithium splines will be studied.

The element size of the oralloy fuel has not been optimized for this study. Future studies should use a model that is consistent with the latest technological advances in fuel design.

All exposures used in this study have been averages. It is estimated that the oralloy could be charged in segments so that the actual exposure of the burned fuel would be nearly twice the average exposure or about 30-40,000 Mwd/ton. Future studies should be made with discharge exposures in order to realistically estimate oralloy throughputs, U-235 burnout, etc.

A PCTR experiment is currently being designed that will serve as a check on the calculational methods for analyzing these supercell arrangements.

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